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Research Article

Evaluation of the effectiveness of level soil bund and soil bund age on selected soil physicochemical properties in Somodo Watershed, Jimma Zone, SouthWestern Ethiopia

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Abstract: This study was conducted to investigate the effect of level soil bund stabilized with Vetiver grass and soil bund age on selected soil physicochemical properties on Somodo watershed, Jimma Zone, South-western, Ethiopia. A reconnaissance survey was conducted to identify a representative sampling site. From the selected sampling site croplands with level soil bund aged three years, six years and adjacent untreated cropland were identified. A total of 108 composite soil samples (3 treatments * 6 replications * 2 depths * 3 zones) were collected. Soil samples were analyzed following standard laboratory analysis. Ages of level soil bund (LSB) significantly affected SMC (soil moisture content) ($p<0.01$), BD (bulk density) ($p<0.01$), and SOC (soil organic carbon) ($p<0.01$). Zones showed significant difference in sand content ($p<0.05$), SMC ($p<0.01$), BD ($p<0.05$) and SOC ($p<0.01$). Moreover, the soil depths also significantly influenced silt content ($p<.05$), SMC ($p<.01$), BD ($p<0.01$), SOC ($p<0.01$), TN (total nitrogen) ($p<0.01$), Av.-P (available phosphorous) ($p<0.01$) and CEC ($p<0.05$). The interaction effect of the age of LSB with zone was significant for SOC ($P<0.05$). To sum up, the effect of the constructed level soil bund had a positive impact on selected soil physicochemical properties of the site. Therefore, the study suggests that it is essential to maintain the structure to sustain the effectiveness and scale up the technology to other watersheds with similar agroecology of the country. Further study is encouraged to understand more about the effect of the slope and Vetiver grass bund stabilization role independently on selected soil properties.

Keywords: *age of soil bund, inter bund zones, soil properties, Vetiver grass*

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Introduction

Soil erosion is the main environmental problems challenging human society and each year about 10 million hectares of cropland are lost due to soil erosion affecting ecosystem productivity and reduction of the arable land available for food production (Boardman et al., 2009; Pimentel and Burgess, 2013; Montanarella et al., 2016). It has been severe throughout the highlands generally and particular on cultivated land. In a single rain, about 1 mm of soil, easily lost. Still, this loss of soil over a hectare of cropland accounts for 15 t/ha (Pimentel and Burgess, 2013). Furthermore, the rate of soil loss by erosion from cultivated land is about 10 to 40 times more rapidly than the rate of soil formation and putting into risk the food security (Pimentel and Burgess, 2013). This soil is no more available to support crops; that threatens food production (Gebreselassie et al., 2009; Hurni et al., 2010; Pimentel and Burgess, 2013; Jaleta et al., 2016).

In Ethiopia, the economy depends mainly on agricultural activities (MoFED, 2010; CSA, 2012). However, the sector is threatening by loss of productivity due to severe soil erosion on agricultural lands. The average annual rate of soil loss in the country is approximated to be 12 t/ha/yr and it can be higher up to 300 t/ha/yr on extremely exposed areas where the slope is steep and less vegetation cover the land (Demeke, 2003). This exceeds the acceptable soil loss level of mean annual soil loss of 11 t/ha/yr (Morgan, 2005; Tulu, 2011). Therefore, soil erosion and land degradation along with other related environmental issues need considerations in the country (Daley, 2015). Farmers use soil and water conservation to reduce the risk of soil and production loss (Kato et al., 2011). Soil bund reduces the velocity of runoff and consequently soil loss and associated soil organic carbon and nutrient losses from cultivated lands (Adimassu et al., 2014). Soil bund is constructed along the contour with an embankment made of soil and/ or stones, with a runoff collection ditch at its upper the slope. It is either graded or level based on the agroecology, the slope gradient, the soil texture, the soil depth and according to farmer's consent. The level soil bund constructed following the contour and its walls retains all runoff between two bunds. The bund can be practiced in a slope range of 3 - 50% and soil depths greater than 50 cm (Hurni et al., 2016). In Somodo Watershed since 2011, more than 47.5% of the watershed, about 190 hectares was covered by level soil bund stabilized with Vetiver grass and Vetiver hedgerow without soil bund (Tesfaye et al., 2018a). The effectiveness of the conservation measures varies based on climate, soil, and topography of the region. This needs consideration when promoting and scaling up the technology; hence, the effect of soil bund construction on soil properties are studied in different areas to quantify its impact (Kato et al., 2011; Haregeweyn et al., 2015). Therefore, this study was intended to investigate and draw conclusions on the effect of soil and water conservation on variations of selected soil physicochemical properties in Somodo Watershed with emphasis on the level of soil bund.

Materials and Methods

Description of the study site

Location

The study was conducted in Somodo Watershed, which is located in the Abay/Blue Nile river basin, the upper part of Dhidhesa catchment, and administratively found at Manna district, Jimma zone in the Oromia Regional State of Ethiopia. It is located at 15 km West of Jimma town and 368 km South-West of Addis Ababa. It is geographically situated between 7°45''30'N-7°47''00'N latitude and 36°48''00'E-36°49''00'E longitude (Figure 1).

Agroecology and soil

Agro-climatic zones of the district are classified into Dega (12%), Woinadega (63%), and Kolla (25%) (ARDO, 2008). The long term means annual rainfall of the watershed is 1954.3 mm and the mean temperature is 19.3°C ranging from 15.0°C to 23.5°C (Figure 2). The altitude of the study area ranges from 1900 - 2050 m (Tesfaye et al., 2018b). Nitisols and Orthic Acrisols are the most dominant soil types of southwestern highlands of the district.

