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Research Article

Effects of Soil and Water Conservation Structures on Selected Soil Physicochemical Properties: The Case of Ejersa Lafo District, Central Highlands of Ethiopia

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Land degradation in the form of soil erosion and fertility depletion is the major environmental problem in Ethiopia. However, to curb this problem, soil and water conservation (SWC) structures are commonly practiced in many rural parts of Ethiopia. This study was conducted to assess the effects of SWC structures on selected soil physicochemical properties in Ejersa Lafo district. For this study, two *kebeles* (peasant associations) were selected purposively from the district based on the severity of soil erosion and information on SWC practices. The research design employed in this study was systematic, randomized, complete block design. A total of 12 composite soil samples were collected from the depth of 0 to 20 cm at two subwatersheds, namely, Jamjam laga batu and Koriso Odo guba with SWC and without SWC structures at three landscape positions. All the soil samples were analyzed following the standard and recommended procedures. The effect of independent variables (SWC practices and landscape positions) on the dependent variables (soil properties) was statistically tested using the SPSS computer program 21. In this study, most of the selected soil physicochemical properties were affected by watershed management intervention (SWC) structures. Soil moisture content (SMC), clay, pH, electrical conductivity (EC), total N (TN), available (AP), available K (AK), and organic carbon (OC) were higher in the subwatershed treated with SWC structures (conserved), whereas bulk density, silt, and sand were higher in the subwatershed without SWC structures (nonconserved). Most of the selected soil chemical properties were significantly varied ($p < 0.05$) between conserved and nonconserved farm land except EC. All the selected soil physicochemical properties did not show any significant variation ($p < 0.05$) at landscape positions except sandy soil. The physicochemical soil properties of selected parameters were in good conditions in the conserved areas with higher N and OM and lower BD, indicating fertility of the soil compared with the nonconserved land. The implementation of SWC structures improved some of the physicochemical properties of soil, such as SMC, clay particle, pH, EC, total N, AP, AK, and OC in the study area. Furthermore, efforts are required to enhance community adoption towards soil and water conservation. Additionally, further research has to be carried out on socioeconomic aspects and impacts of the intervention on crop productivity for better understanding of the sustainable use of the land.

1. Background

The problem of soil erosion is threatening ecosystems and human well-being throughout the world because it results in a significant reduction in economic, social, and ecological benefits of land for crop and other environmental service [1]. It generates strong environmental impacts and major economic losses from decreased agricultural production and off-site effects on infrastructure and water quality by sedimentation processes [2, 3], and Ethiopian case is not exceptional. According to Dessalegn et al., [4], soil erosion is the major environmental problem, which affects half of Ethiopia's agricultural land ha^{-1} year^{-1} and results in a soil loss rate of 35 to 42 t year^{-1} and a monetary value of US$1 to 2 billion.

Ethiopia is one of the oldest agrarian nations in sub-Saharan Africa (SSA) with large agricultural potential. Agriculture is one of the largest sectors in the economy both in terms of its contribution to the GDP and generating employment [5]. The majority of the people in Ethiopia are dependent on agriculture for livelihood, which resulted in fast and vast land degradation. In fact, it has been reported that expansion of cultivated area, reduction of natural forests and grasslands, and intensifying grazing in smaller areas to accommodate a growing population has been underway in Ethiopia highlands for centuries [6].

In Ethiopia, particularly in the highlands of the country, land degradation is a major environmental problem causing severe impacts on natural resource conservation, crop productivity, and food security [7–9]. Moreover, these activities are the known causes of soil erosion, which in turn affects the physical and chemical properties of soils. According to Osman and Sauer [10], erratic and erosive rainfall, steep terrain, deforestation, inappropriate land use, land fragmentation, overgrazing, and weak management practices are among the factors that cause land degradation in the country.

SWC measures play a key role in improving agricultural production and reducing land degradation [11, 12]. Furthermore, SWC activities can change the physical and chemical conditions of the soil [13]. The study conducted by different scholars in various part of Ethiopia showed that the intervention of watershed management implemented, such as soil bund, reduced annual runoff and soil loss at different rates [14]. This is evident from the report of Addis et al. [15] who reported that SWC measures reduced K^{+1}, Na^{+}, Ca^{2+}, and Mg^{2+} loss by 7.05, 0.9, 75.21, and 31.14 kg ha^{-1}, respectively. Similarly, López-Vicente et al., [16] and Novara et al., [17] reported in their study that cover crops as SWC measures are widely accepted as sustainable crop management that reduces soil and water losses, restores organic matter, and increases biodiversity and soil fertility in degraded agriculture soils.

The conservation measures further prevent the loss of mineral fertilizers and organic matter through soil erosion. Improved land management is a key in ensuring better resource use and promotes long-term sustainability to future food production and economic welfare of the rural community's at large [18]. Conserving and improving soil quality is about sustaining the long-term function of the earth-plant-soil relation and improving productivity [19]. Indeed, the report by Wolka, [5] indicated that implemented SWC structures (terracing, gully stabilizations, check dams, and plantation of multipurpose fruit and fodder trees) enhanced in situ moisture conservation, storage of water, and recharge groundwater that are creating opportunities for supplementary irrigation, thereby encouraging farmers to go on for cultivation of high-value commercial crops.

