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The Effects of Integrated Soil Conservation Practices on Soil Physico-Chemical Properties: The Case of Menesibu District, West Ethiopia

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Abstract

The study was conducted in Ethiopia, in Oromia Regional State, West Wollega Zone, Menesibu district to evaluate the effect of integrated soil conservation practices on soil physical and chemical properties. The land treated by integrated soil conservation practices were compared with land untreated. These were again evaluated across three slope gradients and two soil depths. The slope gradients were; gentle slope (3-10%), moderate slope (10-25%) and steep slope (>25%). The study adopted a Randomized Complete Block Design (RCBD) with split-split plot layout. A total of 36 soil samples were collected from the top 0-20 cm and 20-40cm soil depths, which were replicated three times and the selected physical and chemical properties were analyzed in the laboratory. The results of the study showed that soil bulk density (BD), soil pH, electrical conductivity (EC), soil organic carbon (SOC), total nitrogen (N) available phosphorus and potassium (Av-P &Av-K), cation exchange capacity (CEC) and exchangeable cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) were significantly different ($P < 0.05$), with the land treated by soil conservation practices showing better conditions than the untreated control under the three slope gradients and the two soil depths. No significant difference was observed in terms of soil texture between the conserved and un-conserved lands but there were significant differences among the slope gradient and the soil depths. The carbon to nitrogen ratio (C/N) was also not significantly different between the two land types (conserved and un-conserved land), slope gradients and soil depths.

Keywords: Soil conservation practices, conserved land, un-conserved land, soil physical properties, soil chemical properties

1. Introduction

Ethiopia is one of the most environmentally troubled countries in the Sub- Saharan belt. The principal environmental problem in Ethiopia is land degradation in the form of soil erosion, gully formation, soil fertility loss and severe soil erosion (Hurni, 1993). Even though the vast majority of the population of the country derives its livelihood from agricultural sectors, large parts of the agricultural lands are severely eroded. This is to mean that under conditions of subsistence agriculture, in both the densely populated highlands and sparsely populated lowland areas of the country, survival is solely linked to the exploitation of the left minimum land resources (Mushir and Kedru, 2012).

To reverse the problem soil conservation practices are the decisive tool which enables to maintain the productive potential of the soil. The goal of the practices are to preserve and enhance the physical, chemical and biological property of soil in areas that have different slopes, upland areas, down slope areas, flat areas and bottom lands. It also enhances the moisture conservation capacity of a soil and supports the potential of aquifers to serve farm activities. The conservation practices mitigate the adverse effects of earlier land resource misuse which exposes the soil for maximum degradation. It maintains the fertility status of a soil; where pressure from the high populations is severe and where the destructive consequences of upland soil degradation are being felt in far more densely populated areas found in the downstream (Legese, 2008).

The conservation practices can be approached by looking for symptoms of un-sustainability, such as, loss of the productivity potential of agricultural lands, soil erosion, deforestation, overgrazing, etc. Such symptoms are a result of inappropriate land use practices and unsustainable exploitation of resources (Miguel and Clara, 2005). Therefore the approach enables to integrate land, water and biomass resource conservation. In contrary unwise soil conservation can lead to land resource degradation and a significant reduction in the productivity of a soil through exposing the soil for accelerated erosion. Consequently, the conservation practices address both the processes of soil degradation and indicate the possible solutions to conserve the soil in a sustainable way (World Bank, 2006).

In western Ethiopia, like Menesibu district there is a problem of land degradation due to sever termite infestation that causes the loss of vegetation cover. Also inappropriate agricultural land use practices by farmers on their private landholdings. The practices include, continuous ploughing a parcel of land without adequate fallow periods, absence of biological and physical soil conservation measures on agricultural lands, cultivation of fragile or marginal lands and lack of organic fertilizers (farmyard manure and green manure) use are the major problems on farmlands. In addition extensive grazing by livestock and poor management of grass lands decreases the vegetation cover and exposes the soil for erosion. Also deforestation for agricultural land expansion and harvesting of forests resources for their products are also another factor which have aggravated land degradation in the study area.

The communities’ cultural perceptions and inappropriate way of agricultural land use and management systems, which they inherit from their ancestors, has shaped the way they cultivate their land. Also it had been hindrance to implement the proper and scientific soil conservation practices on their private landholdings. This problem is prominent, due to lack of knowledge of soil fertility degradation among the rural landholders and misunderstanding of the impacts on their livelihood. Since land degradation problem has occurred slowly and cumulatively, it has long lasting impacts and significant effect mainly on the rural people who drive their livelihood from agriculture. The objective of the research is to evaluate the effects of integrated soil conservation practices on selected soil physico-chemical properties taking the case of Menesibu district, West Wollega Zone of Oromia Region as the study site.

