Innovations in Agriculture 2023, 6:01-08
www.innovationsagriculture.com

ISSN: 2617-1295
DOI: https://doi.org/10.25081/ia.2023-031

Research Article

Effect of soil and water conservation measures in various slope classes on specified soil physicochemical properties at Libo Kemkem district, Ethiopia

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ARTICLE INFO

Received: September 03, 2023
Revised: October 25, 2023
Accepted: October 28, 2023
Published: October 28, 2023

Keywords:

SWC measures; soil physicochemical properties; split-plot design; slope classes

ABSTRACT

Soil and water conservation activities in erosion hotspot areas of cultivated lands in the Libo Kemkem district have been prioritized. The impact of these treatments on soil physicochemical parameters in different slope classes, however, was not investigated or quantified. This study aimed to look at the effects of soil and water conservation methods on soil properties in farmed regions with various slope gradients throughout the Michael Deber watershed. The experiment was designed as a split plot, with three slope classes as the main plot and four conservation measures as subplots, one of which was reproduced three times. In every plot, composite soil samples were obtained using a sampling auger from 0-20 cm soil depth, air dried, and prepared for evaluation of soil chemical and physical properties using conventional lab techniques. The data was statistically evaluated with R software and utilizing the least significant difference (LSD). Clay, MC, pH, CEC, Ex. p, OC, and Av. P was discovered to be significantly ($p<0.001$) different from slope locations. As a result, the lower slope position produced the most Clay, MC, CEC, Ex. K, OC, and Av. P, whereas the upper slope position produced the least. There was no statistically significant variation in sand, bulk density, or TN with slope position. Soil and water conservation measures had a significant ($p<0.001$) impact on sand and silt, BD, MC, pH, CEC, Ex. K, OC, Av. P, and TN. Thus, non-conserved areas had the greatest sand, BD, and pH values, while vegetation-stabilized bunds had the highest MC, CEC, Ex. p, OC, TN, and Av. P levels, followed by stone-face soil bunds. However, the interaction effects of slope position and SWC measures on soil physicochemical parameters were not significant. Even though slope positions and SWC measures had a significant impact on soil physicochemical properties, the state of soil chemical properties was far below the critical level, and the organic matter base of the soil in the watershed must be enhanced to increase production and productivity of the soil in the study watershed.

INTRODUCTION

Ethiopia is an agrarian nation primarily dependent on rain-fed agriculture for its economic growth. The predominant method of producing livestock in the highlands of Ethiopia is mixed crop-livestock farming. In the mixed farming system, livestock follow crops as the means of livelihood [1]. Since the majority of Ethiopians make their living from agriculture, there has been a rapid and pervasive degradation of the land. Because of this, the majority of Ethiopian farmers believe that one of the most important environmental problems and the main reason for soil nutrient depletion from the top zone of soil is land degradation [2]. For millennia, the Ethiopian highlands have been expanding cultivated land, reducing natural forests and grasslands, and intensifying grazing in fewer regions to support a growing population [3].

Land degradation is a serious environmental issue in Ethiopia, especially in the country's highlands, where it has a negative influence on crop productivity, food security, and the preservation of natural resources [4,5]. The chemical and physical characteristics of soils are impacted by soil erosion. The bulk density, infiltration rate, rooting depth, structure, texture, organic matter content, and water-holding capacity are the main physical parameters. Changes in physical composition have a significant impact on changes in chemical parameters.

Physical conservation structures are intended to minimize runoff and soil erosion in fields when biological control strategies alone are insufficient to reduce soil erosion to a manageable level while also supporting agronomic measures and soil management [6]. The structures' goals are to prevent neighboring lands from flooding, reduce sedimentation of streams, rivers, and waterways, convey runoff at non-erosive velocities, trap sediment and nutrients, and promote the formation of natural terraces over time [7]. They also aim to decrease runoff velocity and water storage, increase land productivity, and provide a variety of ecosystem services.

The threat of erosion is increased by crop nutrient mining, extended farming into sloping areas, decreased fallow systems, decreased vegetative cover, loss of soil organic matter, and improper cropland management. According to the common view, the broad breadth of Ethiopia's farming system, along with environmental crises (erosion, drought, and deforestation), caused a rapid reduction in soil fertility of arable lands throughout Ethiopia [8].