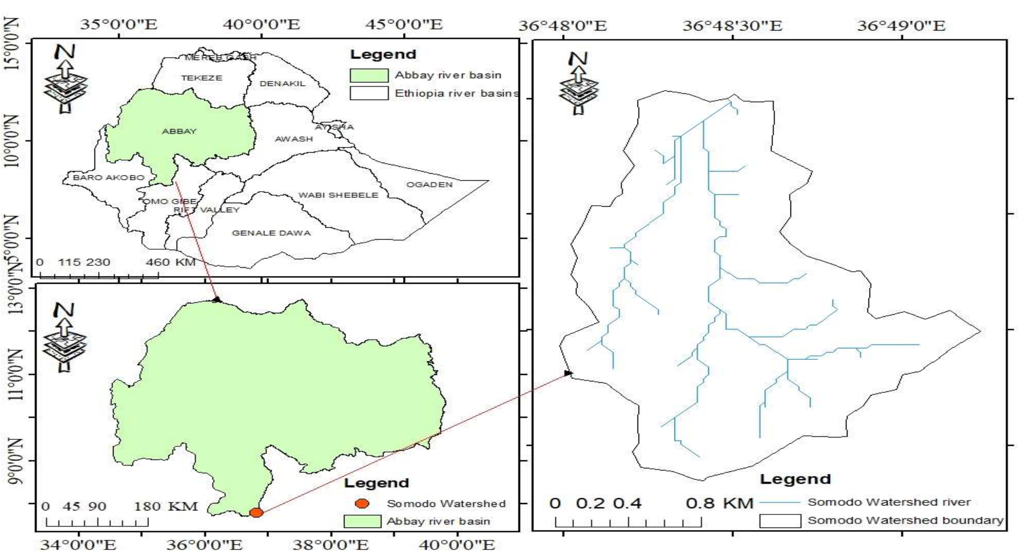

Figure 1. Map of Somodo Watershed, Jimma Zone, South-Western of Ethiopia.

Nitisols account for 64% of the area with slightly acidic as mapped by CASCAPE (CApacity building for SCaling up of evidence-based best practice in Agricultural Production in Ethiopia) (Elias, 2016). The soil pH of the watershed shows a very strong acidic condition 4.5-5 (Table 3).

Farming system and land use

The farming system of the area falls under the mixed farming system. The agricultural land, forest land, grazing land and agroforestry practice are the major land uses practiced in southwestern and particularly in Somodo Watershed (Alemayehu et al*.,* 2019).

Research design and soil sampling

A reconnaissance survey was conducted to identify representative sampling sites. Sampling sites were selected from croplands with level soil bund (LSB) stabilized with Vetiver grass of 3 years aged, 6 years aged and adjacent untreated cropland in the micro-watershed. The composite samples were collected from upper, middle and lower parts of the fields for each treatment within a similar range of altitude and slope to block soil property variation due to micro-topographic differences. The soil samples were collected from consecutive inter bund zones (loss, middle, and deposition) and from adjacent cropland without conservation measure and replicated six times. The soil samples were collected from the zones at two depths (0-20 cm and 20-40 cm) using sharp-edged, closed and circular auger pushed manually down the soil profile. Undisturbed samples were also taken from the sampling position for bulk density determination using a core sampler. At each sampling plot of 10*10 m, six composite disturbed and undisturbed soil samples were collected. A total of 108 soil samples (3 treatments * 6 replications * 2 depths (0-20 and 20-40 cm) * 3 inter bund zones (loss, middle and deposition) were collected for selected soil physicochemical analysis. The soil samples were collected in early December 2017 immediately after harvesting time. The collected soil samples were transported to the Jimma Agricultural Research Centre laboratory and Jimma University, College of Agriculture and Veterinary medicine for analysis and determination of soil property variation.

Laboratory analyses

Soil moisture content was determined according to the formula given by Zobel (1987). Bulk density was determined by the core method (Black et al., 1965). Textural class was determined using the hydrometer method (Bouyoucos, 1927). Soil reaction (pH) was determined by a water suspension method with the microprocessor-based pH system on a 1:2.5 soil to water ratio (Jacson, 1958), and cation exchange capacity (CEC) was determined by extraction with Ammonium acetate method (Amma, 1989). Soil organic carbon (SOC) was determined by Walkley and black method (Walkley and Black, 1934). Kjeldahl digestion, distillation, and titration method (Bremner and Mulvaney, 1982) was used for total N (TN) determination. Bray II extraction method with spectrophotometer analysis (Bray and Kurtz, 1945) was used for available phosphorus (Av.-P) determination.

