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Research Article

Age of Soil and Water Conservation Practices on Selected Soil Properties along the Toposequence of Gerado Watershed, Habru District, Eastern Amhara, Ethiopia

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The government of Ethiopia through community participation has widely implemented soil and water conservation (SWC) measures, especially in the highlands of Ethiopia. However, the effects of these practices on the physicochemical properties of soils have not been well assessed and documented in the study area. Thus, this experiment was conducted to evaluate the effects of SWC practice on selected soil physicochemical properties. Treatments were nonconserved land, 3- and 9-year-old soil conservation practices under three slope positions, namely, lower slope (0–8%), middle slope (9–15%), and upper slope (>15%) positions, and at two soil depths (0–20 and 20–40 cm) with three replications. Accordingly, 54 composite soil samples were collected and analyzed based on standard procedures. The results showed that the age of soil and water conservation practice, topography, and soil depths significantly affected most of the soil properties. Conserving the watershed for nine years improved the subsoil clay content from 37.1 to 46.3%, subsoil soil moisture content from 13.38 to 24.61%, surface total nitrogen content from 18.1 to 81%, available phosphorus content from 13.1 to 33.5 mg kg^{-1}, surface organic carbon from 0.28 to 2.83%, soil carbon stock from 9.26 to 35.59 t ha^{-1}, and surface cation exchange capacity from 21.5 to 57.4 Cmolec kg^{-1}. Therefore, maintaining soil and water conservation practices for long periods can improve soil properties. However, planting different grasses, with the existing physical structures is needed to increase soil nutrient and carbon stock.

1. Introduction

Ethiopian agriculture in the highlands has been challenged due to significant soil erosion, declined soil fertility, and loss of biodiversity that has exposed rural farmers to the risk of food insecurity and poor livelihood [1]. Soil erosion has become the major cause for land degradation and associated reduced crop productivity. The increasing population in the rural community has made unplanned land use changes due to the demand for cultivated land, grazing lands, and settlement [2, 3]. Most of the steep lands have been used for cultivation without appropriate soil and water conservation structures. Soil erosion is seriously affecting cereal potential regions of Ethiopian highlands such as Wollo, Tigray, and Hararghe where more than 50% of the cultivated lands have soil depths less than 10 cm [4].

The rate of soil erosion showed variability due to topography, agroecological zones, land cover changes, and the method used. Based on the reviewed datasets, the reported national average soil erosion rate was 38 t·ha^{-1} $year^{-1}$ [5]. Area-specific studies in Ethiopia also indicated soil loss was above the tolerable range [6, 7]. In the adjacent watersheds to this study, it was reported that the annual soil loss rate of the watershed ranged up to 187.47 t·ha^{-1}·$year^{-1}$ in steep slope areas, with a mean annual soil loss of 38.7 t·ha^{-1}·$year^{-1}$ [8].

Habru district is characterized by a chain of mountains, sparse vegetation cover, and continuously cultivated land over years that could produce accelerated runoff, removing fertile soils from the land surface. Removal of existing trees for charcoal production and house construction has contributed to the observed soil loss, gully formation, and yield decline. In response to the recognized soil erosion, the

Government of Ethiopia initiated community-based participatory soil and water conservation strategies and implemented across regions. Significant improvements were registered in terms of soil organic carbon (SOC), total N, and exchangeable Na^+ and Mg^{2+} in areas where the conservations practices were in place for many years [9]. However, the clay content, soil reaction, cation exchange capacity, and exchangeable K^+ were not significant due to conservation activities. Integration of physical and biological soil and water conservation measures showed higher clay content, soil moisture content (SMC), soil pH, SOC, total N, available P, and CEC in soil bund with desho grass compared to adjacent soil bund only, whereas bulk density, silt, and sand contents were higher in adjacent soil bund only compared to soil bund with desho grass. Reduced runoff velocity and erosion and increased infiltration were observed owing to conservation practices [10]. Such results indicate that there are inconsistent results in different locations. The observed variations were the results of the type of SWC practice, period of SWC, land use, and the nature of the topography.

Soil and water conservation measures have been implemented in Gerdao watershed, a model watershed in Habru district since the 1970s through a food-for-work program. After 1995, the approach was changed to community-based participatory watershed management. The practices are selected by experts in collaboration with farmers and applied in the field following the watershed principle from the top of the catchment to the bottom. However, the impacts of these activities on cultivated lands of the watershed have not been systematically studied and analyzed. Thus, the evaluation of physical and chemical properties of soils following the toposequence approach spatially and temporally is crucial to provide valid recommendations in the district. Therefore, the objective of this study was to determine the effect of SWC practice with different ages on selected soil properties.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in the Gerado watershed, located in the upper part of the Awash River basin, Habru district of North Wollo zone of the Amhara National Regional State. Gerado watershed is found about 18 km distance far from Mersa town, and it is located 508 km away from Addis Ababa to the north. Geographically, the watershed is located between 11°43′30″–11°46′30″N and 39°35′30″–39°39′30″E (Figure 1). The total area coverage of the watershed is about 1,463 ha. Habru district has 74,364 households and a total population of 227,660, of whom 115,242 are males and 111,404 are females.

