

Effects of Campaign-Based Soil and Water Conservation Practice on Soil Properties: The Case of Workkamba Watershed, Debark District, North Ethiopia

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ABSTRACT

Land degradation is a serious environmental problem in Ethiopia. To address the problem, soil and water conservation practices were implemented through campaign. This study was conducted at Workkamba watershed Debark district, North Ethiopia to assess the effect of campaign soil and water conservation (SWC) practice on selected soil properties. Composite soil samples from 1.5 meters above the soil bunds, at the center and 1.5 meters below the soil bunds between the two consecutive structures were collected. The soil samples were analyzed following standard laboratory procedures. Results showed bulk density (BD), electrical conductivity (EC), calcium (Ca²⁺), and sodium (Na⁺) were not significantly affected by slope gradient and terrace position and their interaction. But pH was significantly influenced by the interaction effect. Cation exchange capacity (CEC), exchangeable potassium (K⁺), and clay content were significantly changed with both slope gradient and terrace position. Whereas, total nitrogen (TN), available phosphorus (Av-P), and magnesium (Mg²⁺), and soil organic carbon (SOC) were significantly affected with terrace position and slope gradient, respectively. Because of the conservation barrier, most soil properties were better at the bottom terrace position and gentle slope gradient.

1. INTRODUCTION

Land degradation is a loss of natural capital, the value to society of land, water, plant and animal resources and the direct detriment to primary production in the agricultural system and related industries (Hurni et al., 2010; Tesfa and Mekuriaw, 2014). Farming populations have experienced decline in real income due to demographic, economic, social and environmental changes (Esser et al., 2002). Land degradation has also become apparent in many different angles: vegetation becomes increasingly scarce; footpaths grow into gullies and soils become thin and stony. All of these manifestations have negative impacts on the environment (Berry, 2003; Temesgen et al., 2014).

Soil erosion is one of the main causes of land degradation and environmental change that affect the

physical and chemical properties of the soil and its productive potential (Esser et al., 2002). It is the primary and the most generalized problem in nearly all tropical mountain regions including Ethiopia (Nyssen et al., 2009; Demelash and Stahr, 2010). About 350 million (M) hectares or 20 to 25 percent of the total land area of sub-Saharan Africa is estimated to be severely damaged with about 100 million (M) hectares damaged from agricultural use (Zingore et al., 2015). In Ethiopia, loss of arable land is most common everywhere; the top-soil and even part of the sub-soil in some areas has been removed (Esser et al., 2002). In locations with the most intense population density, the area of greatest livestock density and the area of greatest land degradation, recorded measurements of soil loss range from 3.4 to 84.5 tons/ha/year with a mean of 32.0 tons/ha/year (Berry, 2003). Similarly,

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Dagneu et al. (2015) reported that soil erosion affects half of the agricultural land and results in an annual soil loss rate of 1.5 to 2 billion tons. (Amdemariam et al., 2011; Mekonnen and Michael, 2014) also explained that the extent and scale of the problem has dramatically increased. The issue is also critical in the highlands (greater than 1,500 m.a.s.l.) (Gebremedhin and Swinton, 2003; Demelash and Stahr, 2010).

However, considerable efforts have been made by the government of Ethiopia in collaboration with donor organizations since the 1980s. Rehabilitation of degraded environment, minimizing and stopping further degradation and enhancing soil fertility works were done to arrest the problem (Bewket, 2007; Nyssen et al., 2009; Amdihun et al., 2014; Temesgen et al., 2014; Dagneu et al., 2015). Additionally, afforestation and conservation practices; which include physical soil and water conservation structures like stone bund, hill-side terraces, soil bund, fanya juu, and other biological measures have been introduced at massive scale (Amsalu and Graaff, 2007). Despite these efforts, sustainable utilizations were not expected and the success has been uncertain and limited in addressing the problem (Bishaw, 2001; Amsalu and Graaff, 2007; Amdihun et al., 2014; Dagneu et al., 2015), because the emphasis has been on more of construction of mechanical soil and water conservation (SWC) structures and the conservation activities were applied through blanket recommendation, fundamental truth, and top-down approach (Bewket, 2001; Bewket and Sterk, 2002; Bewket, 2007; Mushir and Kedru, 2012; Amare et al., 2014). Blanket approach to conservation intervention could make the measures inconvenient to local conditions and eventually less accepted by technology users (Amsalu and Graaff, 2007). The practice also largely remained delivery oriented in which the farmers were forced to implement conservation measures designed for them by technical experts (Bewket, 2007). Similarly, it is highly claimed that the local farmers were eventually highly ignorant of land management and were not welcomed to judge on the introduced conservation options (Esser et al., 2002; Bewket 2007; Amdihun et al., 2014).