To address land degradation issues in the Amhara region, the regional government has undertaken numerous soil and water conservation measures since 2015, and some structures have been stabilized and well maintained by vegetative methods. Michael Deber is one of the region's watersheds, with most of the territory protected by various soil and water conservation techniques. However, the influence of these conservation strategies on soil chemical and physical qualities has not been examined, and no persuasive data has been generated for practitioners and policymakers. As a result, the purpose of this study was to assess the impact of soil conservation strategies on some selected soil physicochemical attributes along different slope gradients at Michael Deber.

MATERIALS AND METHODS

Description of the study area

The Michael Deber Watershed is in the Libo Kemkem District of the Amhara National Regional State's South Gondar Zone. The watershed lies 12 kilometers northeast of the district's town/city (Libo Kemkem), as well as between 11057’44.6"N-12025’32.6" N and 37 034’4.89"E-3803’30.9" E. The Watershed's total land area is approximately 289.12 hectares.

Topography, Altitude, and Climate

The woreda's principal features are mountainous (21%), rugged terrain (32%), plain (42%), valley (1%), and water (6%). The woreda's elevation ranges from 1800m to 2850m above sea level [9]. The woreda has three major agro-climatic conditions: Woina dega (73% of the total area), Dega (22%), and Qolla (5%). The woreda has an average annual rainfall of 900-1400mm and an average temperature of 18°-25°C [9]. The elevation of the studied watershed ranges from 2210 to 2570 meters above sea level. The district's average annual rainfall is 1228 mm, with mean low and high temperatures of 12.5 and 25°C, respectively [9].

Soil

Brown soil covers the majority of the woreda's territory (60%), followed by reddish (22%), dark (15%), and gray (3%). Forests occupy around 1.2% of the total area of the woreda. Among the most common tree species are eucalyptus, cordial Africana, and acacia [9].

Materials

Soil auger (to collect soil samples), plastic bags (to transport collected soil samples from the field to the lab), tray (to dry soil samples), Core sampler (to collect undisturbed soil samples for bulk density and moisture content measurement), Clinometer/Ranging pole and water level (to measure slopes), Areal Topo map (1:50,000) (to delineate the watershed location map), Global positioning system (GPS) (to measure altitude, longitude, and latitude), and Arc GIS program (to delineate the district and watershed location map).

Methods of data collection

The research was carried out following crop harvest in the 2022/2023 cropping season. In the study region, a preliminary field observation (transect walk) was performed. The survey highlighted characteristics that are likely to cause variability in soil fertility, primarily slope gradient and soil management techniques. The study area was first defined by the slope gradient. Following that, management methods, including soil and water conservation practices in the research region, were considered to identify their influence on soil physical and chemical properties. Generally, similar locations in terms of slope gradient and management approaches were delimited based on field observations.

