International Journal of Ecotoxicology and Ecobiology
2025, Vol. 10, No. 4, pp. 146–163
https://doi.org/10.11648/j.ijee.20251004.17

Research Article

The Effects of Level Soil Bund Structure on Selected Soil Properties at Menentela Watershed, Habru Woreda, North Wello, Amhara, Regional, National, State, Ethiopia

Mussa Abdula Ibro*

Department of Watershed Management (Soil and Water Conservation), Hawassa University, Hawassa, Ethiopia

Abstract

Different soil and water conservation (SWC) measures have been constructed on farmlands to control runoff surface water, erosion, sedimentation and conserve soil and water on agricultural fields. This study was entitled with: the effects of level soil bund structure on selected soil properties at Menentela watershed, Habru District North Wello Amhara Regional National State, Ethiopia. Objectives of the study includes: to assess the status of selected soil physico-chemical properties under the two adjacent treatments: treated with LSB (Deko) and none-treated (Doba), to observe the persons correlations between the studied soil properties and further to examine their variations with soil depth. The total of 48 composite soil samples (2 treatments * 3 replications*4 sample plots*2 depth layers: 0-15 cm and 15-30 cm) were collected and analyzed for soil (%STF), soil MC %, soil BD g/cm^3, soil pH (1:2.5 soil: water ratio), SOC %) and CEC meq/100g. Also the total of 48 soil samples were separately collected for the determination of soil bulk density and soil moisture contents. Results had showed that sand, clay, MC and BD were significantly varied with treatments ($P<0.001$, $P<0.001$, $P<0.001$, $P<0.001$ and $P=0.018$, respectively). These parameters also showed significant differences with soil depth. Cation exchange capacity (CEC) had showed differences with soil depth ($P=0.005$), but not with treatment ($P=0.63$). Sand%, silt% and bulk density (BD g/cm^3) were the higher in the non-treated farmlands (35.85±0.32, 33.35±0.25 and 1.13±0.02, respectively) than under LSB treated farmlands, while clay, and MC were lower in non-treated farmlands. Silt and clay were declined with soil depth, while, sand, soil MC and soil BD were increased with soil depth. The mean value of soil pH, SOC and CEC were the higher under LSB than none-treated farmlands. Moreover, soil pH, SOC and CEC were the higher (6.72±0.04, 0.58±0.04 and 34.59±1.18) in the top of 0-15 cm of the layers than in the lower of 15-30 cm of the layers. The differences in these selected soils physico-chemical properties were in general resulted from the soil and water conservation practices (LSB) implemented in the study watershed which has reduced runoff water, conserve soil and moisture, provide the better infiltration rate and reduce the removal of soil organic matter and soil colloidal. In general the studied soil properties had showed that well improves due to the farmlands treated with LSB while none treated farmlands had showed that decline of the soil properties.

Keywords

Watershed, LSB, None-treated and Treated Farmland, Soil Depth and Soil Properties

*Corresponding author: mussaibro@gmail.com (Mussa Abdula Ibro)

Received: 30 June 2025; **Accepted:** 16 July 2025; **Published:** 19 December 2025

1. Introduction

Land degradation is a temporary or permanent decline of land productive capacity or its potential for environmental management [24]. It is the results of complex interactions between physical, chemical, biological, socio-economic and political issues. Its processes are easily upset by human activities [67, 80, 66]. According to [24], soil degradation can be described as a reduction of resource potential by or on a combination of processes acting on the land such as erosion by water and wind. It is allowing to deterioration of physical, chemical and biological soil properties. Soil erosion has on-site effects like the deterioration in soil properties such as decline in SOC, decrease in soil depth and reduction in soil moisture content [10] and off-site effects for instance, risk of flooding from sedimentation of downstream [67].

Agriculture in Ethiopia remains as one of the largest sector in the economy, which absorbs for over 85% of the employment forces and accounts over 50% of the GDP and about 90% of export income [52]. In contrast, in Ethiopia crop yield has been declining by 1-3% as stated by World Bank 2001, while the population was growing at the rate of 3.3% per year [66]. According to [82], degraded land in Ethiopia accounts about 8% of the global total area due to soil erosion. As [21] reported, land degradation, mainly due to soil erosion has become one of the most important environmental problems in Ethiopia. Soil erosion by water is the major cause for land degradation in the Ethiopian highland areas (> 1500 m altitude a. s. l.). These highland areas constitute about 46% of the total area of the country and accounts for over 95% of the cultivated area and support about 88% and 75% of the human and livestock populations, respectively [87].

The Soil Conservation Research Project (SCRP) has estimated about 1.5 billion tons of soil loss per year in the Ethiopian highland areas [89, 43] which had costing the country about 1.9 billion US$ during the past two and half decades i.e. between 1985 and 2010 [81]. Out of this about 50% occur in cultivated lands [3]. The past study did [41, 70] had revealed that, the average rate of soil erosion by water measured over four years (1998--2004) was about 14.8 t/ ha/year, which accounts for about 98% of the change in potential energy of the landscape in the northern highlands of Ethiopia. Therefore, the high degree of soil erosion on cultivated lands, call for increasing efforts to application of intervention measures such as SWC activities towards rehabilitation of the natural environment and control further land degradation [16].

Soil and water conservation (SWC) is one of the most important farm technologies for improving agricultural productivity in areas with high land degradation and limited access to modern inputs [52]. The Ethiopian government has recognized the impact of soil erosion on resource degradation and agricultural development and food security [84, 87, 86] after the massive famine and starvation in 1970s [21, 54]. Since then, considerable efforts have been made to rehabilitate degraded lands and control further degradation of lands by the government and its development partners [6, 7, 86], through an extensive physical SWC programme by mobilizing the farmers in areas where soil erosion is sever and food shortage widely spread [87, 6]. However, the initiated SWC programme by Ethiopian government was operational on unplanned basis until 1980s. It was mainly focused on rehabilitating eroded lands with afforestation and construction of soil and stone bunds [21]. According to [84], had reported that, in between 1976 and 1990 in Ethiopia, about 71,000 ha of soil and stone bunds were constructed on cultivated lands, 233,000ha of hillside terraces, about 12,000 km of check dams in gullied lands, 390,000ha of closed areas for natural regeneration, 448, 000ha of land planted with different tree species and about 526,425ha of bench terrace interventions were completed. However, by 1990, only 30% of the soil bunds, 25% of the stone bunds, 60% of the hillside terraces, 22% of land planted in trees, and 7% of the reserve areas still survived [84].

Sustainable soil management systems must be developed to reduce further degradation and restored the productivity of the eroded land. For instances [30], had reported soil and stone bunds are commonly built on cultivated lands to control runoff rainwater, retain soil moisture, conserve soil and increase crop yields.