As shown by experiences of the previous works, these blanket and top-down conservation interventions cannot be expected to be effective (Bewket, 2007). In recognition of the truth on the ground, some efforts towards participatory and community-based

watershed management approaches (public campaign) have been made since 2012 (Haregeweyn et al., 2012; Dagneu et al., 2015). Increasing agricultural productivity with double digit trough maintaining the environment and improving natural resource conservation efforts was the main objective of the program (MoFED, 2010). Following the launch of the program the regional bureaus of agriculture, district agricultural offices, including Debark District and other local administrative bodies, mobilized the farmers to help with the construction of soil and water conservation (SWC) measures. Farmers massively and voluntarily implemented soil and water conservation measures on the farm lands at different watershed within an average of 40 to 50 working days (MoFED, 2013). Within a year, greater than 3,000 community watersheds were treated with mechanical and biological conservation techniques. Except food insecure areas, over 15 million peoples participated without any incentives and over 40,000 hectares of land were covered by different soil and water conservation (SWC) measures (Dagneu et al., 2015). However, beyond presenting a monitoring and evaluation report in terms of area coverage, no more meaningful study was conducted on the effect on selected soil properties. Since the practice is campaign-based, evaluating its effect on selected soil physical and chemical properties would be vital for enhancing and improving the conservation effort. Therefore, the objective of this study is intended to evaluate the effects of soil and water conservation (SWC) practice implemented through mass community mobilization on selected soil physico-chemical properties.

2. METHODOLOGY

2.1 Study area description

The study was carried out in Workamba watershed at Debark District North Gondar zone, Amhara national regional state Ethiopia. The study area is located at about 830 km North of Addis Ababa which is the capital city of Ethiopia (Figure 1). The district is geographically situated at 2,712 m to 3,122 m above sea level (m.a.s.l.) and located between latitude of 13°03' to 13.133°N and longitude of 37°54' to 37.900°E. The mean annual maximum and minimum temperatures are 20.7°C and 6.2°C, respectively and the mean annual rainfall varies between 900 and 1,400 mm.