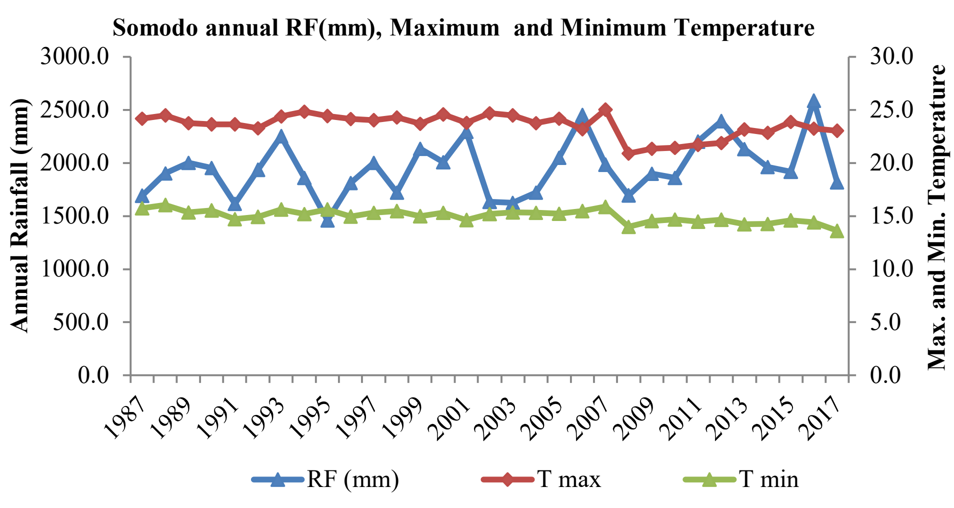

Figure 2. Mean of annual rainfall, maximum and minimum temperature of Sodomo Watershed.

Data analysis

Soil data were tested using ANOVA following General linear model (GLM) procedure at the 5% level of probability using the Statistical software for social science (SPSS) version 16 for windows (Julie, 2001). List significance difference (LSD) was used to separate means of treatments when they are significantly different**.**

Results and Discussion

Effect of soil bund age, inter bund zone and soil depth on selected soil physical properties

Soil particle size fractions

Soil particle size fractions (%) of sand, silt, and clay did not show significant variation between the age of LSB and unconserved adjacent cropland (Table 1). The soil textural class of the site falls under sand clay loam that showing the similarity of parent material that the soil originates from. Brady and Weil (2002) indicate that soil texture is not altered by the management practice on a field scale; because a soil weathering process is a slow rate. Thus, this might show that the observed difference in the physicochemical properties of the soil was not due to inherent properties of the soil rather due to management effects. This result was in line with the findings of Bekele et al. (2016); Ademe et al. (2017) who exhibited no significant variation of soil particle size fractions between conserved and non-conserved cropland. However, the result was not consistent with the finding of Wolka et al. (2011) in which silt and clay fractions showed a significant difference ($p<0.05$) in the cropland with 6 years aged LSB when compared with adjacent non-conserved cropland.

The sand fraction showed a significant difference ($p<0.05$) with zones; while clay and silt fractions did not show a significant variation under zones (Table 1). The mean sand fraction found to be high at a loss, middle and deposition zone, respectively in adjacent cropland without conservation measure than in cropland with 6 years aged LSB and cropland with 3 years aged LSB. This could indicate the washing out of the finer textural fractions from the loss zone by the erosion process. A similar pattern was reported by Hailu (2017) the mean sand content was higher at the upper landscape than at the lower landscape position. The silt fraction exhibited a significant difference ($p<0.05$) under soil depths; while sand, and clay fractions did not show significant variation under the soil depths (Table 2). The overall mean of silt fraction demonstrated a higher mean value in topsoil than subsoil layers; conversely, sand and clay fractions were higher at subsoil than topsoil layer (Table 2). The result was consistent with the finding of Demelash and Stahr (2010); Bekele et al. (2016) who confirms a significant variation of the particle size distribution of percent silt content on topsoil due to SWC measures.

Bulk density

The bulk density (BD, g cm^{-3}) in the cropland with 6 years aged LSB was significantly lower ($p<0.05$) than cropland conserved with 3 years aged LSB and adjacent cropland without soil conservation measure (Table 1). Apparently, this was due to the effect of LSB in conserved croplands contributes to conserving soil moisture that favor plant growth accompanying the input of crop residue and reduced loss of fertile topsoil. This, in turn, reduces the bulk density of the soil. The current result coincides with the finding of Husen et al., (2017) who reported significant differences ($p<0.05$) among the ages of soil bund while a higher mean value of bulk density was observed on a non-conserved plot, on a study conducted in Central Ethiopia. The same trend was found by Gebreselassie et al. (2009) who reported higher mean value for non-conserved than cropland with 9 years aged soil bund. According to Jahn et al. (2006), low bulk density leads to more favourable soil tilth that contributes to easy tillage, water movement, seedling emergence, and plant root development.

The bulk density was contained significant variation ($p<0.05$) with zones and depths (Tables 1 and 2). Similar to the age of level soil bund, bulk density of cropland without soil conservation at all zones (loss, middle, and deposition) and depths were recorded higher mean value than cropland with 6 years aged LSB and 3 years aged LSB. The overall mean of bulk density was showed significant variation at the loss zone (1.16±.17), while the middle (1.13±.17) and deposition (1.13±.17) zones did not show significant variations. Regarding the soil depths, a lower mean value found in the topsoil (1.09±.12) than the subsoil (1.20±.13) layer. Evidently, this was because of the transportation of fine particles and organic matters from the loss zone through the erosion process. Thus, results in the exposure of coarse particles from the loss zone and subsequent accumulation of these materials at the deposition zone. Consequently, it increases the bulk density of the soil at the loss zone. The coarse-textured soils are less likely to be aggregated and the BD commonly higher than in finer textured soils (Gupta, 2010). A similar trend was reported by Bekele et al. (2016); Husen et al. *(*2017) that the mean value of bulk density was the highest at highland and the lowest at lowland due to the transportation of fertile topsoil. The same holds true for the loss and deposition zones. This implicates the requirement of integration with agronomic measures to offset the detachments and transportations of fine particles and fertile topsoil by erosion processes from the loss zone. The BD was showing an increment with increasing depths under all treatments. This in fact due to organic matter input from the crop residue on topsoil than the subsoil layer in the conserved cropland than cropland without conservation measure. The present result was in correspondence with the finding of Yimer et al. (2008); Bekele et al. (2016) who reports the lower bulk density for topsoil than the subsoil layer. Soils with high organic matter likely have lighter weight and better aggregates; hence, tend to have high pore spaces that in turn, reduce the bulk density of the soil. The bulk density also increases with depth because of the effects of the weight of the overlying layer, fewer roots, and low activity of soil organisms (Brady and Weil, 2002; Troeh and Thompson, 2005; Gupta, 2010). In general, according to Troeh and Thompson (2005); Gupta (2010) the bulk density of the A horizons of the mineral soils is usually between 1.0 - 1.6 g/cm; likewise, the bulk density of the study site was ranging from 1.09-1.20 g/cm, which falls within the acceptable range.