In Ethiopia to achieve better soil erosion control, different soil and water conservation activities later started in hydrological units. Hence, watershed approach was adopted in the 1980s. Over the years, this approach has promoted various soil and water conservation measures such as soil bunds, stone bunds, fanyajuu terraces, bench terraces, cut-off drains, waterways, check dams, grass strips and plantations. The efforts made so far using the watershed approach have restored degraded farmlands, improved soil water holding capacities, increased woodlots and improved the productivity of pasturelands [25]. Nevertheless, there are still gaps that negate the optimization of the expected benefits out of these efforts and the results achieved in reducing soil erosion problem and improving soil properties have been unsatisfactory. The scope of the present study was limited within the watershed level in Habru Wereda, North Wollo, and Amhara National Regional State, Ethiopia. The emphasis was on the functional use of level soil bund structural measures in improving selected soil properties for land productivity. Soil degradation is the most immediate environmental problem facing Ethiopia [27], especially in the northern and central highlands, where the largest segment of the population is living, extensive agriculture is common, vegetative cover is very low and soils are already very shallow [44]. Soil erosion and land degradation is very severe; deforestation is common and crop yield has been declining in this area. For example, in Amhara Region yields are estimated to decline by 1-2% per year due to soil erosion [84]. The study done by [44] had reported in Habru Wereda where the study area is located, yields decline at the rate of 1% per year on land without soil conservation measures due to soil loss and poor management practices. In addition, this area has a long history of settled agriculture dominated by cereal based farming systems [47, 71].

The loss of soil and deterioration in soil fertility, limitation of soil moisture storage and damage of soil structure are reducing the agricultural productivity [27].

Most of the earlier studies for example, [14, 51], did not focus on identifying and evaluating of the effects of physical soil conservation structures on soil properties except a few. For instance, effects of level soil bunds and stone bunds on soil properties and its implications for crop production: the case of Bokole watershed, Dawuro zone, Southern Ethiopia [88]; assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western highlands of Ethiopia [68]. The approach in which soil is managed and conserved has a major impact on soil conditions, soil properties and land productivity [46]. In parallel to this study, the past study done by [68] had explained that, soil conservation activities such as soil bunds can modify the soil physico-chemical conditions such as soil organic matter, soil structure, and water holding capacity, bulk density, soil porosity, soil pH and its workability.

The study area is a densely populated and intensively cultivated area without fallow practices, which leads to sever degradation of soil [71]. Specific objectives Include: to assess the status in selected physical and chemical soil properties (texture,%), soil bulk density (BD g/cm^3), moisture content (MC%), soil organic carbon (SOC%), pH (1:2.5 soil: water) and cation exchange capacity (CEC meq/100g) between treated farmlands with LSB and the adjacent non-treated farmlands and to examine the variations in selected soil properties with respect to soil depth: 0-15 cm and 15-30 cm. Research hypothesis in encompasses: there is variation in selected physical and chemical soil properties (soil texture, soil bulk density (BD g/cm^3), moisture content (MC%), soil organic carbon (SOC) (%), pH (1:2.5 soil: water) and cation exchange capacity (CEC meq/100g) between treated farmlands with LSB and the adjacent non-treated farmlands and there is difference in selected physic-chemical soil properties in relation to soil depth: 0-15 cm and 15-30 cm.

2. Materials and Methods

2.1. Description of the Study Area

The Menentela watershed is situated in Habru Wereda, North Wollo Administrative Zone; Amhara National Regional State, Ethiopia. The study watershed lies between 11°30′ and 11°34′N latitude and 39°31′and 31°42′ E longitude within the altitude ranges from 1606 m to 1980 m a. s. l.

2.2. Climate of the study area

According to the agro-ecological classification of the Habru Wereda it is stratified into three regions. These are about 4% of the Habru Woreda is Dega (2200-3400 m), 40% Weyna Dega (1500-2200m) and 56% is Kolla (1000-1500 m) [44]. It has a bi-modal rainfall distribution which the spring or “Belg” (February to April) is a short rainfall and summer or “Kermit” (beginning of July to early September) which is season of high rainfall (Figure 2) than spring rainfall.

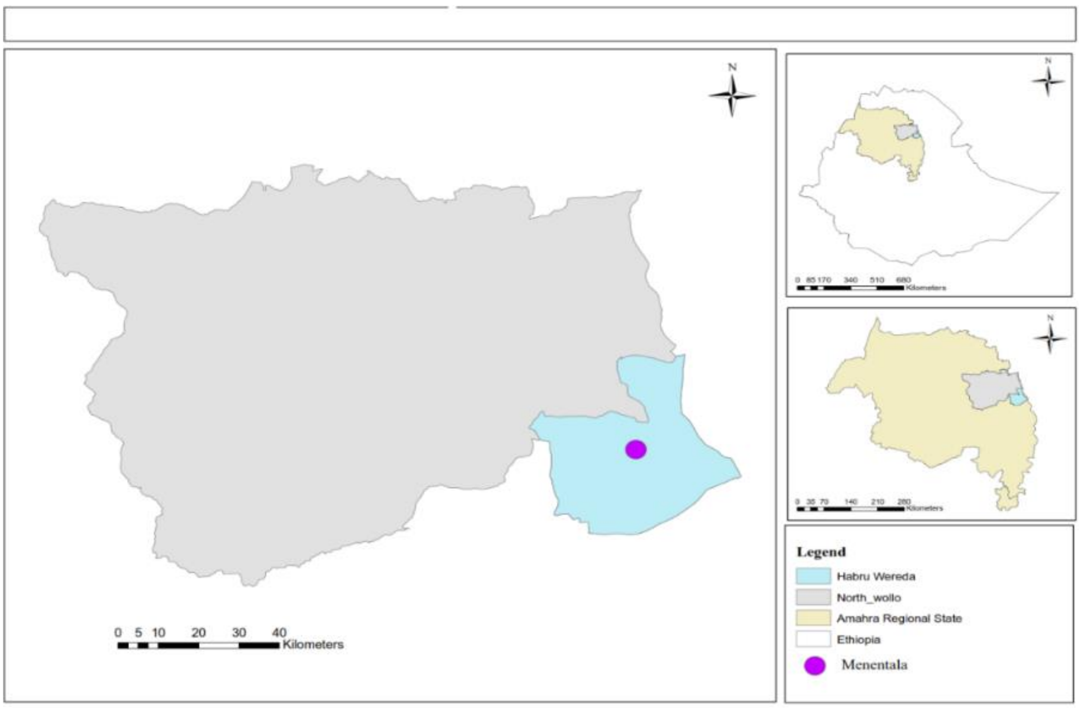
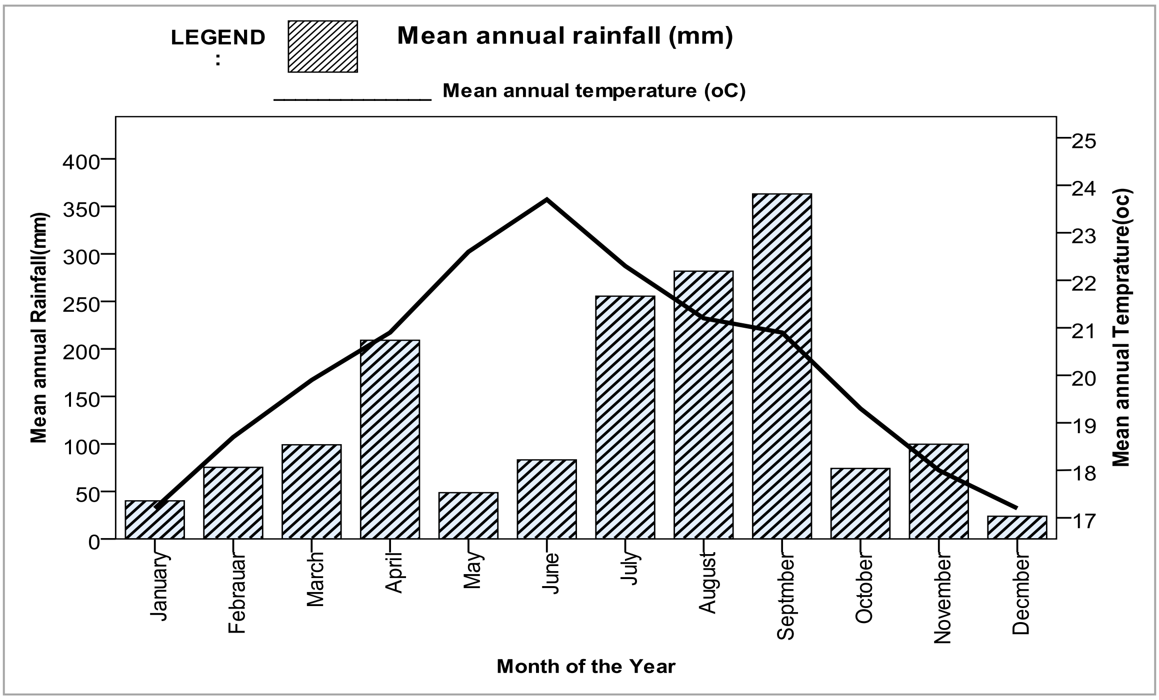