According to Keesstra et al. [20], to avoid further land degradation and promote land restoration, multifunctional use of land is needed within the boundaries of the soil-water system. This in turn play a key role in balancing between the economy, society, and the biosphere using a holistic approach. Sustainable use and management of land resources could only be achieved by adopting a system of improved land, water, and vegetation use.

In this regard, in Ethiopia, the efforts towards sustainable use and management of land and SWC goal was started since the mid-1970s and 80s, to alleviate soil erosion and low crop productivity [21]. Ministry of Agriculture (MoA) and the NGOs, such as GTZ, FAO, and SOS Sahel, have adopted participatory land use planning in different parts of Ethiopia during the past two decades. Currently, campaign for construction and maintenance of SWC structures has offered a great contribution to watershed development and management of the country. However, in spite of having the aforementioned efforts on watershed management and development, the effectiveness of watershed intervention practices in improving soil properties remains understudied. In order to fill this information gap and support the country's effort in combating land degradation, a study that assesses the effectiveness of SWC Structures is of paramount importance.

Comparing changes with selected soil quality parameters between two watersheds (treated with soil conservation structures and untreated with soil conservation structures) could contribute for further improvement of the SWC practices currently underway and to draw some recommendations. Therefore, this study was designed with the objective to investigate the effects of SWC intervention on selected physicochemical properties so as to draw conclusions that contribute in future improvement of SWC structure implementation in improving soil for a better land productivity, erosion control, and sustainable use of resources available in the country, especially at Ejersa Lafo district.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in Jamjam laga batu and Koriso Odo guba Peasant association microwatersheds, Ejersa Lafo district, West Shewa zone, Oromia National Regional State (Figure 1). Ejersa Lafo district is located 70 km west of Addis Ababa and 47 km away from the Ambo Zonal town. According to the current administrative structure, the district is separated from Dendi district and has 17 rural and three urban *kebeles*.

Geographically, the district is located between 900′0″ to $9^0 50'0''$N latitude and $38^0 12'30''$ to $38^0 17'30''$E longitude. The district is bordered with Dawo district in the southwestern Shewa zone from the South, Ejere district from the East, Jeldu from the North, Ilu district from the South East, and Dandi district from the West.

The two watersheds have about 10.105 km. Agroecologically, Ejersa Lafo district is divided in to highland (74%) and midland (26%) agroecologies. The district has a total area of 32,365 hectare (Ejersa Lafo Agricultural and Natural Resources office, 2019). The altitude ranges between 2000 and 3288 m above the sea level. The map of the study area is drawn using ArcGis.

The mean average temperature of the area is 19.67°C with the minimum and maximum value of 5.4°C and 26.41°C, respectively (Holeta Research center, Dendi station, 2019). The warmest month of the area is March (26.41°C). The coldest month of the study area is July and September. The

