Hindawi
Applied and Environmental Soil Science
Volume 2023, Article ID 6927071, 7 pages
https://doi.org/10.1155/2023/6927071

Research Article

Effects of Soil and Water Conservation Practices and Slope Gradient on Selected Soil Physicochemical Properties in Ejersa Watershed, Toke Kutaye District, Ethiopia

Negesu Kebede and Alemayehu Negassa

College of Natural and Computational Sciences, Ambo University, Ambo, Ethiopia

Correspondence should be addressed to Alemayehu Negassa; alemngss2@gmail.com

Received 20 January 2023; Revised 31 July 2023; Accepted 25 August 2023; Published 6 September 2023

Academic Editor: Claudio Cocozza

Copyright © 2023 Negesu Kebede and Alemayehu Negassa. 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.

This study was conducted to assess the effects of soil and water conservation practices and slope gradients on selected physicochemical properties of soil at Ejersa Watershed based on a total of 18 composite soil samples collected and analyzed using standard laboratory procedures. The values of pH, electrical conductivity, cation exchangeable capacity, organic carbon, organic matter, total nitrogen, and available phosphorus determined in soil samples collected from conserved and nonconserved plots were 6.4 and 6.16, 40.26 mS/m and 15.12 mS/m, 33.51 meq/100 g and 21.56 meq/100 g, 2.66% and 2.24%, 4.58% and 3.86%, 0.24% and 0.15%, and 29.45 ppm and 17.68 ppm, respectively. Soil pH, electrical conductivity, moisture, total nitrogen, and available phosphorus were significantly different ($p < 0.01$) between treated and untreated plots and among the slope classes. Values of soil organic carbon and organic matter showed significant differences ($p < 0.05$) between land types but not among the slope classes. Soil cation exchange capacity showed significant difference ($p < 0.05$) between land types as well as among the slope classes. Relatively, higher values of many of the physicochemical parameters were recorded in samples collected from the treated land and lower slopes which might be attributed to the deposition effects of the conservation practices and decline in the rate of soil erosion.

1. Introduction

In developing countries such as Ethiopia, many people have settled in the highlands due to favorable agricultural and ecological conditions, resulting in high population densities and resource degradation [1]. In fact, erratic and erosive rainfall, steep terrain, deforestation, inappropriate land use, land fragmentation, overgrazing, and poor management are among the factors contributing to land degradation in Ethiopia [2]. Soil erosion on steep slopes was identified as a major challenge in the highlands of the north and eastern part of Ethiopia [3] and has been escalating related to expanding arable land, high human population, and livestock density [4]. This is an observable environmental issue that has led to diminishing agricultural productivity, food insecurity, and rural poverty [5, 6]. Soil erosion has also been recognized as one of the major factors challenging sustainability of the Ethiopian agriculture [7] and affected two-thirds of the nation's population and mostly linked to the conversion of forest to agricultural land [8].

Recognizing soil erosion as a major environmental and socioeconomic problem especially on the highlands, the Ethiopian government has implemented several interventions including restoration of degraded lands, reforestation, and integrated physical and biological soil and water conservation (SWC) practices [9]. Consequently, large areas are covered with terraces, stone-faced soil bunds, soil bunds, area closures with different grasses, shrubs, and trees planted on protection measures [10]. Nevertheless, despite the extensive concerted efforts made every year through mass mobilization of farmers, little effort has been made to investigate the effectiveness of the soil and water conservation practices in Ethiopia. Thus, this study was conducted to assess the effects of soil and water conservation practices on selected soil physicochemical properties at Ejersa Watershed along the slope gradient.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted at Ejersa Watershed (Figure 1), which is located at 5 km from Guder Town and 137 km west of Addis Ababa, the capital. Geographically, the watershed is located between 8°58″ and 30°5″N latitude and 37°45″ and 6°29″E longitude at an altitude ranging between 1,880 and 3,194 m.a.s.l., with an average annual rainfall (RF) of 1,300 mm and a mean monthly temperature of 20°C. The total land area of the watershed is about 366 hectares out of which about 173 hectares were covered by soil and water conservation measures including soil bund, cutoff drain, gully stabilization, and tree plantations. About 70% of the total area is moderately steep while the remaining 30% is gentle slope with nitisols (48%), vertisols (27%), and cambisols (25%) constituting the major soil types.