Soil moisture content

The soil moisture content (SMC, %) of the study area was significantly higher ($p < 0.05$) in croplands with 6 years aged LSB (28.5±7.6) than adjacent cropland without conservation measure (27.07±8.1) (Table 1). This seems due to the effect of soil bund construction on conserved cropland; which increases moisture conservation along with the age of soil bund establishment. According to Erkossa et al. (2018), the SMC of a plot with level soil bund consistently exceeded than plot without soil bund. A similar result was reported by Challa et al. (2016), which confirmed that the conserved plot exhibited a significant difference in SMC as compared to the non-conserved plot. The conserved soil moisture enhances biomass production and increases organic matter input on conserved cropland. According to Brady and Weil (2002); Gupta (2010); McCauley et al. (2017), the humus fraction of soil organic matter improves soil aggregate; hence soil structure that increases the infiltration and soil water holding capacity.

The SMC of croplands with 6 years aged LSB in all zones (loss, middle, and deposition) was significantly higher ($p<0.05$) than adjacent croplands without soil bund (Table 1). Apart from the age of level soil bund and zones, an attempt was also made to examine the variation of SMC in soil depth. Accordingly, a statistically significant variation ($p < 0.05$) was observed between SMC of cropland with 6 years aged LSB and without conservation measure. Both the top layer (0-20 cm) and bottom layer (20-40 cm) mean of SMC was higher in the cropland with 6 years aged LSB than cropland without soil conservation measure and LSB with 3 years aged LSB (Table 2). This clearly due to contributions of conservation structures that retards the runoff velocity and giving enough time to infiltrate into the soil rather than running down the slope. Perhaps the water stored at topsoil exposed for evaporation than subsoil. The result was in line with the finding of Gong et al. (2003) in which water content in the soil column was not uniform and the soil column was wetter at the bottom than topsoil. Soil bund extends, soil moisture depletion at the end of the growing season below the bunds than cropland without soil bund (Adimassu et al*.,* 2017; Erkossa et al., 2018).

Effect of soil bund age, inter bund zone and soil depth on selected soil chemical properties

Soil pH

Soil pH (pH, H_2O) was not shown significant variation between the age of LSB and adjacent cropland without conservation measure (Table 3). This might designate leaching of basic cations by high rainfall and level of land degradation induced due to previous land management practice of the site. Furthermore, climate, weathering of minerals, and parent material in the soil derived from are also the possible factors that affect soil pH (McCauley et al., 2017). Likewise, Wolka et al. (2011) reported that the pH of the cropland with LSB was not significantly different as compared to non-terraced cropland. On the contrary, Ademe et al. (2017) indicated that the soil and water conservation improved the pH of conserved cropland than non-conserved cropland. Variation of soil pH affects nutrient availability, microbial activity, and plant root growth (Brady and Weil, 2002). The pH was not exhibited significant difference with respect to zones and soil depths under all croplands (with 3 years aged LSB, 6 years aged LSB, and adjacent cropland without conservation measure) (Tables 3 and 4). The result was in agreement with the finding of Amare et al. (2013), who found no significant variation ($p\leq0.05$) for the mean value of pH for the loss and deposition zones of terraced cropland. Conversely; Bekele et al. (2016) reported that a significant difference ($p<0.05$) of soil reaction for subsoil than topsoil. The mean value of pH was ranging from 4.71–4.78, which is rated as very strong acidic (4.5-5.0) following Elias (2016). However, the most favourable range of pH of the soil is 6.5–7.0

for plant nutrient availability (Tulu, 2011). Therefore, this could imply the requirement of additional soil organic matter management and soil amendment mechanisms such as liming to reduce the acidity of the soil, hence improve the availability of plant nutrients.

Table 1. Mean value of selected soil physical properties in relation to age of level soil bund and zones (±SDM), n=108.