2. Materials and Methods

2.1 Description of the Study Area

Menesibu district is located in West Wollega Zone of Oromia National Regional State. The district lies between latitude of $10^{0}07’45”$ to $10^{0}32’50”$N and longitude of $35^{0}59’46”$ to $36^{0}25’17”$E. The district administrative town is known as Mendi. It is 590kms away from the capital city of the country Addis Ababa to the western direction. The total area of the district is 1,668.1km^2. The district is physiographically characterized by Lowland and Midland. The altitude range is lying between 1249m-1933m above sea level. The district has diversified land forms such as Plateaus, Hills, Plains and Valleys. The agro-ecological zone of the district is 70% *Weynadega* and 30% *Kolla*. The annual Rainfall ranges between 900mm-1500mm and the average temperature is 25^{o}C. The study area has a mono-modal rainfall distribution pattern. The crops mainly produced are Maize, Sorghum, Finger millet, Tef, Haricot bean, Coffee, Noug (Niger seed), Sesame etc. The domestic animals mainly raised are cattle, sheep, goat, mule, donkey and poultry. The total human population of the district is 138,506 out of this 70,641 are males and 67,865 are females. The urban dwellers of the district are 15,309 or 11.1% of the total population and the rural dwellers are 123,197 or 88.9% of the total human population in the district (Menesibu District Administration Office, 2013).

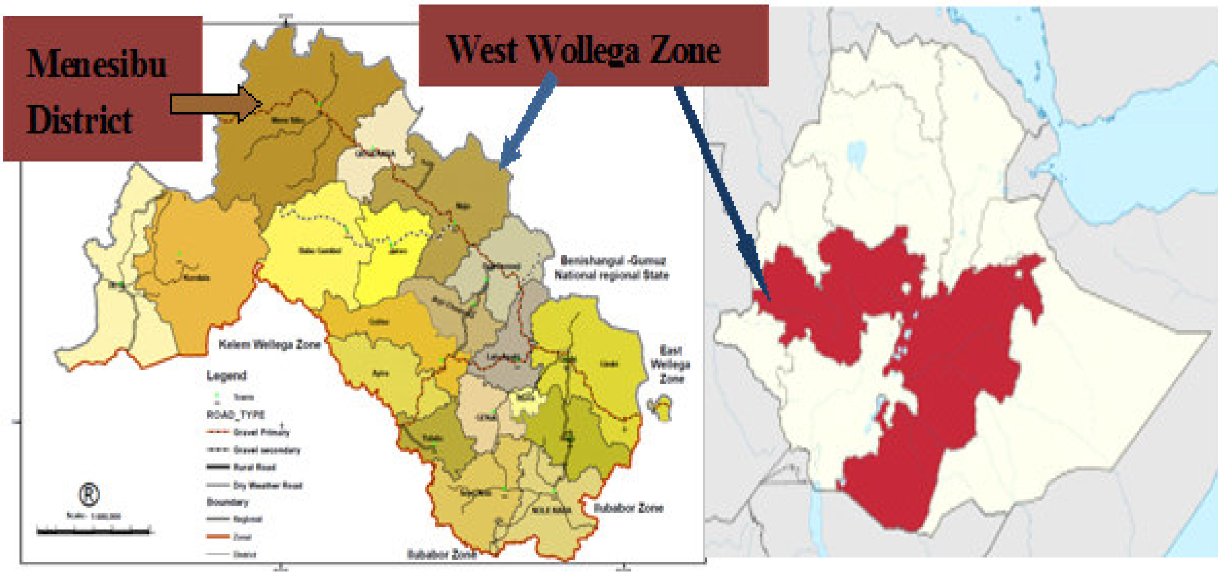

Figure 1: Map of the Study Area
Source: West Wollega Zone Socio-economic Profile of Districts, 2009

2.2 Method of Data Collection

A reconnaissance survey was carried out to select the peasant association (PA) where soil conservation practices were intensively done. A peasant association known as Buke Hena where integrated soil conservation practices were carried out had purposively selected. A sample plot within a sampled PA was selected for their longer age of conservation that was 13 years old. Soil samples were collected both from the land soil conservation practices were carried out and the nearby land without conservation practices which served as a control.

The sampled sites of the conserved and un-conserved land were adjacent to each other to make other factors constant. The soil samples were collected from the top 0-20cm and 20-40cm depth with sharp edged and closed, circular auger pushed manually down the soil profile. The soil samples were collected in a Randomized Complete block Design (RCBD) with split-split plot layout; by using 2 treatments (the land with soil conservation practices and the land with no conservation practices)* 3 slope gradient* 2 soil depths* 3 replications. And the total soil samples collected for the laboratory analysis were 36. The samples were collected in "X" sampling design that is from four corners and center of a plot. And the soil samples were mixed thoroughly to form a composite soil sample. The Collected soil samples were air-dried at room temperature, homogenized and passed through a 2mm sieve before laboratory analysis. Moreover, undisturbed soil samples were taken with a core sampler of height 10cm and diameter 7.2cm for soil bulk density determination. The slope gradient were classified into three slope ranges; gentle slope (3-10%), moderate slope (10-25%) and steep slope (>25%) (Escobedo, 1990).

The selected soil physical and chemical properties were analyzed at Jimma Agricultural Research Center, Jimma University Chemistry laboratory and Jimma University, College of Agriculture and Veterinary Medicine soil science laboratory. Bulk density was determined by Gravimetric method and soil textural class analysis was done by Hydrometric method. Soil pH which was determined by 1:2.5 soil: water suspension, Soil Organic Carbon (SOC) was determined by the Walkley-Black oxidation method, Total Nitrogen (TN) was determined by using the Kjeldahl digestion method, Cation Exchange Capacity (CEC) was determined by extraction with Ammonium acetate method, Available P was determined by using Bray-II extraction method, Available K and Exchangeable Cations (Na^+ and K^+) were determined by Flame photometer, Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrophotometer, Electrical Conductivity (EC) was determined by 1:5 soil: water suspension.