Based on the Ethiopian Meteorological Agency, the mean annual temperature was 20.31°C, and the annual mean minimum and mean maximum temperatures of the district were 13.82°C and 26.8°C, respectively. The 23-years (1995–2018) rainfall data of the nearby 4 stations obtained from the National Meteorological Agency of Ethiopia show that the mean annual rainfall of the watershed varies from 946.17 to 1371.29 mm. The elevation of the watershed ranges between 1,696 m and 2,444 m above the sea level. The district includes three agroecological zones, namely, Kola (low land), Weyina dega, and Dega (high land), with a share of 55.5%, 41%, and 3.5%, respectively. The farming system of the area comprises a mixed system of crop production and livestock husbandry. The major crops grown in the area include sorghum (*Sorghum bicolor* (L.) Moench), teff (*Eragrostis tef* (Zucc.), maize (*Zea mays* L.), and chickpea (*Cicer arietinum* L.). The major land uses practiced were cultivated land, forest land, grazing land, and bare land. The common soil types of the district were derived from basaltic rocks and classified with WRB (Word Reference Base for Soil Resources) as Leptosols on steep lands (19%), Cambisols (45%) and Regosols (20%) on newly weathered soils and rocky profiles of the middle slope, and Vertisols (16%) on gently slope areas of the watershed.

2.2. Sampling Design and Soil Analysis. A reconnaissance survey was carried out before the actual sampling to identify the representative sample plots in the soils described above. The watershed was divided into three slope positions as the lower slope (0–8%), medium slope (9–15%), and upper slope (>15%) according to the FAO soil description [11] (Figure 2).

The quadrant sampling technique was used to collect the data where five subsampling plots were set up and the central point kept a 10 m distance [12]. The composite samples were mixed to obtain a representative sample of the plots determined by setting predefined sampling points (Figure 3). Soil samples were collected from cultivated land treated with soil bund and vetiver grass strips aged 3 and 9 years, and adjacent cultivated land without conservation measures as the control was purposively selected [13]. Soils were collected from 0 to 20 cm and 20 to 40 cm depths. A total of 54 composite soil samples (3 treatments ∗ 3 slope positions ∗ 3 replications ∗ 2 soil depths) were collected by using a randomized complete block design (RCBD) for soil analysis. Undisturbed soil samples were taken from the center of each sampling plot with a core sampler after clearing the top surface crop residues and others. Once the samples from each site have been collected, the stones were removed and placed in the soil sample plastic bag and labeled with the site code number.

The soil samples were collected in early December 2021, immediately after harvesting time. Finally, the collected soil samples were transported to the soil laboratory of the Sirinka Research Center for analysis of selected soil physicochemical properties and carbon stock soil. The collected soil samples were air-dried, crushed, and sieved by a 2 mm mesh. The composited soil samples were analyzed for bulk density, soil texture, soil moisture content, pH, total N, available P, exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+), CEC (cation exchange capacity), and SOC (soil organic carbon).

Soil bulk density was determined by the core method [14], the textural class was determined using the hydrometer method [15], and the soil moisture content was determined by the gravimetric method according to the formula given in [16]. Soil reaction was determined by a water suspension method with the microprocessor-based pH system with a 1 : 2.5 soil-to-water ratio [17]. Total N was determined by the modified Kjeldahl

