UTTAR PRADESH JOURNAL OF ZOOLOGY

43(13): 25-34, 2022
ISSN: 0256-971X (P)

EFFECTS OF SELECTED SOIL AND WATER CONSERVATION STRUCTURES ON SOIL PHYSIOCHEMICAL PROPERTIES, LEMO WOREDA, SOUTHERN ETHIOPIA

MULATU CHERNET MADOLO [a*], YOHANNES HORAMO MORE [a] AND BEREKET TAGESSE SHAMEBO [a]

[a] Department of Natural Resource Management, Wachemo University, Hossana, P.O Box 667, Ethiopia.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.56557/UPJOZ/2022/v43i133078

Editor(s):
(1) Dr. Ana Cláudia Correia Coelho, University of Trás-os-Montes and Alto Douro, Portugal.
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(2) Mihaela Lungu, National Research and Development Institute for soil Science, Romania.

Received: 24 April 2022
Accepted: 28 June 2022
Published: 04 July 2022

Original Research Article

ABSTRACT

Soil erosion is now almost universally recognized as a serious threat to man's well-being, if not his very existence. As a result, we assessed the soil physicochemical properties of two possible levels of level bund and fanya juu. The experiment assessed from seven locations with three replications was used to collect soil samples from each soil conservation structure. Five composite soil samples were collected from each soil structure based on slope (0-30cm). Soil physicochemical properties such as erosion index, dispersion ratio, and erodibility proportionality ratio were investigated. The effect of different soil structure levels revealed that soil properties differed significantly ($P \leq 0.05$) for all parameters studied. The control plots had significantly higher ($P \leq 0.05$) dispersion ratio, erosion indexes, and erodibility proportionality than the soils treated by the level bund and level Fanya juu structures. On the control plot, this result showed lower clay content and higher sand content. The level of soil bund and fanya juu had a significant ($P \leq 0.05$) effect on selected soil parameters. As a result, all related soil properties show a positive relative change when the level of soil bund and fanya juu is compared to the control plot. Aside from this result, the dynamic natures of the sciences compel us to conduct additional research based on the agro-ecological zones of the study area.

Keywords: Fanya juu; soil bund; soil physicochemical properties.

**Corresponding author: Email: cmulachew@gmail.com, Mulatuchernet@wcu.edu.et;*

1. INTRODUCTION

Soil erosion is now almost universally recognized as a serious threat to human well-being, if not survival. Ethiopia's annual soil loss is estimated to be between 1.5 and 3 billion tons ([1], with cropland accounting for roughly half of this amount (296 tons/ha/year) with "teff" crop (Eragrostis abyssinica) on nitisols on a 16 percent slope [2, 3]. In Ethiopia, two million hectares have reached irreversible destruction and will be unable to support cropping in the future [1]. Ethiopia has a long history of conserving natural resources using traditional methods [4]. There are numerous examples of these techniques in use across the country. Random bench terraces in North Shoa and Hararge, contour bench terraces in Hararge, tied ridges in Konso, drainage furrows in North-East Shoa, and sod rotation, trash bunds, trash heap composting, and fallowing are examples of stone terracing in Konso and Gomugoffa. These techniques have not been evaluated, and no attempt has been made to improve or popularize them [2].

The scientific conservation program is still in its early stages. However, large-scale efforts were postponed until the early 1970s, when WFP and UNDP/FAO assistance became available [5]. The Ethiopian highlands probably saw the most extensive soil conservation activity in the 1970s and 1980s (Biratu et al., 2018) [6]. Between 1980 and 1990, approximately 2.3 million hectares of steep slope forestation were covered by hillside terraces; approximately 1 million hectares were planted with various tree seedlings [7].

One of Ethiopia's high land areas is Hadiya zone, Lemmo district, where government soil conservation practices were implemented. According to a Hadiya zone Department of Agricultural and Natural Resources Development report, tree seedlings covered 21,185.89 hectares in one decade and soil conservation structures covered 15,000 hectares in five years [8]. Even though soil conservation structures cover a large amount of land, the effects of long-term funding have yet to be studied. There have been no studies to look into the effects of these soil and water conservation structures on soil physicochemical properties [9-11]. As a result, the goal of this research was to investigate the effects of specific soil and water conservation structures (soil bund and fanya juu) bunds on the physicochemical properties of the soil.