2.3 Method of Data Analysis

Data analysis was carried out; by employing the two types of statistics. The descriptive data parts of the research were analyzed by using descriptive statistics such as mean, percentages and frequency. And the inferential parts of the research were analyzed by using inferential statistics. The Analysis of Variance (ANOVA) was used to test the differences in soil properties due to soil conservation practices with following the General Linear Model (GLM) procedure at $P = 0.05$ level of significance. The least significance difference (LSD) test was used to separate significantly differing treatment means after the main effects were found significant at $P < 0.05$. The conserved land and adjacent un-conserved land which served as a control plot, slope gradients and soil depths were used as independent variables and the soil parameters were used as dependent variables. The Statistical Analysis System (SAS 9.2) software was used to analyze the soil physical and chemical property parameters. In addition, MS-Excel was used to generate tables.

3. RESULTS AND DISCUSSION

3.1.1 Soil texture

Based on the results of soil texture presented in Table 1 the textural fractions of sand, clay and silt showed a significant variation ($p < 0.05$) with the three slope gradients (gentle, moderate and steep). They were also shown a significant difference ($p < 0.01$) between the two soil depths (0-20cm) and (20-40cm). While no significant variations were observed between the two land types. This indicates that the soil texture is the inherent soil property and the position on the landscape (slope gradient) and the soil depths are the factors which cause the variation in soil texture than the soil conservation practices. This agrees with the findings of Ann *et al.* (2005) since soil weathering is a relatively slow process, texture remains fairly constant and is not altered by soil conservation practices. There were no textural class difference between the three slopes and the two soil depths and the textural class was found to be clayey.

The higher mean sand content was (26.34 ± 4.66) when the slope gradient was steep and the lower mean sand content was (18.5 ± 4.22) when the slope gradient was gentle. Based on this result with steep landscapes, transportation and translocation of fine particles are expected. This result also confirms the presence of higher clay fraction in the lower slope gradient due to deposition from the upper slope by flood water. Regina *et al.,* (2004) also reported that on the steep slope the most noticeable changes were a decrease in clay and a corresponding increase in sand and silt fractions as the slope gradient increases. This may be due to the fact that the high mean annual precipitation over the study area may be selectively transported and leached fine soil fractions leaving behind the coarser fraction.

Considering the two soil depths, higher mean sand fraction (25.61 ± 7.30) was observed within the surface soils 0-20cm depth. Opposite to sand, higher clay fraction (54.95 ± 5.84) was found in the subsurface soil 20-40cm depth. Generally, there were significant differences in the soil particle size distribution among the three slope categories and the soil depths. This was also supported by the findings of Gebeyehu (2007) who reported that the sand and silt content decrease while the clay content increases with depth.

Table 1: Soil texture and bulk density analysis result

Land Types	Variables			
	Sand (%)	Silt (%)	Clay (%)	BD (g/cm^3)
Un-conserved Land	22.56 ± 8.25^a	26.28 ± 8.42^a	51.17 ± 5.27^a	1.10 ± 0.043^a
Conserved Land	22.33 ± 3.90^a	26.61 ± 6.18^a	51.05 ± 4.89^a	1.07 ± 0.044^b
LSD (0.05)	**0.778**	**0.924**	**0.618**	**0.005**
SEM	**0.266**	**0.317**	**0.212**	**0.002**
Slope Gradient				
Gentle	18.5 ± 4.22^c	24.17 ± 5.38^c	57.34 ± 2.74^a	1.05 ± 0.032^c
Moderate	22.5 ± 3.27^b	26.17 ± 6.11^b	51.34 ± 3.69^b	1.09 ± 0.032^b
Steep	26.34 ± 4.66^a	29 ± 3.68^a	44.67 ± 3.73^c	1.14 ± 0.024^a
LSD (0.05)	**0.952**	**1.132**	**0.756**	**0.006**
SEM	**0.326**	**0.388**	**0.259**	**0.002**
Soil Depth (cm)				
0 – 20	25.61 ± 7.30^a	27.11 ± 7.48^a	47.28 ± 4.32^b	1.07 ± 0.048^b
20 – 40	19.28 ± 4.85^b	25.78 ± 7.11^b	54.95 ± 5.84^a	1.11 ± 0.034^a
LSD (0.05)	0.778	0.924	0.618	0.005
SEM	0.266	0.317	0.212	0.002
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: - Means within columns followed by different letters are significantly different (p < 0.05) with respect to land types, slope gradients and soil depths

3.2 Soil bulk density

The soil bulk density of the study area was significantly ($p < 0.05$) affected by the soil conservation practices, land slopes and the soil depths. The interaction effects of the three factors ($p = 0.0007$) were also significant for the three factors; which is the surface soil of the conserved gentle slope land has lower mean bulk density value relative to the subsurface soil of un-conserved steep slope land. The conserved land has a lower mean bulk density value (1.07 ± 0.044) than the degraded land (1.10 ± 0.043) as indicated in Table 1. This might be the decomposition of plant biomasses on the field increases organic matter content on the conserved land which in turn decreases the bulk of the soil. The soil bulk density also showed a significant difference ($p < 0.05$) with the slope gradients. The results indicate that soil bulk density has a direct relation with slope gradient which might be attributed to the corresponding decline in soil organic carbon content with the increase in slope gradient/steepness. Li and Lindstrom (2001) also indicated that the bulk density on gentle slope is lower than in the steep or higher slope gradients. There is also a significant difference between the two soil depths in mean bulk density value of the two land types which is (1.07 ± 0.048) for the surface soil and (1.11 ± 0.034) for the subsurface soil.