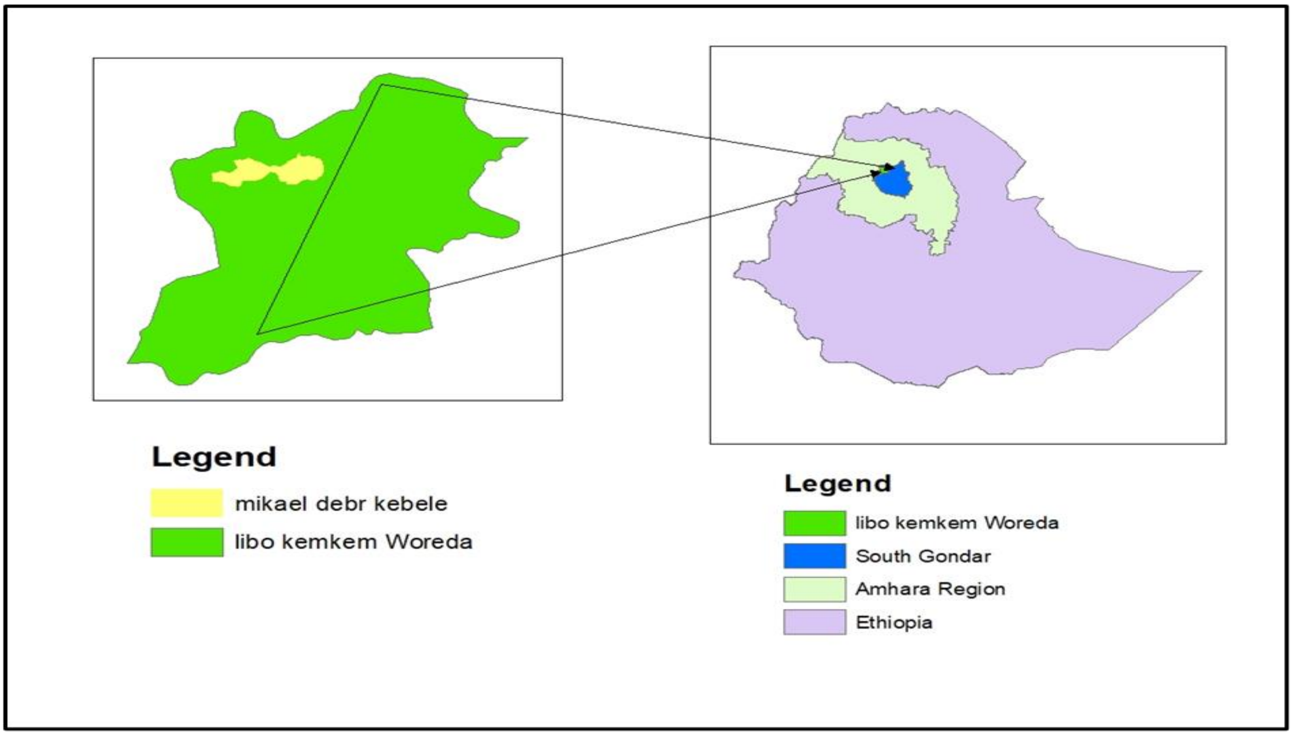

Fig. 1. Location map of the study watershed.

Table 1. Land use types and major crops are grown in the Michael Deber watershed.

S/no	Land use type	Area in(ha)	Area coverage in (%)	Major crops
1	Cultivated land	272.35	79.81	
2	Grazing land	3.5	0.71	
3	Forest land	0.75	0.33	
4	Bushland	0.25	0.15	Teff, Bread wheat, Barley, Maize, Chickpea
5	Settlement	101	18.6	
6	Gully	1.2	0.4	
	Total	379.05	100.00	

Source: [9].

Table 2.Design of field survey.

S/no	Slope category	R1				R2				R3			
1	Upper	SB	SFSB	BSV	C	BSV	C	SFSB	SB	C	BSV	SB	SFSB
2	Medium	SFSB	C	SB	BSV	C	SFSB	BSV	SB	SB	SFSB	BSV	C
3	Lower	BSV	SB	SFSB	C	SFSB	BSV	SB	C	BSV	C	SFSB	SB

Note: C= Control, R= Replication for (1,2 & 3), BSV=Bund Stabilized by Vegetation, SB=Soil bund, SFSB=Soil Faced Stone Bund.

Field research design and arrangement

The experiment was set up in a split-plot design with three slope classes (lower (10%), medium (10-20%), and upper (>20%) as the main plot and four conservation measures (no conservation measure (control (C)), soil bund (SB), stone-faced soil bund. (SFSB), and bund stabilized by vegetation (BSV) as a subplot replicated three times as other researchers have done. There were 36 experimental plots in all for this investigation.

Sampling technique and sampling size

A composite soil sample was taken from each sampling plot (5m*5m) from the four corners and one in the center in an X pattern from 0-20 cm depth and thoroughly mixed, and a one-kilogram sample was stored in a plastic bag, tagged, and transported to a laboratory. Following standard laboratory technique, the samples were air dried, crushed, and sieved with a 2 mm sieve to assess soil texture, accessible phosphorus (Av. P), exchangeable potassium (Ex. K), soil PH, and CEC. TN and SOC were calculated from samples passed through a 0.5mm sieve. Furthermore, representative undisturbed soil samples from each plot were taken using a core sampler, weighed, and oven-dried for 24 hours at 105 C0 to measure bulk density and soil moisture content.

Laboratory analysis

The soil samples were examined for specific soil properties. Day [10] described the Bouyoucous hydrometer method for measuring particle size distribution (soil textures). Total nitrogen (TN) by the Kjeldahl digestion method [11], available phosphorus (Av. P) by the Olsen extraction method [12], exchangeable potassium (Ex. K) by flame photometer and cation exchange capacity (CEC) by ammonium acetate extraction method [11], and soil pH (H_2O-1:2.5) by potesiometric methods [11]. A core sampler (cylindrical metal sampler) to assess bulk density. The gravimetric approach was used to determine the moisture content of the soil at the time of sample [11].

Statistical analysis

The acquired data were statistically analyzed using R software. List Significant Difference (LSD) was used to differentiate the significant means.