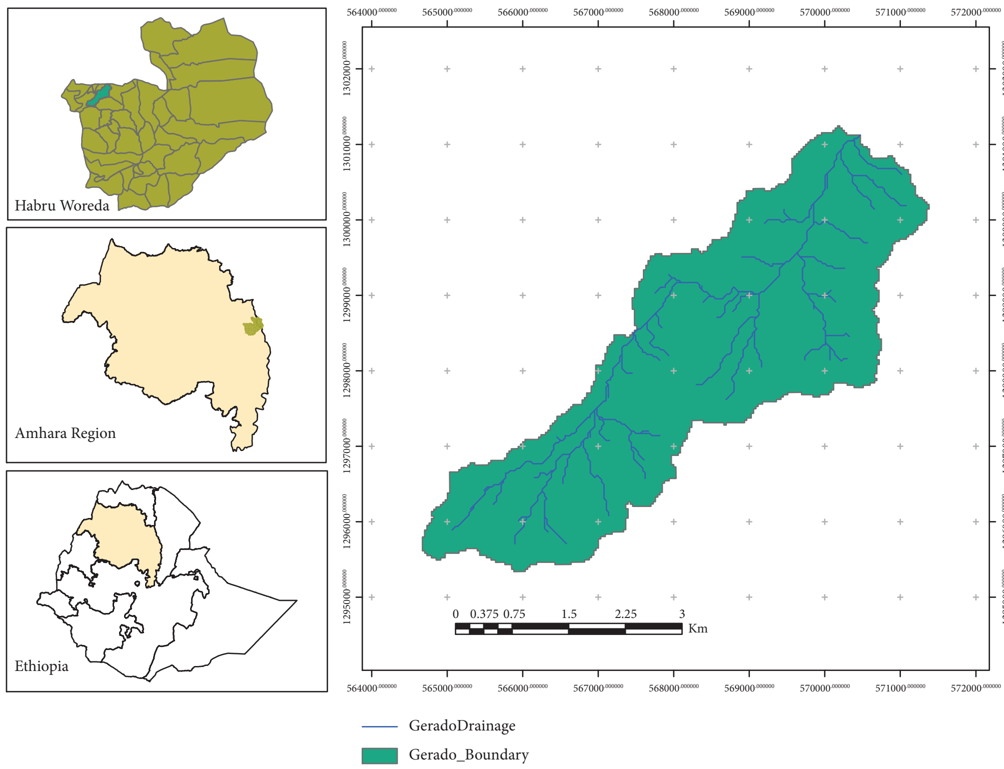

Figure 1: Location of the study area.

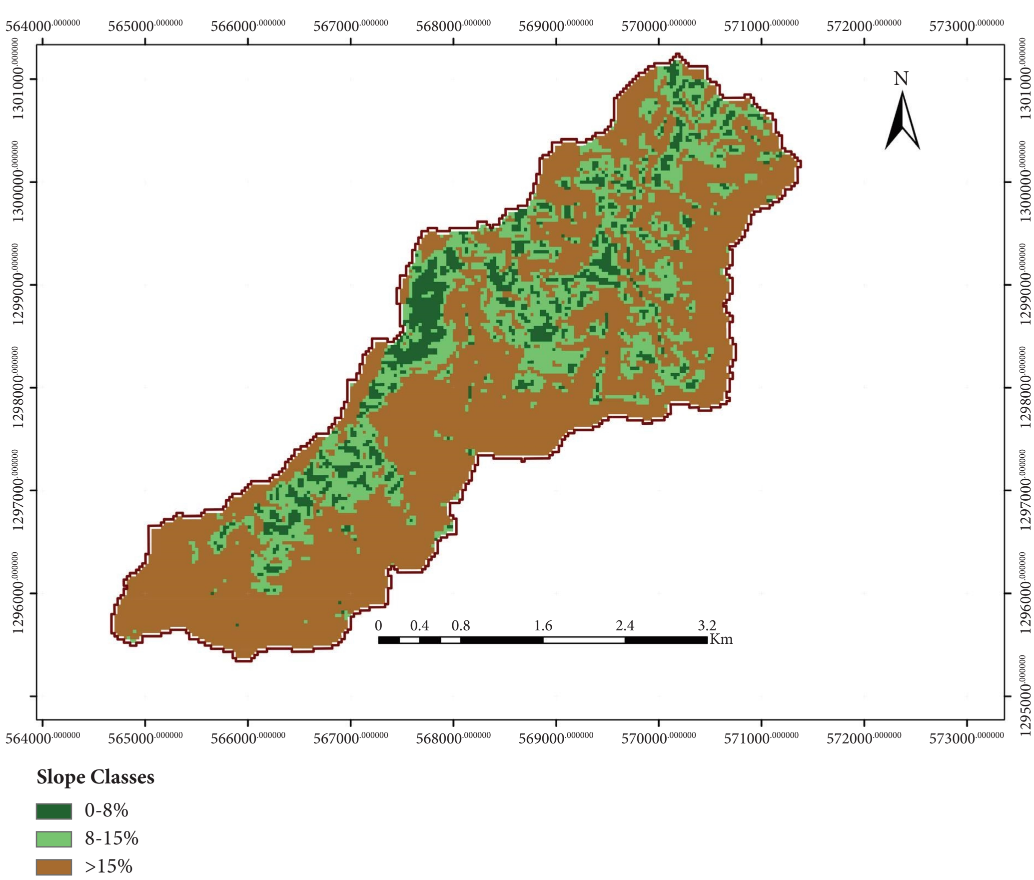

Figure 2: Slope map of Gerado watershed.