Figure 1. *Map of the study watershed.*

According to the 13 years climatic data (1995-2007) obtained from the Meteorological unit of Sirinka Agricultural Research Centre, North Wollo, Ethiopia, the mean annual rainfall of the study watershed is about 1259.5 mm (Figure 2). The highest monthly mean rainfall is recorded from the early July to beginning of September. The mean annual temperature is 20.1 ℃. The mean monthly temperature ranges between 13.7 ℃ and 26.5 ℃. The lowest and the highest maximum monthly temperatures are 22.7 ℃ and 30.7 ℃, respectively, and the lowest and the highest minimum monthly temperatures are 10.7 ℃ and 16.6 ℃, respectively (Figure 2).



Source: Meteorological Station of Sirinka Agricultural Research Centre, North Wollo, Ethiopia

Figure 2. *Mean monthly temperature and rainfall of the study watershed (1995-2007).*

2.2.1. Soil of the Study Area

The soil type in the study area is brown color and locally known as "Boda" and generally classified as Cambisols, Lithosols and Regosols according to Habru Wereda Agricultural and Rural Development office [58]. Cambisols is the dominant soil type in the study watershed covering about 529.04 ha (97.87%). It has characterized by the absence of appreciable quantities of illuviated clay content, organic matter, and aluminum and/or iron compounds [38]. Under intensive agriculture organic matter in Cambisols is rapidly mineralized and becomes exhausted [16]. Cambisols are considered as young soil and SOC content is very low [42].

2.2.2. Topography

The topography of the study watershed is characterized by flat slope, gentle slope; hill, mountainous and ridge land (Table 1).

Table 1. *Topography of the study watershed and its slope and area in hectares.*

Topography	Area/ha	% coverage	Slope class (%)
Flat	56	10	0-8
Gentle slope	144	26	8-15
Hill	237	43	15-30
Mountainous	73	13	30-50
Ridge land	25	18	50<
Total area	535		

Source: [58]

The total area of the study watershed is 535 ha and the dominant land use type is cultivated land; it comprises about 380.48 ha. The other land use types in the study watershed are bush land, grazing land, forest land and settlement land (Table 2).

The farming system in the study area is mixed type based on crop and livestock production. Like other parts of Ethiopia oxen plough agriculture is a common practice using traditional implements called Maresha [44]. The major crop types grown in the study area are teff (Eragrostis teff), maize (Zea mays), chickpea and sorghum.

Table 2. *Menentela watershed land use types.*

Land use land cover	Area (ha)	Percentage
Bush land	27.69	5.1
Grazing land	92	17.01
Forest land	1.01	0.19
Cultivated land	380.48	70.39
Settlement	39.42	7.29
Total area	535	

Source: [58]

Natural vegetation in the study area include: bush, scrub, shrubs and some remnant tree species. The remnant trees and shrubs found in the study watershed are: *Acacia polycanta, Acacia abyssinica (Girar), Ficus vasta (Warka), Carissa edulis (Agam), Croton macrostachys (Bisana), Acacia saligna (Akacha), Rhus glutinosa (Embis), Cordia africana (Wanza), Dodonia viscose (Kitkita), Dovialis abyssinica (Koshim) and Olea african (Woira)* [9].

2.3. Methodology

Before collected soil sample for laboratory analysis sites having similar in soil texture were identified using color identification method. The soil of the study watershed is brown color and locally known as “Boda”. Soil Sample was collected from farmlands having same soil color. This was easy to determine their differences in selected soil properties either the differences with farmlands and soil depths were happened due to the structures.

Composite soil sampling method was employed during soil sample collection. Six closely located farmlands i.e. three treated farmlands with LSB from Deko and three non-treated farmlands from Doba adjacent to each other were selected for sampling sites. This was to minimize the variations in soil type, topography, slope and climatic conditions. Within each of the six selected sampling sites, four sampling plots were randomly assigned per site i.e. 12 sampling plots were placed per site (Deko and Doba) at the selected farmlands. Then, from each sample plot per depth layer, one composite soil sample was collected i.e. from the four corners and one at the centre of X-designed square sample plot. Each composite sample was made from a pool of five samples at each depth class. The square sample plot design (10 m X 10 m) was adjusted at 0.5 m away from level soil bunds where a soil is deposited. The total of 48-composite soil samples were collected from two sites (2 treatments x 3 replications x 4 sample plots x 2 depth layers: 0-15 cm and 15-30 cm) by using auger sampler from farmland’s on which dominant crop (i.e. sorghum) was grown. In addition, 48 soil core samples were collected separately and analyzed for soil bulk density. All soil samples have been gathered from cropland grown on the slope range of 0-8%.

Altitude of the study area ranges between 1606 -1980 m above sea level. Based on the climate of the study site lied under Weyna Dega condition and ranges between 1500-2200 m a. s. l. The selected farmlands were also similar in their fertilizer application and crop growth. On both farmlands sorghum were grown at least for the past two consecutive cropping seasons. This study was parallel with the study done by [16], assessment of the impact of farmland enclosure on soil quality. Sustainability of conservation structures and agricultural production in Hadegulele, East Shoa Zone, assessment of the impact of terraces development and management on soil properties in Anjeni area, west Gojam [7]. Assessing the role of traditional land management practices in improving cropland productivity: the case of Diga Woreda, Oromia [83].

2.4. Source of Data

Source of data were both the primary source and secondary source. The primary source were collected from the field by observation and experimental soil sample collections from treated and none treated farmlands adjacent to each other’s. However, the secondary data were collected from the documented data by Habru Woreda Natural Resource office and from Sirnka agricultural research center.