RESULTS AND DISCUSSION

Effects of slope gradient, SWC measures, and their interaction on soil physicochemical properties

Effects of slope, SWC, and interaction of slope and SWC on soil physical properties

Soil texture

The sand, clay, and silt textural fractions of the soil varied with slope gradient. The average clay percentage of the lower and intermediate slopes was much higher (61.52%), while the upper slope had a substantially lower clay content (57.07%). The upper slope, on the other hand, had a higher average sand content (21.01%), whereas the lower slope had a lower average sand content (18.19%) (Table 3). Rainfall washing down clay from the top slope and depositing it in the lower slope site could explain the significantly greater sand content on the upper slope and the significantly higher clay content on the lower slope. Our findings are comparable with those of previous investigations. According to Amuyou and Kotingo [13], topo-sequence characteristics in soils produced changes in soil properties. Khan et al. [14] discovered a high concentration of clay at the bottom slope and a higher concentration of sand at the top slope position. Obalum et al. [15] discovered that landforms and slopes influence soil properties and fractions (silt, sand, and clay). SWC techniques had a similar effect on the clay, silt, and sand fractions (Table 4). In terms of soil fraction variation at different SWC approaches, the vegetated bund had the highest average clay content (60.68%, 62.01%, and 58.23%), while the non-conserved or control treatment had the lowest (58.03%). The average silt content of the soil-facing stone bund, bund stabilized by vegetation, and soil bund was the highest (24.43%, 22.24%, and 20.54%), whereas the non-conserved plots had the lowest (19.12%). The vegetation-stabilized bund, soil-facing stone bund, and soil bund had the lowest average sand concentration (16.23%, 20.24%, and 17.78%), while non-conserved plots had the highest (20.67%).

Clay and silt concentrations were significantly affected by slope and SWC measurements ($P<0.05$) (Table 4). The non-conserved plot exhibited the highest mean sand content (21.33%), followed by the soil-facing stone bund (20.66%), and the lowest (17.33%) under the lower slope (Table 4). Furthermore, the soil-faced stone bund exhibited the highest clay content (65.34%), followed by the vegetation-stabilized bund (64.70%) and the soil bund (62.71%) on the lower slope (Table 4). The control had the lowest clay content (53.32%) on the same slope (Table 4). The higher clay content in vegetation-stabilized bunds, soil-faced stone bunds, and lower slope soil bunds may be attributed to the accumulation of suspended materials from uphill in SWC measures and its role in enhancing soil texture. Terracing, according to Chow et al. [16], changes the landscape and influences soil moisture and soil characteristics, which confirms the findings.

Bulk density

Soil bulk density varied significantly with slope gradient (Table 3). The average bulk density was highest on the higher slope (1.22 g/cm^3) and lowest on the lower slope (1.16 g/cm^3). The cause could be ascribed to a decrease in soil organic carbon content as slope gradient/steepness increases, hence exacerbating soil loss.

SWC measurements had a statistically significant ($p<0.001$) effect on soil bulk density (Bd). The vegetation-stabilized bund had the lowest average bulk density (1.16 g/cm^3), followed by the soil-faced stone bund (1.19 g/cm^3) and the soil bund (1.22 g/cm^3). While the bulk density in the non-conserved plots was the highest (1.32 g/cm^3). Similar findings were published by Yihenew et al. [17], who found that soil in non-conserved plots has a higher bulk density than soil in SWC measures. The interplay of slope and SWC measures showed no significant influence on bulk density (Table 3), in contrast to the soil and water conservation measure and slope alone.

Soil moisture content

Table 3 depicts the variation in soil moisture content over a slope gradient. The mean soil moisture content varied substantially along slopes ($P<0.001$). The mean soil moisture content was highest on the lower slope (21.24%) and lowest on the top slope (11.57%). This effect may be due to the enormous amount of clay and organic matter created during the erosion process, which has a substantial impact on soil water retention. Clay soils have a finer texture and a greater capacity to hold water. Easton and Petrovic [18] discovered that soil moisture content was higher at the foot of the hill than at the top of the slope.

Soil moisture, like slope classes, varied significantly ($P<0.001$) among soil and water conservation measures (Table 3). The vegetated bund had the highest SMC (20.29%), followed by the soil-faced stone bund (15.57%), soil bund (14.29%), and non-conserved plots (10.24%) (Table 3). The significant difference in moisture content between conserved and non-conserved plots may be because of soil and water conservation practices, which reduced runoff and stored moisture in the field. Terraces are effective at maintaining optimal pH, OC, moisture content, and CEC, according to Chow et al. [16].

