Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.9, No.12, 2017

The Effectiveness of Stone Bund to Maintain Soil Physical and Chemical Properties: The Case of Weday Watershed, East Hararge Zone, Oromia, Ethiopia

Dejene Teressa
Oda Bultum University, PO. Box 226. Chiro, Ethiopia

Abstract
The study was conducted in Weday watershed in East Hararge Zone, Oromia Region to evaluate the effectiveness of stone bund SWC measures to maintain soil physical and chemical properties. The experiment has two treatments (conserved and non- conserved farm land) and three slope classes (3-8 %, 8-13 % and 13-18%) with factorial arrangement in Randomize Complete Block Design (RCBD) replicated nine times. Results indicated that soil organic carbon (SOC), total nitrogen (TN), available phosphorus (Av.P), soil pH (H2O), Cation exchange capacity (CEC) showed significance differences with treatments ($P \leq 0.05$). Conserved farm land demonstrated higher mean values of these parameters than non-conserved one. Soil textural fractions of sand, silt and clay and exchangeable potassium (ex.K) did not show significance variation with treatments. With respect to slope classes, soil textural fractions (sand, silt and clay), pH, Cation exchange capacity (CEC) organic carbon (OC), total nitrogen (TN), available phosphorus (Av.P) and exchangeable potassium (ex.) showed significant difference ($P \leq 0.05$). Except the sand content all these studied soil properties' mean values were higher in the lower slope than in the middle and upper slopes. However, the higher sand content was recorded in soil under the upper slope class. Thus, stone bunds can reduce soil erosion problem in sloppy farm lands and yields some desirable effect on some soil physicochemical properties which in turn improve the productive capacity of the land.
Keywords: Conserved, Farm land, Non-conserved, Soil chemical properties, Stone bund.

1. INTRODUCTION

1.1. Background and justification

In Ethiopia, land degradation in the form of soil erosion and soil fertility depletion are as well serious problems (Hurni, 1993). The main causes of this problem are population pressure, mismanagement of agricultural lands, deforestation, overgrazing and conversion of hill forested areas to cultivated land (Mulugeta & Stahr, 2010). This problem is particularly severe on cultivated marginal and sloping land because such areas are generally susceptible to soil erosion (Million &Belay, 2004). About 45% of the total annual soil loss in the country occurs from cultivated fields, which accounts for only 15.3% of the total area (EPA. 1998). This situation of land degradation has negatively affecting the agricultural sector and becoming major causes of low and in many places declining agricultural productivity and continuing food insecurity and rural poverty in Ethiopia. Lal (1995) estimated that the annual yield losses for major food crops (cereals, pulses, roots and tubers) due to erosion in Africa between 1970 and 1990 to average 0.5 percent. Wiebe (2002) also estimated average annual yield losses for major crops to be 0.3 percent globally, 0.49 percent for Africa.

Recognizing soil degradation as a major environmental and socio-economic problem, the government of Ethiopia has made several interventions. As a result, large areas have been covered with terraces, soil bunds, area closures and millions of trees have been planted (Daniel et al., 2001& Getachew, 2005). Even though conservation activities have been continued until present time, the total land area that needs conservation/treatment in the country is higher as viewed from the perspectives of the magnitude of the problems (Demel, 2001). Therefore, the achievements still below expectations and the country lose a tremendous amount of fertile topsoil, and the threat of land degradation is alarmingly broadening (Teklu &Gezahegn, 2003).

Soil and water conservation (SWC) is basically used for both controlling soil erosion and maintaining the productive capacity. In the highlands Ethiopia structures such as the stone bunds are an indispensable component of soil and water conservation (SWC) measures for the controlling soil erosion. According to Herweg. & Ludi (1999) reports, plots with stone bunds are more productive than those without these structures in semi-arid areas. In the highlands of Ethiopia, the mean annual soil loss of 20Mg ha^{-1} from cultivated lands was reduced to a negligible amount with the introduction of stone bunds (Desta *et al.,* 2005). Depending on the age, soil type, slope, and climate, stones lines reduce more than 60% of net soil losses (Nyssen *et al.,* 2000). Besides reducing soil erosion problem, stone bund also cause some desirable change on some physicochemical properties. Worku *et al.* (2012) found that soil pH, CEC value was higher in farm land treated with 10 years aged fanya juu terrace than non- treated farm land.