2.5. Data Collection Methods

The data collected from six treatments; three were conserved or treated farmlands and three were none treated or none conserved farmlands. By replicated three times per treatments the data of soil samples were collected in composite samples for laboratory analysis and separately without made composite samples the soil data were collected for the determination of soil bulk density and soil moisture contents. The square samples were preferred to collect the soil data from the four corners and the center at two soil depth layers 0-15 cm and 15-30 cm.

2.6. Soil Analysis

Prior to analysis all soil samples were air-dried under the shade at room temperature. Non-soil materials such as litters, stones and roots were removed manually from the samples.

The air-dried sample soils were grinded, mixed well and passed through 2 mm diameter sieve before laboratory analysis. The soil samples analyzed in soil laboratory at Sirinka Agricultural Research Center, North Wollo, Amhara National Regional State, Ethiopia for soil texture (TS%), soil moisture content (MC%), soil bulk density (BD g/cm^3), soil organic carbon (SOC%), soil pH (1:2.5 soil: water) and cation exchange capacity (CEC meq/100g).

The standard soil analysis methods were employed to analyze the selected soil properties. Soil texture was determined by the hydrometer method after dispersion in a mixer-dissolving agent [31]. Bulk density was determined by using Blake method (i.e. core- sample method) and calculated by dividing the oven dry mass at 105℃ for 24 hrs by the volume of the core [12, 72]. Gravimetric soil moisture content was determined following the method described by [49]. Soil pH was determined with a combination of electrode in a 1:2.5 soil: water suspension [77]. Soil organic carbon (SOC) was determined by wet digestion method using the Walkley and Black procedure [77]. Cation exchange capacity (CEC) was determined titrimetrically by using the distillation of ammonia electrode following the procedures outlined by Chapman [32, 36].

2.7. Data Analysis

The soil data produced from soil laboratory analysis were subjected to one-way Analysis of Variance (ANOVA). Furthermore, to distinguish the presence of significant difference between the two practices in selected soil properties all statistical calculations were made following the General Linear Model (GLM) procedure of SPSS windows version 19.0 computer software. The least significant difference (LSD) mean separation method was used to determine the means that were significantly different at (P <0.05) significance level.

They were conducted person's correlation to determine the relationship of soil organic carbon (SOC %) with clay%, soil pH (1:2.5: soil: water) and moisture content (MC %).

3. Results

3.1. Physical Soil Properties

The SWC interventions lead to reduced soil and nutrient loss through erosion [78]. In the study watershed LSB has been implemented primarily to control runoff surface, conserve soil, retain moisture and increases crop yield by farmers. However the structures is not properly and regularly repaired after the establishment as informed by developmental agents and observed during field survey.

3.1.1. Soil Textural Fractions

The statistical analysis of the study results had showed that, the soil textural fractions of sand and clay soils were the significant variations between farmlands at (P <0.001, and P<0.001) and with respect to the soil depth at (P=0.002, and P<0.001), respectively, while they were not observed the significant variations at (P = 0.29, and P=0.35) within their interaction effects, respectively (Table 4). Silt soil textural fraction had not showed the significant variations with respect to farmlands at (P= 0.10), soil depth at (P=0.22) and its interaction effects at (P=0.59) (Table 4). The study results had indicated that, the mean value of clay soil textural fraction was the higher under treated farmlands with LSB (36.52±0.53) than none-treated farmlands (30.67±0.35). The overall mean value of sand and silt soil textural fractions were the lower inside LSB treated farmlands (31.08 ±0.57, and 32.44±0.39) as compared to none-treated farmlands (35.85±0.32 and 33.35±0.34), respectively. The overall mean value of sand soil textural fraction was the lower in the topsoil of 0-15 cm (32.46±0.79) soil depth, however it was increased with respect to soil depth. The overall mean value of silt and clay soil textural fractions were the higher in the topsoil of 0-15 cm layers of soil depth than in the subsurface layers of soil depth. The results of the study interpretation had been parallel with the past study interpretation done by [88]. As the statistical analysis of one-way of ANOVA followed by General Linear Model of SPSS software version 19 the study results of significance level and average of treatments and soil depth there interpretations were in line with the past study interpretations did by [15, 68].

The result of the study had showed that, the significant variations of silt plus clay soil textural fraction between farmlands at (P< 0.001) and with respect to soil depth at (P= 0.002) while it was not showed that, the significant differences between interaction effects of soil depth with farmlands at (P=0.293) (Table 5). The overall mean value of silt plus clay soil textural fraction was the higher in the topsoil of 0-15 cm of soil depth layers (67.54±0.75) than in the subsoil of 15-30 cm of soil depth (65.52±0.54). the mean value of SC (silt plus clay soil textural fraction) was the higher under farmlands treated with LSB of 0-15cm of soil depth (70.25±0.90) than under subsoil of 15-30 cm of soil depth (64.83±0.47) than none-treated farmlands (67.58±0.58) of topsoil of 0-15 cm soil depth and subsoil of 15-30 cm of soil depth (63.46±0.33), respectively. Overall mean value of SC was the higher under farmlands treated with LSB (68.92±0.59) than in the none-treated farmlands (64.15±0.54).

3.1.2. Soil Moisture Content (MC %)

The findings of the study had showed that, the significant variations at (P<0.001) between farmlands and with respect to soil depth at (P<0.001) while there were not observed the significant differences at (P =0.124) in its interaction effects (Table 5). As the findings of the study had indicated, the mean value of the soil moisture content was significantly the lower in none-treated farmlands (20.16±0.69) than under farmlands treated with LSB (25.23±0.99) (Table 6). The overall mean value of soil moisture content was the lower (18.41 ±1.09) in the topsoil of 0-15 cm layers of soil depth than in the subsurface soil of

15-30 cm layers of the soil depth (Table 6). The results of the study interpretation had been parallel with the past study interpretation done by [88]. As the statistical analysis of one-way of ANOVA followed by General Linear Model of SPSS software version 19 the study results of significance level and average of treatments and soil depth there interpretations were in line with the past study interpretations did by [1, 15, 68].

3.1.3. Soil Bulk Density (g/cm^3)

The results of this study had pointed out that, the soil bulk density (g/cm^3) were significant variations between farmlands at (P=0.018) and with respect to soil depth at (P= 0.006) (Table 5), whereas there were not observed the significant variation (P= 1.00) in its interaction effects. It was investigated the higher mean value of soil bulk density under the none-treated farmlands (1.13±0.02 g/cm^3) than in the adjacent farmlands treated with LSB (1.05±0.02 g/cm^3). But, the lower value of soil bulk density was observed in the topsoil of 0-15cm layers of soil depth than in the lower subsoil of 15-30cm layers of soil depth. The results of the study interpretation had been parallel with the past study interpretation done by [88]. As the statistical analysis of one-way of ANOVA followed by General Linear Model of SPSS software version 19 the study results of significance level and average of treatments and soil depth there interpretations were in line with the past study interpretations did by [15, 68].