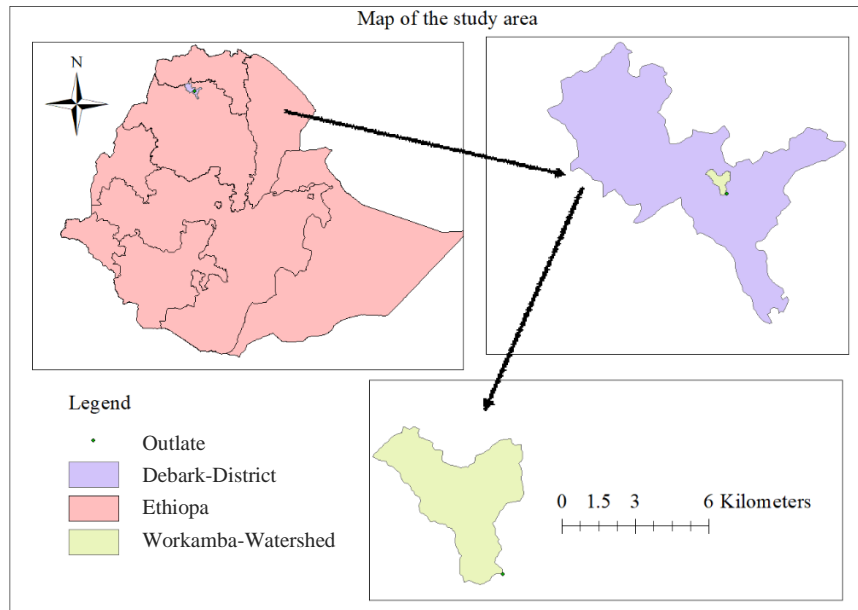


Figure 1. Study area map

The area is mostly mountainous and degraded. Most commonly shallow soil is predominant. The major soils types of the area are Andosols, Cambisols, Vertisols, Luvisols and Lithosols (FAO, 1986; Hurni, 1988). The natural vegetation is almost removed, but in some areas and around the Orthodox Church *Juniperus procera* is sparsely populated. Proportionally, the vegetation coverage of the area dominated by manmade plantation with eucalyptus.

The total human population of the district was estimated to be about 159,193, out of which 80,274 are male and 78,919 are female (CSA, 2007). The major farming systems of the people are subsistence farming practicing mixed crop and livestock agriculture. Among the annual crops, barley (*Hordeum vulgare*), wheat (*Triticum* spp.), fava bean (*Vicia faba*), pea (*Pisum sativum*) and flax (*Linum usitatissimum*) are the most common in the area (Tefera et al., 2014).

2.2 Methods of data collection

Before sampling, a visual field survey of the study area was made to identify appropriate sampling site. Based on the slope gradient, the study watershed was divided in to three slope classes (steep, moderate, and gentle). Composite soil samples were collected from crop lands found in each slope gradient (steep, moderate, and gentle) treated with campaign soil and water conservation practices at nine separate fields up to 20 cm depth using auger. Soil samples from the bottom spot (1.5 meter from the lower soil bunds or above the bunds), center spot (midpoints between the

two successive bunds), and upper spot (1.5 meter from the upper soil bunds or below the soil bunds) between the two consecutive soil and water conservation (SWC) structures were collected following Vancampenhout et al. (2006). A total of 27 composite soil samples 3 (slope class: gentle, moderate and steep) *3(terrace position: bottom spot, center spot or midpoint and upper spot) *3(replications) were collected for laboratory analysis. Additionally, undisturbed soils were collected using core sampler for soil bulk density determination.

2.2.1 Soil laboratory analysis

Soil physical and chemical properties analysis were conducted in the soil laboratory at the Srinka Regional Agricultural Research Institute (SRARI). Soil samples were air-dried, ground and passed through 2 mm sieve for analysis. The particle size distributions (texture) were determined using standard hydrometer methods. The soil bulk density also estimated by using a core sample method, after the soil dried in an oven at 105°C for 24 h.

The pH (pH-H₂O) of the suspension was read using a pH meter. The Total nitrogen (TN) was determined by macro-Kjeldahl digestion-distillation and titration procedures, available phosphorus (Av-P) by using Bray-II extraction method, and exchangeable bases (Ca²⁺, Mg²⁺, K⁺, and Na⁺) determined by ammonium acetate (NH₄OAc) at pH 7.0. Exchangeable Ca²⁺ and Mg²⁺ in the extracts were analyzed using atomic absorption spectrophotometer,

while Na⁺ and K⁺ were analyzed by flame photometer. The cation exchange capacity (CEC) was determined by extraction with ammonium acetate. Electrical conductivity (EC) was determined by EC-meter. Additionally, the soil organic carbon (SOC) was determined by the Walkley-Black oxidation wet digestion and titration method.

2.3 Methods of statistical analysis

The data were subjected to analysis using statistical package for social science (SPSS v.22) software. In order to evaluate the effect of campaign-based soil and water conservation (SWC) practices on selected soil properties, soil physical and chemical properties were subjected to two-way factorial analysis of variance (ANOVA) through the general linear model (GLM). Slope categories and terrace position/sampling spot considered as factor variables and the selected soil properties were dependent variables. Additionally, mean values were compared using Tukey's Honest Significant Difference test (Tukey-Kramer test) at (p<0.05).