Most parts of the study area are characterized by rugged topography and steep slopes. These features are the main factors accounting to the severe erosion losses in undulating topographic conditions and farming practices which don't consider conservation measures are the major ones. To solve these problems, a number of soil conservation measures have been undertaken by the government and non -government organization, while their success is highly questioned. Accordingly in Weday watershed project site different physical and biological soil and water conservations have been constructed in 2005 GC. Among different mechanical soil conservation constructed, stone bunds was the major one. Although the project has treated the watershed by constructing stone bund their performance particularly with respect to soil fertility maintenance has been not investigated. On the other hand, there is a deficiency of research based empirical evidence concerning the effects of stone bund on soil physicochemical properties. Therefore, this study was initiated to assess the effects of stone bund SWC measures on some selected soil properties in Weday watershed.

2. MATERIALS AND METHODS

2.1. Description of the study area

2.1.1. Location

Weday Watershed is found in, Kersa district, East Hararge Zone, Oromia Regional State. It is about 44km from Harar town. The study area is geographically located in between 9^{0}25'25" to 9^{0}29'11" N Latitude and 41^{0}43'12"E to 41^{0}45'3" Longitude (Fig 1). It covers a total area of 1167 ha.

The watershed is characterized by diverse topographic features such as undulating to rolling plains, rugged and hilly topography with an altitude ranging from 1500 to 2800 m a.s.l. In terms of agro-climatic zone, the watershed falls within *woyena-dega*. It has two rainy seasons: the main rainy season occurs from July to September and the short rainy season is extend from February to April. Generally the annual rainfall ranges from 900-1400mm. The lowest and highest mean annual temperature ranges between 18 and 26°C.

The dominant soil type of the study area is Leptosols (FAO, 2008). Leptosols are very shallow soils over laying continuous rock and are extremely gravelly and/or stony particularly common on mountainous and hills of the study area (Jalloh et al., 2011). They are characterized by unconsolidated parent materials with less than 20 percent (by volume) fine earths. These soils are generally occurs on lands of medium to high altitude with strongly dissected topography where erosion has removed the top of the soil profile.

There are different exotic and indigenous types of tree species found in the study area; for instance, *Juniperus procera, Cupruss lustanica, Olea Africana, Eucalyptus globulus, Eucalyptus camaldulensis, Cordia africana, Grevellia robusta, Croton macrostachyus, Sesbania sesban and Leucaena leucocephala* are the common tree species in an area.

The total area of the study area is about 1167 hectares of which 51% is cultivated land, 47% is covered by shrubs and remnant natural forests, and the rest 2 % is grazing land. The major crops grown in the study area includes maize, sorghum and haricot bean and most of the farm land are covered with perennial crops mainly *Catha edulis*, which is the main cash crop. Potato and onion are also widely cultivated vegetables. Fattening of large and small ruminants are also the main sources of households' livelihood.

According to the CSA (2007), the population of Kersa woreda was estimated to be 160,466 of which 82241 are male, and 78225 are female. Weday watershed covers 2.6% of total population (i.e. 4225 peoples out of which 2109 are male and 2116 are female).