3.2. Chemical Soil Properties

3.2.1. Soil pH (1:2.5, Soil: Water)

The findings of the study had indicated that, the soil pH values were insignificant variations between farmlands whereas showed the significant variations with respect to soil depth at (P=0.082) and (P <0.001), moreover, the study had pointed out that, the significant differences in their interaction effects (Table 6). The finding of the study had revealed that, the overall mean value of soil pH was the higher under farmlands treated with LSB (6.70±0.05) than in the none-treated farmlands (6.64±0.02) with level soil bunds (LSBS). The result had also revealed that the soil pH was the higher (6.72±0.04) in the topsoil f 0-15 cm layers than in the subsoil layers of 15-30 cm of soil depth. The results of the study interpretation had been parallel with the past study interpretation done by [87]. As the statistical analysis of one-way of ANOVA followed by General Linear Model of SPSS software version 19 the study results of significance level and average of treatments and soil depth there interpretations were in line with the past study interpretations did by [15, 68].

Table 3. *Summary of GLM ANOVA results for sand (%), silt (%) and clay (%) in relation to treatment and soil depth (n=48).*

SOV	Df	Sand		Silt		Clay	
		MS	P	MS	P	MS	p
TR	1	273.13	<0.001*	10.083	10.083	388.172	<0.001*
SD	1	49.005	0.002*	5.333	0.224	22.005	0.016*
TR*SD	1	5.005	0.293	1.021	0.593	1.505	0.516
Error	44	4.422		3.512		3.504	

TR - treatment, SD -soil depth, Df - degree of freedom, the significant level or P-values indicated by * sign were showed the significant variations between treatments or farmlands conserved with level soil bunds and none conserved and in relation to soil depths.

Table 4. *Summary of GLM ANOVA results for SC (%), MC (%) and BD (g/cm^3) in relation to treatment and soil depth (n=48).*

SOV	Dff	SC		MC		BD	
		MS	P	MS	P	MS	P
TR	1	273.13	<0.001*	410.55	0.011*	0.072	0.018*
SD	1	49.005	0.002*	155.38	0.111	0.101	0.006*
TR*SD	1	5.005	0.293	18.327	0.579	0	1.00
Error	44	4.422		58.656		0.012	

TR = treatment, SD = soil depth the significant level or P-values indicated by * sign were showed the significant variations between treatments or farmlands conserved with level soil bunds and none conserved and in relation to soil depths.

Table 5. Summary of GLM ANOVA results for SOC (%), pH (%) and CEC (meq/100g) in relation to treatment and soil depth (n=48).

SOV	Df	SOC		pH		CEC	
		MS	P	MS	P	MS	P
TR	1	0.22	0.005*	0.04	0.082	0.559	<0.001*
SD	1	0.02	0.382	0.135	0.002*	280.817	0.116
TR*SD	1	0.011	0.515	0.738	<0.001*	21.2	0.01*
Error	44	0.025		0.013		48.817	

TR = treatment, SD = soil depth the significant level or P-values indicated by * sign were showed the significant variations between treatments or farmlands conserved with level soil bunds and none conserved and in relation to soil depths.

Table 6. Description of (Mean ±SE) soil texture (sand, silt, clay, silt plus clay (%), MC (%), BD (g/cm^3), SOC (%), pH (%) and CEC (meq/100g) in relation to soil depth and treatments (n=48).

SOV	SD (cm)	Treatments		
		CFLS LSB	NCFLS	Over all mean
Sand (%)	0-15	29.75 ±0.90	35.17 ±0.47	32.46 ±0.75a
	15-30	32.42 ±0.58	36.54 ±0.33	34.48 ±0.54b
	Over all	31.08 ±0.59a	35.85 ±0.32b	
Silt (%)	0-15	32.92 ±0.71	33.54 ±0.44	33.23 ±0.41a
	15-30	31.96 ±0.52	33.17 ±0.45	32.56 ±0.36a
	Over all	32.44 ±0.44a	33.35 ±0.31a	
Clay (%)	0-15	37.33 ±0.48	31.29 ±0.33	34.31 ±0.69a
	15-30	35.63 ±0.75	30.29 ±0.52	32.96 ±0.71b
	Over all	36.48 ±0.47a	30.79 ±0.32b	
	Texture Class	Clay loam	Clay loam	
Silt plus clay (%)	0-15	70.25 ±0.90	64.83 ±0.47	67.54 ±0.75
	15-30	67.58 ±0.58	63.46 ±0.33	65.52 ±0.54
	Over all	68.92 ±0.59	64.15 ±0.32	
MC (%)	0-15	21.32 ±4.10	14.24 ±0.84	17.78 ±2.18
	15-30	23.69 ±1.01	19.07 ±1.00	21.38 ±0.85
	Over all	22.51 ±2.08	16.66 ±0.82	
BD (g/cm^3)	0-15	1 ±0.04	1.08 ±0.03	1.04 ±0.03
	15-30	1.09 ±0.03	1.17 ±0.03	1.13 ±0.02
	Over all	1.05 ±0.03	1.13 ±0.02	
SOC (%)	0-15	0.56 ±0.06	0.39 ±0.03	0.48 ±0.04a
	15-30	0.49 ±0.06	0.38 ±0.03	0.44 ±0.03a

SOV	SD (cm)	Treatments		
		CFLS LSB	NCFLS	Over all mean
	Over all	0.52±0.04a	0.39±0.02b	
pH (%)	0-15	6.88±0.05	6.57±0.03	6.72±0.04a
	15-30	6.52±0.02	6.71±0.01	6.62±0.02b
	Over all	6.69±0.05a	6.64±0.02a	
CEC (meq/100g)	0-15	33.16±2.32	34.27±1.71	33.71±1.41a
	15-30	29.65±1.87	28.1±2.12	28.88±1.39a
	Over all	31.4±1.50a	31.19±1.48b	

Overall means followed by the same letters across the columns and along the rows are significantly different at ($P \leq 0.05$) with respect to treatments and soil depth, SOV - source of variations, CFLS w LSBS - conserved farmlands with level soil bunds, NCLS-none conserved farmlands and SD - soil depth.

3.2.2. Soil Organic Carbon (SOC %)

The findings of the study of SOC had showed that, the significant variations between farmlands at ($P<0.001$), however it was not observed the significant variations with respect to soil depth at ($P= 0.37$) and its interaction effects at ($P=0.89$) (Table 6). The mean value of SOC was the higher inside farmlands treated with LSB (0.69±0.04) than in the none-treated farmlands. The overall mean value of SOC was the higher in the topsoil of 0-15 cm (0.58±0.04), while it was declined as soil depth increases. These interpretations of the study results were similar with past study results interpretations by [1, 88].

3.2.3. Cation Exchange Capacity (meq/100g)

The study results of CEC had not been shown the significant variations between farmlands at ($P= 0.63$) and their interaction effects at ($P=0.68$), while there was not examined also the significant variations with respect to soil depths at ($P=0.01$, Table 6). The overall average value of soil CEC was the higher (32.24±1.41) under treated farmlands with LSB than in the none-treated farmlands (31.31±1.27). The overall mean value of CEC was the higher in the topsoil of 0-15 cm (34.59±1.42) than in the subsoil layers of 15-30 cm soil depth. These study results of the interpretations had been in parallel with the past study results of interpretations by [88, 68].