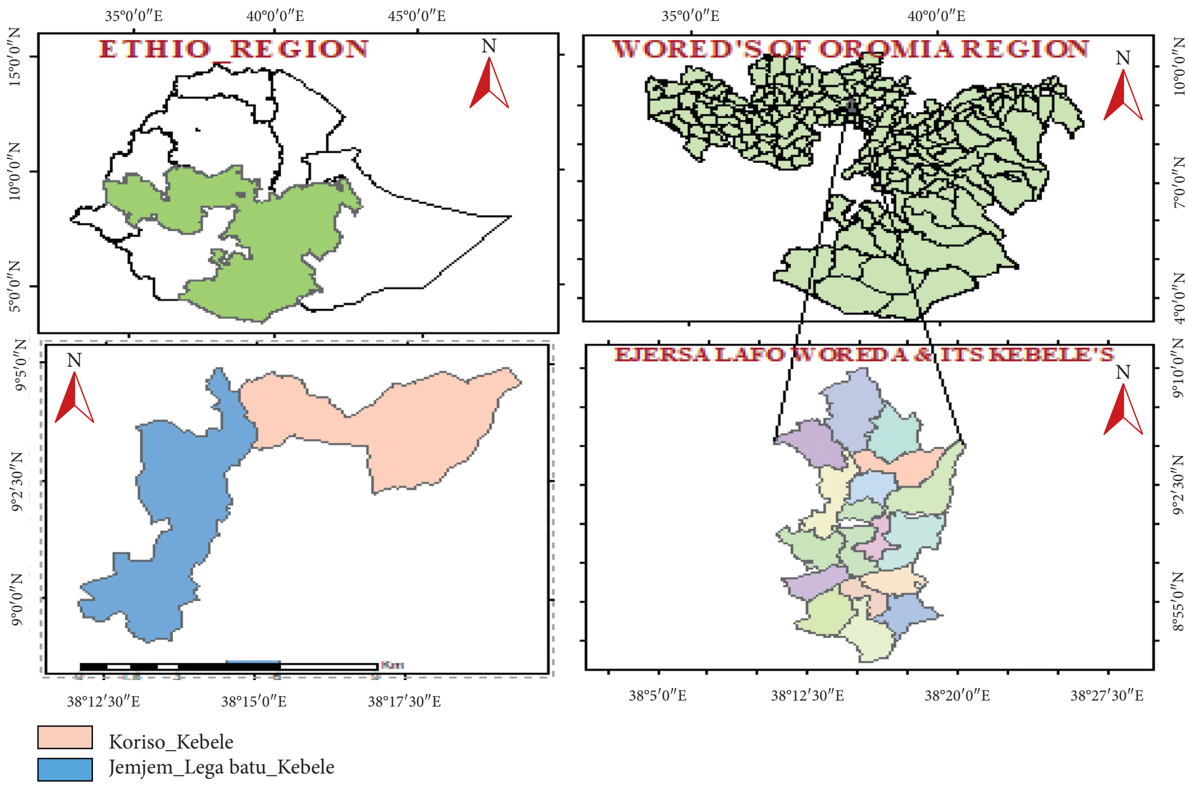

Figure 1: Map of the study area.

annual rainfall has been reported to be 750–1170 mm [22]. The soil of the study area is mainly dominated by Vertisols, Luvisols, and Cambisols [23].

Generally, the vegetation of the microwatersheds is characterized by the presence of tree species, such as *Podocarpus falcatus*, *Juniperus procera*, *Olea africana* subspecies *cupsidata*, *Grevillea robusta*, and Acacia spp on both conserved and nonconserved lands, although the number is less on nonconserved farm land. Additionally, the land treated with SWC consists of the forage species, such as *Sesbania sesban*, tree Lucerne (*Chamaecytisus palmensis*), and Desho grasses (*Pennisetum pedicellatum*). The natural vegetation in the study area is under heavy pressure due to rapid population growth. The indigenous trees are removed mainly to expand agricultural farm lands, fuel woods and construction of houses, fences around farmers' settlement, and charcoal production for market [22]. The remnants of tree species are observed scattered here and there in the study water sheds.

2.2. Methodology. A reconnaissance survey was carried out before the actual samplings, to identify the representative watersheds and assign sample lands. Then, judgment sampling was used to take representative sampling sites for both treated with SWC and control microwatersheds and landscape positions; we followed the judgment sampling method USEPA (United State Environmental Protection Agency) [24].

Two representative *kebeles* were selected purposively for each site at three different landscape positions based on recommendation by District agricultural expert and development agent (DA) for soil sample collection. Stratified random sampling techniques were used for soil samples collection. Soil samples were collected from purposively selected croplands/plot with soil bund (aged 7) and nonconserved (adjacent to the conserved farm land) at various landscape positions.

In this study conserved land is the land under the implementation of SWC structures (soil bund), whereas nonconserved means without implementation of SWC structures.

Based on the landscape positions, the farmland of the study watersheds was categorized into three slope classes: 3–8% is considered as lower slope, 8–15% as middle slope, whereas 15–30% as upper slope.

The research design used in this study was systematic randomized complete block design. There were two treatments (SWC practices and land positions) and three landscapes positions. The soil samples were collected 20 cm from the top surface both with and without soil bund following the published procedure [9] through composite sampling techniques to obtain a representative sample of the lands determined by setting predefined sampling points from February 10 to 18, 2019.

A total of 6 composite samples from 2 croplands of watershed with SWC soil bund (3 landscape position from upper, middle, and lower slope position within the field) were collected using auger, while core sampler was used for taking undisturbed soil sample for bulky density. All the soil samples were taken from a depth of 0–20 cm and packed with plastic bags.

In all cases from where the soil samples taken, the history of land management particularly of fertilizer application was recorded, and all the interviewed farmers responded that they use the same type and amount of fertilizer per hectare on their farm land both conserved and nonconserved. The farm lands from where the soil samples taken were under wheat cultivation.

The collected soil samples were taken to laboratory and air dried in the laboratory, crushed, and sieved by a 2-mm mesh sieve [25]. The soil samples were analyzed at the Ambo University Chemistry laboratory following the standard and recommended laboratory procedures.

The composited soil samples were analyzed for pH, available P, total N, and soil organic carbon (SOC).The pH of the soil was measured in water suspension in a 1:2.5 (soil:liquid ratio) potentiometrically using a glass-calomel combined electrode [26]. Total nitrogen was determined by the modified Kjeldahl digestion and distillation procedure [27]; organic carbon content was determined by the wet combustion or dichromate oxidation methods [28]. Available potassium was determined by the ammonia acetate method [29]. The soil physical property of texture is analyzed using a hydrometer method [30]. Bulk density (BD) is analyzed using the core method calculated by dividing the oven-dry mass at 105°C by the volume of the oven dry core [31].

$$\rho_d = \frac{W_d}{V_c}, \tag{1}$$

where ρ_d is dry bulk density ($g\,cm^{-3}$), W_d is mass of dry soil (g), and V_c volume of soil cores ($196.25\,cm^3$).