The district has a total population of 128,259 individuals and 18,323 households whose livelihood is mainly based on crop production and animal husbandry. The most typically cultivated crops in the area are wheat (*Triticum vulgare*), maize (*Zea mays*), teff (*Eragrostis tef*), fruits and vegetables such as onion (*Allium cepa*), potato (*Solanum tubersum*), and banana (*Musa paradisicum*). Forage trees and grasses such as tree Lucerne (*Chamaecytisus palmensis*), *Sesbania sesban*, leucaena (*Leucaena leucocephala*), elephant grasses (*Pennisetum purpureum* Schumach), and Desho grasses (*Pennisetum pedicellatum*) are growing in the area. The major trees and shrubs grown in the area include *Carissa edulis*, *Phytolacca dodecandra*, *Euphorbia abyssinica*, *Olea africana*, *Croton macrostachyus*, *Rhamnus prinoides*, *Acacia abyssinica*, *Cordia africana*, and *Ficus vasta* [9].

2.2. Data Sources. The study involved both primary and secondary data. The primary data were generated through direct field observation and laboratory analyses of the soil samples collected while secondary data were obtained from relevant documents collected from concerned offices.

2.3. Soil Sampling. The study watershed was divided into three separate slope classes (upper >30%, middle from 15 to 30%, and lower <15%) and a total of 18 composite soil samples (9 from treated and 9 from untreated plots) were taken from January 15 to 25, 2022, during the dry season. Samples were collected from four corners and centers of predefined plots of a land with the conservation practices implemented in 2013 and nonconserved areas of the watershed using a 1.2 m soil auger at a depth of 0–20 cm. For determination of bulk density, undisturbed grab soil samples were collected from the center of each slope class by a core sampler to a height of 6 cm and a diameter of 5 cm. The soil samples collected using auger were later mixed; 1 kg of the samples were bagged separately with appropriate labels and then transported to the Chemistry Department Laboratory at Ambo University for analyses.

2.4. Laboratory Analyses. The soil samples collected were air-dried, crushed with mortar and pestle, well mixed, and screened through 2 mm sieve with grinding and sieving repeated till all aggregate particles were fine enough to pass through 2 mm sieve. For the analysis of total nitrogen and organic carbon, extra sieving of the soil samples was conducted by a 0.5 mm sieve. Soil moisture content was determined by the gravimetric method [11] and calculated using Diop et al.'s [12] formula as follows:

$$\text{Moisture content (wt\%)} = \frac{\text{wet soil weight} - \text{oven dry soil weight}}{\text{oven dry soil weight}} \text{x100}. \quad (1)$$

Soil bulk density (ρ) was determined by the core method [13] and calculated by dividing mass of the oven-dried soil to volume of the sampling core.

$$\text{Bulk density}\left(\frac{g}{\text{cm3}}\right) = \frac{\text{mass of oven} - \text{dried soil sample}}{\text{volume of the sampling core}\left(\pi r^2 h\right)}. \quad (2)$$

Soil pH and electrical conductivity were determined by a 1 : 2.5 (soil : water) ratio using a pH meter [14]. Cation exchange capacity, soil organic carbon, and organic matter were determined by the ammonium acetate method [15], Walkley and Black rapid titration method [15], and multiplying percent of the organic carbon by 1.724, respectively. Total nitrogen was determined following the modified Kjeldahl method [15], while the Olsen extraction method was used to determine available phosphorus as described by Diop et al. [12].

2.5. Statistical Analysis. Significance of the differences in soil physicochemical parameters between the treated and untreated plots was tested using the independent sample Tukey test, while one-way ANOVA was used to compare the parameters among three slope classes. Data analyses were carried out by using the Statistical Package for Social Sciences (SPSS) version 23.