Variables	Zones	Age of soil bund			Overall
		6 years	3 years	Control	
SMC (%)	Loss	27.69±8.8	27.61±8.6	26.80±8.9	27.37±8.5^{a}
	Middle	27.82±7.3	27.16±8.5	27.01±8.0	27.30±7.7^{a}
	Deposition	30.03±6.4	29.10±7.5	27.40±7.4	28.80±7.2^{b}
	Over all	28.50+7.6^{b}	27.96+8.1^{ab}	27.07+7.9^{a}	
BD (g/cm)	Loss	1.11±.17	1.17±.13	1.21±.16	1.16±.17^{b}
	Middle	1.11±.14	1.13±.19	1.18±.16	1.13±.17^{a}
	Deposition	1.07±.13	1.13±.07	1.20±.13	1.13±.15^{a}
	Over all	1.09±.15^{a}	1.14±.14^{b}	1.20±.15^{c}	
Sand (%)	Loss	58.38±14.6	60.71±13.3	61.57±9.4	60.22±12.6^{a}
	Middle	56.76±6.1	57.62±11.2	58.81±9.2	57.73±9.0^{b}
	Deposition	55.52±11.3	55.76±8.1	56.05±11.9	55.78±10.3^{b}
	Over all	56.89±11.1	58.03±11.4	58.81±10.3	
Silt (%)	Loss	9.92±4.6	9.63±4.4	7.94±4.2	9.16±4.3
	Middle	9.73±6.3	10.77±3.5	9.69±9.2	10.06±6.7
	Deposition	11.92±3.5	10.80±4.2	9.32±6.1	10.68±4.7
	Over all	10.52±5.2	10.40±4.1	8.98±6.8	
Clay (%)	Loss	32.43±15.3	29.90±14.8	29.62±8.2	30.65±13.0
	Middle	31.42±11.7	31.95±11.0	33.29±5.6	32.22±9.6
	Deposition	33.90±10.1	32.86±9.2	33.71±12.3	33.49±10.4
	Over all	32.59±12.3	31.57±11.8	32.21±9.5	
Textural class		SCL	SCL	SCL	

Overall means within rows and column followed by the same letter are not statically different at $p \leq 0.05$ with respect to age of LSB and zones, respectively; SMC = soil moisture content; BD = bulk density, SCL = sand clay loam, SDM = standard deviation of mean, n = number of samples.

Table 2. Mean value of soil physical properties in relation to age of level soil bund and soil depths (±SDM), n=108.

Variables	Depth (cm)	Age of soil bund			Overall
		6 years	3 years	control	
SMC (%)	0-20	24.91±4.0	24.14±3.3	23.07±2.5	24.04±3.6^{a}
	20-40	32.11±2.7	31.77±4.0	31.07±2.0	31.65±3.1^{b}
	Over all	28.51±7.6^{b}	27.96±8.1^{ab}	27.07±7.9^{a}	
BD (g/cm)	0-20	1.03±.09	1.09±.09	1.13±.08	1.09±.12^{a}
	20-40	1.16±.10	1.19±.12	1.26±.08	1.20±.13^{b}
	Over all	1.09±.15^{a}	1.14±.14^{b}	1.20±.15^{c}	
Sand (%)	0-20	56.67±12.5	58.79±8.5	57.35±11.4	57.60±10.8
	20-40	57.11±10.0	57.30±13.9	60.30±9.8	58.22±11.5
	Over all	56.89±11.1	58.03±11.4	58.81±10.8	
Silt (%)	0-20	11.43±4.6	11.01±3.5	9.43±4.1	10.62±4.0^{b}
	20-40	9.62±5.3	9.79±4.4	8.61±8.8	9.34±6.4^{a}
	Over all	10.52±5.2	10.40±4.2	8.98±6.8	
Clay (%)	0-20	31.62±13.3	30.70±10.3	32.98±9.7	31.77±11.1
	20-40	33.56±11.4	32.44±13.2	31.43±9.5	32.48±11.3
	Over all	32.59±12.3	31.57±11.8	32.21±9.5	
Textural class		SCL	SCL	SCL	

Overall means within rows and column followed by the same letter are not statically different at $p \leq 0.05$; SMC = soil moisture content; BD = bulk density; SCL = sand clay loam; SDM = standard deviation of mean, n = number of samples.

Cation exchange capacity

Cation exchange capacity (CEC, meq/100 g) was not shown a significant difference with the age of LSB and zones. However, the higher mean CEC was observed under cropland with 6 years aged LSB (19.40±8.30) than cropland with 3 years LSB (18.47±8.30) and adjacent cropland without conservation measure (18.90±9.85) and under the deposition zone (19.22±7.95) than the respective middle (18.93±8.90) and loss (18.65±9.65) zones (Table 3). This might be due to a slightly lower soil pH of the soil under cropland with 6 years aged LSB and deposition zone because CEC can be affected intensely by pH changes. This result did not agree with the finding by Amare et al. (2013) who reported the mean value of CEC showed a significant difference ($p<0.05$) for conserved cropland than cropland without conservation measure. A similar trend was also reported by Hailu (2017) that CEC was not significantly different between higher, middle, and lower landscape positions of the study site. In contrast, Amare et al. (2013) reported significant differences ($p\leq0.05$) of CEC among loss and deposition zones and discussed the possible reasons for the reduction in CEC at the loss zone could be induced by erosion and transportation of clay and organic matter at the loss zone. CEC was showed higher mean value under the topsoil (0-20 cm) in the croplands with 6 years aged LSB than 3 years aged LSB and adjacent cropland without conservation measure. While the higher mean value of CEC was recorded under the subsoil (20-40 cm) in the croplands without soil conservation measure than 6 years and 3 years aged LSB. The overall mean value of CEC was exhibited a significant difference in the subsoil (20.12±9.1) than the topsoil (17.74±8.0) layer (Table 4). This probably due to higher clay content and a relatively higher mean of soil pH at subsoil than the topsoil layer. CEC determines the sensitivity of base cation depletion through leaching, which is less sensitive for soils having a high cation exchange capacity that in turn affects the soil reaction (Nawaz et al., 2011).