Moisture content was determined by initially weighing the field samples and drying the field samples at 105°C for 24 hours and weighing them again according to Sertsu and Bekele [32].

$$\text{SMC} = \frac{W_i - W_f}{W_f} \times 100, \tag{2}$$

where SMC = soil moisture content on volume basis (%), W_i = initial weight of soil (g), and W_f = final weight of soil (g).

2.3. Statistical Data Analysis. The effect of independent variables (SWC practices and landscape positions) on the dependent variables (soil properties) was statistically tested. The data collected were subject to analysis of variance (ANOVA) using general linear model (GLM) procedures in SPSS, to analyze the effects of soil and water conservation on soil physical and chemical properties as well as soil fertility. Paired samples t-test analysis were done to check whether the differences in soil chemical properties under the soil bund are controlled or not changed.

3. Result and Discussion

3.1. Effects of SWC Interventions on Soil Physical Properties

3.1.1. Soil Texture. Soil textural fractions, such as sand, silt, and clay, soil bulk density, and moisture content showed no significant difference with SWC treatments. The nonsignificant difference in texture may be due to the age of the implementation of watershed practice, which was eight years that cannot make significant change on weathering. There was no significant difference of soil texture in landscape position except sandy soil (Table 1). This study is contrary to the finding of Wolka et al. [33], who reported significant variations of soil textural classes of farm lands undertreated with SWC measures with that of untreated farm lands.

The highest mean value of clay content was observed in the conserved land (51.79% ± 3.36), and the lowest was in the NCP (47.6% ± 1.36). This is in line with the study of Masha et al. [34], who reported the highest mean value of clay content in the conserved plot (54.58%) than in the nonconserved plot, which is 52.96%. However, the mean value of sand content was relatively greater in nonconserved farm lands than in the conserved farm lands. This might be due to soil aggregation greater in untreated for less contents of organic matter that minimize the sandy aggregates to contain moisture (Table 1).

The result of ANOVA revealed highly significant differences ($p = 0.001$) for sand at landscape positions. The recorded mean values of the sand for upper (15–30%), middle (8–15%), and lower (3–8%) were 34.27 ± 1.889, 31.125 ± 2.09, and 26.725 ± 1.56, respectively. These results are in agreement with those in the literature [21, 35]. The result of study indicated that the proportion of sand in soil untreated with SWC practice was higher compared with that in soil under SWC practices. This study is in agreement with that of Gadana et al. [36].

Soils of the conserved farm land with SWC structures had higher percent of clay compared with the soils of the untreated/nonconserved with SWC structures, although did not showed significant difference. However, sand and silt percent were lower in land treated with SWC structures. The sand contents of the soil of cultivated farm lands decreased from upper to lower landscape positions. Similarly, high moisture content is present in the lower landscape position (6.047 ± 0.73) compared with the upper and middle one, which can be considered to enhance better condition for decomposition.

On the other hand, the silt contents of the recorded results from the two microwatersheds was not significantly varied ($p > 0.05$) among nonconserved and conserved with SWC structures farm lands and across landscape position (Table 1).The silt contents of cultivated field untreated with SWC practices were relatively smaller than that of untreated farm lands, which might be because farm lands treated with conservation structures contain greater organic matter contents.

The recorded results indicated that the mean value of the silt contents from both micro watersheds of similar slope position from upper streams to lower streams relatively decreased because the silt is of very fine particle size that was formed from sediments deposited in the lower sides and large mass of grass cover and residue present on the lower side that increase fine particles so that silt contents increased.

Furthermore, the result depiction shows that the farm lands mainly dominated by clay contents (Table 1). The

Table 1: Soil physical properties (sand, silt clay, and BD fractions) in relation to the type of conservation practices and slope gradient (mean ± SE) of top soil (0–20 cm) depth.

Land use type	Variables				
	Sand	Silt	Clay	SMC	BD
Conserved land	29.65 ± 3.44	18.54 ± 0.88	51.79 ± 3.36	10.64 ± 1.73	1.23
Nonconserved land	31.76 ± 4.2	19.88 ± 1.74	47.6 ± 1.36	5.529 ± 1.435	1.37
Overall mean	30.0 ± 3.66	18.2 ± 1.67	51.8 ± 3.26	8.096 ± 3.14	1.3
LSD (0.05)	0.641	0.642	0.175	0.22	
SEM	1.49	0.685	1.326	1.284	
Slope gradient					
Upper (15–30%)	34.27 ± 1.889	18.2 ± 1.621	47.525 ± 1.51	5.25 ± 0.884	
Middle (8–15%)	31.125 ± 2.09	19.5 ± 2.415	49.875 ± 2.26	5.679 ± 0.862	
Lower (3–8%)	26.725 ± 1.56	19.95 ± 1.865	51.725 ± 4.38	6.047 ± 0.732	
LSD (0.05)	0.001	0.467	0.189	0.371	
SEM	1.053	0.567	0.932	0.871	

Note: SMC = soil moisture content; BD = bulky density.

mean value of clay contents of the farm lands was relatively lower in farm lands with SWC structures than in those without SWC structures (Table 1). The farm lands of the study area are mainly dominated by clay contents in conserved lands than that of nonconserved due to large mass of sand and silt mixed with organic matter.