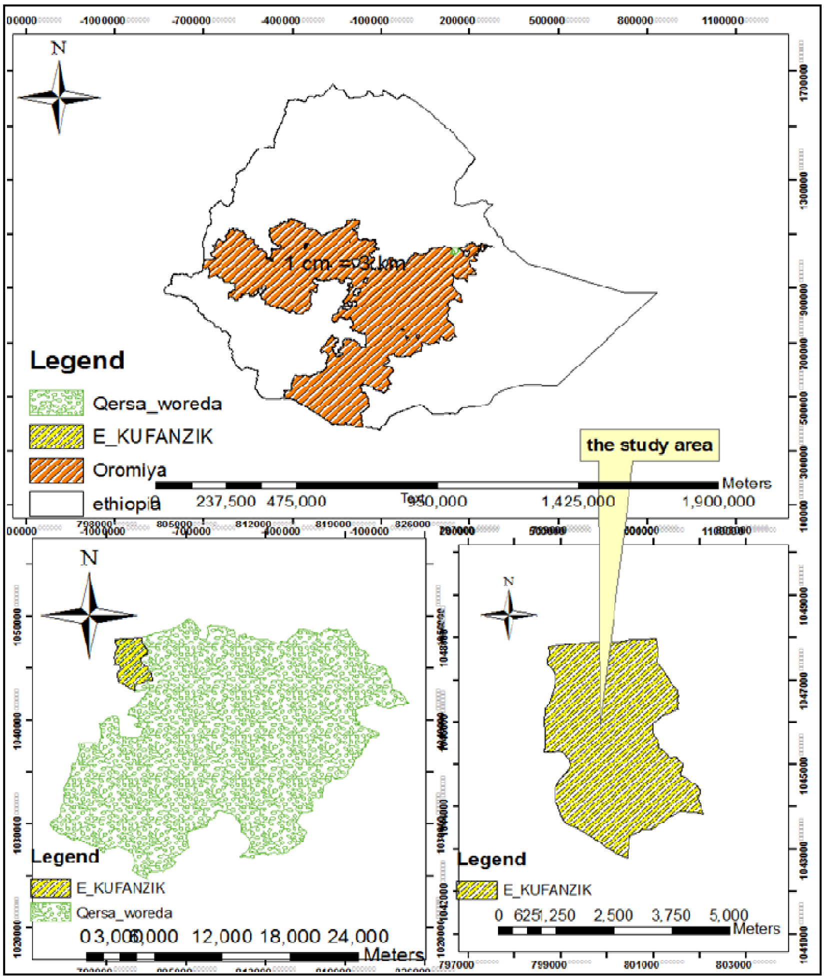

Figure 1. Map showing location of the study area.

2.2. Data collection method

2.2.1. Experimental design and sampling

A reconnaissance survey was first carried out to assign sample plots. Then plots were selected from farm lands treated with 8 year old stone bund structures and with no SWC practices as a control (cultivation land adjacent to each structure) with the same land use system. Even though the structures are common between 3 to above 30% slope, the samples were collected from 3−18% slope based on land use practice. Accordingly the farm land was divided into three slope classes (3-8 % is considered as lower slope (3-8 %), middle slope (8-13 %), and upper slope (13-18%). The plots were grouped into six with three replications and a total of 18 sampling plots were identified with each slope category represented by six plots. In farm lands where the stone bund structures are practiced, sampling was done between the two successive structures at three positions (upper, middle and lower) with their respective control outside the structure (adjacent). The soil samples were collected from the top 20cm depth using sharp edged and closed circular auger pushed manually down the soil profile. Then a total of 54 composite soil samples were collected for laboratory analysis. In this study experiment design with 6*3*3 factorial arrangements of treatments in Randomize Complete Block Design (RCBD) was used. The collected samples were mixed thoroughly in a plastic bucket to form a composite sample. Collected soil samples were air-dried at room temperature, homogenized and passed through a 2mm sieve before laboratory analysis.

2.2.2. Statistical analysis

Statistical differences were tested using analysis of variance (ANOVA) following the general linear model (GLM) procedures of SAS (SAS, 2002) at 5% significant level.

The model is given as:

$$y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

Where; yij= dependent variables (soil physico-chemical properties) μ = sample mean, α_i = effect of slope β_j = effects of treatments $(\alpha\beta)_{ij}$ = interaction effect of slope and treatments. $£_{ij}$ = random error

Tukey's honest significance difference (HSD) test was used for mean separation when the analysis of variance showed statistically significant differences ($p < 0.05$). In addition, Pearson correlation analyses were carried out to reveal the relationships within different parameter.

3. RESULTS AND DISCUSSION

3.1. Soil physical properties

3.1.1. Soil textural fraction

The soil textural fractions of sand, silt and clay didn't vary with treatments ($p = 0.07$, $p = 0.63$ and $p = 0.19$, respectively, Table 1) but variations were significant with slope ($P \leq 0.0001$, $P = 0.05$ and $P = 0.01$, respectively, Table 1). Their interaction effects didn't show any significant variation ($p > 0.05$, Table 1). The overall mean sand content was found to be higher in the middle (73.20±0.35) and upper (73.86±0.48) slopes than in the lower (Table 2) while the silt (13.33±0.41) and clay (16.14±0.65) contents were higher in the lower slope position than in middle and upper (Table 2)

Even though stone bund can reduce runoff effects, the similarity of soil textural fraction between treatments could be happened due to the impact of erosion prior to terracing. Moreover, since the collected samples at different distance positions between structures were not treated separately the insignificant variation among treatments became an evident. Worku *et al.,* (2012) also reported that the soil textural fractions of sand, silt and clay of the surface layers didn't show significant variations within conserved and non-conserved farm plots. Nevertheless, this result is in contrast with Mulugeta (2010) and Teklu &Gezahegn (2003) in that clay and sand contents were, respectively, higher and lower in soils under non-conserved and conserved farm plots.