4. Discussions

4.1. Physical Soil Properties

The finding showed that soils under LSB have lower in sand and silt fractions whereas higher in clay fraction than non-treated farmlands. This could be attributed to the truth that the mean annual rainfall (1259.5 mm) over the study watershed (Appendix, Figure 2) might have leached down and/or transported silt and clay fractions selectively from the surface of soil leaving behind sand fraction. This result agreed with the result of [7] in that clay soil was higher in terraced farmlands while sand soil was higher in the non-terraced farmlands due to selective removal of clay fraction by runoff rainwater. This author also pointed out in his study that terraces conserve topsoil and essential nutrients from removal by runoff rainwater when properly constructed and regularly repaired. Soil textural variation with farmlands could be related to erosion and deposition processes [78]. Similar result was reported by [70], soil with terraces contains higher clay fraction than soil with non-terraces. This was perhaps due to the structures are prevent clay soil dispersal by coating its susceptibility to runoff rainwater [50]. Different research [33, 66, 65], results have shown that LSB structures tends to reduce erosion and prevent removal of topsoil, which contains fine- textured soils, SOC and other nutrients which essential for plant growth. When SOC reduces in the soils; the soils are more susceptible to erosion [65].

The statistical analysis showed that soil textural class of the study watershed in both farmlands was clayloam (Appendix). This was probably due to texture is not subjected to change by management practices implemented in the study watershed i.e. LSB. Since, texture is an inherent soil physical property and it is not readily influenced by soil management [73, 11, 15, 45]. Sand fraction revealed increasing trends although silt and clay fractions showed declining trends all along soil depths. This might have suggested the disturbance near the surface layers by ploughing retarded particles aggregation than the subsurface layers [59].

The result exhibited that soil moisture content under LSB was significantly higher than non-treated farmlands. This was due to the effects of LSB structures serves as barriers against runoff velocity, soil erosion, increased infiltration rate and thereby increased storage of water in the soil which agree with other studies [29, 33, 48, 75, 40]. As [57, 33], had showed soil and water conservation technologies increased the amount of moisture content in the soil by reducing moisture evaporation from surface soil. Other research [85, 53, 62, 88, 65], results have shown that the amount of soil moisture content for the treated land units with bunds were significantly higher than untreated land units. One of the main reasons for increased the amount of moisture content (MC %) was due to increased soil organic carbon storage inside LSB structures which improves soil structure, water retention and reduced moisture loss from runoff surface, evaporation and offer deep drainage [40, 28], also pointed out in their study, soil organic carbon (SOC) is an important soil property that improves soil water retention. The extent of erosion in the non-treated farmlands was resulted in lower moisture content. This was probably due to erosion sealing surface soil, losses organic matter and topsoil which in consequences reducing infiltration rate and water retention [8, 76].

The accumulated soil organic matter beneath the LSB structures might have improves the amount of moisture content in the soil as compared to non-treated farmlands. This was perhaps SOM stable soil pore spaces, particles aggregation size and then resists soil movement by wind or water erosion [35]. Soil organic matter in the soil viewed as the thread that links biological, chemical and physical soil properties which associated with numerous soil functions, for instance, nutrient cycling, water retention and erosion control [34]. They serve as sponge in the soil and reduce evaporation of water from soil surface. As a result, more water goes into the soil and less water runs off surface [22].

Soil moisture contents on both farmlands were showed increasing trends with soil depth. This was due to water vapour in the soil close to the surfaces is higher than the subsoil layers [48]. [70] reported water found in the surface soil was further infiltrated down to the subsurface layers. There was a positive significant ($P \leq 0.05$) correlation between soil moisture content and SOC ($r = 0.19$) which implies that high soil organic carbon resulted in high moisture content (Appendix). This result was in agreement with the result of [61] in that there was a positive significant correlation ($P \leq 0.05$) between SOC and soil moisture content ($r=0.66$).

The finding of this study showed that soil bulk density under LSB was lower than in the non-treated farmlands due to differences in SOC concentration, moisture content and clay fraction. This variation was probably favoured by the presences of SWC measures (LSB) that have better effects in organic matter accumulation, clay deposition and moisture retention in the soil [13, 65]. [90] , had also reported higher soil bulk density in the control farmlands than in the 5 and 10 years aged fanya juu based SWC structures. The higher organic matter accumulation inside LSB was effected in lower soil bulk density compared with untreated farmlands [68]. The extent of erosion in the non-treated farmlands might have resulted in higher soil bulk density compared with LSB. This was maybe due to erosion leached clay fraction from the topsoil surface leaving behind sand fraction on the surface soil [20]. This result was agreed with the result of [76] in that soil bulk density increased in eroded soils than un-eroded soils due to selective removal of clay fraction by rainwater from untreated land units.

The increased amount of soil moisture content in LSB was caused lower soil bulk density. This could be due to increased moisture content in the soil has reduced soil particles aggregation and compaction [46, 5, 20]. Soil bulk density increased with soil depth in both farmlands. The lower soil bulk density was recorded at 0-15 cm than at 15 -30 cm soil depth due to high particles aggregation in subsurface layers than surface layers [59]. Besides, the low organic matter content in the subsurface layer, the pressure exerted by the weight of overlying soils compared to surface layer probably has reasoned in higher bulk density in the 15-30 cm soil depth [56].

4.2. Chemical Soil Properties

The GLM result confirmed that soil pH value was higher in the soil under LSB than in non-treated farmlands. The variation might be occurred due to the restoration of more basic cations after the establishment of LSB in the study watershed. This finding was in agreement with the finding of [88] in that soil pH under LSB aged 6 years was higher than in the adjacent non- terraced farmlands. Different research [29, 90], results have revealed that soil pH in the control farmlands were lower than in level fanya juus structures aged 15 years and 10 years, respectively. [65], also pointed out soil pH under treated land units with SWC measures has higher as compared to untreated land units.

The higher soil pH in LSB might be due to the fact that the structures has played a positive role in conserving soil organic matters and clay fraction [17] which increases buffering of soil pH changes by attracting and holding positively charged cations from leaching [63]. Besides, the high level of CEC under LSB was provides a buffering capacity against soil pH changes [18]. However, the extent of soil erosion and runoff rainwater within the non-treated farmlands were reduced soil pH. This was probably due to leaching of positively charged ions and then replaced by H^+ and Al^{3+} ions which increased soil acidity [33, 7, 68]. The past study done by [7] had showed that, continuous cropping systems without conservation structures increased leaching of basic cations and resulted in lower soil pH. The high level of sand fraction in the non-treated farmlands was sourced in lower pH. This was probably due to sand fraction has a low buffering capacity against soil pH changes [63, 64]. According to [55] soil pH of the study area in both farmlands was put under neutral ranges.

The amount of soil pH was decreased as soil depth increases from 0-15 cm to 15-30 cm between both farmlands with corresponding to clay fraction, soil organic matters and CEC declines [68]. In addition to that there might be high oxidation of SOM into CO_2 due to more oxygen and less carbon found in the subsurface layers than surface layers [79, 26]. There were a positive correlation observed between SOC, clay and soil pH (r= 0.28, r = 0.26, P = 0.05), which implies that higher soil pH might be resulted from increased SOC and clay fraction. The result showed that the amount of SOC under LSB was higher than in non-treated farmlands. This might be show that the SWC structures such as LSB has played a positive role in conserving SOC [65, 4]. These were perhaps due to LSB has reduced runoff rainwater, conserve soil and retain much moisture in the soil that improves growth of crops and donates to SOC inputs [88]. One of the main reasons for increased the amount of SOC under LSB was probably due to the structures have a better effects in building up organic matter and deposition of clay in the soil [68]. Terraces could be significantly reduced further transportation of the added litter from none-arable land [78]. The past study done by [29], had showed that, SOC percentage had increased after the establishment of LSB on cultivated lands. This was probably the structures (LSB) offers a long-lasting and substantial sink for carbon in the soil [57].