3. Results and Discussion

3.1. Effects on Soil Physical Parameters

3.1.1. Bulk Density. The average value of bulk density (BD) of the soil sample taken from the conserved land (1.16 g/m^3) was lower than that taken from nonconserved land (1.45 g/cm^3) (Table 1). This might be attributed to accumulation of organic matter on the treated land due to the conservation practices and the washing away of the organic matter by the

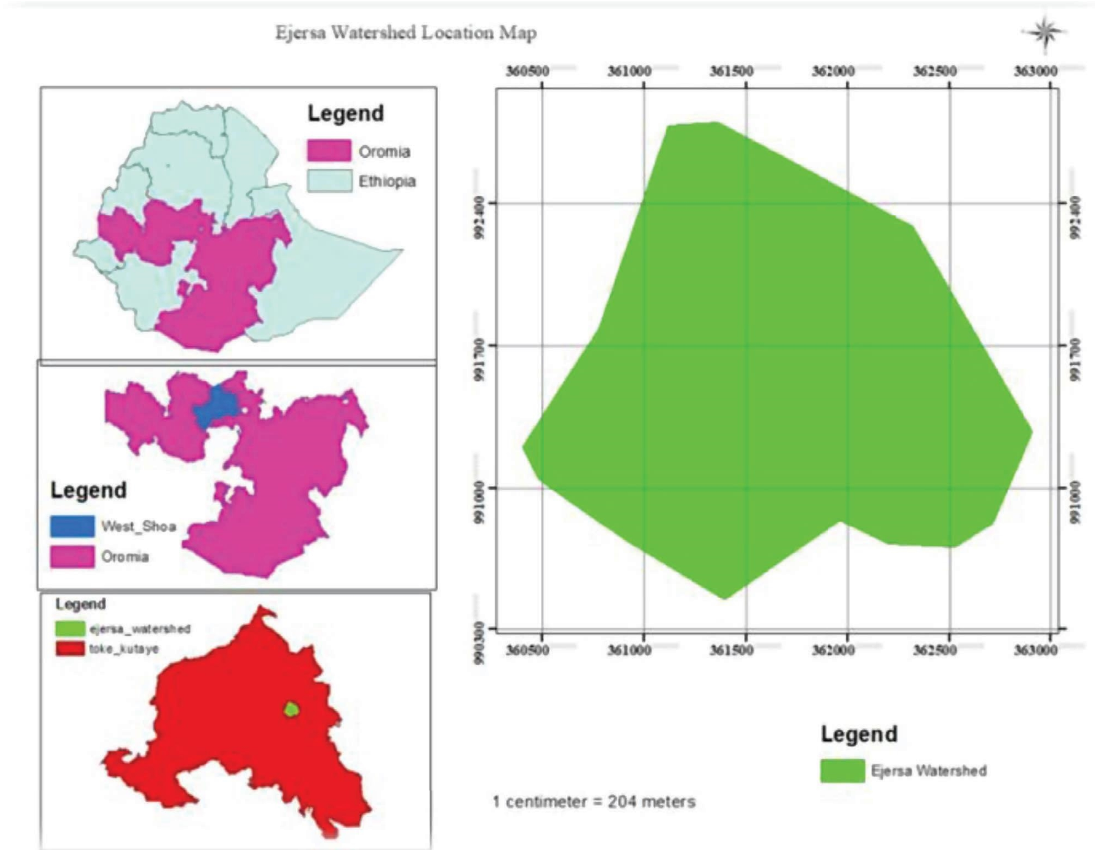

Figure 1: Map of the study area.

Table 1: The soil physical parameters determined.

Treatments	BD (g/cm^3)	MC (%)
Treated	1.16^{a}	8.72^{a}
Untreated	1.45^{b}	4.44^{c}
Treated higher	1.21^{c}	7.07^{a}
Treated medium	1.16^{c}	9.03^{b}
Treated lower	1.13^{c}	10.07^{c}
Overall mean	1.16	8.72
SD	±0.04	±1.32
CV (%)	4	15
Untreated higher	1.62^{b}	3.41^{a}
Untreated medium	1.42^{b}	4.79^{b}
Untreated lower	1.31^{b}	5.11^{c}
Overall mean	1.45	4.44
SD	±0.2	±0.78
CV (%)	14	18
LSD (5%)	0.0756	1.8884

Means within a column indicated by the same letter are not significantly different ($p > 0.05$), while those represented by different letters are significantly different ($p < 0.05$).