Table 1. Summary of ANOVA for soil textural fractions of sand, silt and clay

SV	df	Sand		Silt		Clay	
		MS	P	MS	P	MS	P
TR	1	12.5	0.07	0.91	0.63	6.69	0.19
SP	2	56	<.0001	12.24	0.05	22.24	0.01
TR×SP	2	0.07	0.98	8.91	0.11	10.24	0.08
Error	48	3.68		3.92		3.92	
Total	53						

Where;SV=sources of variation, df = degree of freedom, MS= mean square, TR = treatments SP = slope

The textural fractions of sand silt and clay showed significant variation with slope. Sand contents were higher in the middle and upper slope than in the lower while the silt and clay contents were higher in the lower slope position than in middle and upper. This could be related to the selective transportation and translocation of fine soil particles along the slope/gradient leaving behind the coarser materials (sand, gravel, and stones) and deposited at lower slope positions. Shimeles *et al.,* (2012) confirmed that soil textural fractions of sand significantly increased with increasing slope while clay content decreased. Regina *et al.,* (2004) Reported higher clay content at lower slope due to deposition of sediment eroded from upper slope.

Table 2. The mean ± SE values of soil textural fraction of sand, clay and silt with slope and treatments

Variable	Slope classes	Treatments		
		Conserved	Non conserved	Over all
Sand	3_8%	70.97 ±0.60^{a}	70.08 ±0.85^{a}	70.53±0.52^{A}
	8_13%	73.75 ±0.45^{a}	72.64 ±0.47^{a}	73.20±0.35^{B}
	13_18%	74.31 ±0.73^{a}	73.42 ±0.64^{a}	73.86±0.48^{B}
	Over all	73.01 ±0.44^{a}	72.05 ±0.47^{a}	
Silt	3_8%	13.33 ±0.73^{a}	13.33 ±0.44^{a}	13.33±0.41^{A}
	8_13%	12.22 ±0.66^{a}	11.22 ±0.52^{a}	11.72±0.43^{B}
	13_18%	11.33 ±0.76^{a}	13.11 ±0.77^{a}	12.22±0.57^{AB}
	Over all	12.30 ±0.43^{a}	12.56 ±0.38^{a}	
Clay	3_8%	15.69 ±0.90^{a}	16.58 ±0.98^{a}	16.14±0.65^{A}
	8_13%	14.03 ±0.60^{a}	16.14 ±0.40^{b}	15.08±0.43^{B}
	13_18%	14.36 ±0.47^{a}	13.47 ±0.31^{a}	13.92±0.29^{B}
	Over all	14.69 ±0.40^{a}	15.40 ±0.44^{a}	

Mean values followed by different small letters along the same rows and capital letters along the same column are significantly different at ($p < 0.05$)

4.1.1. Soil chemical properties

4.1.1.1. Soil pH (H_2O) and Cation exchange capacity (CEC)

Table 3. Summary of ANOVA for pH, CEC, SOC, TN, Av.P and Ex.K.

SV	df	PH		SOC		TN		Av.P		Ex.K		CEC	
		MS	P	MS	P	MS	P	MS	P	MS	P	MS	P
TR	1	2.75	<.0001	1.82	<.0001	0.014	<.0001	29.38	0.001	0.02	0.21	2.68	0.04
SP	2	6.26	<.0001	3.33	<.0001	0.025	<.0001	23.5	0.003	0.07	0.01	3.95	0.003
TR×SP	2	0.00	0.96	0.24	0.08	0.001	0.16	2.04	0.56	0.00	0.94	2.06	0.04
Error	48	0.09		0.09		0.001		3.45		0.01		0.61	
Total	53												

Mean values followed by different small letter (s) along the same row and capital letters along the same column are significantly different at (p < 0.05). Where SV= sources of variation, CEC= Cation exchange capacity, SOC= Soil organic carbon, TN= total nitrogen, Av.P = available phosphorus and ex.K= exchangeable potassium, TR = treatments SP = slope

Soil pH showed significantly variation with treatments and slope classes (P <.0001, P <.0001, respectively, Table 3). However their interaction effect was not statistically different (P = 0.96, Table 3).