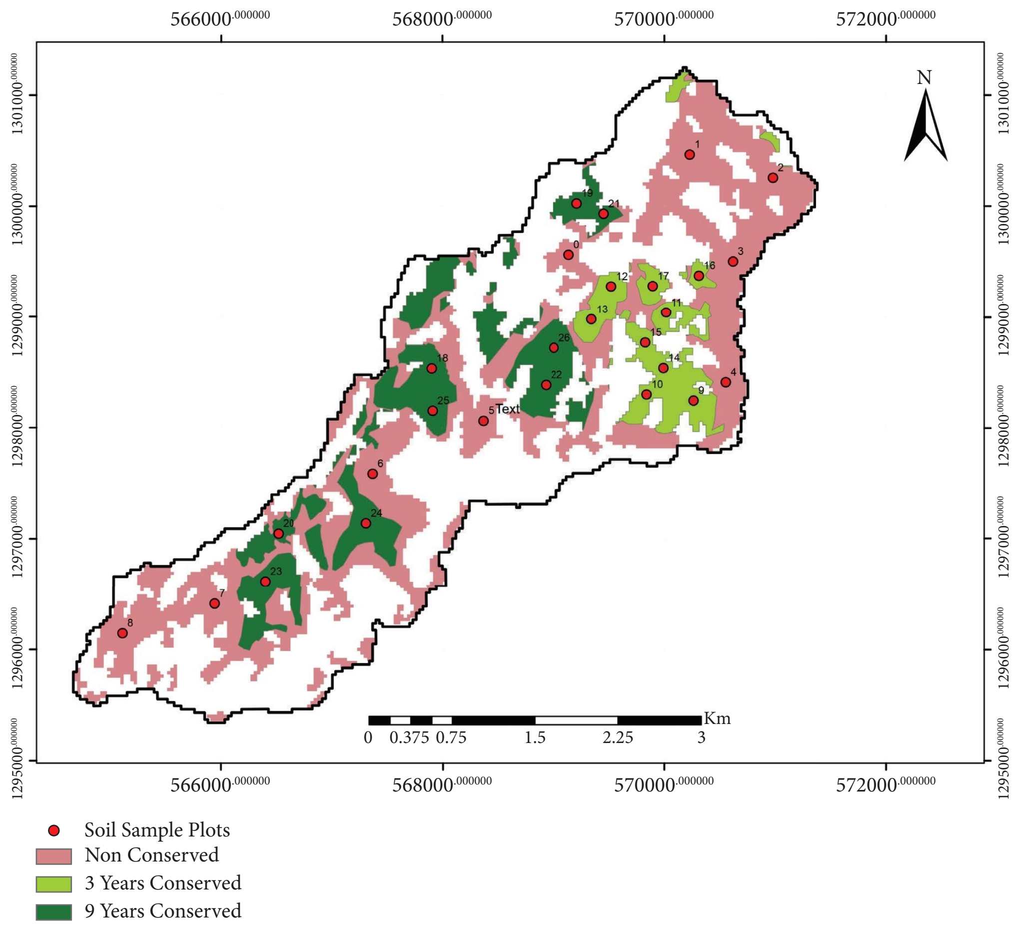

Figure 3: Soil sample plot and treatment of the study area.

digestion and distillation procedure [18]. Available P was determined using the Olsen method [19]. Cation exchange capacity was determined by extraction with the ammonium acetate method [20], and exchangeable Ca^{2+} and Mg^{2+} from the leachate were determined by using the atomic absorption spectrophotometer; while exchangeable Na^{+} and K^{+} were determined using the flame photometer. Soil organic carbon was determined by the Walkley and Black method [21]. The SOC stock was calculated for the incremental layers of 0–20 cm and 20–40 cm soil depth. The calculation was done using the measured SOC, BD, and depth or thickness of each layer separately. The SOC stock was calculated using the following formula [22]:

$$\text{SOCS} = \left(\rho\text{b}\left(\text{g cm}^{3}\right) * D\ (\text{cm}) * \%C\right), \tag{1}$$

where SOCS is soil organic carbon, Db is the bulk density, D is the depth of the soil, and $\%C$ is the percentage of carbon found in the soil laboratory. Furthermore, the total SOC stock up to 40 cm was calculated by summation of the SOC stock of 0–20 cm and 20–40 cm.

2.3. Data Analysis. The soil physicochemical properties were subjected to analysis of variance tests using SAS software version 9.4. A three-way analysis of variance (ANOVA) was executed to evaluate the statistically significant effects of aged SWC practice, slope positions, and soil depth on selected soil physicochemical properties. For means with significant ($P < 0.05$) differences, mean comparisons were performed using the least significant difference (LSD) at a 5% level of significance.

3. Results and Discussion

3.1. Effects of Soil and Water Conservation Practices on Selected Soil Physical Properties

3.1.1. Soil Texture. According to the results of analysis of variance, SWC, age, slope position, and soil depth showed significant differences on the particle size distribution of sand and clay, while there was no significant difference on silt (Table 1). The highest clay percentage (56.4%) was found in the subsurface soil of the nonconserved lands at the lower slope position. In contrast, the lowest clay content (35.9%) was obtained in the surface soil of nonconserved land in the upper slope positions. Taking the upper slope position alone, the subsoil clay content was found in the order of 9 years SWC practice >3 years SWC practice > nonconserved land. The sand fraction showed a significant difference ($p \leq 0.05$) due to the age of SWC practice, slope position, and soil depth. Both the highest (34.6%) and the lowest (17.9%) sand

Table 1: Effects of SWC age, slope position, and soil depth on soil physical properties.

