

Soil quality variation under Enset based conservation tillage and cereal based conventional tillage system in southern highlands of Ethiopia

Abstract

With the objectives of assessing the variation of soil quality indicators; two land use types: Enset based conservation tillage system (EBCSTS) and Cereal based conventional tillage system (CBCVTS) were selected in Gedeo zone, Bule woreda, Southern Ethiopia. A total of 48 composite and undisturbed (for bulk density determination) soil samples (2 land use types_4 blocks_3 replication_2 soil depth: 0-15cm and 15-30cm) were collected for laboratory analysis. The result showed that soil textural fractions (sand, $p < 0.001$; silt, $p = 0.003$ and clay= $p = 0.001$) and soil pH ($p < 0.001$) significantly varied with land use types. Moreover, soil moisture content ($p < 0.001$), bulk density ($p = 0.016$, $p = 0.002$), SOC ($p < 0.001$), TN ($p < 0.001$) and CEC ($p < 0.001$, $p = 0.001$) have shown significant variation with land use types and soil depth respectively. Sand and clay were higher in EBCSTS and CBCVTS, respectively. Higher amount of sand fraction was observed under 0-15cm on EBCSTS and 15-30cm on CBCVTS land use types. Lower soil bulk density (gcm⁻³) and higher amount of SOC (%), TN (%), soil pH, CEC (meq/100g soil) and SMC (%) were observed at 0-15cm soil layer under the EBCSTS. Soil bulk density (gcm⁻³), soil pH and SMC (%) increased while SOC (%), CEC (meq/100g soil) and TN (%) decreased with soil depth in both land use types. Improvement in the soil quality under EBCSTS was due to the presence of less soil disturbance coupled with higher addition of organic matter (SOM) in the soil. Thus, through implementing EBCSTS, it is possible to protect and maintain soil qualities for sustainable soil management and cropping practices in the area.

Keywords: land use types, conventional tillage, soil quality, enset

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Abbreviations: EBCSTS, *enset* based conservation tillage system; CBCVTS, cereal based conventional tillage system; SMC, soil moisture content; SOC, soil organic carbon; TN, total nitrogen; CEC, cation exchange capacity; SOM, soil organic matter; ASL, above sea level; RCBD, randomized complete block design; GLM, general linear model; ANOVA, analysis of variance; LU, land use; SD, soil depth; BD, bulk density; ACLU, annual crop land use; AGFLU, agroforestry land use

Introduction

Soil quality can be recognized as the capacity of a soil to function within natural or managed ecosystem to sustain plants and animal productivity, maintain or enhance water and air quality and finally support human health.¹ Soil quality could be understood through biological, chemical and physical properties of the soil and it is a function of soil management practices.^{1,2} The spatio-temporal variation in soil quality would be as a result of differences in soil management practice which itself becomes the cultural manifestation of the people residing in certain districts. However, the spatio-temporal variation in soil quality should not only take into account the inherent human soil management practices, but the field location and topography themselves influence and become the source of variation in soil quality. Soil tillage is one of soil management practices,² that could be subjected to variation based on bio-physical arrangements of the environment and become the influencing factor for soil quality. Spatial variation in soil quality as a result of tillage practice has been

commonly observed³ at watershed scale. Understanding of soil quality variation at watershed level would play an important role in locating homogenous sites that requires an immediate, careful and sustainable soil management practices. From those relatively local homogenous site, cereal based conventional tillage and *enset* based conservation tillage are the common land use types in the southern highlands of Ethiopia.

Tillage affects the soil natural system and ecological processes leading to a remarkable change in soil properties.^{2,4} Cereal based conventional tillage system deprives soil's capacity to hold water, deteriorates structure stability, nutrient supply and storage as well as its biological life.^{5,6} It is widely recognized as a factor for decline in soil productivity. Frequent cultivation in general increases the potential for soil erosion to deteriorate soil quality indicators.³ This is due to the breakdown of soil aggregate and reduction of soil cohesion and further this compel the soil to reduce its nutrient content.^{7,8} Moreover, cereal based conventional tillage system (CBCVTS) promote soil organic carbon loss through exposing/inverting micro-aggregate organic carbon to microbial decomposition.^{9,10} The continual process of soil inversion using traditional *Maresha* could mostly lead to a degradation of soil structures which further results compacted soil with low levels of SOM.¹¹ Previous study in Ethiopia around Butajira highland area on cereal based conventionally tilled soil has shown lower soil organic carbon, total nitrogen, lower pH and higher bulk density compared to *enset* based conservation tillage system. Similar findings were observed by Moges et al., Yimer F et al., Yimer F et al.,

Lemenih, et al.^{1,10,12-14} For instance, Yimer F¹² has compared croplands (i.e. cereal based conventionally tilled soil) with other land use system and found that significant changes on selected physical and chemical soil properties in the Southeastern highlands of Ethiopia. Another study conducted by Alemayehu et al.¹⁴ also found lower OC, TN, pH and EC under cereal based land use system as compared to *enset* and grassland land use system in Southern Ethiopia.