The clay contents of the soil from both micro watersheds relatively increase through slope gradients (from upper to lower). The presence of higher clay fraction in the lower slope might be due to larger deposition of silt and sand mixed with organic matter and then large mass of clay and clay loam that are mainly used for crops growth.

3.1.2. Soil Bulk Density (BD). BD (g cm^{-3}) was affected by the implementation of SWC practices (Table 1). The result of the study indicated that the overall mean of soil bulk density of the study areas covered with SWC practices at effective soil depth (0–20 cm) was lower than that of the areas not treated (nonconserved) with structures. This study is in line with that of Masha et al. [34]. This is due to the presence of high organic matter content in the conserved farm lands [37].

This can be attributed to the presence of relatively higher sand content of the soil at the nonconserved land than in the conserved one, which contributed to the presence higher bulk density of the nonconserved land and the lower bulk density of the conserved land. Similarly, Aşkin and Özdemir [38], and Chaudhari et al. [39] indicated that soil bulk density is significantly influenced by sand content more than other soil properties. Similar results were reported elsewhere, for example, Terefe et al. [40], Husen et al. [41], Mulugeta and Karl [42], and Anshebo [43] reported higher mean value of BD in nonconserved lands than in the conserved farm lands.

The unconserved lands were found to exhibit significantly higher mean value of BD than treated lands at both sites. Lower soil bulk density of 1.23 g cm^{-3} was observed in treated farm lands as compared with nonconserved farm land, which was 1.37 g cm^{-3} (Table 1), which might be due to soil bulk density increase with subsurface compaction and also due to the presence of significantly higher organic matter and moisture availability differences in conserved farms.

The finding of this study in this regard is in agreement with that of Terefe et al. [40], Husen et al. [41], Challa et al. [44], Bezabih et al. [45], and Demelash and Karl [46], who reported that the mean value of bulk density in conserved farm lands with SWC practice was lower than that of nonconserved farm lands mainly because the decomposition of plant biomasses on the conserved field increase organic matter contents, which reduces soil bulk density. Alemayehu and Fisseha [47] also found higher bulk density in untreated farm land than the conserved farm land in Ethiopia. Heuscher et al. [48] described that soil bulk density has inversely proportional relationship with soil organic matter. Land management practices like SWC can accumulate soil organic matter and modify soil properties, such as bulk density, and this innovation have agreement with present study [49]. Low bulk density was observed for conserved crop lands than for nonconserved one [50].

3.1.3. Soil Moisture Content (SMC). Soil moisture contents of the study areas have shown significant ($p < 0.05$) variation between conserved and nonconserved land with SWC structures (Table 1). The highest mean SMC recorded from conserved farm lands with SWC was 10.94, whereas the mean SMC for nonconserved farm lands was 5.87% both from microwatersheds, which may be a result of water conservation structures that reduces runoff and evaporation and increases infiltration and soil moisture content [35, 51].

The overall mean of SMC recorded on conserved areas was 10.64 ± 1.73, whereas it was 5.53 ± 1.43 from nonconserved farm lands, which might be due to slope length shorten by structures that makes barrier to runoff and enhance soil water holding capacity, thereby filling soil pores with moisture within the conserved areas (Table 1).The finding is in line with that of Challa et al. [44] and Terefe et al. [40], who stated that moisture contents of farms land with SWC practices was higher than that of cultivation farms without any conservation structures. The area covered with improved soil bunds have higher infiltration capacity than cultivation fields without bunds due to runoff reduction for decreased slope length and allow longer time for infiltration on conserved areas with bunds in Melka watershed [52]. Therefore, improving infiltration to make rain water available for plant uptake, erosion control, and fertility management practices are necessary [53].

The variation of SMC was not significantly different ($p > 0.05$) in relation to landscape position. The result showed that SMC is higher in the lower slope (3–8%) with a value of 6.047 ± 0.732 followed by middle slope (8–15%) and upper slope position (15–30%) with a value of 5.679 ± 0.862 and 5.25 ± 0.884, respectively (Table 2), because organic matter contents of the study areas increase from upper steep slopes to lower parts of the watersheds. The area having larger organic matter contents has the ability to capture moisture. The results in line with Haweni [50], report in which moisture availability in lower slope is greater than that of upper and middle slopes of untreated farm lands that might be related to accumulation of moisture in the lower which eroded from upper slope. Soil moisture plays a key role in the absorption of nutrients and increase in yield [54].