2. MATERIAL AND METHODS

2.1 Description of the Study Area

This research was carried out in Lemo District, Hadiya Zone, Southern Ethiopia. The study area is geographically located at 070 41'N Latitude and 0370 31'E Longitude. The study area's topography consists of rugged high land and hilly areas with slopes ranging from 2-35%. The district is in the agro-climatic zone of 'Woina Dega,' with elevations ranging from 1950 to 2400 meters above sea level. The temperature ranges from 15 to 18^0C, and the average rainfall is 1150mm. There are several rivers and seasonal streams that drain into the study area. Human activities and intervention have had a significant impact on the natural vegetation in the study area (Biratu et al., 2018).

2.2 Design of the Research

Plot Layout: Level bund and level fanya juu are two different soil and water conservation structures. Fig. 2 depicts the entire sample area from each made subsample collected from different spots, upper, middle, and lower of the plot.

2.3 Sampling Techniques and Data Collection

Using a Randomized Completely Block design, a composite auger whole sample (each made from subsamples collected from three different spots, upper, middle, and lower portion of the plot) was taken along the major slope to a depth of 0-30cm (RCBD). A total of 63 composite samples were collected, 42 for treated plots and 21 for untreated plots. For some parameters, such as bulk density, each experimental plot yielded 63 undisturbed core soil samples with the original pore geometry. The soil parameters and methods for analyzing them are listed below. The undisturbed core soil samples and disturbed soil samples were bagged separately with appropriate labels and transported to the University Laboratory, where all disturbed soil samples were air dried by separating them in canvas or trays and exposing them to the elements for several days. The air-dried soil samples were ground to pass through a two-mm sieve in preparation for laboratory analysis. Soil texture, bulk density (gm.cm-3), total pore space (percent), water holding capacity (percent), dispersion ratio, erosion index, pH (1:2.5), organic carbon (%), total nitrogen (%), available potassium CEC, available phosphorus (%), and mg.kg-1 were all investigated (meq.100gram-1). Soil samples were collected prior to crop planting and analyzed for various physicochemical properties of the soil. For the parameters required, standard laboratory procedures were used. The density of soil-water suspension was measured with a Bouyoucos hydrometer to determine particle size, as described by Melaku., [12]. Bulk densities were measured in a natural setting by carefully driving a cylindrical cutter into the soil, digging it out, cleaning, trimming, and weighing it. Available Using a pressure plate apparatus, water holding capacity was calculated by subtracting the soil water potential at the wilting point (-15 bar) from the field capacity (-1/3 bar) [13]. A pH meter was used to measure soil pH in the supernatant suspension of a 1:2.5 mixture of soil and liquid. The moisture loss equation (1) was used to calculate total porosity [14].

Total porosity (%) =

$$\frac{wt.\ of\ \ sat.\ \ soil - wt.\ \ of\ \ ovendry\ \ soil}{volume\ \ of\ \ core\ \ x\ \ density\ \ of\ \ water} x100 \qquad (1)$$

To determine soil organic carbon, the Walkley-Black oxidation method with potassium dichromate was used ($K_2Cr_2O_7$) in a sulfuric acid solution using the method described by Ruiz et al. [15]. The Kjeldahl procedure [16] was used to determine the total nitrogen based on the principle that treats the soil with concentrated sulfuric acid. Two methods [17, 18] were described for the determination of available phosphorus. The Olsen extraction method, which was used for acidic and nonacidic soils [19], was employed [20]. Erodibility was determined by [21] method using equation (2). Dispersion ratio was found out by using equation (3) as given by Närhi et al. [22].

$$EP= \frac{\%sand + \%silt}{\%clay} \qquad (2)$$

Where: EP = erodibility proportionality, % sand = percent sand found in the texture separation, %silt = percent silt obtained in texture separation, and% clay = percent clay obtained in texture separation.