The interaction of SWC measures and slope significantly ($P<0.001$) affected soil moisture content; the highest soil moisture content was recorded from the bund stabilized by vegetation (30.98%), followed by the soil-faced stone bund (22.45%), and soil bund (20.51%), with the lowest from the control (10.92%) in the lower slope (Table 4).

According to the data, SWC significantly enhanced soil moisture content. Soil moisture content was higher in SWC-conserved farm plots compared to non-conserved farm plots, which is an important factor in determining agricultural success in water-stressed locations. This could be because SWC measures result in considerably higher SOM and lower runoff velocity, in contrast to the faster runoff flow down the slope for non-conserved farm plots. Ullah et al. [19] contend that proper management of sloppy fields is required to retain soil moisture and nutrients for crop growth, which would otherwise be depleted due to water erosion.

Effects of soil and water conservation measures, slope, and their interaction on soil chemical properties

Soil reaction (PH)

The change in mean soil PH along the slope gradient was statistically significant ($P< 0.001$). The higher slope had a lower mean soil pH (5.9) than the lower slope (6.72) (Table 5). This could be because rising altitude increases rainfall, which causes increased leaching and a decrease in soluble base cations, resulting in more H+ activity and a decrease in PH. Similar findings were reported by Garcia et al. [20], who concluded that the increase in soil PH at the bottom slope could be ascribed to the buildup of bases eroded from the top slope location. The difference in mean soil pH between soil and water conservation methods was statistically significant ($P<0.001$). The highest soil pH was obtained from the vegetation-stabilized bund (6.8), followed by the soil-faced stone bund (6.3), and the soil bund (6.0), with the lowest obtained from the non-conserved plot (control) (5.8) (Table 5).

The effects of slope and SWC measures on soil pH were not significant ($p<0.05$) (Table 5). Soil pH varied because of the interaction impact of slope and soil and water conservation methods (Table 5). Challa et al. [21] found that the soil pH did not differ significantly between slope-treatment interactions at ($p<0.05$). Tekalign [22] assessed the soil pH of the research region as moderately acidic to moderately alkaline.

Table 3. Effect of slope and SWC measures on soil physical properties.

Slope	Texture (%)			BD (g/cm3)	MC (%)
	Clay	Silt	Sand		
Upper	57.07	21.01	21.02	1.22	11.57
Medium	63.50	20.31	18.62	1.19	12.39
Lower	61.52	24.29	18.19	1.16	21.24
LSD (5%)	5.34	4.35	1.32	0.06	9.55
CV (%)	0.09	0.19	0.19	0.15	0.46
SWC					
BSV	60.68	24.43	16.23	1.02	20.29
SFSB	62.01	22.24	20.24	1.19	15.57
SB	58.23	20.54	17.78	1.25	14.29
C	58.03	19.12	20.67	1.32	10.24
LSD (5%)	4.00	5.34	4.45	0.29	10.04
CV (%)	0.09	0.19	0.19	0.15	0.46
P-value	0.109	0.0018**	0.036*	<0.001***	<0.001***

Note: Texture (T), bulk density (BD), and moisture content (MC), Vegetation-stabilized bund (BSV), stone face soil bund (SFSB), stone bund (SB), and control (C)

Table 4. Effect of SWC and slope on soil physical properties.

Slope	Treatments	Texture			Textural class	BD(g/cm3)	SMC
		Clay	Sand	Silt			
Lower	BSV	64.70	17.00	26.00	Clay soil	1.02	30.98
	C	53.32	21.33	24.70	Clay soil	1.28	10.92
	SB	62.71	17.33	23.32	Clay soil	1.17	20.51
	SFSB	65.34	20.66	23.34	Clay soil	1.09	22.45
Medium	BSV	62.67	16.33	26.66	Clay soil	1.01	13.44
	C	64.67	20.66	15.33	Clay soil	1.34	11.32
	SB	56.66	15.33	19.33	Clay soil	1.270	11.94
	SFSB	62.00	20.00	20.00	Clay soil	1.138	12.82
Upper	BSV	54.67	15.33	20.66	Clay soil	1.00	16.45
	C	56.00	20.00	17.33	Clay soil	1.28	8.48
	SB	55.33	20.66	18.66	Clay soil	1.24	10.36
	SFSB	58.67	20.00	23.33	Clay soil	1.32	11.41
LSD (5%)		6.55	5.81	5.91		0.19	5.03
CV (%)		0.08	0.19	0.19		0.14	0.45
P-value		0.014*	0.738	0.023*		0.322	0.002**