3.2. Effect of SWC Interventions on Soil Chemical Properties

3.2.1. Soil pH. The mean value of soil pH recorded was significantly different ($p \leq 0.05$) among conserved and nonconserved lands. The maximum and minimum pH values recorded in the study area were 6.735 and 4.265, respectively (Table 2). The mean pH value recorded in conserved areas was 6.33 ± 0.36, and that of nonconserved area was 4.97 ± 0.45 (Table 2), which might be due to more cation ion (hydrogen ions) (H^+) release from nonconserved areas as a result of leaching than that of conserved farm lands. In general, the mean value of soil pH recorded in the cultivation fields was 5.65 ± 0.84. This pH value fall in moderately acidic, which is favorable for the growth of crops according to the soil rating made by Hazelton and Murphy [55] and Tekalign and Haque [56].

This study is in agreement with that of Worku [57], Bezabih et al. [45], and Bezabih [58], who reported that the mean value of soil pH was lower in nonconserved farm land as compared with conserved farms due to leaching of cations in controlled farm lands for the absence of SWC practice used to trap soil and lower ground cover in the farms as compared with the conserved farm lands. This can be explained by the difference in the extent of soil loss between cropland treated with soil conservation structures and those merely cultivated without any means of protection at least to keep the soil in place.

The study revealed that there is no significant difference in pH levels between slope positions at $p \leq 0.05$. This is shown in Table 2, where the mean pH value was lower in the upper slope (15–30%), which was pH 5.25 ± 0.88, in middle slope (8–15%), pH 5.67 ± 0.86, and was higher in the lower slope (3–8%) which was pH 6.05 ± 0.73, which might be attributed to the removal of some organic matters from steep slope and deposition on the lower side. The result of this study is found to be in line with that of Bekele et al. [59], who found that pH value was lower in steep slopes and higher in gentle slopes due to the fact that the high rainfall coupled with steeper slope might have increased leaching, soil erosion, and the reduction of soluble base cations leading to higher H+ activity.

3.2.2. Soil Electric Conductivity (EC). The finding of this study indicated that EC did not show significant variation ($p > 0.05$) both in between the treatment and along the slope gradient, which is in agreement with the report of Worku [57]. The mean value of soil electric conductivity recorded on conserved farm lands was 0.0485 ± 0.015 dS/m, and it was 0.0402 ± 0.005 dS/m in nonconserved farm lands (Table 2). Attributed to the minimization of soil acidity due to the leaching of cations (H^+), the mean value of EC recorded from conserved farm land is relatively greater than the mean recorded value on nonconserved farm lands. Fertile soil with high amount of mineral compounds will have high conductivity, whereas depleted soil with fewer minerals will have lower conductivity, and soil conductivity also depends on types of mineral salts present.

The finding is also in line with that of Gankiso, [60] who reported the mean value of EC recorded from farm land treated with SWC Structures was greater than that of the EC recorded from nonconserved farm lands. However, contradictory to Anania, [52] who reported that the higher electrical conductivity in soil obtained from non-conserved might be due to higher clay content than that of a farm with soil conservation.

Moreover, the mean value of EC increased from upper to lower slope position because soil pH has positive correlation with soil EC. The increases were due to erosion and leaching of soluble salts from the upper slope and accumulation at the downslope land positions [61]. The overall mean value of EC recorded in the study areas was 0.045 ± 0.0073 dS/m so that soil of the selected farm lands is free of salt following Scherer [62] of rated electric conductivity.

3.2.3. Total Nitrogen (TN). The result has shown that TN contents of the soil in both (Jamjam laga batu and Koriso odo guba) selected areas were significantly different ($p \leq 0.01$) with conserved and nonconserved watershed as well as along slope gradients. As depicted in Table 2, the overall mean contents of TN under the conserved land and nonconserved land were measured to be $0.228 \pm 0.091\%$ and $0.154 \pm 0.012\%$, respectively. This is because of the conserved areas were covered with biological structures, such as Acacia spices and *Sesbania sesban*, which were used to conserve the soil. These biological structures, also used as fodder, are known to have nodule on their roots that are useful in the fixation of nitrogen. The higher TN recorded on conserved area was 0.247%, and the lower content of soil nitrogen identified was 0.137% mainly in the upper parts of the watershed areas (Table 2).

This study is in line with other finding [42, 52, 63], who reported that farm land with physical SWC structures have high TN as compared with the nonconserved land. In general, TN content of a soil is directly associated with its SOC content and become lower in continuously and

Table 2: Mean values of selected soil chemical properties.