Age of SWC	Slope positions	Depth (cm)	%Clay	%Silt	%Sand	Textural class	MC	BD
9-years-aged SWC	Upper	40	46.3^{a-d}	25.3	28.4^{a-e}	Clay	24.61^{a}	1.23^{f}
	Upper	20	38.6^{cd}	32.8	28.6^{a-e}	Clay loam	17.08^{h}	0.97^{h}
	Middle	40	39.1^{d}	34.9	26.0^{a-c}	Clay loam	24.37^{a}	1.45^{d}
	Middle	20	42.7^{b-d}	31.1	26.2^{fg}	Clay	20.61^{e}	0.73^{i}
	Lower	40	41.8^{b-d}	32.4	25.8^{b-e}	Clay loam	23.75^{c}	1.45^{d}
	Lower	20	48.5^{a-c}	26.9	24.6^{b-e}	Clay	23.61^{b}	0.55^{j}
3-years-aged SWC	Upper	40	40.7^{b-d}	32.7	26.6^{d-g}	Clay	21.72^{d}	1.77^{ab}
	Upper	20	44.2^{b-d}	28.6	27.2^{b-e}	Clay	15.74^{i}	1.09^{g}
	Middle	40	36.3^{d}	37.8	25.9^{b-e}	Clay loam	19.49^{f}	1.66^{c}
	Middle	20	43.6^{b-d}	30.9	25.5^{ab}	Clay	17.72^{g}	1.34^{e}
	Lower	40	41.2^{b-d}	33.2	25.6^{a-d}	Clay loam	20.72^{e}	1.69^{bc}
	Lower	20	43.0^{b-d}	30.9	26.1^{b-e}	Clay	15.25^{i}	1.45^{d}
Nonconserved	Upper	40	37.1^{d}	28.3	34.6^{a}	Clay loam	13.38^{k}	1.85^{a}
	Upper	20	35.9^{b-d}	35.0	29.1^{c-g}	Clay	13.63^{k}	1.22^{f}
	Middle	40	41.2^{b-d}	31.4	27.4^{a-e}	Clay	13.33^{k}	1.77^{ab}
	Middle	20	48.8^{a-c}	25.8	25.4^{b-e}	Clay	13.38^{k}	1.45^{d}
	Lower	40	56.4^{a}	25.7	17.9^{g}	Clay	14.45^{j}	1.75^{bc}
	Lower	20	49.2^{ab}	29.3	21.5^{e-g}	Clay	13.38^{k}	1.65^{c}
LSD			10.354	8.477	7.322		0.643	0.0951

SWC: soil water conservation in years; MC: moisture content in %; BD: bulk density in g cm^{-3}. Means within a column followed by the same letter are not significantly different at $P < 0.05$.

contents were found in the subsoil of the nonconserved lands in the upper and lower slope positions, respectively. Considering the distribution of sand content along the topographic positions, it decreased from upper to lower slope positions in both SWC ages and nonconserved land. The reason for the presence of a higher proportion of sand particles in the upper catchment could be related to the resistance of the coarser fractions to detachment by runoff. Similar results indicated that sand and clay fractions showed a significant difference with the age of SWC practice and compared with adjacent nonconserved cultivated land [23]. However, no significant variation in the soil particle size fraction between conserved and nonconserved cultivated land was reported [24].

3.1.2. Moisture Content. The soil moisture content (SMC) was significantly ($p \leq 0.01$) affected by the age of SWC practice, slope position, and soil depth. The highest (24.61%) mean SMC was recorded on the upper slope position of the conserved farmlands for 9 years. On the other hand, the lowest (13.33%) mean value of SMC was found in the middle slope position of the nonconserved (Table 1). This could be due to the effect of SWC practices on cultivated land, which increases moisture conservation along with the age of SWC establishment. The SMC of a plot with SWC practice consistently exceeded that plot without SWC practice [25]. Apart from the age of SWC practice and slope position, an attempt was also made to examine the variation of SMC with soil depth. Accordingly, the subsoil SMC was higher as compared to surface soil for both upper and middle slope positions.

The observed significantly higher moisture content in aged SWC practice could be related to the availability of higher organic matter content derived from the biomass of the vetiver grass and fine soil particles. Besides, the role bunds to dissipate the speed of running water and giving enough time to infiltrate into the soil could improve SMC.

In a similar study conducted by Habtamu [26], higher SMC observed in soils with conservation structures was related to the reduction of runoff length and speed by these structures and the subsequent increase in infiltration rates. According to Leta et al. [27], the accumulation of crop residue inputs and better soil humus contents are likely along the conservation structures, which could improve soil aggregation and thereby the soil structure, infiltration rate, and water-holding capacity of soils.

3.1.3. Bulk Density. Significant variations in the mean value of bulk density were obtained due to SWC age, slope positions, and soil depth (Table 1). Compared with the age of SWC, maintaining the SWC structure for 9 years reduced the soil bulk density, in which the lowest value was observed in the lower slope position of the surface soil. Higher values of bulk density were recognized for nonconserved lands. For example, the highest value (1.85 g cm^{-3}) was obtained in the subsoil of the nonconserved land on the upper slope position but lower values of soil moisture could also increase the BD. The accumulation of organic matter in the conserved lands might contribute to the observed low bulk density value in the 9-years-old conserved lands. On the other hand, compaction of soil particles as a result of plowing combined with sealing of pores with finer particles might increase bulk density on the nonconserved lands in the watershed. In line with this finding, a higher mean value of bulk density was observed on nonconserved cultivated land [28]. The bulk density values of most soils across ages and topographic position were below the critical value for crop production in clay loam soils [29].