By placing 10 gm of 10 mesh (2mm) sieved soil in an open mouth measuring cylinder and gently shaking after filling to 1000 cc with distilled water, the easily dispersible silt and clay were determined. Allowing sufficient time for setting in proportion to room temperature, a portion was 27ipette out, dried, and weighed to a constant weight [23]. This is the amount of easily dispersible material (silt + clay) in the sample. The total silt + clay content of the soil were determined using mechanical analysis. The erosion index was calculated using the expression (3) proposed by Kumawat et al. [24].

$$EI= \frac{Dr}{C/0.5whc} \qquad (3)$$

Where: EI is the erosion index, C= clay, *whc*= water holding capacity which was determined using a pressure plate apparatus.

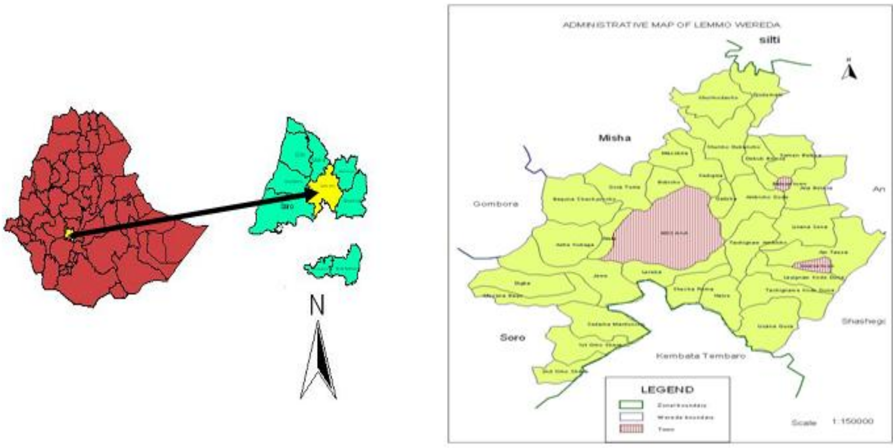

Fig. 1. Location of Lemo District in Hadiya zone, Ethiopia
(Source: Survey result)

► 50 Meter ⟵	⟶ 50 Meter ⟵	⟶ 50 Meter ⟵
UPPER POSITION	**UPPER POSITION**	**UPPER POSITION**
MIDDLE POSITION	**MIDDLE POSITION**	**MIDDLE POSITION**
LOWER POSITION	**LOWER POSITION**	**LOWER POSITION**
LEVEL BUND	**CONTROL**	**LEVEL FANYA JUU**

Fig. 2. Plot layout of the field

D = Suspension Percentage / (Silt +Clay) Under Dispersed Conditions (4)

Where, D = is dispersion, Silt = % of silt, Clay = % of clay during hydrometer reading of soil suspension with dispersant [25].

2.4 Data Analysis

The data collected for different parameters related to a physicochemical property of soil were statistically analyzed using analysis of variance for 7 replications of Randomized Complete Block Design. It was computed using SAS version 9.0 to see if there was a significant difference between the treatment means for the various variables. Least significance difference was used to separate means from each other among the locations using the 5% probability level of significance of the recorded soil characteristics.

3. RESULTS AND DISCUSSION

3.1 Textural Classification of the Experimental Plots

The average clay and sand content of the level bund and level Fanya juu are significantly higher and lower, respectively ($P \leq 0.05$) than the average clay and sand content in the control plots (Table 1). However, the amount of soil erosion that occurs under specific conditions is influenced not only by the soil itself, but also by the treatment or management that it receives [26]. The low clay content and abundance of sand in the control plot indicate that erosion was more severe in the study area, affecting unmanaged plots more than managed plots. The findings of this study agree with those of [27], who found that erodibility (erosion intensity) is positively and significantly correlated with high water content.