Table 3. Mean value of selected soil chemical properties in relation to age of level soil bund and zones (±SDM), n=108.

Variables	zones	Age of soil bund			Overall
		6 years	3 years	Control	
pH(1:2.5)	Loss	4.76±.29	4.72±.24	4.64±.29	4.71±.30
	Middle	4.76±.45	4.74±.31	4.72±.27	4.74±.34
	Deposition	4.79±.35	4.76±.36	4.78±.35	4.78±.34
	Over all	4.77±.36	4.74±.30	4.71±.33	
CEC (meq/100g)	Loss	18.78±10.2	18.10±10.1	19.08±11.4	18.65±9.6
	Middle	20.50±7.9	18.88±9.6	17.41±8.9	18.93±8.9
	Deposition	19.02±6.9	18.45±8.1	20.20±9.1	19.22±7.9
	Over all	19.40±8.3	18.47±8.3	18.90±9.8	
SOC (%)	Loss	2.30±.57	2.10±.56	1.71±.60	2.09±.83[a]
	Middle	2.33±.68	2.11±.67	2.06±.78	2.16±.69[b]
	Deposition	2.35±.73	2.25±.71	2.25±.69	2.23±.68[b]
	Over all	2.33±.64[c]	2.15±.64[b]	2.0±.80[a]	
TN (%)	Loss	0.21±.06	0.19±.06	0.21±.10	0.20±.08
	Middle	0.22±.10	0.19±.08	0.18±.08	0.20±.08
	Deposition	0.22±.10	0.22±.07	0.21±.10	0.21±.08
	Over all	0.22±.07	0.20±.07	0.19±.09	
C:N	Loss	10.96±2.7	11.19±3.5	8.50±3.9	10.21±4.0
	Middle	10.72±2.8	11.57±6.9	12.23±6.2	11.51±5.6
	Deposition	11.72±10.8	10.50±3.1	12.01±10.7	11.41±8.8
	Over all	11.13±6.5	11.08±5.5	10.91±7.8	
Av.-P (ppm)	Loss	0.96±.48	0.76±.55	0.72±.59	0.81±.56
	Middle	0.99±.57	0.78±.77	0.82±.65	0.86±.67
	Deposition	1.05±.77	0.96±.67	0.97±.80	0.99±.73
	Over all	1.00±.61	0.83±.67	0.83±.69	

Overall means within rows and column followed by the same letter are not statically different at $p\leq0.05$ with respect to age of LSB and zones, respectively, SOC = soil organic carbon; TN = total nitrogen; C:N = carbon to nitrogen ratio; pH = hydrogen ion concentration; Av-P = available phosphorus; CEC = cation exchange capacity, SDM = standard deviation of mean, n = number of samples.

Table 4. Mean value of selected soil chemical properties in relation to age of level soil bund and soil depths (±SDM), n=108.

Variables	Depth (cm)	Age of soil bund			Overall
		6 years	3 years	Control	
pH (1:2.5)	0-20	4.74±.29	4.75±.29	4.70±.35	4.73±.31
	20-40	4.81±.41	4.73±.30	4.73±.31	4.76±.35
	Over all	4.77±.35	4.74±.30	4.71±.33	
CEC (meq/100 g)	0-20	18.90±4.0	17.60±7.9	17.60±9.6	17.74±8.0[a]
	20-40	19.13±9.4	19.40±8.5	20.20±9.7	20.12±9.1[b]
	Over all	19.43±8.30	18.50±8.3	18.90±9.8	
SOC (%)	0-20	2.57±.32	2.38±.49	2.24±.75	2.40±.60[b]
	20-40	2.08±.54	1.92±.47	1.77±.59	1.92±.58[a]
	Over all	2.33±.64[c]	2.15±.64[b]	2.00±.80[a]	
TN (%)	0-20	0.24±.08	0.21±.08	0.21±.10	0.22±.09[b]
	20-40	0.20±.04	0.19±.06	0.19±.09	0.19±.06[a]
	Over all	0.22±.07	0.20±.07	0.20±.09	
C: N	0-20	11.52±8.5	11.72±4.7	11.76±9.67	11.74±7.8
	20-40	10.75±3.7	10.43±4.6	10.06±5.9	10.48±5.1
	Over all	11.13.±6.5	11.08±4.7	10.91±8.0	
Av.-P (ppm)	0-20	1.09±.65	0.96±.73	0.94±.67	1.00±.69[b]
	20-40	0.91±.51	0.71±.53	0.72±.67	0.78±.59[a]
	Over all	1.00±.61	0.83±.67	0.83±.69	

Column and rowwith the same letter are not statically different at p≤0.05 with respect to depths and ages, respectively, SOC = soil organic carbon; TN = total nitrogen; C:N = carbon to nitrogen ratio; pH = hydrogen ion concentration; Av-P = available phosphorus; CEC = cation exchange capacity, SDM = standard deviation of the mean, n = number of samples.

This result was in agreement with the finding of Bekele et al. (2016) who reported significant and higher mean was observed in the subsoil than the topsoil layer. However, the reverse trend was reported by Abegaz and Adugna (2015) the topsoil of cultivated land had higher CEC than subsoil under cultivated land use. The mean of the CEC of the study site varied from 17.74-19.43 meq/100g soil, which was rated as medium 12-25 meq/100g soil (Landon, 1991; Elias, 2016).