3. RESULTS AND DISCUSSION

3.1 Effects of soil and water conservation (SWC) practice on properties of soil

3.1.1 Soil texture

Based on the two-way factorial ANOVA test result (Table 1), the particle size distribution of the soil was not significantly (p>0.05) influenced by the interaction effect of slope gradient by terrace position. However, it was significantly (p<0.05) affected by the slope gradient and terrace position.

The highest percentages of clay (49.770% and 53.611%) (Significance p<0.05) were observed in samples when the slope and terrace position were gentle and at bottom spot, respectively (Table 2). While, the slope and terrace position were steep and upper position, greater (32.278% and 34.639%) percentage of sand content were recorded respectively. The clay content showed an increasing trend as slope gradient decrease while sand content showed a decreasing trend (Aytenew, 2015). Similarly, Guadie et al. (2020) the overall mean of sand fraction was found to be higher in the upper slope and low in the lower slope positions.

Table 1. Interaction effect of slope gradient by terrace position on some physical properties of soil

Sources of variation	SS	Df	MS	F-value
Clay (%)				
Slope	439.014	2	219.507	4.761*
Terrace position	1444.264	2	722.132	15.662*
Slope*Terrace position	303.306	4	75.826	1.645 ^{Ns}
Silt (%)				
Slope	304.222	2	152.111	4.047*
Terrace position	550.125	2	275.062	7.317*
Slope*Terrace position	129.069	4	32.267	0.858 ^{Ns}
Sand (%)				
Slope	204.292	2	102.146	4.751*
Terrace position	527.764	2	263.882	12.274*
Slope*Terrace position	129.736	4	32.434	1.509 ^{Ns}
Bulk density (g/cm³)				
Slope	0.083	2	0.041	0.522 ^{Ns}
Terrace position	0.258	2	0.129	1.624 ^{Ns}
Slope*Terrace position	0.087	4	0.022	0.273 ^{Ns}

^{Ns}=not-significant at p>0.05; (*)=Significant at p<0.05; Slope*Terrace=interaction effect

3.1.2 Soil bulk density (BD)

As shown in (Table 1), soil bulk density analysis was not significantly (p>0.05) varied with either the change in slope gradient and terrace position or their interaction effect. Dagnachew et al. (2020) also determined that bulk density of the soil did not

show any significant variations with slope gradient and positions within the terraces as well as their interaction effects. Nevertheless, the significant different results of this study revealed that higher bulk density (1.663 g/cm³ and 1.729 g/cm³) values were

observed in the steep slope gradient and upper terrace position, respectively (Table 2).

The lower bulk density (1.539 g/cm^3) from gentle slope gradient and (1.491 g/cm^3) bottom spot position is due to the presence of organic materials transported from the steeper slope. As the land slope gradient decreases, the runoff speed also decreases,

causing sediments and organic matter to settle. At the position of lower slope gradient, the presence of significantly greater organic matter evidently reduced the bulk density of the soil (Demelash and Stahr, 2010). Hailu et al. (2012) also reported that soil bulk density has a direct relationship with slope gradient.

Table 2. Some physical properties of soil in relation to slope gradient and terrace position

Soil properties	Slope gradient				Terraced position/sampling spot			
	Steep	Moderate	Gentle	F-value	Upper	Center	Bottom	F-value
Clay (%)	40.972 ^a	41.500 ^a	49.770 ^b	4.760*	35.833 ^a	42.806 ^a	53.611 ^b	15.662*
Silt (%)	26.750 ^a	31.972 ^{ab}	23.861 ^b	4.048*	29.528 ^a	31.778 ^a	21.278 ^b	7.317*
Sand (%)	32.278 ^a	26.528 ^b	26.361 ^b	4.751*	34.639 ^a	25.417 ^b	25.111 ^b	12.274*
Bulk density (g/cm^3)	1.663 ^a	1.649 ^a	1.539 ^a	0.522 ^{Ns}	1.729 ^a	1.631 ^a	1.491 ^a	1.624 ^{Ns}