Note: Texture (T), bulk density (BD), Moisture content (MC), Bund stabilized by vegetation (BSV), stone face soil bund (SFSB), Stone bund (SB), Control (C)

Soil total nitrogen and organic carbon

Total nitrogen concentrations varied along the slope gradient (Table 5). The lower slope had a greater TN concentration (0.18%), while the upper slope had a lower content (0.08%) (Table 5). This could be attributed to the removal of organic matter from steep slopes due to soil erosion or leaching. Similarly, the lower slope position had a larger SOC content than the top slope position. SWC measurements, like slope positions, had a highly significant ($p<0.001$) effect on total nitrogen concentration (Table 5). The bund stabilized by vegetation yielded the highest total nitrogen (0.18%), followed by the soil-faced stone bund (0.13%), and the non-conserved area yielded the lowest (0.08%) (Table 5). The total nitrogen content in the vegetation-stabilized bund was 125% higher than in the non-conserved plot, while the total nitrogen content in the vegetation-stabilized bund was 38.5% higher than in the soil-faced stone bund. In response to soil and water conservation measures, the trend in soil organic carbon content was like the trend in total nitrogen content (Table 5). The outcome is consistent with other research studies. According to Miller and Grardiner [23], the mean total nitrogen concentration of terraced sites was higher than that of non-terraced slopes. Quraishi et al. [24] made similar observations. Landon [25] classified tropical soil nitrogen levels as very low if less than 0.1%; low, between 0.1-0.2%; medium, between 0.2-0.5%; high, between 0.5-1%; and very high, greater than 1%. As a result, the total nitrogen of the soils in the current research watershed was classified as extremely low to low. This suggests that the organic matter base of the soil in the watershed should be improved at all levels (conserved and non-conserved plots).

Soil available phosphorus

Slope positions had a substantial ($p<0.01$) influence on soil-accessible phosphorus (Table 5). The lower slope had the highest accessible phosphorus concentration (2.62 ppm), while the upper slope had the lowest (1.91 ppm). The increase in accessible phosphorus on the lower slope could be attributed to the downward migration of nutrients with runoff water from the higher slope and buildup at the lower slope position. The decline of accessible P at the upper slope position may have been hastened by soil erosion. The findings are consistent with those of Yonas Ademe et al. [26], who found that the P content rose from top to bottom. Similarly, SWC measures had a substantial ($p<0.001$) effect on available phosphorus (Table 6). The non-conserved plots had the lowest accessible phosphorus content (1.25 ppm), whereas the bund stabilized by vegetation had the highest (3.41 ppm), followed by stone soil facing stone bund (2.76 ppm) (Table 6).

Even though there was a significant difference in available phosphorus content among the plots under different soil and water conservation measures and slope positions, the available P content in all plots, including the higher amount recorded from the bund stabilized by vegetation, was classified as very low according to the ratings reported by Tisdale et al. [27]. The lower available content from all plots could be attributed to continuous crop removal and transporting out of the crop field, a failure to incorporate organic inputs for competitive uses such as energy sources, construction, and feed sources, and the parent rock's phosphorus content. The lower plant-accessible P may be attributed to natural soil features such as P fixation by iron and aluminum, but the changes between terraces across a slope of the terrain might be linked to variances in organic matter (OM) input [28].

Soil exchangeable potassium

The exchangeable potassium (ex. K) concentration was significantly ($p<0.001$) impacted by slope location (Table 5). The lowest exchangeable K (potassium) was 84.95 from the upper slope location, whereas the maximum was 144.90 from the lower slope position (Table 5). The increase in exchangeable K at the lower slope could be attributed to the downward flow of nutrients with upper slope runoff water and deposition at the lower slope. Soil erosion may have reduced the status of important plant nutrients (K) at the high slope level while increasing its status at the lower slope level. According to Olarieta et al. [29], water has a longer residence period at lower slope positions, causing soluble materials to precipitate down.

Similarly, there was a statistically significant ($P<0.001$) difference in exchangeable K content between plots subjected to various soil and water conservation methods (Table 5). The exchangeable potassium content of non-conserved plots (66.64) was substantially lower than that of soils under bund stabilized by vegetation (151.01), soil-facing stone bund (117.74), and soil bund (88.85) structures (Table 5). Even though there was a considerable difference in available phosphorus content between plots with varied soil and water conservation methods and slope positions. The bund stabilized by vegetation treatments at the lower slope position had the maximum exchangeable potassium content (8.23), while non-conserved plots in the upper slope position had the lowest (Table 6). The exchangeable potassium range in the watershed was 49.96-219.96. According to Berhanu Debele [30], the exchangeable potassium of the soils in the watersheds studied was in the high range.