3.3 Soil pH

The soil pH was significantly ($p < 0.05$) varied within land types, slope gradients and the soil depths. Their interaction effects of the three factors were also ($p = 0.0471$) significantly different; this shows that the surface soil of the conserved gentle slope land has higher mean pH value relative to the subsurface soil of un-conserved steep slope land. The mean soil pH value was (4.67 ± 0.07) in un-conserved land and (5.26 ± 0.09) in conserved land (Table 2). The integrated physical and biological soil conservation practices applied on the conserved land might minimize the loss of basic cations through leaching by flood; this comfortable condition can increase the pH of the soil.

The significant variation was observed between the slopes categories. The mean value of pH was lower in steep slope (4.83 ± 0.059) and higher in gentle slope (5.10 ± 0.05). This could be due to the fact that the high rainfall coupled with steeper slopes might have increased leaching, soil erosion and a reduction in soluble base cations leading to higher H^+ activity (Fantaw, *et al.,* 2006). Chun-chih *et al.* (2004) also indicated that soil in steeper slope had significantly lower pH value than those on the gentle and moderate slope positions due to the accumulation of soluble cations on the level slope. According to Landon (1991) the overall mean pH value of the study site ranges between (5.42 – 4.52); which is categorized in moderately acidic to strongly acidic soil pH class.

Table 2: Soil pH, soil electrical conductivity (EC) analysis result, soil organic carbon (SOC) and cation exchange capacity (CEC)

Land Types	Variables			
	pH (H_2O-1:2.5)	EC (dS/m-1:5)	SOC (%)	CEC (meq/100g soil)
Un-conserved Land	4.67 ± 0.07^{b}	0.031 ± 0.006^{b}	1.93 ± 0.26^{b}	32.22 ± 2.85^{b}
Conserved Land	5.26 ± 0.09^{a}	0.055 ± 0.006^{a}	3.81 ± 0.18^{a}	39.05 ± 3.52^{a}
LSD (0.05)	**0.0097**	**0.0016**	**0.027**	**0.415**
SEM	**0.003**	**0.0006**	**0.009**	**0.142**
Slope Gradient				
Gentle	5.10 ± 0.05^{a}	0.047 ± 0.006^{a}	3.22 ± 0.2^{a}	40.33 ± 2.39^{a}
Moderate	4.96 ± 0.05^{b}	0.043 ± 0.00^{b}	2.90 ± 0.08^{b}	35.65 ± 2.00^{b}
Steep	4.83 ± 0.059^{c}	0.039 ± 0.006^{c}	2.50 ± 0.16^{c}	30.93 ± 1.97^{c}
LSD (0.05)	**0.012**	**0.002**	**0.033**	**0.508**
SEM	**0.004**	**0.0007**	**0.011**	**0.174**
Soil Depth (cm)				
0-20	4.93 ± 0.09^{b}	0.045 ± 0.006^{a}	3.00 ± 0.21^{a}	33.35 ± 2.80^{b}
20-40	5.00 ± 0.07^{a}	0.041 ± 0.006^{b}	2.74 ± 0.24^{b}	36.92 ± 3.56^{a}
LSD (0.05)	0.0097	0.0016	0.027	0.415
SEM	0.003	0.0006	0.009	0.142
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: - Means within columns followed by different letters are significantly different ($p < 0.05$) with respect to land types, slope gradients and soil depths

3.4 Soil electrical conductivity (EC)

Electrical conductivity (EC) of soil solution shows indirect measurement of salt content (Brady and Weil, 2002). The research result showed that there is a significant variation ($p < 0.05$) between mean values of the two treatments the un-conserved land (0.031 ± 0.006) and the conserved land (0.055 ± 0.006). Since pH has positive correlation with EC, relative increasing of soil pH increases the value of EC in soil of the conserved land. The variation between the three slope gradients and the two soil depths were also highly significant ($p < 0.001$). Relatively, higher EC values (0.045 ± 0.006) were recorded in the surface soil than in the subsurface soils (0.041 ± 0.006). In addition to this the interaction effects between the three factors were also highly significant ($p < 0.001$) this is due to the surface soil of the conserved gentle slope land has higher mean electrical conductivity value relative to the subsurface soil of un-conserved steep slope land. According to Landon (1991) salinity classification range, the soil in the study area could be regarded as a non saline.