Ns=not-significant at $p>0.05$; (*)=Significant at $p<0.05$; Rows having the same letters are not statistically significant at 0.05 significance level (Tukey-Kramer)

3.1.3 Soil reaction (pH)

Soil reaction was significantly ($p<0.05$) affected with slope gradient, terrace position and their interaction effect (Table 3). The result of this study is in-contrast with other findings. Vancampenhout et al. (2006) stated that pH values did not vary with respect to terrace position. Amare et al. (2014) also found a non-significant difference in soil pH value between the loss and depositional zone of the two consecutive soil and water conservation structures. Similarly, Challa et al. (2016) reported there was no significant difference in soil pH value between slope gradient. However, the result of this study is in line with a previous study done by Alemayehu and Fisseha (2018) who reported the soil pH significantly varied between slope gradient.

The highest pH (5.902 and 5.959) values were observed at gentle slope and bottom terrace position and the lowest (5.139 and 4.923) at steep and upper spot of the terrace position, respectively (Table 4). In line with this finding, Aytenuw (2015) reported the highest pH (6.8) value was obtained on gently sloping gradient soils. Based on the rating of Landon (1991), the overall mean pH value of the study soil was from 4 to 6, which is categorized as moderately acidic.

3.1.4 Soil electrical conductivity (EC)

According to Brady and Weil (2002), the electrical conductivity (EC) of a soil solution is an indirect measurement of salt content. The overall means of electrical conductivity of the sampled soils were not significantly ($p>0.05$) influenced by slope

gradient and terrace position, and their interaction effect (Table 3).

Even though, the statistical test showed no significant ($p>0.05$) difference, the mean value was slightly changed with slope gradient. Relatively higher electrical conductivity values (0.077 dS/m and 0.072 dS/m) were found at gentle and bottom terrace position. Whereas lower values (0.021 dS/m and 0.022 dS/m) were recorded at steep slope gradient and upper terrace position, respectively (Table 4). The results of this study are somewhat inconsistent with the study of Hailu et al. (2012), that found the electrical conductivity variations of the soil was significant with respect to the slope gradient. Based on Landon (1991) salinity range classification, the soil in the study area could be regarded as salt free.

3.1.5 Soil organic carbon (SOC)

The soil organic carbon contents in Table 3 were significantly ($p<0.05$) affected by the conserved land slope gradient. However, it was not significantly ($p>0.05$) influenced by terrace position and their interaction effect. The organic carbon content under steep slope gradient (1.554%) was significantly lower ($p<0.05$) than gentle (2.957%) and moderate (2.802%) slopes (Table 4). This might be due to accumulation of organic materials that are transported from the higher sloping due to the speed of running water.

The results of this study contradicted with the study conducted by Gadisa and Hailu (2020) who reported there was no significant difference between slope gradient in soil organic carbon content.

However, the result agreed with the finding of [Hailu et al. \(2012\)](#) who observed soil organic carbon content significantly varied with slope gradient. The results of this study are again consistent with [Ayteneu \(2015\)](#)

who found that the minimum soil organic carbon was recorded under soils of the strongly sloping area, whereas the maximum was recorded in soils of the gently sloping area.

Table 3. Interaction effect of slope gradient and terrace position on some chemical properties of soil