Soil cation exchange capacity

The slope had a substantial effect on the CEC value ($P<0.001$) (Table 5). It dropped as the slope of the soil increased. The lowest CEC (33.00cmolc kg^{-1}) was obtained from the upper slope position and the maximum CEC (43.88cmolc kg^{-1}) was obtained from the lower slope location (Table 5). This was attributed to the drainage of basic cation through water streams formed from the upper slope to the lower slope, where it collected and may have raised the CEC. SWC measurements, like slope locations, had a substantial ($p<0.001$) effect on CEC (Table 5). The bund stabilized by vegetation had the highest CEC (43.9cmolc kg^{-1}) while the non-conserved plot had the lowest CEC (32.78cmolc kg^{-1}) (Table 5). This could be related to clay minerals and a modest alteration in organic matter.

The effects of slope and SWC measurements on CEC were statistically significant ($P<0.001$). The bund stabilized by vegetation in the lower slope position has the highest CEC (56.98) (Table 6). The non-conserved plot in the upper slope position yielded the lowest CEC (Table 6). According to Chow et al. [16], terraces are effective at maintaining optimum pH, OC, moisture content, and CEC. The CEC of the research site was high, according to Landon [25], and this was backed by Curtis and Courson [31], who noted that the CEC of soil is highly affected by the amount and type of clay, as well as the amount of organic matter contained in the soil.

Soil organic carbon (SOC)

Soil organic carbon was significantly ($p<0.001$) impacted by slope position (Table 5). The lower slope had the highest SOC content (1.87%), followed by the midrange (1.71%), while the top slope had the lowest (1.08%). Table 5 shows that soil organic carbon is negatively related to slope position. This could be due to the organic matter being transported from the upper to the lower slope. Our findings are consistent with those of Yihenew et al. [17], who found increased SOC concentration in the lower slope position. Similarly, SWC measurements significantly influenced soil organic carbon content ($p<0.001$) (Table 5). Soil organic carbon concentration was significantly greater in cultivated land under bunds stabilized by vegetation, followed by land under soil-facing stone bunds, whereas

SOC content was significantly lower in non-conserved areas compared to land under conservation measures.

The findings are consistent with those of Fantaw Yimer et al. [32], who found that terraced sites had higher soil organic carbon content than non-terraced sites with similar slopes. According to Yihenew et al. [17] found significantly lower SOC in non-conserved fields than in fields subjected to various conservation strategies. The impact of slope and soil and water conservation strategies on soil organic carbon concentration was not significant (Table 5). Even though the difference in SOC content in farmed land under different slope positions and SWC measures was highly significant, the SOC content was classified as very low by Landon [25]. This suggests that the organic matter base of the cultivated field needs to be improved to improve soil chemical and physical qualities, consequently enhancing soil health and agricultural production and productivity.

CONCLUSIONS

The experiment confirmed that when compared to non-conserved plots, soil and water conservation techniques improved soil erosion management on steep slopes and had a substantial impact on some soil physical and chemical parameters. Some soil physical and chemical parameters were considerably impacted by slope classes. Unlike soil and water conservation measures and slope classes alone, interaction effects on soil physical and chemical parameters had no meaningful influence.

The findings were conducted in the Michael Deber watershed to assess the impact of soil and water conservation methods. The soils were thoroughly studied and classified according to soil depth. Across the study region, three representative soil depths were uncovered and described. Soil physicochemical parameters were altered by soil conservation techniques. The majority of soil physicochemical parameters were significantly lower in non-conserved land and significantly higher in stone-faced soil bunds stabilized with grass, soil bund, and stone-faced soil bund. The non-conserved watershed, on the other hand, had a greater mean value of soil bulk density than the conserved watershed. Much research has demonstrated that the lower soil bulk density in the preserved watershed may be attributed to the presence of increased soil organic matter because of conservation measures and crop residue degradation. The clay concentration of the preserved watershed is higher than that of the non-conserved watershed.

Soil depth also influences soil physicochemical parameters. The surface soil has the highest level of soil physicochemical attributes, followed by the subsurface soil.

Most soil physicochemical variables were strongly negatively linked with soil bulk densities. Whereas most soil physicochemical properties were significantly positively associated. Soil and water conservation measures were found to have a pronounced positive effect on some selected soil physical and chemical parameters at the Michael Deber watershed. Soil attributes are often better on conserved farms than on non-conserved farmland. Conservation techniques such as grass bund stabilization were discovered to be useful not just for reducing soil erosion but also for maintaining soil fertility such as soil organic matter, total nitrogen, and cation exchange capacity.