3.5 Soil organic carbon (SOC)

The soil organic carbon showed a significant variation ($p < 0.05$) with respect to the two land types, the un-conserved and the conserved land. The organic carbon content under the un-conserved land was significantly lower than the content in the conserved land (Table 2). The result agrees with the findings of Million (2003) who reported that soil organic carbon content in soils under the well conserved site were higher compared to the un-conserved sites of similar slopes and depths. Gebresilase *et al*. (2009) also reported that the non-conserved fields had significantly lower SOC as compared to the conserved fields. This might be because of the decomposition of different plant biomasses on the soil of conserved land. The two soil depths have showed a highly significant variation ($p < 0.01$). The mean soil organic carbon content of the surface soil (0-20cm) was (3.00 ± 0.21) and the subsurface soil (20-40) was (2.74 ± 0.24) as indicated in Table 6.

Variations in SOC contents were also significant ($p = 0.0003$) with slope gradient. Higher mean SOC (3.22 ± 0.2) was observed in the gentle slope (3-10%) than in the steep slope gradient >25% (2.50 ± 0.16). The results indicated that soil organic carbon is inversely related with slope gradient (Table 2). This may be due to the organic matter removal (transportation) from the upper slope to the lower gentle slope. Gregorich *et al*. (1998) increasing of soil water content and fertile soil deposition at lower slope position would favor higher crop biomass production and thereby higher SOC content. According to Hao *et al*. (2002) SOC content at higher slope (steep) gradients are normally lowest for different soil depths. The highest SOC contents were found at the lower slope or gentle slope positions for soil of the study area. The mean values of organic carbon content of the conserved land (3.81 ± 0.18) and the un-conserved land (1.93 ± 0.26); according to Barber (1984) both of them are found in the range of very low soil organic carbon content. This might be due to the former sever degradation level of the soils of the study area. The interaction effects of the three factors were also shown a significant variation ($p = 0.047$); which is the surface soil of the conserved gentle slope land has higher soil organic matter content relative to the subsurface soil of un-conserved steep slope land.

3.6 Cation exchange capacity (CEC)

The overall mean of CEC values were statistically significant ($p < 0.05$) with respect to the two land types, slope gradients and the soil depths. The interaction effects of the land types, slope gradient and soil depths were also significant ($p = 0.0143$); that is the surface soil of the conserved gentle slope land has higher mean cation exchange capacity value relative to the subsurface soil of un-conserved steep slope land. The mean CEC value was higher in the conserved land than in un-conserved land (Table 2). Based on the (r = 0.99875) value of Pearson's correlation matrix; soil organic carbon has strong positive correlation with CEC, as organic matter content of the soil increases the CEC of the soil increases. The overall mean CEC (cmolc/kg) value in the study area ranges from (32.22 ± 2.85) to (39.05 ± 3.52) among the land types, from (30.93 ± 1.97) to (40.33 ± 2.39) among the slope gradients and from (33.35 ± 2.80) to (36.92 ± 3.56) among the soil depths. The mean CEC value was lower (30.93 ± 1.97) in steep slope and higher (40.33 ± 2.39) in gentle slope. Following Landon (1991) rating, the soils of the study area have higher CEC value. This might be because of high clay content of the soil in the study area.

3.7 Total nitrogen (TN)

The total nitrogen content of the soil also showed a significant variation ($p < 0.05$) with respect to the two land types. The overall mean total nitrogen content in soils under the un-conserved land was (0.17 ± 0.024); which is significantly lower than the nitrogen content under the conserved land (0.33 ± 0.028) as indicated in (Table 3). Similarly Mulugeta and Karl (2010) also reported that the land treated with different soil conservation measures have high total nitrogen as compared to the un-conserved land.

Gebresilasse *et al.* (2009) also found that the mean total N content of the terraced site were higher as compared to the average total N contents of the corresponding non-terraced sites. This might be; because of the nitrogen fixing tree species planted in the conserved land such as (*Sasbania sesban and Acacia species*) had increased the total nitrogen content of the soil. The variation in total nitrogen was also highly significant ($p < 0.01$) with the slope gradient, higher in the lower slope or gentle slope (0.29 ± 0.022) than in the higher slope or steep slope gradients (0.22 ± 0.018). This might be due to the removal of organic matter (materials) from the higher or steep slopes as a result of soil erosion. The other reason was associated with the absence of incorporation of leguminous plants in the soil conservation practices which have the capacity to fix nitrogen from the air through the nodules of their roots.

The total N content of the soils was also significantly ($p < 0.05$) affected by the soil depth. The mean N content decreased considerably from (0.27 ± 0.034) in the surface soil (0-20cm) to (0.24 ± 0.024) in the subsurface (20-40 cm) soil layers, which revealed a reduction by about (11.11%) compared to its amount in the surface layer (Table 3). And also the interaction effects of the land types, the slope gradients and the soil depths were shown a significant difference ($p = 0.0398$). Following Landon (1991) total nitrogen content rating of the soil, the study area's conserved soil has very high Nitrogen content and the un-conserved soil has medium nitrogen content.

3.8 Carbon to Nitrogen ratio (C/N)

The carbon to nitrogen ratios (C:N) of the soils of the study area were not significantly affected by the conservation practices and the slope gradients ($p > 0.05$). Considering the soil depth, even though there is no statistically significant effects of the soil depth on C:N ratio; slightly higher mean C/N ratio value of (11.58 ± 1.23) was found within the subsoil layer than the surface layer (11.49 ± 0.94) as indicated in (Table 3). Generally, the C/N ratios were relatively small in the surface soil 0-20cm soil depth of the conserved land and the un-conserved land, while there were relatively higher in the subsurface soil layers. This indicates that the rate at which total N decreased with soil depth was much higher than reduction in carbon.