Sources of variation	SS	Df	MS	F-value
pH (H₂O)				
Slope	2.728	2	1.364	8.523*
Terrace position	4.893	2	2.446	15.286*
Slope*Terrace position	1.821	4	0.450	2.844*
Electrical conductivity (EC Ds/m)				
Slope	0.015	2	0.077	2.398 ^{Ns}
Terrace position	0.011	2	0.006	1.865 ^{Ns}
Slope*Terrace position	0.77	4	0.002	0.680 ^{Ns}
Soil organic carbon (SOC %)				
Slope	10.637	2	5.318	13.913*
Terrace position	1.434	2	0.717	1.876 ^{Ns}
Slope*Terrace position	0.784	4	0.196	0.513 ^{Ns}
Total nitrogen (TN %)				
Slope	0.380	2	0.190	2.775 ^{Ns}
Terrace position	1.5799	2	0.789	11.5838*
Slope*Terrace position	0.172	4	0.043	0.628 ^{Ns}
Available phosphorus (Av-P mg/kg)				
Slope	2.915	2	1.457	0.268 ^{Ns}
Terrace position	2.915	2	37.589	6.915*
Slope*Terrace position	75.17	4	5.497	1.011 ^{Ns}
Cation exchange capacity (CEC cmol/kg)				
Slope	113.790	2	56.895	4.171*
Terrace position	284.451	2	142.226	10.427*
Slope*Terrace position	24.707	4	6.177	0.453 ^{Ns}

Ns=not-significant at $p>0.05$; (*)=Significant at $p<0.05$; Slope*Terrace=interaction effect

3.1.6 Total nitrogen (TN)

Total nitrogen analysis [Table 3](#) revealed that there was a significant ($p<0.05$) difference between the three terrace positions. On the other hand, there was no significant variation ($p>0.05$) related with the topographic slope of the area. Similar trends were also observed in the interaction effect of slope gradient by terrace position. The result of this study is inconsistent with the result of [Dagnachew et al. \(2020\)](#) who reported total nitrogen was not significantly varied with terrace position, but statistically significant different with slope and the interactions effects.

Significantly ($p<0.05$) higher value (1.097%) of total nitrogen at the bottom spot position and slightly greater mean value (0.890%) at gentle slope gradient were recorded ([Table 4](#)). This indicated total nitrogen

content of the study soil showed decreasing trend towards the steep slope and upper terrace position. According to [Ayteneu \(2015\)](#), an increasing trend in the total nitrogen content of the soil of the study site from moderately steep to gently sloping gradient was observed. Similarly, [Guadie et al. \(2020\)](#) reported the highest total nitrogen was recorded in the lower slope gradient than in the higher slope gradients.

The reason might be due to the transportation of organic material and clay particles that hold some easily transportable plant nutrient inside the inter-structural terrace area. According to [Amdemariam et al. \(2011\)](#), terraced land where soils are actively eroded and deposited to the soil accumulation zone, forming spatial variability in nutrient availability within the inter-terrace space.

3.1.7. Available phosphorus (Av-P)

The available phosphorus of the sampled soils was not significantly varied ($p>0.05$) with respect to slope gradient and interaction effect. However, available phosphorus was significantly influenced ($p<0.05$) by terrace position (Table 3). Significantly greater value (10.321 mg/kg) was observed at the bottom terrace position as compared to upper and midpoint (Table 4). Alemayehu and Fisseha (2018) and Gadisa and Hailu (2020) also stated there were statistically significant differences in available phosphorus with respected to terrace position.

Significant accumulation of phosphorus at the bottom terrace position might be the inherent capacity of phosphorus to adhere with other soil materials and

easily transported by erosion effect and accumulate due to structural barriers of conservation practice. Vancampenhout et al. (2006) also reported higher values of available phosphorus in the accumulation zone was observed due to tillage and water erosion and formation of slow forming terraces.

In terms of slope gradient, slightly greater mean available phosphorus was found at the gentle slope gradient (8.4251 mg/kg) than the steep (7.703 mg/kg) and moderate slope (7.7561 mg/kg). According to the ratings following Olsen (1965), the overall means of available phosphorus was (5-9 mg/kg) which is low concentration in the study soils. This might be due to low availability of phosphorus in the low pH soil.