Clay content was found to differ significantly between location one-six and the other five locations. In the study area, there was also a significant difference in sand content between locations six, four and five (Table 2). The level bund and level fanya juu treated plots had lower sand content than the control plots. Furthermore, in a wetter climate, such as the one found in the study area, soils with a higher pH are more likely to grow. Low-organic-content soils erode faster and are typically less moisture-retentive [28].

3.2 Bulk Density, Total Porosity and Available Water

Measurements of bulk density on treated and untreated experimental plots revealed that there were no significant differences between level bund and level fanya juu (See Table 3). Because bulk density decreases as clay content in soil increases, the mean bulk density of the level bund treated plot is lower ($p \leq 0.05$) than the control plot and the level fanya juu, and the level fanya juu is significantly lower than the

Table 1. Comparison between treatments versus soil type

Treatment	Clay (%),		Silt (%),		Sand (%),	
	Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**
Level bund	21.429a	3.67*	43.095a	8.91*	35.95a	12.29*
Level Fanya juu	20.333a	2.57*	41.905a	7.72*	37.29a	10.95*
Control	17.762b	-	34.19b	-	48.24b	
LSD (0.05)	1.62		3.65		4.86	
CV (%)	13.09		14.75		19.22	

*N.B. *Significant at ($p \leq 0.05$), and means in a column followed by the same letter are not significantly different. (Source: analysis results)*

Table 2. Comparison of means of soil textural classes by location

Locations	Clay%	Silt%	Sand%
North-Belesa-one	20.889a	38.11b	41.00b
North-Belesa-two	26.24a	36.05c	37.71a
Ana-Ballesa-three	19.444b	45.667a	36.00b
Ana-Ballesa-four	18.333b	38.00b	43.667a
Ana-Ballesa-five	18.333b	42.00b	39.667b
Ambicho-six	21.444a	34.11b	44.889a
Ambicho-seven	20.222b	36.11b	42.556b
LSD(0.05)	2.47	5.576	7.4

N.B. Means with in columns followed by the same letter are not significantly different at (p≤0.05). (Source: analysis results)

unprotected plot. With decreasing bulk density, water retention is expected to increase. The total porosity of sandy soils is lower than that of fine-textured soils (Salem et al., 2010). Differences in total pore space are primarily responsible for the differences, with finer texture soils having more pore space and lower bulk density than sandy soils [29-31]. Organic matter has two effects on bulk density. Furthermore, when soil organic matter is lost due to cultivation, bulk density increases (Salem et al., 2010).

As shown in (Table 3), the porosity of the soil was statistically significant among the selected conservation structures and locations (p≤0.05). The total pore volume was significantly higher (p≤0.05) on level bund and level fanya juu plots than on control plots (Table 3). The level bund and fanya juu have no discernible difference, but there is a significant difference between the control plots and the conservation structures that were chosen. Soil degradation due to removal of soil organic matter and exposure occurred in the study area of subsoil by water erosion resulted in a low average pore volume in the control plot. The importance of soil organic matter to soil porosity, especially in clay-dominated soils, has long been recognized (Salem et al., 2010).

The amount of water available for uptake by plants, which is held at suctions between the wilting point and field capacity, is known as available soil water (ASW). The holding capacity in the soil increases as the porosity of the soil increases and the bulk density decreases, according to the available water (Table 3). The water content of 244 soil samples was studied by Sadegh et al. [32], who discovered that the (ASW) of well-structured soils was one-third to twice as large as that of poorly-structured soils. Bearing in mind that ASW varies with natural weathering and management, (Table 3) gives typical values of a for different treatments selected.

3.3 Soil pH, Organic Matter and Organic Carbon

Soil pH is an important consideration for farmers and gardeners for several reasons; including the fact that many plants and soil life forms prefer either alkaline or acidic conditions, which some diseases tend to thrive when the soil is alkaline or acidic, and that the pH can affect nutrient availability in the soil. The mean pH of the soils sampled from untreated and treated plots of all locations are found between 5.86 and 6.405 which are slightly acid with level fanya juu and level bund and control plots approaching medium acid, (Table 4). The average pH of the control plot was smaller than those of the treated plots. This is due to the removal of base from the soil by leaching processes, which tends to lower the pH over time (Salem et al., 2010). The pH is significantly higher on level fanya juu and level bund than the control plot. This was also confirmed by Bogale and Tilahun [1], who discovered that greater soil loss due to erosion may have removed the topsoil and exposed the subsoil to the surface, resulting in lower pH. Leaching processes are accelerated under acid conditions because more cations are released by acid weathering and fewer are held by cation exchange (Salem et al., 2010).