Table 4. The means ± SE values of soil pH and CEC as with treatments and slope classes.

Variable	Slope classes	Treatments		
		Conserved	Non conserved	Over all
PH	3_8%	8.15 ±0.05^{a}	7.72 ±0.08^{b}	7.94 ±0.07^{A}
	8_13%	7.41 ±0.10^{a}	6.98 ±0.02^{b}	7.20 ±0.07^{B}
	13_18%	7.01 ± 0.19^{a}	6.53 ± 0.05^{b}	6.77 ±0.11^{C}
	Over all	7.53 ±0.12^{a}	7.07 ±0.10^{b}	
CEC	3_8%	13.13 ±0.36^{a}	11.95 ±0.28^{b}	12.54 ±0.26^{A}
	8_13%	12.20 ±0.25^{a}	12.36 ±0.18^{a}	12.28 ±0.15^{A}
	13_18%	11.79 ±0.24^{a}	11.47 ±0.21^{a}	11.63 ±0.16^{B}
	Over all	12.37 ±0.19^{a}	11.93 ±0.15^{b}	

Mean values followed by different small letter (s) along the same row and capital letters along the same column are significantly different at (p < 0.05).

Conserved farm land showed higher soil pH (7.53 ± 0.12) than non-conserved farm land (7.07 ± 0.10, Table 4). Soil pH was higher (7.94 ±0.07) in the lower slope and lower in the upper than in the remaining slope positions (Table 4). This could be due to the effect of removal of soluble bases and organic matter through sheet wash /erosion from non-treated farm lands because of the absence of SWC structure that trap soil as compared to the conserved one. (Mulugeta & Stahr, 2010) reported that soils with high organic matter content have higher soil pH which favor better exchangeable bases and increase availability of nutrients that are needed for plants growth. The result is also in line with Worku *et al.,* (2012) report which stated that soils pH were higher in farm land treated with 10 years aged *fanya juu* terrace than non -treated one. However, Kebede *et al.,* (2011) reported that soil pH of four year aged level soil bund and six year aged stone bunds were lower than their adjacent-non terraced cropland.

With respect to slope position, soil pH was higher and lower, respectively, in the lower and upper slope than the rest, probably suggesting the washing out of solutes from these parts. This implies that land gradient has capacity to cause soil property variation due to elevation differences which favour formation of runoff that increases soil erosion and leaching of soluble base cations. These variations could be happened because of past erosion effects prior to stone bund construction. In line with this result, Fantaw *et al.,* (2006) reported that soil in steeper slope had significantly lower pH than those on other slope positions due to the accumulation of soluble cations on the lower slope. Similarly Worku *et al.,* (2012) also found lower soil pH in upper slope position than lower one. However this result is in contrast with of Tadele *et al.,* (3013) which confirmed that the mean of soil pH for the loss and depositions zones were similar.

Soil CEC also showed significant difference with treatments, slope (P = 0.04 & P = 0.003, respectively, Table 3) and interaction effect (P = 0.04, Table 3). Conserved farm land demonstrated higher CEC (12.37 ±0.19) than non-conserved farm land (11.93 ±0.15, Table 5).. The soil CEC illustrated significance difference with treatments and slope position. Soil under terraced farm plot showed higher CEC than none terraced farm land. This implies that soil CEC was significantly influenced by implementation of stone bund. The higher mean of this parameter in conserved farm plot could be related to the presence of higher soil organic matter. In other hands, this parameter was positively correlated with pH and SOC. Its contents increase with increasing of these parameters. According to Daniel *et al.,* (2001) soils with high amount of organic matter and clay content have higher CEC because of their surface, which is negatively charged. As soil pH is increased, the surface negative charge on clay colloids increases and repulsive forces between particles dominate (Renault *et al.,* 2009). Thus, soil CEC is dependent on soil pH (Bortoluzzi *et al.,* 2006). Similarly, Million (2003) as well stated that terraced area with original slope of 25 and 35% were found to have 6 and 49% higher CEC than the corresponding non-terraced slope respectively. Based on these results it is possible to say that CEC is strongly affected by the amount of mineral and organic colloid maintained in the soil due to implementation of stone bund. With respect to slope, the lower and middle slopes showed higher CEC (12.54 ± 0.26 & 12.28 ± 0.15, respectively) than the upper slope position (11.63 ± 0.16, Table 5). Lower slope revealed higher CEC than the middle and upper position. This could be occurred due to higher SOC and clay contents in the lower slope positions as a result of past soil erosion. In conformity with this result Lal et al., (1999) reported that CEC can be reduced by soil erosion through the loss of soil organic carbon. Similarly, it showed positive relationship with pH and SOC ($r = 0.50$, $P \leq 0.0001$ and $r = 0.99$, $P \leq 0.0001$, respectively, Appendices 1). Furthermore, [12] also stated that CEC was positively associated with organic matter content. Thus in many weathered tropical soils, the maintenance of organic matter are vital in order to maintain the CEC at a satisfactory level (Hesse, 1998).