On the other hand, *enset* based conservation tillage system which is the common practice of the study area, has a capacity to improve the soil qualities relative to that of cereal based conventional tillage system.¹⁴ This improvement in soil properties relative to conventionally tilled land use systems was as a result of organic matter addition from the *enset* based conservation tillage system.^{6,15,16}

Apart from an initial investigation¹⁷ and recent report on characterization of the study area soil¹⁸ and Bamboo related study,¹⁹ there has been no study conducted so far addressing soil quality variation in the study area. This has become an area of particular concern due to the presence of high population pressure and expansion of CBCVTS on the expense of EBCST practice. This study, therefore, intended to investigate the soil quality variations along land use types in southern highlands of Ethiopia.

Materials and methods

Description of the study area

The study was undertaken in Bule wereda, Gedeo Zone, Southern Ethiopia (Figure 1). Geographically, it extends from 6° 04' 16" to 6° 23' 50" N latitude and from 38° 16' 20" to 38° 26' 11" E longitudes. The altitude ranges from 1700m to 3000m above sea level. The area is characterized by a bimodal rainfall distribution (Figure 2). The mean annual rainfall and temperature of the study area ranges from 1200mm to 1800mm and from 15.10°C-22.5°C, respectively.

The dominant soil type of the study area is Nitisols.¹⁹ Its surface horizon is characterized by a granular to crumb structure, porous and

well aerated with good internal drainage potentials that can be suitable for a wide range of agricultural uses. The land use system of the study area is a mixture of crop farming and agroforestry system (Table 1). Cereal crops such as Barley and Wheat are the dominant crops in the area. In addition, Beans, Pease and haricot beans are grown. Moreover, tree species like *Aningeria attissima* (*Kerero*), *Erythrina Abyssinica* (*Korch*) and *Eucalyptus globules* are dominantly grown in the area. In addition to cereal based land use system, agroforestry practices such as *Enset* based were also used commonly by the local people. In the study area, the soil under cereal based conventional tillage was commonly manipulated using a traditional farm tool known as *Maresha*. Off course, *maresha* is a simple and common tool (Figure 3) dated traditional farm implement almost common to all farmers in Ethiopia for cereal crop production. The tool is commonly drafted by two oxen²⁰ with average shallow tilling depth of 10-15cm.

Soil sampling and laboratory analyses

Two land uses *Enset* based conservation tillage system (EBCSTS) and Cereal based conventional tillage system (CBCVTS), hereafter referred to as "land use types") were selected. The land use types were contiguous and have similar environmental conditions (e.g. in soil conditions and slope) except their differences in the land use management practices. Experimental design employed for this research was Randomized Complete Block Design (RCBD) and layouts was performed by using a transect line.²¹ Long transect lines were laid along the longest side of the individual land use type. Five meter away from the transect line, each sampling point (pit) was marked at every 10-15m interval (Figure 4). This was done just to avoid biasness during the time of soil sampling. Accordingly, a total of 48 soil samples [2 treatments_3 replications_4 blocks^1_2 soil depth layers: 0-15cm, 15-30cm] were collected for laboratory analyses. Prior to laboratory analysis, the soil samples were air-dried at room temperature, crashed and passed through a 2mm diameter sieve. Undisturbed soil samples were also collected separately using core sampler from each soil depth for the determination of soil bulk density.

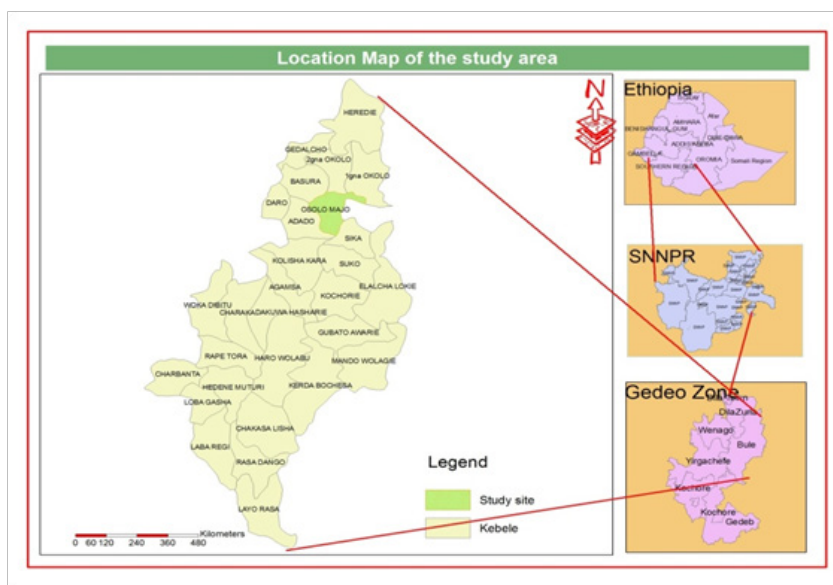


Figure 1 Map of the study area.