Table 3. Comparison of treatments versus soil physical properties

Treatment	Bulk density $gm.cm^3$,		Porosity (%),		Available water holding capacity	
	Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**
Level bund	1.381a	0.016*	47.565a	2.049*	17.8452a	5.25*
Level fanya juu	1.383a	0.014*	47.052b	1.536*	17.4233a	4.83*
Control	1.399b		45.516c	-	12.591b	-
LSD (0.05)	0.0082		0.474		1.536	
CV%	0.9434		1.6298		15.46	

** Significant at (P≤ 0.05), and Means in a column followed by the same letter are not significantly different at (P≤0.05). (Source: analysis results)*

Table 4. Comparison of treatments versus soil chemical properties

Treatment	pH value,		Organic matter (%),		Organic carbon (%),	
	Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**
Level bund	6.405a	0.545*	3.621a	0.648*	2.098a	0.649*
Level fanya juu	6.129a	0.269*	3.663a	0.69*	1.962a	0.513*
Control	5.86b	-	2.973b	-	1.449b	-
LSD (0.05)	0.157		0.2875		0.2738	
CV%	4.11		13.515		23.98	

N.B. The starred values in the column indicate pairs of means that are significantly different. Means with the same letter in the column are not significantly different. (Source: analysis results)

Table 5. Comparison of location versus pH values, between organic carbon and organic matter

Location	pH	Organic matter %	Organic carbon %
North belesa-one	6.21b	3.44c	1.94a
North-Belesa-two	6.24a	3.05c	1.67a
Ana-Belesa-three	5.99b	3.51b	1.68a
Ana-Belesa-four	6.11b	3.21c	1.90a
Ana-Belesa-five	6.14b	3.42c	1.83a
Ambicho-six	6.06b	3.88a	1.90a
Ambicho-seven	6.16b	3.41c	1.90a
LSD(0.05)	0.2397	0.4391	0.418

N.B Means with the same letter in the column are not significantly different
(Source: analysis results)

The lowest pH (5.99) was observed in Ana Ballesa three (Table 5), which is the most affected by erosion based on the above physical characteristics. Usually the optimum pH is somewhere between 6 and 7.5 because in this range, all plant nutrients are reasonably available. The rate at which plant nutrients are released by weathering is influenced by the pH of the soil. The solubility of all soil materials, and the amount of nutrients stored on cation exchange sites (Salem et al., 2010).

The chemically active form of carbon in the soil is of higher interest than the other forms. This includes the immediate decomposition of products of raw organic material and soil humus. In this study, the conservation structures chosen had a significant ($P \leq 0.05$) soil organic carbon; soil pH, soil organic matter, available potassium, available phosphorous, cation exchange capacity and total nitrogen. All soil samples had organic carbon content ranging from 0.56 to 2.73 percent. The level bund treated plot had higher and significant organic carbon followed by level fanya juu than the control plot. The mean organic carbon content of the level bund, level fanya juu, and control plot was 2.098%, 1.962%, and 1.449 percent in each case (Table 5). These values indicated as an increment of 47.79% and the respective structures contained 35.4 percent more organic carbon than the control plot.

3.4 Erodibility, Dispersion Ratio and Erosion Index

In the present investigation, the soils in the level bund and level Fanya juu treated plots had significantly lower ($P \leq 0.05$) erodibility proportionality ratio than the control plots (Table 6). This shows that soils in the control plots are more erodible than the conservation treated plots as also reported by Ademe et al. [33]. This indicates that the amount of soil erosion which occurs under a given conditions is, however, influenced not only by the soil itself, but by the treatment or management it receives. Erodibility proportionality of location four was significantly different from the other six locations (Table 6). This was due to the particle size distribution in the control plot.