process of soil erosion from the nontreated land which clearly indicated the benefits of the conservation measures. The mean value of the soil bulk density was significantly different ($p < 0.01$) between treated and untreated lands which is in line with Tanto and Laekemariam [16]. The mean values of bulk density recorded on higher, middle, and lower slopes of the treated land were 1.21 g/cm^3, 1.16 g/cm^3, and 1.13 g/cm^3, respectively, and the corresponding values for untreated land were 1.62 g/cm^3, 1.42 g/cm^3, and 1.31 g/cm^3 (Table 1). The higher values on upper slopes and the untreated land might be attributed to more severe erosion, which might have washed the organic matter away clearly indicating the positive impact of the treatment. This result was supported with the study by Shafi et al. [17] who reported the highest mean value of BD on the upper slope. Nevertheless, slope gradients did not cause significant difference ($p > 0.05$) in the study watershed.

3.1.2. Soil Moisture Content. The mean value of the percentage of the soil moisture content (MC) determined in samples collected from treated land (8.72%) was higher than that determined in samples collected from the untreated land (4.44%) and is generally low which might be attributed to collecting samples during the dry season (Table 1) which might be attributed to the runoff trapped by the conservation measures and penetrated into the soil, and the values are significantly different ($p < 0.01$). The result is in agreement with the study by Gadana et al. [18] who reported a higher percentage of soil MC from treated land as compared to that from the untreated land. The MC determined from lower, middle, and higher slopes of the treated area was 10.07%, 9.03%, and 7.07%, respectively, and the corresponding values for the untreated land were 5.11%, 4.79%, and 3.41%, respectively (Table 1). The highest MC determined at the lower slope as compared to middle and higher slopes might be attributed to the accumulated crop residue and better soil humus, which is line with the study by Gadana et al. [18]. The values were significantly different ($p < 0.01$) among slope classes both in treated and untreated lands.

3.2. *Effects on Soil Chemical Parameters*

3.2.1. Soil pH. The average soil pH for the untreated land (6.16) was less than that of the treated land (6.40) (Table 2), and the results were significantly different ($p < 0.01$) which might indicate the considerable positive effects of the soil management practices. This finding agrees well with the study by Tolesa et al. [19] who attributed the lower soil pH in the unconserved land to the relatively high release of H^+ from high intensity of leaching and erosion compared with the conserved land. The pH values on the conserved land were 6.25, 6.41, and 6.52 on higher, medium, and lower slopes, respectively (Table 2), and significantly different ($p < 0.05$) among the slope classes. The values of pH in the upper, middle, and lower slopes of the nonconserved land were 6.13, 6.17, and 6.19, respectively (Table 2), and the results were statistically not significantly different ($p > 0.05$). The maximum value recorded under the lower slope could be caused by leaching, erosion by water, and decline in base cations and in line with the study by Bekele et al. [9].

3.2.2. Soil Electrical Conductivity. The result of the analysis indicated a significant difference ($p < 0.01$) in the mean values of soil electrical conductivity (EC) between treated (40.26 mS/m) and untreated (15.12 mS/m) lands (Table 2), which is in agreement with the study by Terefe et al. [20]. The higher value determined in soil samples collected from the treated land could be attributed to the conservation structures that might have increased levels of cations and anions including TN, AvP, exchangeable K, and OC. The treated land demonstrated 35.17 mS/m, 42.00 mS/m, and 43.60 mS/m values of soil EC on higher, medium, and lower slopes, respectively (Table 2), and the increased soil EC in the lower slope might be due to high accumulation of organic matter at lower slopes as compared to the upper and middle slopes and in agreement with the study by Bekele et al. [9]. The mean values of soil EC among the slope classes were significantly different ($p < 0.01$) for the treated land. The mean values of the soil EC for untreated land were 24.83 mS/m, 10.50 mS/m, and 10.02 mS/m in the lower, middle, and upper slopes, respectively (Table 2), and the difference between values of the upper and middle slopes were not statistically significant ($p > 0.05$).

3.2.3. Cation Exchange Capacity. The average cation exchange capacity (CEC) determined in treated land (33.51 meq/100 g) exceeded the amount determined in the untreated land (21.56 meq/100 g) (Table 2), which might be due to the higher organic matter content in the former, and the values are significantly different ($p < 0.05$). The result was supported with the study by Gebraselassie et al. [21] and Guadie et al. [3] that attributed the matter to the difference in management practices. The CEC was also significantly different ($p < 0.05$) among the slope classes both in treated and untreated land. The highest mean CEC (45.67 meq/100 g) was recorded at the lower slope in the treated land (Table 2), which might be attributed to the high amount of organic matter and clay content at the particular slope class and in accordance with the study by Yitbarek et al. [14] and Bufebo et al. [22].