3.2. *Effects of SWC Age, Slope Positions, and Soil Depths on Selected Soil Chemical Properties*

3.2.1. Soil pH. Soil pH showed significant variation ($p \leq 0.01$) between the ages of SWC practice and adjacent cultivated land without conservation measures (Table 2). Nine-years-aged SWC practice showed relatively highest pH (7.77) at the lower slope position of surface soil, while the lowest (6.15) was at the upper slope position of surface soil depth of the nonconserved farmlands. Soils having a pH value of 6-7 are classified as slightly acidic in their reaction, while soils with pH values of 7-8 are slightly alkaline [30]. Thus, the soils across the landscapes in all cases were slightly acidic except the 9 -years-aged surface soils on the lower topography. Such soil reactions are favorable for agricultural production without reclamation measures.

3.2.2. Total Nitrogen. The total nitrogen showed significant variation across topographic position, soil depth, and age of SWC (Table 2). The highest total *N* (0.81%) was found on the upper slope position of the surface soil conserved for 9 years. In contrast, the lowest total *N* (0.15%) was observed in the subsurface soil of the upper slope position on the nonconserved lands. Considering the age of conservation alone, 9-years-aged SWC practice was richer in total *N*, followed by 3 years of age. The total N content across topographic positions showed a decreasing pattern from surface to subsurface soil depths in all cases except in the middle and lower slope positions of the 3-years-aged SWC practice. The observed total *N* was high in the conserved parts of the watershed while it was medium in the adjacent nonconserved lands [31].

This is perhaps due to improved organic matter accumulation in conserved cultivated land that serves as a source of N through mineralization on cultivated lands with 3- and 9-years-aged SWC practice. Contrary to the findings, total *N* did not significantly differ in the cultivated land on terraced compared to nonterraced [23, 24]. The observed total N depth showed higher contents in the surface soil compared to the subsurface soil in both ages of SWC. This could indicate the effects of organic matter input from crop residues in the topsoil layer to the subsoil layer and create a favorable environment for active microbial activity for mineralization of incorporated organic material and release of *N*.

3.2.3. Available Phosphorus. Statistically significant ($p \leq 0.01$) variations were observed for available P due to the age of SWC practice, slope, and soil depths (Table 2). The highest (33.5 ppm) available P content was obtained in 9-years-aged SWC practice followed by 3-years-aged SWC practice and the lowest (13.1 ppm) in the nonconserved lands. Generally, the available P variation was pronounced due to the age of SWC. Considering 9-years SWC age, the surface soil available P content increased from the upper to lower slope positions. The available P content did not show numerical variations across slope positions and soil depth on nonconserved land.

This was in agreement with the finding of Hagos et al. [28], who reported that the available P was significantly different between the age of SWC practices in conserved and nonconserved lands. However, the result was not in agreement with the finding of Erkossa et al. [25], who reported that the available P was not significantly different between conserved and nonconserved lands. In addition, the result of Leta [23] also reported that the available P was more concentrated in the surface soil layer. Surface soil shall be supplied with inorganic fertilizer that increases the concentration of phosphorus in the soil solution to meet the amount demanded by crops. The higher soil organic matter content in the conserved cultivated lands was due to the higher available P status [32]. Similar report [33] suggested that the available P content was improved in soil bunds stabilized with besom grasses than in soils from nonconserved lands. This result implies that the implementation of soil and water conservation measures can maintain soil fertility by reducing the removal of relatively fertile and phosphorus-rich surface soil. Generally, the available P content was in the medium range for nonconserved lands while it was high [34] in all conserved lands of the watershed.

3.2.4. Organic Carbon. Organic carbon (OC) was highly significantly ($p \leq 0.01$) varied with the age of SWC practice, slope positions, and soil depth (Table 2). Nine years of integrated SWC practice markedly improved the soil OC content in all landscape positions with a mean value of 2.85, 2.44, and 1.84% in upper, middle, and lower slope positions, respectively. Such variations showed that the soil OC content followed an increasing pattern as moving from upper to lower slope transect. In most of the landscapes, more soil OC was accumulated on the surface soil depth as compared with the subsurface soil depth. This was due to the role of the grass biomass input to the conserved topsoil that improved the SOC content in aged SWC practice. Furthermore, as the age of the conservation structure increases, the soil erosion between the intersoil bund zone decreases and OC accumulation on cultivated land also increases. This might show the removal of fertile topsoil from the upper catchment by the effect of soil erosion and associated accumulation at the down slope area as the velocity of runoff is reduced by the soil bund. This, in turn, improves the SOC content at the lower slope zone. On nonconserved lands, there is a fast velocity of runoff, removing all soil materials that could lower the SOC content.

The result was in agreement with the finding of [32], who reported that the older age of soil bund stabilized with a vegetative measure has a better effect on SOC. Similarly, the authors in [28] reported a significant difference in the mean value of SOC contents between conserved and nonconserved cultivated land. However, the result was in contrast with the finding of [24], who reported that cultivated land with aged SWC practices implemented did not significantly vary compared to adjacent nonconserved cultivated land.