Soil organic carbon

Soil organic carbon (SOC, %), is a key attribute that affects many soil physical, biological, and chemical properties that serve as a major source of plant nutrients (Brady and Weil, 2002; Gupta, 2010), was significantly ($p < 0.05$) varied with the age of LSB and adjacent cropland without soil conservation (Table 3). The SOC has exhibited a higher mean value of SOC in croplands with 6 years aged LSB (2.33±.64), 3 years aged LSB (2.15±.64) and adjacent cropland without SWC (2.0±.80), respectively (Table 3). This clearly points out the role of the age of establishment of soil bund on the accumulation of organic matter in the conserved cropland. The result was in agreement with the finding of Demelash and Stahr (2010) who reported the older age of soil bund stabilized with vegetative measure to have a better effect on soil organic matter accumulation. Likewise, the present result revealed similar patterns with the finding of Gebreselasse et al. (2009) who reports that fields having the older soil bund had high organic carbon content. Similarly, Bekele et al. (2016) and Husen et al. (2017) reported that significant difference at $p<0.05$ in the mean value of organic carbon (SOC) contents among conserved and un-conserved farmland. However, the result was in contrast with the finding of Wolka et al. (2011) who reports cropland with four and six-year aged LSB did not significantly different as compared to adjacent cropland without conservation measure.

Variation of SOC has exhibited a significant difference ($p<0.05$) with zones. The SOC at all zones (loss, middle, and deposition) in cropland with 6 years aged LSB (2.30±.57, 2.33±.68, and 2.35±.73) was higher than croplands with 3 years aged LSB (2.10±.56, 2.11±.67, and 2.25±.71) and adjacent cropland without soil conservation measure (1.71±.60, 2.06±.78, and 2.25±.69), respectively. Similarly, there was a higher mean of SOC in cropland with 3 years aged LSB than adjacent cropland without soil conservation measure (Table 3). This might show the washing out of fertile topsoil from the loss zone by the effect of soil erosion and associated accumulation at the deposition zone as the impeded velocity of runoff by soil bund. This in turn improves the soil organic carbon content at the deposition zone. This result supports the finding by Amare et al. (2013) that soil organic matter contents between accumulation and loss zones were significantly different ($p \leq 0.01$). A similar trend was reported by Husen et al. (2017) in which soil organic carbon was significantly different ($p<0.05$) for lowland where the soil was deposited than the high land from which soil was eroded. According to Wang et al. (2008), upland eroding areas have significantly less SOC than in deposition areas, which was consistent with the results of the present study. This implies if the soil bund regularly maintained; through time it will develop to bench terrace that reduces erosion and improves SOM accumulation. According to Tesfaye et al. (2018a), the level soil bund stabilized with Vetiver grass was reduced the slope of the cultivated land by 2.5% within two years at Somodo Watershed, hence reduce the velocity of runoff and associated soil loss.

The SOC was significantly higher ($p < 0.01$) in topsoil than the subsoil layer (Table 4). Higher SOC was observed under soil depths (0-20 cm and 20-40 cm) in the croplands with 6 years aged LSB (2.57±.32, 2.08±.54), 3 years aged LSB (2.38±.49,1.92±.47), and adjacent croplands without conservation measure (2.24±.75, 1.77±.59), respectively. Apparently, this was due to the role of crop residue input on topsoil than the subsoil horizon that in turn improves the organic carbon content of the soil. A similar pattern was reported by Yimer et al. (2008), that soil organic carbon was higher for topsoil (0-20 cm) and decreasing with depths in the study conducted on different land use in the Bale Mountains, Ethiopia. According to Gupta (2010), the topsoil is a major zone for crop plant root development and crop residue input that modify it than the subsoil layer.

The interaction effect of the age of LSB with zone was significantly different ($p<0.05$) for SOC. This possibly due to the age of the LSB; because as the age of the conservation structure increases the soil erosion between the inter bund zone decreases and SOC accumulation on cropland also increases. A similar result was reported by Bekele et al. (2016), SOC was significantly different from the interaction of the factors. However, the result was inconsistent with the finding of Husen et al. (2017) in which the interaction effects between site (landscape position) and age were not significantly different at $p<0.05$ for SOC. In general, the overall mean of SOC of the site ranges from 1.9–2.44%; according to Elias (2016) the rating criteria adopted by CASCAPE for the soil of the Ethiopian highlands, SOC of the cropland was categorized in the high range (1.7-2.5%).

Total nitrogen

The total nitrogen (TN, %) was not significantly different between age of LSB and zones. However, the higher mean value of TN was observed under croplands with 6 years aged LSB than cropland with 3 years aged LSB and adjacent cropland without conservation measure and in zones (deposition, middle, and loss) of croplands, respectively (Table 3). This perhaps due to improved organic matter accumulation in conserved cropland and under deposition zone that serves as a source of nitrogen through mineralization in croplands with 6 years aged. The result was consistent with the finding of Wolka et al. (2011) who reported total nitrogen did not significantly differ in the cropland with LSB as compared to non-terraced. However, in contrast to the finding of Gebreselasse et al. (2009) who reports 9 years aged soil bund stabilized with Vetiver grass was exhibited a significant difference as compared to non-conserved cropland. A similar trend was also found by Amare et al. (2013), the highest total N content was found under the deposition zone.