3.2.4. Soil Organic Carbon. The soil organic carbon (OC) content of the conserved soil determined (2.66%) was higher than that of nonconserved soil (2.24%) (Table 2), and the values are significantly different ($p < 0.05$). The lower value for the land with no treatment measures might be due to the unavoidable soil erosion that might have caused loss of organic fraction as land with management practices store runoff water and reduce the loss of soil particles and organic carbon. This finding is in line with the study by Bekele et al. [9], Belayneh et al. [23], Gadana et al. [18], as well as Dagnachew et al. [24]. The average values of soil OC on treated land were 2.73%, 2.70%, and 2.54% on lower, medium, and higher slopes, respectively (Table 2). The corresponding values determined in the samples taken from untreated land were 2.34%, 2.26%, and 2.11%. The reduction of soil OC at the upper slope could be attributed to removal of carbon-rich topsoil from the upper slope to the middle and lower slopes. The result from one-way ANOVA on the values of soil OC revealed that variations among slope classes did not show a significant difference ($p > 0.05$).

3.2.5. Soil Organic Matter. The average value of soil organic matter (OM) determined in treated soil (4.58%) exceeded that from the untreated land (3.86%) (Table 2) and might be attributed to depletion of the productive soil layer in the latter as compared to the former. The result agrees well with the study by Tolesa et al. [19] who reported a relatively higher value of soil OM from the conserved land than that from the nonconserved farm land. The mean values of the soil OM were significantly different ($p < 0.05$) between treated and untreated lands. The highest percentage (4.71%) was obtained from the lower slope, whereas 4.66% and 4.37% were recorded from middle and upper slopes, respectively. This might be attributed to translocation of the organic material from the loss zone to the deposition zone. The result from the one-way ANOVA indicated that soil OM did not show a significant difference ($p > 0.05$) by slope classes.

3.2.6. Total Nitrogen. The level of total nitrogen (TN) determined in treated soil (0.24%) exceeded the amount determined in untreated soil (0.15%) (Table 2) and might be explained by the accumulation of organic matter in the conserved field. The results indicated positive impacts of the soil and water conservation intervention on TN and are

Table 2: The soil chemical parameters determined.

Treatments	Chemical parameters						
	pH	EC (mS/m)	CEC (meq/100 g)	OC (%)	OM (%)	TN (%)	AvP (ppm)
Treated	6.40^{a}	40.26^{a}	33.51^{a}	2.66^{a}	4.58^{a}	0.24^{a}	29.45^{a}
Untreated	6.16^{b}	15.12^{b}	21.56^{b}	2.24^{b}	3.86^{b}	0.15^{b}	17.68^{b}
Treated higher	6.25^{a}	35.17^{a}	25.87^{a}	2.54^{a}	4.37^{b}	0.22^{a}	25.86^{a}
Treated medium	6.41^{b}	42.00^{b}	29.00^{b}	2.70^{a}	4.66^{b}	0.22^{b}	28.18^{b}
Treated lower	6.52^{c}	43.60^{c}	45.67^{c}	2.73^{a}	4.71^{b}	0.24^{c}	34.31^{c}
Overall mean	6.4	40.26	33.51	2.66	4.58	0.24	29.45
SD	±0.12	±3.89	±9.25	±0.23	±0.39	±0.02	±3.84
CV (%)	2	10	28	9	9	9	13
Untreated higher	6.13^{a}	10.02^{a}	17.80^{a}	2.11^{c}	3.64^{a}	0.12^{a}	15.66^{a}
Untreated medium	6.17^{ab}	10.50^{ab}	21.60^{b}	2.26^{c}	3.90^{a}	0.15^{b}	17.98^{bc}
Untreated lower	6.19^{b}	24.83^{c}	25.27^{c}	2.34^{c}	4.04^{a}	0.20^{c}	19.41^{c}
Overall mean	6.16	15.12	21.56	2.24	3.86	0.15	17.68
SD	±0.03	±7.29	±3.26	±0.21	±0.37	±0.03	±1.65
CV (%)	1	48	15	10	10	21	9
LSD (5%)	0.498	0.044	0.451	0.414	0.860	0.551	0.349

Means within a column represented by the same letter are not significantly different ($p > 0.05$), while those represented by dissimilar letters are significantly different.