Table 4. Some chemical properties of soil in relation to slope gradient and terrace position

Soil properties	Slope gradient				Terraced position/sampling spot			
	Steep	Moderate	Gentle	F-value	Upper	Center	Bottom	F-value
pH (H ₂ O)	5.139 ^a	5.388 ^a	5.902 ^b	8.523 [*]	4.923 ^a	5.547 ^b	5.959 ^b	15.286 [*]
EC (Ds/m)	0.021 ^a	0.036 ^a	0.077 ^a	2.398 ^{Ns}	0.022 ^a	0.041 ^a	0.072 ^a	1.865 ^{Ns}
SOC (%)	1.554 ^a	2.802 ^b	2.957 ^b	13.913 [*]	2.191 ^a	2.376 ^a	2.746 ^a	1.876 ^{Ns}
TN (%)	0.605 ^a	0.798 ^a	0.890 ^a	2.775 ^{Ns}	0.529 ^a	0.666 ^a	1.097 ^b	11.533 [*]
Av-P (mg/kg)	7.703 ^a	7.756 ^a	8.425 ^a	0.268 ^{Ns}	6.759 ^a	6.802 ^a	10.321 ^b	6.915 [*]
CEC (cmol/kg)	41.896 ^a	43.828 ^{ab}	46.882 ^b	4.171 [*]	41.600 ^a	42.228 ^a	48.778 ^b	10.427 [*]

Ns=not-significant at $p>0.05$; (*)=Significant at $p<0.05$; Rows having the same letters are not statistically significant at 0.05 significant level (Tukey-Kramer); EC=Electrical conductivity; TN=Total nitrogen; Av-P=Available phosphorus; CEC=Cation Exchange Capacity

3.1.8 Cation exchange capacity of soil (CEC)

According to Table 3, the cation exchange capacity (CEC) of the study soil was significantly ($p<0.05$) affected by both slope gradient and terrace position; but the interaction of the two factors was not statistically significant ($p>0.05$).

Significantly ($p<0.05$) lower CEC values were measured at steep slope (41.896 cmol/kg) and upper terrace position (41.600 cmol/kg) and significantly ($p<0.05$) higher values were measured at gentle slope (46.882 cmol/kg) and bottom terrace position (48.778 cmol/kg) were observed (Table 4). This might be due to the fact that the high rainfall, coupled with a steep slope gradient, accelerates leaching of cations. The same holds true for Aytenuw (2015), which reported an increasing trend of exchangeable basic cations available from moderately steep to gently sloping gradient. This might be due to their loss through runoff erosivity and erosion in the high sloping areas and concentration in areas having lower slope gradient.

3.1.9 Exchangeable bases (K^+ , Na^+ , Ca^{2+} , and Mg^{2+})

The interaction of slope gradient by the terrace position were not significantly ($p>0.05$) affected the K^+ , Na^+ , Ca^{2+} , and Mg^{2+} values of the sampled soil properties. On the other hand, the exchangeable potassium (K^+) significantly ($p<0.05$) altered with both the slope gradient and the terrace position (Table 5). Likewise, exchangeable Mg^{2+} was significantly ($p<0.05$) influenced by terrace position. The results of this study are somewhat consistent with Amare et al. (2014). Regardless of soil depositional variation, the value of exchangeable bases i.e., Na^+ , K^+ , Ca^{2+} , and Mg^{2+} did not show significant change.

The highest mean values of exchangeable potassium (K^+) were measured at the gentle slope land (6.371 cmol/kg) and bottom terrace position (5.662 cmol/kg), and the lowest means were recorded at the steep slope gradient (3.455 cmol/kg) and upper terrace position (4.027 cmol/kg) (Table 6). Similarly,

exchangeable Na⁺ was also slightly higher under gentle slope gradient (4.342 cmol/kg) and bottom terrace position (4.299 cmol/kg) and moderately lower under steep slope (2.378 cmol/kg) and upper terrace position (2.651 cmol/kg).

Considering Table 6, statistically slightly different increments in the mean value of exchangeable magnesium at the gentle slope gradient

(2.305 cmol/kg) was observed as compared to steep (1.559 cmol/kg) and moderate slope (1.132 cmol/kg). Similarly, slightly higher mean values of exchangeable calcium were observed at the gentle slope gradient (7.526 cmol/kg) and bottom terrace position (7.788 cmol/kg) as compared to at the moderate slope (6.4267cmol/kg) and upper terrace position (6.148 cmol/kg).