3.2.5. Soil Organic Carbon Stock (SOCS). Soil organic carbon was significantly ($p \leq 0.01$) varied with the age of SWC practices, slope position, and soil depth (Table 2). The

TABLE 2: Effects of SWC age, slope position, and soil depth on pH, total N (%), available P (mg kg^{-1}), SOC (%), and SOCS (t ha^{-1}).

Age of SWC	Slope position	Depth (cm)	pH	Total N	Available P	SOC (%)	SOCS
SWC 9 years	Upper	40	6.57^{c-f}	0.61^{c-e}	31.2^{c}	1.27^{def}	62.78^{c}
		20	6.73^{bc}	0.81^{a}	31.2^{c}	1.84^{c}	35.59^{g}
	Middle	40	6.77^{bc}	0.59^{c-f}	31.2^{c}	1.21^{e-g}	69.86^{b}
		20	6.84^{b}	0.73^{a-c}	32.2^{b}	2.44^{b}	35.62^{g}
	Lower	40	6.71^{b-d}	0.60^{b-d}	31.2^{c}	1.13^{fgh}	66.08^{b-c}
		20	7.77^{a}	0.78^{ab}	33.5^{a}	2.85^{a}	31.38^{g-h}
SWC 3 years	Upper	40	6.59^{c-f}	0.44^{f}	19.3^{f}	1.04^{fgh}	73.63^{a}
		20	6.33^{e-h}	0.47^{ef}	19.3^{f}	1.57^{c-e}	34.47^{g}
	Middle	40	6.49^{c-g}	0.44^{f}	19.3^{f}	0.86^{g-i}	57.30^{c-d}
		20	6.48^{c-g}	0.49^{d-f}	22.3^{e}	1.61^{cd}	43.24^{f}
	Lower	40	6.59^{c-f}	0.46^{ef}	19.3^{f}	0.85^{g-i}	57.70^{c-d}
		20	6.58^{c-f}	0.59^{c-f}	26.2^{d}	1.85^{c}	53.76^{d}
Nonconserved	Upper	40	6.63^{c-e}	0.26^{g}	13.2^{g}	0.47^{j-l}	34.78^{g}
		20	6.15^{h}	0.23^{g}	13.1^{g}	0.78^{i-l}	19.03^{h}
	Middle	40	6.39^{e-h}	0.15^{g}	13.1^{g}	0.46^{j-l}	32.51^{g-h}
		20	6.20^{gh}	0.16^{g}	13.1^{g}	0.41^{l}	12.03^{h-i}
	Lower	40	6.17^{gh}	0.15^{g}	13.1^{g}	0.60^{i-l}	41.93^{f-g}
		20	6.30^{fgh}	0.18^{g}	13.1^{g}	0.28^{l}	9.26^{i}
LSD			2.979	0.159	0.139	0.390	0.240

SOC: soil organic carbon; SOCS: soil organic carbon stock. Means within a column followed by the same letter are not significantly different at $P < 0.05$.

highest (73.63 t ha^{-1}) mean value of SOCS was exhibited on the subsurface soil of a 3-years-aged SWC at the upper slope position, followed by subsurface soil (69.86 t ha^{-1}) of 9-years-aged SWC at the middle slope position, and the lowest (9.26 t ha^{-1}) on the surface soil of nonconserved lands in the lower slope positions (Table 2). Looking depth wise in both ages of SWC practice, higher SOCS was observed on the subsurface soils in all landscape positions. In spite of higher SOC content with 9-years SWC practice, SOCS exceeded in 3-years SWC practice due to the higher bulk density value in these soils. This pointed out the role of the age of SWC structure establishment in the increase of SOCS value than adjacent nonconserved cultivated lands, but due to the high bulk density value, 3-years-aged SWC brought more SOCS value than 9-year-aged SWC practice. This integrated intervention also increased the conservation of the SOC content through reduced erosion rates, which helps to sequester more carbon and plant nutrients and recycle them into the soil through the decomposition of plant residues. Likewise, the older age of soil bund stabilized with the vegetative measure has a better effect on soil organic matter accumulation. Although SOC concentrations decrease rather linearly with increasing depth, total SOCS values were greater in subsurface soil layers than at the surface soil depth [32]. This could be related to the increased mass of the soil in the subsoil due to compaction.

3.2.6. Exchangeable Bases and CEC. Exchangeable potassium showed no significant variation with the effects of SWC age, slope position, and soil depth (Table 3). Although the variation in all factors was not consistent, higher numerical values (1.09 and 0.91 kg^{-1}) were obtained in the 3-years- and 9-years-aged SWC practices, respectively. The lowest exchangeable K^+ (0.21 meq/100 gr) was obtained from the middle slope position of surface soil in the nonconserved part of the watershed (Table 3). Although there was no consistent variation in exchangeable K^+ across slope positions, it was observed that exchangeable K^+ decreased from 0.79 to 0.36 and to 0.24 meq/100 gr on the surface soils of 9-years-aged SWC practice, 3-years-aged SWC practice, and nonconserved lands, respectively, in the lower topographic positions. Unlike this finding, exchangeable K^+ concentrations in cultivated lands with soil conservation measures were found to be significantly higher in the nonconserved cultivated lands [35, 36].