Table 3: Pearson's correlations of the soil physicochemical parameters determined.

Variable	*r* and *p*	BD	MC	pH	EC	CEC	OC	OM	TN	AvP
BD	*r*	1	-0.931^{**}	-0.840^{*}	-0.942^{**}	−0.780	-0.968^{**}	-0.967^{**}	-0.974^{**}	-0.907^{*}
	p		0.007	0.037	0.005	0.067	0.002	0.002	0.001	0.013
MC	*r*		1	0.974^{**}	0.947^{**}	0.880^{*}	0.988^{**}	0.989^{**}	0.968^{**}	0.985^{**}
	p			0.001	0.004	0.021	0.000	0.000	0.001	0.000
pH	*r*			1	0.888^{*}	0.929^{**}	0.930^{**}	0.933^{**}	0.921^{**}	0.967^{**}
	p				0.018	0.007	0.007	0.007	0.009	0.002
EC	*r*				1	0.794	0.973^{**}	0.972^{**}	0.976^{**}	0.939^{**}
	p					0.060	0.001	0.001	0.001	0.006
CEC	*r*					1	0.824^{*}	0.826^{*}	0.865^{*}	0.921^{**}
	p						0.044	0.043	0.026	0.009
OC	*r*						1	1.000^{**}	0.983^{**}	0.964^{**}
	p							0.000	0.000	0.002
OM	*r*							1	0.984^{**}	0.964^{**}
	p								0.000	0.002
TN	*r*								1	0.954^{**}
	p									0.003
AvP	*r*									1
	p									

significantly different ($p < 0.01$). This finding is in accordance with previous studies such as studies by Shafi et al. [17], Belayneh et al. [23], Alemayehu and Fisseha [25], and Hailu [26]. The average values of TN determined in soil samples collected from treated land were 0.26%, 0.24%, and 0.21% at the lower, middle, and upper slopes, respectively (Table 2), and the corresponding values in the untreated land were 0.19%, 0.15%, and 0.12%. The values were significantly different ($p < 0.01$) among slope classes. The decline in the values with the increasing slope in both treatments might be due to the high rate of erosion on the upper slope and accumulation of organic materials at the bottom portion of the study area, which is in agreement with the study by Tolesa et al. [19] who reported high TN at the lower slope than the upper slope.

3.2.7. Available Phosphorus. The treated soil had a higher value of available phosphorus (AvP) (29.45 ppm) than untreated soil (17.68 ppm) (Table 2), and the results were significantly different ($p < 0.01$) which might be attributed to restoration of organic carbon, changes in soil pH, and external addition of phosphorus by reducing soil erosion and runoff. The result showed that soil AvP was affected by the conservation intervention, which is in agreement with the study by Tanto and Laekemariam [16]. The result from multiple comparisons revealed significant differences ($p < 0.01$) of the average values of soil AvP among the slope classes. The values recorded from the lower, middle, and upper slopes of the treated land were 34.31 ppm, 28.18 ppm, and 25.86 ppm, respectively (Table 2). This is in agreement with Legasse et al. [27] and might be explained by removal of phosphorus from upper slopes. The result is not in agreement with the study by Tellen et al. [28] who reported the highest value from the upper slope.

3.2.8. Correlations of the Soil Physicochemical Parameters Determined. Soil moisture content (MC) showed strong positive correlation with pH, EC, CEC, OC, OM, TN, and AvP (Table 3). Soil pH also had a strong positive correlation with EC, CEC, OC, OM, TN, and AvP. Soil EC was positively correlated with CEC, OC, OM, TN, and AvP. Soil OC had a positive correlation with clay, pH, EC, OM, TN, CEC, and AvP, and TN and AvP also showed strong positive correlation. The positive correlations indicated simultaneous changes (increase or decrease) of the soil physicochemical parameter with the particular parameter in focus. Similar studies conducted in other parts of the country by Demelash and Stahr [29] and Tellen et al. [28] also indicated a strong positive correlation between soil OM and TN which is in agreement with the present finding.