Relatively highest erodibility proportionality ratio was observed on Ana Ballesa four (4.54%) and the lowest erodibility proportionality ratio on Amibicho six (3.79%) (Table 7). In this study, the soils on the level bund and level Fanya Juu had significantly lower ($P \leq 0.05$) dispersion ratio than the control plots (Table 8). Dispersion ratio was significantly different between North Ballesa one and two, and the other five locations (Table 7). The highest dispersion ratio (76.48) was found in North Ballesa one, while the lowest was found in Ana Ballesa four (69.78). This was due to the textural variation of the control plot in the areas. The level bund and the level fanya juu are comparatively more resistant to erosion than the control plots due to the treatment the soils received. From (Table 7), the control plots had the highest dispersion ratio (78. 57) has the greatest susceptibility to erosion. This finding was supported by Demelash and Stahr, [34], who confirmed that crop management influences erodibility more than any other factor and defined crop management decisions.

Whereas the lowest was recorded by level bund (19.23) followed by level fanya juu (20.24) (Table 7). An increase in surface soil dispersibility increases erodibility, this in turn enhanced by ESP (exchangeable sodium percentage) (Ziadat and Taimeh 2013). From (Table 7), the lowest value (20.29) of erosion index was observed in Ana-Ballesa three and the highest (24.83) was observed in North-Ballesa one. There is a significant difference in erosion index between location one and the other six locations (Table 7). This might be due the difference in texture and the amount and cumulative effect of other elements of the soil.

Table 6. Comparison of treatment versus erodibility, desperation ratio, and erosion index

Treatment	Erodibility		Dispersion ratio		Erosion index	
	Mean	Stv	Mean	Stv	Mean	Stv
Level bund	3.816a	0.89*	70.10a	8.47*	19.23a	6.28*
Level fanya juu	3.93a	0.78*	71.72a	6.85*	20.24a	5.27*
Control	4.71b		78.57b	-	25.51b	
LSD (0.05)	0.389		2.92		2.16	
CV (%)	15.054		6.38		16.02	

N.B. The starred value in the table indicates pairs of means that are significantly different. Means with the same letter in the column are not significantly different. (Source: analysis results)

Table 7. Comparison of location versus erodibility, dispersion ratio, and erosion index

Location	Erodibility	Dispersion ratio	Erosion index
North belesa-one	3.93b	76.48a	24.83a
North-Belesa-two	4.19b	74.68a	20.87b
Ana-Belesa-three	4.26b	74.19b	20.29b
Ana-Belesa-four	4.54a	69.78b	21.02b
Ana-Belesa-five	4.49b	72.51b	22.57b
Ambicho-six	3.79c	73.23b	20.56b
Ambicho-seven	3.85c	73.4b	21.48b
LSD (0.05)	0.595	4.457	3.33

N.B. Means with the same letter in the column are not significantly different. (Source: analysis results)

Table 8. Comparison of treatment versus CEC and soil minerals

Treatment	CEC (meq/100gr),		Total Nitrogen (%),		Available potassium mg/kg,		Available phosphorus (ppm),	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Level bund	27.75a	6.72*	0.2a	0.036*	15.71a	3.28*	5.77a	1.8*
Level fanya juu	25.45b	4.42*	0.185a	0.021*	14.06a	1.63*	5.18b	1.21*
Control	21.03c	-	0.164b	-	12.43b	-	3.97c	-
LSD(0.05)	2.153		0.0074		1.07		.5045	
CV (%)	13.97		6.525		12.2		16.29	

N.B. The starred values in the columns are pairs of means which are significantly different. (Source: analysis results)

3.5 Cation Exchange Capacity and Soil Nutrients

When soil is removed from a field, it contains available and potential plant nutrition's, the inert mineral material, as well as soil particles that makes up the soil's resources, is carried away. As indicated (Table 8), level bund and level fanya juu structures had higher values of cation exchange capacity (CEC) (27.75) and (25.45 meq/100g) respectively than the control plots (21.03meq.100gram-1). These indicate that intervention areas are not affected by soil erosion than untreated areas which is affected by soil erosion.