3.1.2. Soil Organic carbon (SOC), Total nitrogen (TN), Available phosphorous (Av.P) & Exchangeable Potassium (k+)

The overall mean of soil SOC content showed significant variation with respect to treatments as well as slope (P <.0001 and P <.0001, respectively Table 3). However, their interaction didn't show significant variation (P = 0.08, Table 3). The treated farm land demonstrated higher soil organic carbon content than the non-conserved farm land (Table 5). The lower slope position has higher SOC (1.66 ± 0.13) than in the rest while the upper slope showed smaller (Table 5). Similarly, it showed positive relationship with SOC ($r = 0.99$, $P \leq 0.0001$, respectively, Appendices1). The treated farm land showed higher SOC contents than non- treated one. This implies that implementation of stone bund can maintain soil organic carbon content. This variation could be due to implementation of stone bund that reduce surface runoff and soil loss, retain water that enhances crop growth and contributes to SOC input. It might be also associated to higher biomass production in conserved farm land. In agreement with this result, Yihenew *et al.,* (2009) & Worku *et al.,* (2012) also reported that non-conserved fields showed significantly lower SOC as compared to conserved fields. Correspondingly, Million (2003) also stated that soil organic carbon content fewer than three terraced sites were higher as compared to the adjacent non-terraced sites of similar slopes. With respect to slope position, the lower slope has higher SOC whereas the upper slope showed lower. This lower soil OC content might be happened due to the decreasing width of Ap horizon with uniform sheet erosion. This variation could be also related to soil fertility declining thereby reduce organic matter input in the upper slope than in the lower one. In line with this result Million (2003) & Gregorich (1998) reported that SOC content is higher in the lower landscape position /gradient due to increasing in soil water content and fertile soil deposition which favor higher crop biomass production. Bot (2005) also confirmed that the accumulation of organic matter would be favored in the lower slope positions due to wetter soil moisture and transportation of soil organic matter through runoff. In general, according to Landon (1991) ratings, SOC contents of the studied watershed are very low (Appendices 2). This could be happened due to practices such as intensive tillage, continuous cropping, removal of crop residues, and low organic carbon input in croplands. The overall low SOC level could be also due to oxidation as a consequence of continued tillage and residue removal (Bergmann, W., 1992 & Loveland, 2003). Unless soil nutrient export is compensated through use of fertilizer, residues and manure, SOC degradation will be continued (Desta *et al.,* 2005).

Table 5. The means ± SE values of soil OC, TN, Av.P and Ex. K with treatment and slope.

Variable	Slope classes	Treatments		
		Conserved	Non conserved	Over all
OC	3_8%	1.97 ± 0.17[a]	1.34 ± 0.15[b]	1.66 ± 0.13[A]
	8_13%	1.29 ± 0.04[a]	1.12 ± 0.03[b]	1.21 ± 0.03[B]
	13_18%	0.95 ± 0.08[a]	0.64 ± 0.05[b]	0.80 ± 0.06[C]
	Over all	1.40 ± 0.10[a]	1.04 ± 0.08[b]	
TN	3_8%	0.17 ± 0.01[a]	0.12 ± 0.01[b]	0.14 ± 0.01[A]
	8_13%	0.11 ± 0.00[a]	0.09 ± 0.00[b]	0.10 ± 0.00[B]
	13_18%	0.08 ± 0.01[a]	0.06 ± 0.00[b]	0.07 ± 0.01[C]
	Over all	0.12 ± 0.01a	0.09 ± 0.00[b]	
Av. P	3_8%	18.21 ± 0.66[a]	16.31± 0.62[a]	17.26 ± 0.50[A]
	8_13%	16.39 ± 0.46[a]	14.56 ± 0.81[a]	15.48 ± 0.51[B]
	13_18%	15.48 ± 0.47[a]	14.78 ± 0.62[a]	15.13 ± 0.39[B]
	Over all	16.69 ± 0.37[a]	15.22 ± 0.41[b]	
Ex. K	3_8%	0.62 ± 0.03[a]	0.57 ± 0.02[a]	0.59 ± 0.02[A]
	8_13%	0.60 ± 0.07[a]	0.56 ± 0.04[a]	0.58 ± 0.04[A]
	13_18%	0.49 ± 0.01[a]	0.47 ± 0.01[a]	0.48 ± 0.01[B]
	Over all	0.57 ±0.03[a]	0.53 ± 0.02[a]	