Land use type	Variables						
	pH	SOM	TN	Av. P	Av. K	EC	OC
Conserved land	6.33 ± 0.36	4.915 ± 0.47	0.228 ± 0.091	6.627 ± 0.77	0.874 ± 0.009	0.0485 ± 0.015	2.789 ± 0.2263
Nonconserved land	4.97 ± 0.45	3.404 ± 0.473	0.154 ± 0.012	4.13 ± 0.3	0.835 ± 0.013	0.0402 ± 0.005	1.974 ± 0.275
Overall mean	5.65 ± 0.84	4.159 ± 0.94	0.191 ± 0.043	5.37 ± 1.47	0.85 ± 0.023	0.045 ± 0.003	2.435 ± 0.5566
LSD (0.05)	0.0205	0.0205	0.003	0.0085	0.0195	0.175	0.014
SEM	0.343	0.384	0.087	0.601	0.0095	0.003	0.227
Slope gradient							
Upper (15–30%)	5.25 ± 0.88	3.8 ± 0.86	0.177 ± 0.039	4.798 ± 1.13	0.84 ± 0.025	0.0384 ± 0.0055	2.272 ± 0.579
Middle (8–15%)	5.67 ± 0.86	4.06 ± 0.99	0.192 ± 0.046	5.49 ± 1.61	0.858 ± 0.23	0.0449 ± 0.006	2.356 ± 0.574
Lower (3–8%)	6.05 ± 0.73	4.61 ± 0.97	0.205 ± 0.044	5.84 ± 1.63	0.864 ± 0.21	0.0499 ± 0.006	2.675 ± 0.564
Overall mean	5.66 ± 0.23	4.16 ± 0.92	0.1913 ± 0.04	5.37 ± 1.41	0.855 ± 0.23	0.045 ± 0.007	2.435 ± 0.548
LSD (0.05)	0.431	0.494	0.675	0.611	0.424	0.068	0.595
SEM	0.238	0.266	0.0118	0.407	0.0066	0.00212	0.158

Note: pH = hydrogen ion concentration; SOM = soil organic matter; TN = total nitrogen; EC = electric conductivity; Av. P = available phosphorous; Av. K = available potassium; SOC = soil organic carbon.

intensively cultivated and highly weathered soils of the humid and subhumid tropics due to leaching and then low SOM content [50, 64]. The result of this study is also in line with the report of Haweni [50] who stated that total nitrogen in conserved lands of Dimma watershed was higher than the total nitrogen content in the corresponding sites without conservation structures and Shafi et al. [65] who reported an increment of total nitrogen in conserved soil of Ezha district.

There was also significant difference in TN ($p \leq 0.01$) in relation to slope. The mean value of TN higher in the lower slope (3–8%) was $0.205 \pm 0.044\%$ followed by middle slope (8–15%) and upper slope position (15–30%) with a value of $0.192 \pm 0.046\%$ and $0.177 \pm 0.039\%$, respectively (Table 2). Following Landon [66], the overall mean contents of the study areas was low ($0.191 \pm 0.043\%$), which need nitrogen recommendation for the areas.

3.2.4. Available Phosphorous (Av. P). The relative higher value of Av. P recorded from conserved farms (Table 2) was 7.481 mg/kg and the lowest value from nonconserved cultivation lands was 4.358 mg/kg. The mean value of Av. P in soil under lands with conservation structures (from both Jamjam and Koriso) was $6.627 \pm .77$ mg/kg, whereas the mean value of Av. P in nonconserved farm lands was 4.13 ± 0.3 mg/kg. This could be due to the accumulation of higher humus and other organic matter contents in conserved farm lands with SWC structures compared with the nonconserved farm lands [57]. The overall mean value of available phosphorous recorded from the farm lands was 5.37 ± 1.47 mg/kg; in that, the available phosphorous in soil of the study areas was low following Barber [67].

The finding is similar to the report made by Worku [57], who reported that the mean Av. P in soil under conserved lands was relatively better than that in the nonconserved farm lands. The results indicated that Av. P was significantly different ($p < 0.05$) with the conserved and nonconserved farm lands. Kediro [68] also reported that the level of Av. P in Sebata central Ethiopia is significantly higher on treated farm land (11.87 ppm) compared with the nonconserved farm lands (6.84 ppm) and its level decreased down the slope.

There was no significant variation shown in soil Av.P across slope position. The recorded result indicated that the mean value of Av. P increased down the slope from steep slope (>30%) to middle (15–30%) and lower (8–15%) slope in both watersheds, which were 4.798 ± 1.13 mg/kg, 5.49 ± 1.61 mg/kg, and 5.84 ± 1.63 mg/kg, respectively (Table 2), which might be due to limited organic matter that make better condition for soil microorganism used to breakdown other fresh organic matter so that phosphorous present in the form of immobility can be changed into plant available forms.

3.2.5. Available Potassium (Av. K). The result of soil Av. K of the study areas was significantly affected ($p < 0.05$) by land management. The mean value of the Av. K was relatively higher in conserved farm lands, which is 0.874 ± 0.009 cmol (+)/kg (341.756 mg/kg), than that of Av. K of nonconserved areas of the farm lands (Table 2). This might be due to excessive rainfall that cause potassium to leach out soils in nonconserved areas with the structures and less surface cover (barriers) that hinders the runoff velocity of rainfall.

The finding is similar to the study of Bekele et al. [59], who reported that the mean value of the Av. P in soil of conserved areas with structures was relatively greater than that of nonconserved farm lands due to the fact that soil conservation practices that were applied on the land have created conducive environment for the progress of the nutrients available in the soil.