3.6 Changes in Soil Characteristics within the Inter- Structural Spaces of the Soil

In terms of clay, silt, and sand content, there was a significant difference ($P \leq 0.05$) between the lower, upper, and middle positions (Table 9). The lowest values of clay (18.1) and silt (36.05) content were observed on the upper position whereas the highest values were observed on the lower position. One possible explanation is that erosion removed more top soil from the upper position and deposited it to the lower position between the two conservation structures. According [35] reported that the increase in clay content caused by erosion in the upper segment of a slope between bunds. The nutrient content and soil physical characteristics also showed a considerable difference because of erosion.

In the lower position, total nitrogen, organic carbon, organic matter, available phosphorous, available potassium, cation exchange capacity, and pH were the highest (Table 9). According to farmer's and own field observation, lower crop yield was observed in the upper position. The primary reason for this is

Table 9. Means of physicochemical properties in interstructural space of the soil

Soil properties	Positions on the conservation structures			
	Upper	**Middle**	**Lower**	**LSD (0.05)**
TN (%)	0.179b	0.18b	0.19a	0.01
OC (%)	1.65b	1.824b	2.027a	0.25
OM (%)	3.14c	3.36b	3.75a	0.22
Av.P (%)	4.82b	4.69b	5.4a	0.46
AV.K (mg/kg)	13.44b	13.28b	15.47a	0.77
CEC (meq/100g)	23.45b	23.13b	27.64a	1.51
AWHC (%)	15.11b	15.29b	17.46a	1.34
Porosity (%)	46.29b	46.61b	47.23a	0.38
Bulk density (gm/cm^3)	1.39a	1.38b	1.38b	0.07
PH	6.01b	6.11b	6.28a	0.14
Clay (%)	18.1c	19.67b	21.67a	1.81
Silt (%)	36.05c	38.86b	44.29a	2.62
Sand (%)	45.86a	41.95b	33.47c	2.83

N.B. Means with the same letter in the column are not significantly different. (Source: analysis results)

increased spatial variability in soil fertility and its translocation and deposition in lower positions. Missong et al. [36] discovered that the top soil beneath the structure is gradually moved down the slope and accumulates above the next soil and water conservation structures during the erosion process that forms the terraces.

4. CONCLUSION AND RECOMMENDATIONS

Soil is a critical natural resource in crop production. It is critical to ensure good soil management to keep this resource available for current and future generations. The soil and water conservation structures (level bund and level fanya juu) studied in Lemmo District influenced the soil Physicochemical properties significantly ($P \leq 0.05$). Silt, clay, and sand were significantly affected by position and location and they are affected significantly by soil conservation structures ($P \leq 0.05$). No significant differences were observed on clay, silt, and sand content between level bund and level fanya-juu. The level fanya juu and level bund plots had higher clay content (20.333 and 21.429 percent, respectively). The level bund had the highest silt (43.095 percent), while the control plot had the highest sand. Although non-significant higher bulk density ($1.399 gm/cm^3$) was observed on the control plot than on level bund (1.381 gm/cm3) and level fanya juu (1.383 gm/cm3) plots. No significant difference was observed between level bund and level fanya juu. The level bund has the highest average (47.565 percent) pore volume, while the control plot has the lowest (45.51 percent). Soil and water conservation structures significantly affected available potassium, total nitrogen, organic matter content, phosphorous, organic carbon, soil pH, and cation exchange capacity.

Hence, in the future we should have to give special attention to the construction of soil and water conservation by the farmers equally or more than the attention given to crop production. If the level of awareness is high regarding the importance of soil and water conservation structures, there will be little need for intensified technical assistance, implementation of other programmes and strategies.

ACKNOWLEDGEMENTS

The authors would like to express their deepest thanks and gratitude to Wachemo University for the grant of field survey expenses and to all those participated in one way or another for the accomplishment of this study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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