Exchangeable bases (Ca^{2+}, Mg^{2+}, and Na^+) had no significant variation with the age of SWC measures practice, slope position, and soil depth (Table 3). Lands conserved for 3 years on the lower slope position were relatively higher (9.05 meq/100 gr) as compared to nonconserved lands on the same slope where the lowest (3.93 meq/100 gr) exchangeable Ca^{2+} was obtained. Exchangeable Mg^{2+} was the highest (3.76 meq/100 gr) on the subsurface soil of 3-years-aged SWC practice implemented on the upper slope positions while the lowest (2.44 meq/100 gr) was on the surface soil of the nonconserved lands on the same slope position.

3.2.7. Cation Exchange Capacity. Cation exchange capacity (CEC) indicated significant variation ($p \leq 0.01$) due to SWC age, slope position, and soil depth. The highest (57.4 meq/100 gr) CEC was found on the surface soil of a 9-years-aged SWC practice implemented at lower slope positions while the lowest (19.16 meq/100 gr) was on the surface soil of the nonconserved lands on the lower slope position. The CEC values fall in the range of high to very high class for the 3-years- and 9-years-aged SWC practice, respectively. Whereas the CEC value of the nonconserved lands was in the medium range [29]. The presence of CEC helps not only to hold more nutrients but they were also better able to buffer

Table 3: Effects of SWC age, slope position, and soil depth on exchangeable bases and CEC.

Age of SWC	Slope position	Depth (cm)	Exchangeable bases (meq/100 gr)				CEC (meq/100 gr)
			K^+	Ca^{2+}	Mg^{2+}	Na^+	
9-years-aged SWC	Upper	40	0.04	4.09	2.67	0.43	44.4[b]
		20	0.77	7.40	3.22	0.91	48.2[b]
	Middle	40	0.91	7.59	3.65	1.02	47.4[b]
		20	0.26	6.38	2.75	0.33	51.4[ab]
	Lower	40	0.54	6.92	3.28	0.80	53.1[ab]
		20	0.79	6.04	3.15	1.01	57.4[a]
3-years-aged SWC	Upper	40	0.90	8.33	3.76	1.26	27.0[d]
		20	0.87	5.17	3.25	0.99	28.2[c]
	Middle	40	0.75	7.26	3.14	0.94	26.3[d]
		20	0.78	7.20	2.75	1.09	27.1[d]
	Lower	40	1.09	9.05	3.28	1.19	27.3[d]
		20	0.36	8.16	3.36	0.75	28.3[d]
Nonconserved	Upper	40	0.23	6.18	2.72	0.43	20.1[e]
		20	0.32	4.89	2.44	0.64	21.5[e]
	Middle	40	0.59	6.69	3.55	0.69	20.3[e]
		20	0.22	7.92	3.50	0.70	21.5[e]
	Lower	40	0.39	3.93	2.81	0.65	21.2[e]
		20	0.24	6.73	3.24	0.36	21.5[e]
LSD			0.75	3.57	1.12	0.71	1.2371

Means within a column followed by the same letter are not significantly different at $P < 0.05$.

or avoid rapid changes in the soil solution levels of these nutrients [37]. Generally, the results show that the slope position and soil depth of soil did not affect CEC, rather it was affected by the age of the SWC practice. In line with this result, nonsignificant CEC value was reported among the higher, middle, and lower landscape positions of the study site [23].

The CEC exhibited a decreasing trend from 9-years-aged SWC practice to 3-years-aged SWC practice and adjacent cultivated land without soil conservation measures, respectively (Table 3). In all slope positions and temporal variations, CEC values decreased with the depths of soil. The observed higher CEC values in conserved cultivated could be related to a better accumulation of OM and clay fractions than in the nonconserved cultivated lands. In agreement with these results, different researchers also pointed out the role of SWC measures in conserving SOM and hindering the transportation and translocation of clay particles, thereby increasing the CEC of the soil [38]. This is probably due to the higher clay content and a higher mean of soil pH in the topsoil than in the subsoil layer.

4. Conclusion

Soil erosion as part of land degradation contributed to the removal of soil, depletion of nutrients, and subsequently yield decline. In Ethiopia, SWC practices have been conducted since the 1970s with different working approaches. The activities have been implemented in Gerado watershed and significant improvements in crop yields were obtained. However, the effects of these SWC practices on soil properties were not well evaluated. Thus, this study was undertaken on a small watershed with an area coverage of 1,463 ha. The study has revealed that aged SWC practices also significantly affected the physicochemical properties of soil at different soil depths and slope positions. The aged SWC practices highly significantly affected the MC, BD, pH, total N, available P, CEC, OC, and SOCS. In general, the effects of integrated SWC measures had a positive impact on selected soil physicochemical properties and the carbon stock of the soil. Therefore, feasible SWC practices, land use planning, and soil management practices are needed on nonconserved lands to reduce soil erosion, improve soil properties, and increase the ecosystem service generated from the watershed.

Data Availability

The data used to support the findings of this study available on request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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