The topsoil layer (0-20 cm) mean value of TN was significantly higher ($p<0.05$) than the bottom layer (20-40 cm) in all croplands (Table 4).This could specify the effect of organic matter input from crop residues for topsoil layers than subsoil layers and creating a conducive environment for active microbial involvement for mineralization of incorporated organic material and release of nitrogen. The present result was in line with Bekele et al. (2016) who indicated significant differences ($p<0.05$) of TN for topsoil (0-20cm) than subsoil layer (20-40cm). Jobbagy and Jackson (2001) stated similar results that total nitrogen was one of the most limiting nutrients for plants consistently higher concentrations in the topsoil. The overall means of the total nitrogen content of the croplands were ranging from 0.19-0.22%, which falls under the medium (sufficient) range (0.15-0.25%) as rating criteria used by CASCAPE (Elias, 2016).

Carbon to nitrogen ratio

The carbon to nitrogen ratio (C:N) was not shown a significant difference with the age of LSB, zones, and soil depths in all croplands. However, the higher mean value of C:N was recorded in the croplands with 6 years aged LSB (11.13±6.5) than cropland with 3 years aged LSB (11.08±5.5) and adjacent cropland without conservation (10.91±7.8), respectively. The higher overall mean value of C:N was exhibited in topsoil than the subsoil layer (Tables 3 and 4). This might show that the requirement of crop residue management that improve SOC accumulation. This result was consistent with the finding of Bekele et al. (2016) who reported no significant variation of C:N ratio among conserved and adjacent cropland without soil conservation. Similarly, Brady and Weil (2002) indicated that C: N variation is less in a given climatic region and under similarly managed soil. Furthermore, Bekele et al. (2016), reported that C:N has not displayed a significant difference ($p<0.05$) between the topsoil and subsoil layer. According to Brady and Weil (2002), C:N is higher at the topsoil than the subsoil layer that was consistent with the present result of carbon to nitrogen ratio recorded. C:N of cultivation land ranges from 8:1 to 15:1, the average being around 12:1; therefore, the mean of C:N of the site range from 10:1-11:1, which could be categorized under the normal range that provides nitrogen in excess of microbial needs (Brady and Weil, 2002; Hazelton and Murphy, 2007).

Available phosphorus

Available phosphorous (Av.-P, ppm) was contained no significant variation with the age of LSB and zones (Table 3).This might be due to the strong acidity of the soil, which influences the soil phosphorus availability because it inhabits the soil microorganisms to mineralize organic matters and release organic phosphorus. This in agreement with the finding of Erkossa et al. (2018) who reported available phosphorus was not significantly different between a plot with level soil bund and non-conserved plot. The result was also in line with the finding of Amare et al. (2013) in which available phosphorus was not significantly different between the deposition zone and loss zone on the study conducted in the Anjeni watershed, Central Highlands of Ethiopia. However, the result was inconsistent with the finding of Husen et al. (2017) who reported available phosphorous was significantly different ($p < 0.05$) between the age of soil bund.

Available phosphorous was exhibited higher mean value under soil depths (0-20 cm and 20-40 cm) in croplands with 6 years aged LSB, 3 years, aged LSB and adjacent cropland without soil conservation measure, respectively. The higher overall mean value of Av-P was observed in the topsoil layer (1.00±.69) than the subsoil layer (0.78±.59) (Table 4). This might be due to the nutrient cycling effect of plant roots in the topsoil layer, organic matter input, and addition of inorganic phosphorus in the topsoil layer. The result was comparable to the finding of Abegaz and Adugna (2015) in which Av-P was higher under cultivated land in the topsoil than the subsoil layer. According to the finding of Jobbagy and Jackson (2001), phosphorus is one of the most essential plant nutrients, which is more concentrated in the topsoil (0-20 cm) layer that in line with the present result. In contrast, Bekele et al. (2016) reported significant differences ($p < 0.05$) of Av-P for subsoil (20-40 cm) than topsoil layer (0-20 cm). The overall mean value of available phosphorus was ranging from 0.78–1.00 ppm, which is in the very low range according to rating by Elias (2016). This probably due to the effect of previous land management, inherent properties of soil parent material, and strong acidic soil characteristics of the site that affect the availability of the phosphorus. Surface soil shall be supplied with inorganic fertilizer that increases the concentration of phosphorus in the soil solution to meet the amount demanded by crops.

Conclusion

The result revealed that the age of level soil bund has shown a significant variation of the mean value for SMC, SOC, and BD. However, soil particle size fractions, pH, TN, Av.P, C: N, and CEC were not affected. Regarding zones, the loss zone was shown a higher mean value for Bd and sand content; whereas the deposition and the middle zone was indicated a higher mean value for silt content, SOC, and Av-P while SMC at the deposition zone. In contrast, clay content, TN, C:N, pH, and CEC did not affect by zones. Considering the soil depths, the higher mean value was observed for silt content, SOC, TN, and Av-P in the topsoil. Conversely, SMC, BD, and CEC exhibited higher mean value in the subsoil. Sand content, clay content, pH, and C: N did not influence by soil depths. The interaction effect of the age of LSB, zones, and depths was significantly different for SOC. This indicates the role of conservation measure that improves organic matter content in cropland. To summarize, the effects of soil bund intervention at the watershed were found to have pronounced positive effects on some selected soil physicochemical properties. Based on the above findings, the following recommendation can be suggested for further consideration and improvement of the physical and chemical properties of the soil in the study area in particular and in the country in general. It is essential to create awareness and scale up the technology at the watershed level in the area and to other similar agro-ecology. Further study is encouraged to understand more about the effect of the slope and the role of Vetiver grass in bund stabilization independently on selected soil properties.

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