4. Conclusion and Recommendation

Higher values of many of the soil physicochemical parameters were recorded in soil samples collected from the treated land and lower slopes, which might be explained by the deposition effects of the soil and water conservation practices and decline in the rate of soil erosion. Results further revealed that most soil physicochemical properties determined such as bulk density, moisture content, pH, electrical conductivity, cation exchange capacity, organic carbon content, organic matter, total nitrogen and available phosphorus were significantly positively affected by soil and water conservation practices comprising soil bund, cutoff drain, gully stabilization, and tree plantations. The slope gradients also significantly affected all the parameters determined except bulk density, and significant values of fertility indicators were recorded in the treated area of the study watershed. Thus, sustainable integrated watershed management should be widely implemented particularly in erosion prone areas in a more coordinated manner to harness the associated multiple benefits.

Data Availability

All necessary data have been included in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors would like to thank the Ambo University for material support during sample collection and access to use laboratory facilities. The authors also extend their sincere gratitude to other institutions and individuals who contributed to the study in one way or the other. This research did not receive any specific grant but was performed as part of the employment of the authors by Ambo University.

References

[1] N. Haregeweyn, A. Tsunekawa, J. Poesen et al., "Comprehensive assessment of soil erosion risk for better land use planning in river basins: case study of the Upper Blue Nile River," *Science of the Total Environment*, vol. 574, pp. 95–108, 2017.

[2] M. Osman and P. Sauerborn, "Land and water resources management in Ethiopia: what did we learn, where do we go? deutscher tropentag, hohenheim," 2001.

[3] M. Guadie, E. Molla, M. Mekonnen, and A. Cerdà, "Effects of soil bund and stone-faced soil bund on soil physicochemical properties and crop yield under rain-fed conditions of Northwest Ethiopia," *Land*, vol. 9, no. 1, p. 13, 2020.

[4] Daley Ben, "Environmental issues in Ethiopia and links to the Ethiopian economy," *Evidence on Demand*, Department for International Development, Ethiopia, 2015.

[5] O. K. Kirui, "Impact of land degradation on household poverty: evidence from a panel data simultaneous equation model (No. 310-2016-5325)," 2016, https://ageconsearch.umn.edu/record/246396/?ln=enhttps://ageconsearch.umn.edu/record/246396/?ln=en.

[6] T. Gashaw, A. Bantider, and H. G. Silassie, "Land degradation in Ethiopia: causes, impacts and rehabilitation techniques," *Journal of Environment and Earth Science*, vol. 4, pp. 98–104, 2014.

[7] T. Molla and B. Sisheber, "Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia," *Solid Earth*, vol. 8, no. 1, pp. 13–25, 2017.

[8] H. Hurni, B. Debele, and G. Zeleke, "Saving ethiopias soils," in *Eastern and Southern Africa Partnership Programme: Highlights from 15 Years of Joint Action for Sustainable Development*, A. Ehrensperger, C. Ott, and U. Wiesmann, Eds., Centre for Development and Environment, University of Bern with Bern Open Publishing, pp. 27–30,Bern, Switzerland, 2015.

[9] M. Bekele, M. Lemenih, and A. Regassa, "The effects of integrated soil conservation practices on soil physico-chemical properties: the case of Menesibu District, West Ethiopia," *Journal of Natural Sciences Research*, vol. 6, no. 23, pp. 35–45, 2016.

[10] G. Ayana, "Effects of different land use systems on selected physicochemical properties of soils in Northwestern Ethiopia," *Journal of Agricultural Science*, vol. 5, p. 4, 2005.

[11] P. A. Hazelton and B. Murphy, *Interpreting Soil Test Results*, common wealth scientific and industrial research organization publishing, Clayton, Victoria, 2016.

[12] M. Diop, N. Chirinda, A. Beniaich, M. El Gharous, and K. El Mejahed, "Soil and water conservation in africa: state of play and potential role in tackling soil degradation and building soil health in agricultural lands," *Sustainability*, vol. 14, no. 20, Article ID 13425, 29 pages, 2022.

[13] G. R. Black, "Bulk density in methods of soil analysis," *Investigating Land-Use Change on Street Tree Ecosystems*, vol. 4, pp. 374–390, 1965.