The interaction effect of land types, slope gradients and the soil depths were also statistically not significant ($p > 0.05$); this means the surface soil of the conserved gentle slope land has no mean carbon to nitrogen ratio difference; relative to the subsurface soil of un-conserved steep slope land. This relatively small C/N ratio at the surface soil may be due to higher microbial activity and more CO_2 evolution and its loss to the atmosphere in the surface (0-20 cm) soil layer than in the subsurface (20-40 cm) soil layer. Based on Landon (1991) rating of carbon to nitrogen ratio, <10 is good and 10-14 is medium, >14 is poor. Therefore the soil of the study area is categorized in the medium level carbon to nitrogen ratio.

Table 3: Total nitrogen (TN), carbon to nitrogen ratio (C/N), available phosphorus (Av-P) and available potassium (Av-K) analysis result

	Variables			
Land Types	TN (%)	C/N	Av-P (mg/kg)	Av-K (mg/kg)
Un-conserved Land	0.17 ± 0.024^{b}	11.55 ± 1.53^{a}	8.07 ± 2.28^{b}	104.57 ± 18.29^{b}
Conserved Land	0.33 ± 0.028^{a}	11.51 ± 0.73^{a}	12.12 ± 6.00^{a}	177.52 ± 43.40^{a}
LSD (0.05)	**0.004**	**0.146**	**0.541**	**3.913**
SEM	**0.001**	**0.05**	**0.185**	**1.34**
Slope Gradient				
Gentle	0.29 ± 0.022^{a}	11.52 ± 0.76^{a}	10.63 ± 2.74^{a}	145.82 ± 17.25^{a}
Moderate	0.26 ± 0.012^{b}	11.55 ± 0.67^{a}	9.79 ± 2.69^{c}	138.25 ± 21.50^{b}
Steep	0.22 ± 0.018^{c}	11.5 ± 0.84^{a}	9.89 ± 2.86^{b}	139.10 ± 22.94^{c}
LSD (0.05)	**0.004**	**0.179**	**0.663**	**4.793**
SEM	**0.002**	**0.061**	**0.227**	**0.011**
Soil Depth (cm)				
0-20cm	0.27 ± 0.034^{a}	11.49 ± 0.94^{a}	9.63 ± 5.16^{b}	137.52 ± 36.73^{b}
20-40cm	0.24 ± 0.024^{b}	11.58 ± 1.23^{a}	10.57 ± 3.14^{a}	144.59 ± 24.96^{a}
LSD (0.05)	0.004	0.146	0.541	3.913
SEM	0.001	0.05	0.185	1.34
p-value	< 0.0001	0.6022	< 0.0001	< 0.0001

Note: - Means within columns followed by different letters are significantly different ($p < 0.05$) with respect to land types, slope gradients and soil depths

3.9 Available phosphorus (Av-P)

The research results showed that available phosphorous were significantly varied ($p < 0.05$) within the land types, slope gradients and the soil depths. The mean values of Av-P for the un-conserved land were (8.07 ± 2.28) and for the conserved land were (12.12 ± 6.00); this showed that there is a high significant variation between the land types (Table 3). The mean value of Av-P in soil under conserved lands was relatively higher than in the non-conserved lands. This could probably be due to higher organic matter content in the conserved plots than in the non-conserved ones. This agrees with the findings of Worku *et al*. (2012) who stated that Av-K and Av-P concentrations in farm plots with soil conservation structures were found to be significantly higher than in the adjacent non-conserved farm plots. According to the ratings of available P by Barber (1984), there was medium to low concentration of available P in the soils of the study area. This might be because of low availability of phosphorus in acidic soil, since both the pH of the conserved as well as the un-conserved land were low and found in the range of acidic soil.

The mean values of available phosphorus for the gentle slope were (10.63 ± 2.74), for the moderate slope was (9.79 ± 2.69) and for the steep slope were (9.89 ± 2.86). Due to this, there is a significant variation among the slope gradients. The mean value of Av-P for the two soil depths were (9.63 ± 5.16) in the surface soil (0-20cm) and (10.57 ± 3.14) in the subsurface soil (20-40); based on this result there is also a significant variation between the two soil depths. Generally, variations in available P contents in soils are related with the intensity of soil weathering and the degree of P- absorption with Fe and Ca as indicated by Paulos (1996). The interaction effects of the three factors land types, slope gradients and the soil depths were shown a significant variation ($p = 0.0125$); which is the surface soil of the conserved gentle slope land has higher mean available phosphorus value relative to the subsurface soil of un-conserved steep slope land.