The result obtained from laboratory indicated that the mean value of Av. K was not significantly affected ($p > 0.05$) by slope position. The mean value of Av. K recorded with both watersheds of similar slope position from upper (>30%), middle (15–30%), and lower (8–15%) was 0.84 ± 0.025 cmol (+)/kg, 0.858 ± 0.23 cmol (+)/kg, and 0.864 ± 0.21 cmol (+)/kg, respectively (Table 2). The mean value of Av. K relatively increases from upper to lower in the watersheds, this could be due to larger biomass of grass cover present on the lower parts, so that less leaching of potassium and better soil conditions of soil for microorganisms to decompose organic nutrients to available nutrients used plant growth. The available potassium present in the soil of the study area was fallen in high. There was no potassium deficiency in the cultivation field of the farmer's farm lands.

3.2.6. Soil Organic Matter (SOM) and Soil Organic Carbon (SOC). Results of the study indicated that there was significant difference in SOM contents between conserved and nonconserved areas in the watersheds. The higher OM contents recorded from conserved areas were 5.983% and 4.584%, while the lower were 2.930% and 3.204% in Jamjam and Koriso microwatersheds, respectively. The overall mean recorded in conserved areas was $4.915 \pm .47\%$ and $3.404 \pm .473\%$ in nonconserved areas (Table 2). This might be due to loss of larger mass of effective soil depth by erosion from nonconserved farm lands. This finding agrees with the findings of Million [69], who reported that soil organic matter content of the conserved farm land is higher than that of nonconserved farm land.

The recorded SOM in the upper slope (>30%) was $3.8 \pm 0.86\%$, $4.06 \pm 0.99\%$ in the middle (15–30%), and $4.16 \pm 0.97\%$ at the lower part (8–15%), which indicated SOM increased from upper to lower due to greater available soil condition to convert litter and other cover crops to soil. This study is in agreement with Kediro [68] who stated that organic matter content of the soil increased down the slope in conserved and nonconserved areas, suggesting that the accumulation of humus-rich fine particles eroded from upper slopes and levels of increasing OM contents down the slope were higher in the treated fields, suggesting the accumulating of sediments behind the conservation structures. The mean value of SOM was not significantly different across slope position.

The depletion of SOC as a result of soil degradation within intensified agricultural systems can lead to loss of nutrients and soil structure, loss of soil resilience, a loss of soil biodiversity, and disruption of key biotic and abiotic processes necessary for productivity [70]. The mean value of organic carbon (OC) obtained was significantly affected ($p < 0.05$) between conserved and nonconserved cultivation lands. The overall mean of SOC recorded in conserved farms was 2.789 ± 0.2263, whereas that of nonconserved areas was $1.974 \pm 0.275\%$ (Table 2). The mean value of carbon contents of soil in conserved areas was relatively greater than that of soil in nonconserved area, and it might be due to greater land cover by residues as mulching thereby greater carbon sequestration (carbon stock) than that of nonconserved area, where severity of erosion cause land left bare and soil carbon contaminate with air and react and released to environment. The study agree with that of Gebreselassie et al. [71], Wolka et al. [33], and Shafi et al. [65] who reported the presence of higher SOC in the field with different conservation structures.

Generally, different SWC strategies favour the reduction of soil and water losses, reduce slope, and improve soil quality parameters. This has supported with different studies made elsewhere on different SWC measures by different scholars, for example, Keesstra et al., [72], López-Vicente et al [16], and Novara et al, [17].

4. Conclusions

The study was conducted to assess the effects of conservation structures implemented through a watershed management practices approach on selected physicochemical properties of soils by comparing conserved and nonconserved farm lands in the Ejersa Lafo district, West Shewa of Ethiopia. Assessing the effectiveness of SWC practices on physicochemical properties of soil is very important for promoting soil fertility and achieves food security.

The findings showed that the implementation of soil bund structure had brought about significant improvement in some of the selected soil physicochemical properties considered, such as SMC, pH, TN, SOC, SOM, Av. P, and Av. K, than in the adjacent farm land without SWC structures in the same microwatershed. This indicates the positive impacts of watershed management practices in improving the nutrient status, which in turn plays a great role in benefiting the local households and farmers, the local community, and the society at large. Generally, the implementation of soil and water conservation structures is promising in preventing the cultivated land from erosion and improving the fertility of soil, which in turn improve the income and the livelihood communities.

There is a need to conduct further research on analyzing the cost-effectiveness of recommended SWC techniques on soil fertility and crop productivity. There should be a continuous awareness creation method for technically efficient implementation and a follow-up process on the proper maintenance of optimum soil properties improvement.

Abbreviations

Av.K: Available Potassium
Av.P: Available Phosphorus
CEC: Cation exchange capacity
EC: Electrical conductivity
FDG: Focus group discussion
pH: Hydrogen ion concentration
SOC: Soil organic carbon
SOM: Soil organic matter
SWC: Soil and water conservation
TN: Total nitrogen
USEPA: United State Environmental Protection Agency.

Data Availability

Data are obtained upon request to the corresponding author.

Consent

Prior oral informed consent was obtained from the local communities and from all individual participants.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors made a valuable and unreserved contribution as well as read and approved the final article. The authors agreed to submit the manuscript for publication in Environmental Systems Research and approved the manuscript for submission.

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