Mean values followed by different small letter (s) along the same rows and capital letters along the same columns are significantly different at ($p \le 0.05$). Where OC = organic carbon, TN= total nitrogen, Av.P =available phosphorus and Ex.K= exchangeable potassium

The results presented in Table 3 illustrated the significant variations in TN content with treatments (p<.0001) and slope (p<.0001). However, their interaction effect didn't show significant variation (P =0.16, Table 3).The treated farm land demonstrated higher total nitrogen contents than the non-treated one (Table 5). Total N was higher in the lower slope position (0.14 ±0.01) and lower in the upper slope (0.07 ± 0.01) than in the rests (Table 5). The total nitrogen content showed significant variation due to treatment effects and slope position. The treated farm lands have higher TN content than non- treated one. These variations could be occurred due to implementation of stone bund structures which maintain soil fertility by reducing SOC and TN removal through soil erosion. TN also correlated positively with SOC contents. This implies that its contents depend on biomass production, litter quantity and organic matter decomposition. Similarly, Havlin et al., (2002) reported strong positive relationship between soil nitrogen and organic carbon. Bezuayehu et al., (2002) also confirmed that the availability of nitrogen is dependent on organic matter content of the soil. According to Mulugeta & Stahr (2010) report, farm land with physical SWC measure has higher total nitrogen as compared to the non-conserved land. Furthermore, Million (2003) confirmed that total nitrogen content of the terraced site with slopes of 15, 25 and 35% were higher by 26, 34 and 14%, respectively, as compared to the average total nitrogen contents of their corresponding non-terraced sloping lands. Yihenew et al., (2009) was also reported similar result. Furthermore, the total nitrogen contents of the study area were influenced by slope position. Lower slope showed superior mean of TN content while the upper slope positions have lower. These events could be happened due to variation of soil organic carbon across the slope classes as a result of soil erosion. In conformity with these results, Regina et al., (2004) found lower TN contents in the upper slope position. Similarly, Wolde (2005) also reported that upper slope position has lower TN than the middle and foot slopes. However this result wasn't in agreement with Shimeles et al., (2012) which stated that TN didn't show significant changes across four slope class considered in his study. Generally, the TN content of the studied watershed is very low. According to Landon (1991) rating, the nitrogen content of the study area is classified under very low (< 2) (Appendices 2). Similarly Mesfin (1998) & Yihenew et al., (2009) also reported that nitrogen is the most deficient element in the tropics for crop production.

Soils available phosphorous showed significant variation with treatments and slope (p = 0.001 & p = 0.003, respectively, Table 3). However, their combined effects didn't show significant variation (p = 0.56, Table 3). The treated farm land illustrated higher overall mean of available phosphorous than the non-conserved farm land (Table 5). With respect to slope position, the lower slope showed higher mean of Av.P than both in the middle and upper slope position (Table 5). It also revealed positive relationship with SOC and TN (r = 0.41, P = 0.002 and r = 0.4, P = 0.004, respectively, Appendices 1). This result implies that implementation of stone can maintain soil fertility by reducing the removal of available phosphorous and organic matter through soil erosion. Av.P also showed positive relationship with SOC and TN. This might be due to creation of favorable soil organic matter. According to Pruess (1992) report, the amount of soil organic matter in the semi-arid region is the main factor of controlling available P and other soil fertility parameters. In line with this result Mulugeta & Stahr (2010) also reported that due to the higher soil organic matter content in conserved farm land; the total available phosphorus is also much higher. The availability of phosphorous content of the soil is dependent on the organic matter content of the soil (Bezuayehu et al., 2002). Similarly, Worku et al., (2002) also indicated that the mean of soil Av-P under conserved farm lands was relatively higher than non-conserved one. Kjell et al., (2002) as well reported that soils from terrace benches had higher concentrations of available P than soils from non-terraced land. Due to slope factor, the mean of available phosphorous also showed significant variation across the gradient. The lower slope position has higher available phosphorous than the middle and upper slope. These variations could be happened due to washing of top soil and organic matter from the higher slope position and accumulation at the lower gradient/deposition zone. Phosphorus is normally strongly fixed with soil particles. Therefore it is easily transported down slope during erosion, giving higher concentrations of available P in the soil accumulation zone. As reason erosion is responsible for the reduction of soil available phosphorus in the upper slope (Ohwoghere**,** 2012). This result is also in line with Vagen (1996) report which confirmed that available phosphorus content was higher in the deposition zone than loss zone. In contrast to this result, Tadele et al., (2013) reported that the mean values of soil available phosphorus between the loss and deposition zones were not significant.