3.10 Available potassium (Av-K)

Like phosphorus available potassium (Av-K) of the study area's soil was significantly affected by the land types, the slope gradients and the soil depths ($p < 0.05$). The mean value of the available potassium for the un-conserved land was (104.57 ± 18.29) and for the conserved land was (177.52 ± 43.40) as indicated in (Table 3). This shows that there is a significant difference in potassium content between the two land types. Relative to the un-conserved land the conserved one has higher potassium content; this is due to the fact that soil conservation practices which were applied on the land have created conducive environment for the progress of the nutrient availability in the soil. The mean value of available potassium in the lands was higher in gentle slope

(145.82 ± 17.25) and lower in the moderate slope which was (138.25 ± 21.50). This is due to the minimum loss of soil nutrients on the gentle slope and high susceptibility of nutrient losses from the soil of steep slope areas by flood water erosion in the study area.

The depths of the soil also indicated a higher mean value in subsurface soil (144.59 ± 24.96) and lower mean value in surface soil (137.52 ± 36.73). Like that of phosphorus the available potassium content of the study area's soil was increasing down wards in the soil depth. The interaction effects of the three factors were also shown a significant variation ($p = 0.0082$). The interaction effects of land with slope was highly significant ($p < 0.0001$), the interaction effect of land with depth was significant ($p = 0.0464$) and the interaction effects of slope with depth was also significant ($p = 0.0063$); this indicates that the surface soil of the conserved gentle slope land has higher mean available phosphorous value relative to the subsurface soil of un-conserved steep slope land.

3.11 Exchangeable sodium (Na^+)

Based on the conducted research in the study area the content of exchangeable Na^+ was significantly affected by the soil conservation practices, the slope gradients and the soil depths ($p < 0.05$) as indicated in (Tables 4). Considering the main effects of land types, exchangeable Na content was highest (1.27 ± 0.19) under the conserved land and lowest (1.08 ± 0.25) in the un-conserved land. Similarly, the highest mean value of exchangeable Na^+ contents were (1.33 ± 0.16) in gentle slope and the lowest (1.01 ± 0.14) were in steep slope. The higher mean value (1.23 ± 0.20) was also recorded at the surface soil layer of (0-20cm) depth and lower (1.12 ± 0.24) is at the subsurface layer (20-40cm) as indicated on (Table 4).

The interaction of the three factors the land types, the slope gradients and the soil depths were shown a significant difference ($p \leq 0.05$); which is the surface soil of the conserved gentle slope land has higher mean exchangeable sodium content relative to the subsurface soil of un-conserved steep slope land. Gebeyehu (2007) reported that, deforestation, leaching, limited recycling of dung and crop residue in the soil, declining of fallow periods or continuous cropping and soil erosion have contributed to the depletion of basic cations (Na^+, K^+, Ca^+, Mg^+) and CEC on the un-conserved agricultural lands as compared to the adjacent forest land.

3.12 Exchangeable potassium (K^+)

Exchangeable K^+ content of the soil was also significantly ($p < 0.01$) affected by the conservation of the lands, the slope gradients and the soil depths (Tables 4). It was highest (1.22 ± 0.17) in the conserved land and lowest (0.96 ± 0.20) in the un-conserved land. The highest content in the conserved land was related with its high pH value. This is in agreement with the study results reported by Mesfin (1996) who stated that high K^+ is a common property of soil under high pH tropical soils. The interaction effects of the land types by the slope gradients and soil depths was highest in gentle slope (1.25 ± 0.13) and the lowest (0.92 ± 0.15) in steep slope.

The interaction effects also showed higher mean value (1.16 ± 0.17) at the surface (0-20 cm) layers and lower mean value (1.03 ± 0.20) at the subsurface layer (20-40cm) depth. The mean exchangeable K contents of the three factors were significantly different ($p < 0.05$) from each other due to the interaction effects; which is the surface soil of the conserved gentle slope land has higher mean exchangeable potassium content relative to the subsurface soil of un-conserved steep slope land. And the ranges of mean exchangeable K values observed in the study area were found in the range of high to very high level as the rating of soil nutrients indicated by Barber (1984). Generally, there are lower exchangeable K^+ contents in the un-conserved area than in the conserved area. This might be due to its continuous losses of the cation through lack of proper management, continuous cultivation of crops on the land and free grazing of the land by cattle beyond its carrying capacity as also reported by Baker *et al*. (1997).

3.13 Exchangeable calcium (Ca^{2+})

The content of exchangeable calcium (Ca) was significantly ($p < 0.01$) affected by the land types, the slope gradient and the soil depths. The mean values of exchangeable calcium (Ca) under the conserved land were (12.80 ± 3.10) and (11.59 ± 1.27) of soil under the un-conserved land (Table 4). When we contrast the slope gradients; gentle slope had higher mean value of exchangeable Ca^{2+} (13.12 ± 2.75) and the steep slope had lower mean value (11.59 ± 1.10). Considering the two soil depths, it was higher value (12.42 ± 3.11), at the surface layer than (11.98 ± 2.26) at the subsurface layer of soil (20-40 cm) depth. Considering the interaction effects, the land types by the slope gradient and the soil depth; it was shown a significant variation with ($p = 0.0014$) among of the three factors. The mean exchangeable Ca^{2+} contents of the three factors combination were significantly different from each other due to the interaction effects.