Soil textural variations between both farmlands were produced differences in SOC content. Clay dominated soil under LSB structures was associated with high level of SOC content than sand dominated soil in the non-treated farmlands. This was due to organic matter in fine textured soils is two to four times that of the coarse textured soils under similar conditions [73]. Many research [23, 37], results have shown that clay soil provides a greater protection of organic materials from decomposition by organisms. On the other hand, the lower level of SOC in the non-treated farmlands was tied with high level of sand fraction. This was due to the amount of oxygen in sand soil is higher than in clay soil under related environmental conditions [11, 37]. The higher amount of soil moisture content in LSB structures was probably contributed to the higher level of SOC content compared with non-treated farmlands. This result decided with the result of [18] in that the higher soil water content tends to conserve SOM by limiting the amount of oxygen in wet soils and slows the decomposition of SOM by soil microbes.

The overall mean SOC was generally lower in the study watershed and ranges 0.69% in LSB to 0.41% in untreated farmlands. Also it ranges 0.58% at 0-15 cm to 0.53% at 15-30 cm with soil depths on both farmlands. These were due to intensive and continuous tillage, monoculture cropping system, removal of crop residues for fodder and fuel that resulted in removal of organic matter and declined SOC in the soil [73, 18, 78, 69, 68, 40, 19]. Besides, the study area is located in tropical zone where the soil is highly weathered and old [48, 60].

Difference in SOC content among soil depths was recorded within both farmlands. The amount of SOC content was decreased as soil depth increases. Similar results were reported by [79, 26, 23], in that SOC decreases with soil depth due to low levels of organic materials such as litters, roots and leaves in the subsurface layers than in the surface layers. Furthermore, there is high oxidation of SOM due to more oxygen and less carbon in the subsurface layers than in the surface layers [79, 26]. The effects of land use and residue management on SOC stocks are highly dependent on the climate and soil conditions at any given location [39].

The finding had exhibited that the average CEC beneath LSB was the lower than none-treated farmlands. This could be perhaps as a result of the differences in clay soil textural fraction and soil organic matters. As [65], had reported, that the lower CEC was observed on none-treated farmlands than under LSB. This might be due to removal of organic matters and clay soil textural fraction by erosion agents and open nutrient cycling. Similar results were reported by [88] and [90] in that CEC in the non-terraced croplands were lower than under stone bunds aged 4 and 6 years and under fanya juu structures aged 5 and 10 years old, respectively. [78], also reported that terracing could enhance deposition of eroded or leached bases within a watershed.

The higher CEC under LSB was probably coupled with the high level of clay fraction, pH and SOC/organic matter compared to none-treated farmlands [18, 64, 74]. These were due to negatively charged surfaces of clay and organic matters have strongly attracts, holds and releases more basic cations on surface soils [63, 7, 17]. However, the lower amount of CEC in the non-treated farmlands could be induced by high level of erosion that transported clay fraction and organic matter [4] and leave behind sand fraction on topsoil surface. Sand dominated soils contain lower CEC due to little or no negatively charged ions that attracts and holds more cations from leaching [7]. According to [80], cations are a property not associated in sand soil.

Soil CEC was decreased with soil depths (0-15 cm and 15-30 cm) in both farmlands. This result was in agreement with the result of [26] in that following the same trends as SOM concentration, the soil CEC decreased with soil depth due to lower SOM in the subsurface layers. Soil pH also influences the percent base saturation (PBS %) and directly affected the amount of CEC in the soils [64]. As the PBS% increases, the soil pH and the availability of basic cations to plant increases [2]. As a rule of thumb, for every one-half unit drop in soil pH, the PBS% declines by about 15 percent [18, 64]. PBS% of the study area was varied between farmlands that are 91% under LSB aged 8 years and 88.9% in the non-treated farmlands. With regard to soil depth the PBS% was 91.3% at 0-15 cm layers and decline to 88.6% at 15-30 cm layers. According to [4] the relatively lower soil pH might be attributed to the relatively lower PBS% and lower soil organic matter content whereas the highest pH value might be attributed to the presence of the higher exchangeable cations due to reduced soil erosion.

5. Conclusions

The finding of this study has been shown that, LSB structures have the positive effects on selected soil physico-chemical properties. This comparative study between treated farmlands with LSB and none-treated farmlands had revealed that, the significant differences with sand, and clay soil textural fractions, soil moisture content, and soil bulk density. These measureable parameters had also showed that, the significant variations with respect to soil depth (0-15 cm and 15-30 cm) under both treated farmlands and none- treated farmlands. SOC had been shown that, the significant variations with farmlands while did not disclosed with soil depth. The result also had indicated that, soil pH and soil CEC were not showed the significant differences between farmlands whereas showed the significance differences with soil depth.

The finding had revealed that, soil under LSB (Deko) had indicated that, significant variations at ($P<0.05$). The higher levels of silt and clay soil textural fractions, soil moisture content, soil pH, SOC and CEC were investigated under conserved farmlands with LSB as compared to none-treated farmlands (Doba). On the other hand, soils taken from none-treated farmlands had revealed that, the significant at ($P<0.05$). The higher sand soil fraction and bulk density, were observed under NCFLS than CFLS with L1SB

These variations were probably due to absence of LSB structures that serves as barriers against runoff velocity, loss of clay and removal of organic matters. With reference to soil depth sand fraction, moisture content and bulk density were significantly ($P<0.05$) increases and the rest parameters showed a decreases. Therefore, this study result had showed that LSB structures are a better option to maintain soil physico-chemical properties and soil health. Finally, from the finding we understood that the implementation of LSB structural measures alone on farmlands without proper maintenance and repairing the structures have not improved soil properties very well compared with the adjacent non-treated farmlands.

In order to improve the soil properties of the study watershed the LSB structures should be repaired frequently or yearly before and after the onset of rainy seasons by farmers and entrance of animals and free grazing should be avoided after crop harvesting. Beside this, rehabilitation of the upper stream watershed should be encouraged to reduce inflow of water from upper stream watershed.

The LSB structures should be repair frequently and properly before and after the onset of rainy seasons by farmers; specifically it should be done after harvested crops by all the members of household.

Feed animals from the treated farmlands by cut and carry system should be practiced.

Rehabilitation of the upper stream watershed should be encouraged and continuously done to reduce inflow of water into Menental watershed from upper stream watershed which removes organic matter, loss topsoil and damaged the structures.

This study has considered only selected physical and chemical soil properties due to budget limitation and time shortage. Thus, further studies should be made for better generalizations about the effects of level soil bund on soil properties in comparison with none-treated farmlands.