[14] T. Yitbarek, H. Gebrekidan, K. Kibret, and S. Beyene, "Impacts of land use on selected physicochemical properties of soils of Abobo area, western Ethiopia," *Agriculture, Forestry and Fisheries*, vol. 2, no. 5, p. 177, 2013.

[15] Haldar and Sakar, *Physical and Chemical Method in Soil Analysis: Fundamental Concepts of Analytical Chemistry and Instrumental Techniques*, New Age International, New Delhi, India, 2005.

[16] T. Tanto and F. Laekemariam, "Impacts of soil and water conservation practices on soil property and wheat productivity in Southern Ethiopia," *Environmental Systems Research*, vol. 8, no. 1, pp. 13–19, 2019.
[17] A. Shafi, A. Chimdi, and T. Yitbarek, "Effects of soil and water conservation practices in selected soil physicochemical properties: the case of Ezha district, Southern Ethiopia," *Journal of Biology, Agriculture and Healthcare*, vol. 9, no. 7, pp. 6–14, 2019.
[18] D. B. Gadana, P. D. Sharma, and D. T. Selfeko, "Effect of soil management practices and slope on soil fertility of cultivated lands in Mawula watershed, Loma district, Southern Ethiopia," *Advances in Agriculture*, vol. 2020, Article ID 8866230, 13 pages, 2020.
[19] A. Tolesa, S. Mammo, and E. Bohnett, "Effects of soil and water conservation structures on selected soil physicochemical properties: the case of ejersa lafo district, central highlands of Ethiopia," *Applied and Environmental soil science*, vol. 2021, Article ID 9910237, 2021.
[20] H. Terefe, M. Argaw, L. Tamene, K. Mekonnen, J. Recha, and D. Solomon, "Effects of sustainable land management interventions on selected soil properties in Geda watershed, central highlands of Ethiopia," *Ecol Process*, vol. 9, no. 1, p. 14, 2020.
[21] Y. Gebraselassie, F. Anemut, and A. Solomon, "The effects of land use types, management practices and slope classes on selected soil physico-chemical properties in Zikre watershed, North-Western Ethiopia," *Environmental Systems Research*, vol. 4, no. 1, pp. 1–7, 2015.
[22] B. Bufebo, E. Elias, and G. Agegnehu, "Effects of landscape positions on soil physicochemical properties at Shenkolla Watershed, South Central Ethiopia," *Environmental Systems Research*, vol. 10, no. 1, pp. 14-15, 2021.
[23] M. Belayneh, T. Yirgu, and D. Tsegaye, "Effects of soil and water conservation practices on soil physicochemical properties in Gumara watershed, Upper Blue Nile Basin, Ethiopia," *Ecological processes*, vol. 8, no. 1, pp. 36–14, 2019.
[24] M. Dagnachew, A. Moges, and A. Kebede, "Effects of soil and water conservation measures on soil quality indicators: the case of Geshy subcatchment, Gojeb River catchment, Ethiopia," *Applied and Environmental Soil Science*, vol. 2020, Article ID 1868792, 16 pages, 2020.
[25] T. Alemayehu and G. Fisseha, "Effects of soil and water conservation practices on selected soil physico-chemical properties in Debre-Yakob Micro Watershed, Northwest Ethiopia," *Ethiopian Journal of Science and Technology*, vol. 11, no. 1, pp. 29–38, 2018.
[26] W. Hailu, "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.
[27] L. B. Asmamaw, A. A. Mohammed, and A. Mohammed Assen, "Effects of slope gradient and changes in land use/cover on selected soil physico-biochemical properties of the Gerado catchment, north-eastern Ethiopia," *International Journal of Environmental Studies*, vol. 70, no. 1, pp. 111–125, 2013.
[28] Tellen, A. Valentine, and P. Yerima Bernard, "Effects of land use change on soil physicochemical properties in selected areas in the North West region of Cameroon," *Environmental systems research*, vol. 7, no. 1, pp. 1–29, 2018.
[29] M. Demelash and K. Stahr, "Assessment of integrated soil and water conservation measures on key soil properties in South Gondar, North Western Highlands of Ethiopia," *Journal of Soil Science and Environmental Management*, vol. 1, no. 7, pp. 164–176, 2010.