Table 4: Exchangeable cations analysis result

Land Types	Variables			
	Na^+ (cmol(+)/kg)	K^+ (cmol(+)/kg)	Ca^{2+} (cmol(+)/kg)	Mg^{2+} (cmol(+)/kg)
Un-conserved Land	1.08 ± 0.25^b	0.96 ± 0.20^b	11.59 ± 1.27^b	4.20 ± 0.90^b
Conserved Land	1.27 ± 0.19^a	1.22 ± 0.17^a	12.80 ± 3.10^a	6.31 ± 0.99^a
LSD (0.05)	**0.026**	**0.022**	**0.417**	**0.113**
SEM	**0.009**	**0.007**	**0.143**	**0.039**
Slope Gradient				
Gentle	1.33 ± 0.16^a	1.25 ± 0.13^a	13.12 ± 2.75^a	6.34 ± 0.70^a
Moderate	1.19 ± 0.14^b	1.12 ± 0.11^b	11.89 ± 0.52^b	4.98 ± 0.52^b
Steep	1.01 ± 0.14^c	0.92 ± 0.15^c	11.59 ± 1.10^c	4.47 ± 0.68^c
LSD (0.05)	**0.032**	**0.027**	**0.51**	**0.139**
SEM	**0.011**	**0.009**	**0.175**	**0.048**
Soil Depth (cm)				
0-20cm	1.23 ± 0.20^a	1.16 ± 0.17^a	12.42 ± 3.11^a	5.66 ± 1.11^a
20-40cm	1.12 ± 0.24^b	1.03 ± 0.20^b	11.98 ± 2.26^b	4.86 ± 0.79^b
LSD (0.05)	0.026	0.022	0.417	0.113
SEM	0.009	0.007	0.143	0.039
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: - Means within columns followed by different letters are significantly different ($p < 0.05$) with respect to land types, slope gradients and soil depths

3.14 Exchangeable magnesium (Mg^{2+})

The exchangeable magnesium content was significantly ($p < 0.01$) affected by the land types, the slope gradients and the soil depths. Considering the main effects of land types, the higher mean value of exchangeable magnesium (Mg^{2+}) was (6.31 ± 0.99) under the conserved land and the lowest value was (4.20 ± 0.90) on the un-conserved land (Table 4). When we contrast the slope gradients of the land, higher mean value (6.34 ± 0.70^a) were observed on the gentle slope and the lower mean value (4.47 ± 0.68) were observed on the steep slope. When we see the soil depths surface layers showed higher mean value (5.66 ± 1.11) of exchangeable magnesium content than the mean value of (4.86 ± 0.79) the subsurface layer. These indicate that there was higher down ward leaching of basic cations in the subsurface layer than in the surface layer. The contents of both exchangeable Mg^+ and Ca^+ were decreased with the soil depth**.**

The interaction effects of the three factors land types, slope gradient and the soil depth has shown a significant difference for bulk density, soil pH, electrical conductivity (EC), soil organic carbon (SOC), cation exchange capacity (CEC), total nitrogen (TN), available phosphorus and potassium and exchangeable cations (Na^+, K^+, Ca^+ and Mg^+). This shows that the surface soil of conserved gentle slope has shown a lower bulk density value than the subsurface soil of un-conserved steep slope. These might be because of the un-conserved land is still serving as the grazing land and it has no control for the entrance of animals due to the trampling effects, the bulk density value of the area increases. Also the conserved site has higher organic matter content because of the availability of different plant species; it can minimize the bulk density value of the soil.

The soil pH, soil electrical conductivity (EC), soil organic carbon (SOC), cation exchange capacity (CEC), total nitrogen (TN), available phosphorus and potassium and exchangeable cations (Na^+, K^+, Ca^+ and Mg^+) value of the conserved gentle slope surface soil were higher relative to the un-conserved steep slope subsurface soil. These might be because of the soil parameters are positively correlated to each other for instance the relative increasing of soil pH has positive impact on the electrical conductivity of the soil due to this; the EC of the soil able to increase. The soil organic carbon has also a positive correlation with the cation exchange capacity of the soil. Based on this the cation exchange capacity of the soil; increases with the relative increasing of soil organic carbon content. Consequently as the CEC of the soil increases; the available phosphorus and potassium content of the soil increases.

4. CONCLUSION

Based on results of the research carried out; the soil of an area which was treated by integrated soil conservation practices has shown a significant physicochemical property improvement than the soil of the adjacent un-conserved land. It minimizes the bulk density of the soil relative to the un-conserved land thereby creates a conducive condition for the development of plants on the conserved land. The pH of the soil also able to increase which in turn facilitates the availability of major nutrients such as phosphorus in the soil of conserved land. Generally, the major macronutrients required for green plants such as the soil organic carbon, nitrogen, potassium and phosphorus concentrations in the rehabilitated lands which were maintained by various soil conservation practices were found to be significantly higher than the concentration in adjacent unmanaged degraded lands.

The research result indicates that the soil conservation practices have positive impacts in improving the fertility status of the degraded lands. And it addresses the problem of improper land use practices and maintains the productive capacity of the lands by minimizing the soil nutrient deterioration rate. Therefore it is mandatory to apply the soil conservation practices in all agricultural land use types such as farmlands, grazing lands, coffee and private forestlands of the study area. The result of the study also indicated that soil conservation practices can benefit farmers through restoring the productivity potential of the degraded land as well as improving its nutrient content. Consequently it is better if proper attention will be given to the practices by the government to achieve the transformational plan in agricultural sector.

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