Abbreviations

ANOVA	Analysis of Variance
a.s.l.	Above Sea Level
BD	Bulk Density
CEC	Cation Exchange Capacity
cm	Centimetre
CO_2	Carbon Dioxide
Etal	Extra
FAO	Food and Agricultural Organization
g/cm^3	Gram per Cubic Centimetre
GLM	General Linear Model
GDP	Growth Domestic Production
HWARDO	Habru Woreda Agricultural and Rural Developmental Office
Km	Kilometre
LSB	Level Soil Bund
m	Meter
MC	Moisture Content
mm	Millimetre
Meq	Mill Equivalent
℃	Degree Centigrade
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SWC	Soil and Water Conservation
SPSS	Statistical Package for Social Science
r	Regression of Personal Correlation
PBS	Percent of Base Saturation
%	Percent
ST	Soil Texture
STF	Soil textural fraction
>	Greater Than

Acknowledgments

First of all, my Praise and Thanks to the Almighty the most Gracious and Merciful Allah; the Lord of the universe, Who creates all living things and none living things on this Planet and who gave to me with the potential of ability, health to done and completed this thesis work in my lifespan.

Second, I offer my heartfelt gratitude goes to my major Advisor, Dr. Fantaw Yimer for his professional support, guidance and advise me during my study period. His review of the manuscript was very essential for the completion of my thesis work. Next my special thanks also goes to my Co-Advisor, Dr. Menefese Taddesse for offering me the opportunity to work under his direction and observation. Third I would like to acknowledge greatly to Federal Ministry of Agricultural and Rural Development Bureau of agricultural technical, vocational, educational training (ATVET) office for its financial support for the success of my thesis work. Fourth I would like to thank you to Mersa ATVET for gave to me the chance of competition to continue my second Degree and support me until I was finished my education by any means of resources. Fifth I want to present the special thanks to Sirinka

Agricultural Research Center of North Wello Amhara Regional National State Ethiopia for their support me to analyze my soil data. Also I would like to thanks to Ato Tesfay, Laboratory assistant who helped me in preparation and analysis of soil data at Serinka Agricultural Research Centre. Sixth I would like to thank you to Meresa Agricultural and Rural Development office of Habru Woreda, North Wello, Amhara, Regional, National, state, Ethiopia for their gave of permission to work at Menenetela watershed. Besides to that, I would like grateful thanks to Menentela watershed farmers and developmental agents for their helped me during my field data collection. What's more a special word of tanks goes to my friends, fellows, colleagues and seniors for their intellectual suggestions, comment, support and sharing hard comments with me during my study period.

Finally, my warm feeling and genuine gratitude, deepest love and value go to my wife and our children Mother who was provide her sacrifices, love and support have been the driving force behind me throughout my study period.

At last but not the least my special thanks goes to for my sisters and brothers who help me until I was finished my thesis work with financial.

Author Contributions

Mussa Abdula Ibro is the sole author. The author read and approved the final manuscript.

Data Availability

The data used to create or prepared this manuscript are available upon the request from the author of this manuscript only but no elsewhere.

Conflicts of Interest

No conflict of interest in declare of this manuscript work.

Appendix

Table 7. Thirteen years average monthly rainfall and monthly mean temperature of the study watershed.

Month	Mean RF (mm)	Mean Max. Temp (℃)	Mean Mini. Temp (℃)	Mean Temp (℃)
January	40.1	22.7	11.6	17.2
February	75.4	25.2	12.1	18.7
March	99.1	26.1	13.6	19.9
April	209.1	27.2	14.6	20.9
May	48.7	29.2	16.0	22.6
June	83.2	30.7	16.6	23.7
July	255.5	28.6	16.0	22.3
August	281.8	27.0	15.3	21.2
September	363.1	27.0	14.7	20.9
October	74.2	26.0	12.6	19.3
November	99.7	24.8	11.1	18.0
December	23.9	23.7	10.7	17.2
Average	1653.8	26.5	13.7	20.1

Table 8. Soil textural classes of the study watershed (Mean value %) in relation to soil depth (cm) and treatments.

Treatments	Soil depth (cm)	%sand	%silt	%clay	Texture class
		27.4	34.3	38.4	Clay loam
C	0-15	31.6	31.4	37.0	Clay loam

Treatments	Soil depth (cm)	%sand	%silt	%clay	Texture class
C	0-15	30.3	33.1	36.6	Clay loam
C	15-30	31.5	32.6	35.9	Clay loam
C	15-30	32.6	31.4	36.0	Clay loam
C	15-30	33.1	31.9	35.0	Clay loam
NC	0-15	35.5	33.0	31.5	Clay loam
NC	0-15	34.1	34.5	31.4	Clay loam
NC	0-15	35.9	33.1	31.0	Clay loam
NC	15-30	36.9	32.9	30.3	Clay loam
NC	15-30	36.6	32.4	31.0	Clay loam
NC	15-30	36.1	34.3	29.6	Clay loam

C = Conserved plot with LSB, NC = Non-conserved plot.

Table 9. *Person's correlations of selected soil properties.*

SOV	SOC	pH	CEC	sand	Silt	Clay	SC	BD	MC	LU	SD
SOC	1	.28*	-.07	-.50	.04	.46	.50	-.34	.19	-.40	-.12
pH	.28*	1	.09	-.36	.16	.26*	.36	-.20	.13	-.17	-.30*
CEC	-.07	.09	1	.01	-.17	.09	-.01	-.45	.18	-.02	-.34
sand	-.50	-.36	.08	1	-.21	-.84	-1.00	.37	-.18	.72	.31*
silt	.04	.16	-.17	-.21	1	-.35	.21	.11	-.26*	.24*	-.18
Clay	.46	.26*	.09	-.84	-.35	1	.84	-.42	.32*	-.83	-.20
SC	.50	.36	-.01	-1.00	.21	.843	1	-.37	.18	-.72	-.31*
BD	-.34	-.20	-.45	.37	.11	-.416	-.37	1	-.42	.32*	.38
MC	.19	.13	.18	-.18	-.26*	.316*	.18	-.423	1.00	-.36	.22
LU	-.40	-.17	-.02	.72	.24*	-.828	-.72	.322*	-.36	1	.00
SD	-.12	-.30*	-.34	.31*	-.18	-.197	-.31*	.380	.22	.00	1

*Correlation is significant at the 0.05 level.

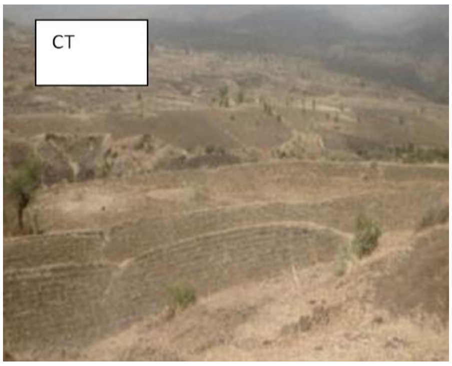


Figure 4. *Conservation treatment with level soil bund.*

Figure 5. *None-conserved treatment.*

Figure 6. Soil texture Laboratory photo texture analysis.

Figure 7. Laboratory photo CEC analysis.

Figure 8. Laboratory photo SOC analysis.

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