Table 5. Interaction effect of slope gradient and terrace position on exchangeable bases

Sources of variation	SS	Df	MS	F-value
Ca²⁺ (cmol/kg)				
Slope	5.528	2	2.764	0.951 ^{Ns}
Terrace position	12.163	2	6.082	2.092 ^{Ns}
Slope*Terrace position	7.316	4	1.829	0.629 ^{Ns}
Mg²⁺ (cmol/kg)				
Slope	6.349	2	3.175	2.569 ^{Ns}
Terrace position	12.626	2	6.313	5.108*
Slope*Terrace position	1.758	4	0.440	0.356 ^{Ns}
K⁺ (cmol/kg)				
Slope	38.355	2	19.178	10.866*
Terrace position	12.704	2	6.352	3.599*
Slope*Terrace position	1.717	4	0.429	0.243 ^{Ns}
Na⁺ (cmol/kg)				
Slope	17.420	2	8.710	2.246 ^{Ns}
Terrace position	12.562	2	6.281	1.620 ^{Ns}
Slope*Terrace position	17.638	4	4.409	1.137 ^{Ns}

Ns=not-significant at p>0.05; (*)=Significant at p<0.05; Slope*Terrace=interaction effect

In general, regardless of the significant difference all the exchangeable bases showed increasing trend when the slope and terrace position go towards gentle and bottom (Table 6). The results of this study coincide with Ademe et al. (2017) who found average exchangeable K⁺ values of 5.70, 5.50

and 4.53 ppm from the bottom, middle and upper position of the field, respectively. The overall relative mean concentration of basic cations of the sampled soil was in the order of Ca²⁺>K⁺>Na⁺>Mg²⁺, which is different from the finding of (Miheretu and Yimer, 2018).

Table 6. Exchangeable bases of soil in relation to slope gradient and terrace position

Soil properties	Slope gradient				Terraced position/sampling spot			
	Steep	Moderate	Gentle	F-value	Upper	Center	Bottom	F-value
Ca ²⁺ (cmol/kg)	6.851 ^a	6.4267 ^a	7.526 ^a	0.951 ^{Ns}	6.148 ^a	6.868 ^a	7.788	2.092 ^{Ns}
Mg ²⁺ (cmol/kg)	1.559 ^a	1.132 ^a	2.305 ^a	2.569 ^{Ns}	0.931 ^a	1.488 ^{ab}	2.578 ^b	5.108*
K ⁺ (cmol/kg)	3.455 ^a	5.041 ^b	6.371 ^b	10.866*	4.027 ^a	5.179 ^{ab}	5.662 ^b	3.599*
Na ⁺ (cmol/kg)	2.378 ^a	3.466 ^a	4.342 ^a	2.246 ^{Ns}	2.651 ^a	3.236 ^a	4.299 ^a	1.620 ^{Ns}

Ns=not-significant at p>0.05; (*)=Significant at p<0.05; Rows having the same letters are not statistically significant at 0.05 significance level (Tukey-Kramer)

4. CONCLUSION

Land degradation is one of the major environmental problems that limit the productive capacity of agriculture lands in Ethiopia. Some efforts

towards a campaign for soil and water conservation practice were made to reduce the problem. Since the practices is a campaign, evaluation of its effect on selected soil properties were critical.

Soils analyzed in the study area indicated moderately acidic condition. The soil pH, texture, cation exchange capacity (CEC), and exchangeable potassium (K⁺) were changed with both slope gradient and terrace position, whereas, total nitrogen, available phosphorus, magnesium, and calcium were changed with terrace position. Soil organic carbon significantly varied only with slope gradient. Soil properties were significantly higher at gentle slope gradient and bottom terrace position than the steep and the upper terrace position between the two consecutive soil and water conservation structures. The observed soil property gradient is due to the effect of past soil erosion and inappropriate tillage implementation and conservation barrier. Integration of biological conservation practice, proper maintenance and appropriately following the contour line during tillage practice are important for soil property improvement.

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