The exchangeable potassium didn't show significance difference within treatments ($p = 0.21$, Table 3) but variation with slope was significant ($p = 0.01$, Table 3). Their interaction effects also didn't show any significant variation ($p = 0.94$, Table 3). The upper slope has lower exchangeable k^+ (0.48 ±0.01) than the lower (0.59 ± 0.02) and middle (0.58 ±0.04) slope position (Table 5). This could be due to past erosion effects and/ leaching. According to Olarieta et al., (2008) & Chen et al., (1997) the differences in the exchangeable bases within a given watershed could also depend on variation in parent material or micro-climate. With respect to slope, soil exchangeable potassium (k^+) demonstrated significant variation. The upper slope showed lower mean of exchangeable k^+ than the lower and middle slope positions. These results indicate that slope can influence soil exchangeable potassium (k^+). In line to these results, Shimeles et al., (2013) reported that under farmland terraces exchangeable K^+ showed decreasing trend with increase slope. These variations were happened probably due to leaching effect. According to Pimentel et al., (1995) the differences in exchangeable bases in the same watershed were attributed to erosion, deposition and leaching processes. However, Tadele et al., (2011) found non-significant difference of exchangeable bases between loss and accumulation zones including K^+. Similarly Aweto and Enaruvbe (2010) also found higher exchangeable K^+ in the upper slopes position.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

According to this study, implementation of stone bund can reduce soil erosion problem in farm lands and cause some desirable change on some physicochemical properties of the soil which in turn improves the productive capacity of the land. Laboratory result showed that except the mean of soil textural fractions (sand, silt and clay) and exchangeable potassium, all other studied soil physicochemical properties such as soil organic carbon, total nitrogen, available phosphorus, pH, Cation exchange capacity (CEC) showed significance difference with respect to treatments (conserved and non conserved farm plot). In conserved farm land these parameters demonstrated higher mean as compared to non conserved one. Generally, the soil condition, measured by the various soil physical and chemical properties is relatively better in the conserved farm lands than non conserved one. This implies that construction of stone bund can maintain soil fertility by reducing soil and nutrient loss through runoff.

Similarly, soil textural fractions (sand, silt and clay), pH, Cation exchange capacity (CEC), soil organic carbon (SOC), total nitrogen (TN), available phosphorus (Av.P) and exchangeable potassium (k^+) showed significant variation among slope positions. Except sand content, the rest parameters were higher in the lower slope positions than in middle and upper. However, sand content demonstrated higher mean in upper slope position. These results indicate that slope can cause soil property variation by supplementing runoff to detach and transport soil particles across the gradient.

4.2. Recommendation

Based on the result of this study, the following points are recommended.

- The study showed soil property variation with slope. Thus, due attention should be given according to the susceptibility of slope position to soil erosion and a corresponding fertility decline.
- Even though the intervention with stone bund causes significance variation in soil properties within treatments (conserved and non conserved form plot) by minimizing soil loss through runoff, the soil fertility status in the watershed is still very low. Thus should incorporate biological soil conservation measures and other soil management activities to improve the soil.
- Further research is needed on key socio-economic aspects, cropping and tillage systems for better understanding of the effects of stone bund and other SWC structures, and improvements in the livelihoods of the community.

Acknowledgements
The author would like to thank Ministry of Agriculture financial support to carry out this research and He also appreciate Kersa district agriculture and natural resource office and Haramaya University for their support during data collection and laboratory analysis.

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