RECOMMENDATIONS

- It is critical to integrate physical SWC structures with biological measures because they can stabilize structures and reduce the need for regular maintenance, make bunds productive, and boost soil fertility and ecosystem services.
- More research is needed on integrated SWC measures on steep slopes for farming.
- It is essential to create awareness, scale up the technology, and soil bund with grass at the watershed level.
- More research on the impact of soil and water conservation methods, slope gradient, soil depth, land use, agronomic techniques, and conservation age on soil physical, chemical, and biological characteristics, nitrogen balance, and crop yield is needed in the watershed.
- Government and non-governmental rural development programs and strategies to invest in affordable integrated soil fertility management techniques.

Conflicts of interests

I declare that they have no conflict of interest.

Author Statement

I contributed to the conceptualization of research work and designing of experiments (GTA); Execution of field/lab experiments and data collection (GTA); Analysis of data and interpretation (GTA); Preparation of manuscript (GTA).

Table 5. Effect of slope and SWC measures on soil chemical properties.

Slope	Soc (%)	Ava. P (ppm)	TN (%)	CEC (cmolc kg 1)	PH (1: 2.5 H2O)	SOM (%)	Ex. K(ppm)
Upper	1.08	1.91	0.12	33.00	5.91	1.84	84.95
Medium	1.71	2.62	0.14	34.72	6.17	2.93	88.30
Lower	1.87	2.43	0.13	43.88	6.72	3.21	144.90
LSD (5%)	0.79	0.70	0.02	10.90	0.83	1.36	60
CV (%)	0.39	0.45	0.43	0.19	0.09	0.39	0.46
SWC							
BSV	2.12	3.44	0.18	43.90	6.811	3.64	151.01
SFSB	1.69	2.66	0.13	36.80	6.36	2.92	117.74
SB	1.31	1.95	0.11	35.32	6.007	2.25	88.85
C	1.06	1.18	0.08	32.78	5.87	1.83	66.64
LSD (5%)	1.06	2.26	0.1	11.12	0.94	1.82	84.38
CV (%)	0.4	0.46	0.44	0.19	0.09	0.4	0.46
p-value	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

Note: Soil Organic Carbon (soc), Phosphorus (p), Total Nitrogen (TN), Cation Exchange Capacity (CEC), Soil Reaction (PH), Soil Organic Matter (SOM), and Exchangeable Potassium (EX. K) are the elements found in soil. Vegetation-stabilized bund (BSV), stone face soil bund (SFSB), stone bund (SB), and control (C).

Table 6. Effect of SWC and slope on soil chemical properties.

Slope	Treatment	Soc	AVa. P (ppm)	TN (%)	CEC (cmolc kg -1)	PH (1:.5 H2O)	EX. K(ppm)	SOM (%)
Lower	BSV	2.25	3.41	0.17	56.92	7.44	219.96	3.85
	C	1.41	1.25	0.08	36.97	6.22	89.96	2.40
	SB	1.82	2.31	0.11	40.01	6.33	113.3	3.15
	SFSB	1.97	2.76	0.15	41.53	6.86	156.63	3.41
Medium	BSV	2.61	3.52	0.18	38.64	6.81	116.34	4.44
	C	1.09	1.44	0.12	31.77	5.76	49.94	1.88
	SB	1.23	2.18	0.13	33.74	5.81	83.32	2.13
	SFSB	1.86	3.22	0.16	34.67	6.21	103.31	3.25
Upper	BSV	1.52	3.30	0.20	36.05	6.16	116.62	2.61
	C	0.69	0.80	0.05	29.57	5.62	59.94	1.23
	SB	0.84	1.41	0.08	32.19	5.8	69.94	1.46
	SFSB	1.21	2.05	0.10	34.19	6.01	93.32	2.07
LSD (5%)		3.33	0.07	1.02	27.42	0.46	1.03	3.34
CV (%)		0.19	0.45	0.43	0.47	0.09	0.45	0.19
p-value		0.273	0.872	0.767	<0.001***	0.295	0.146	0.265

Note: Soil organic carbon (soc), phosphorus (p), total nitrogen (TN), cation exchange capacity (CEC), soil response (pH), soil organic matter (SOM), and exchangeable potassium (EX. K), Bund stabilized by vegetation (BSV), stone face soil bund (SFSB), stone bund (SB), and control (C).

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