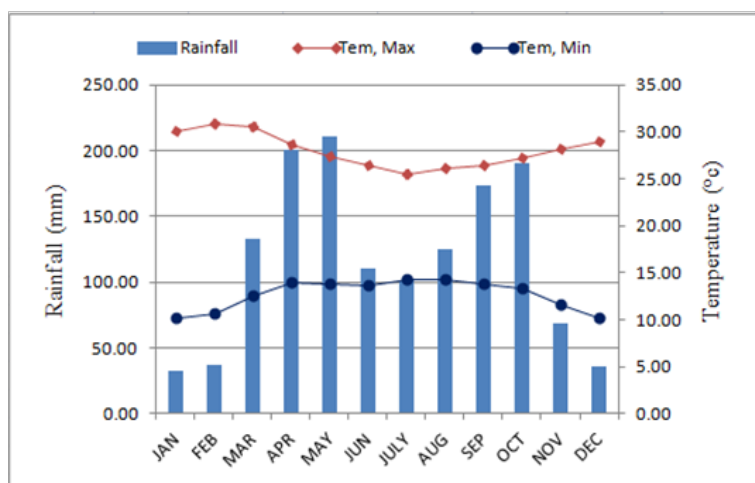


Figure 2 Average monthly rainfall (mm) and temperature of the study area (From the year 1988 to 2012).

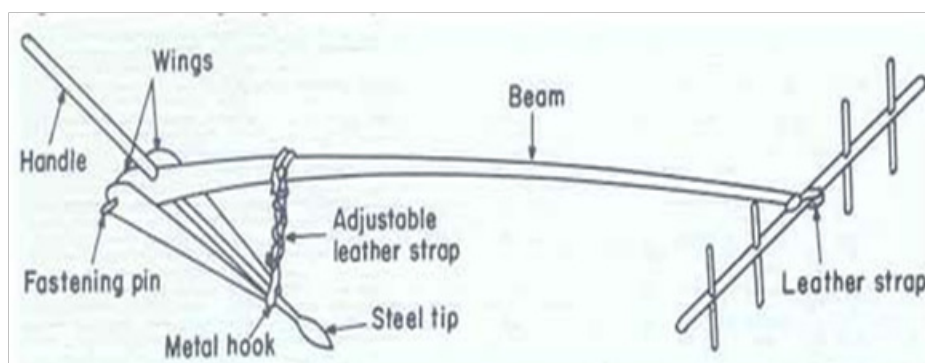


Figure 3 Traditional Maresha and its neck Yoke.

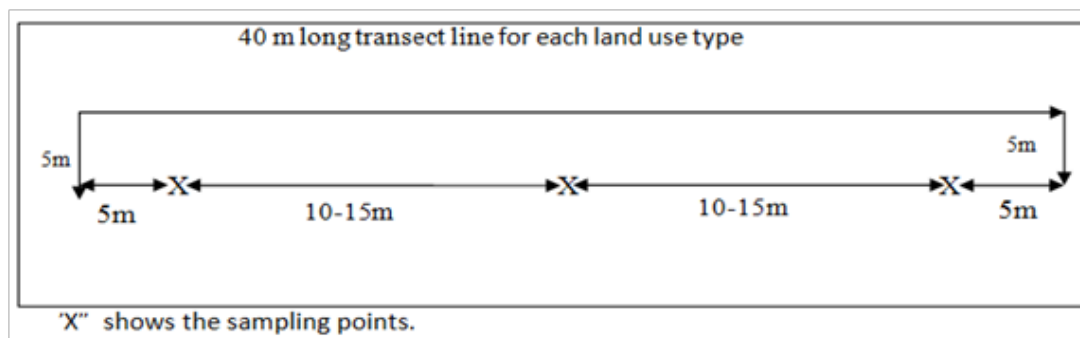


Figure 4 Soil sampling points.

Table 1 Major land use allocation of Bule Wereda

Land use types	Area coverage (ha)	Percent (%)
Permanent Crop Land	12,355.48	41.7
Annual Crop Land	13,497	45.5
Forest Land	1,904	6.4
Grazing Land	496.95	1.7
Others	1,403.75	4.7
Total Area in ha	29,657.18	100%

Source: Bule Wereda Agricultural Development Office (2008/09)

The soil textural fractions were determined following the hydrometer method after the soil was dispersed using sodium hexametaphosphate solution.²² Soil bulk density was determined after the soil was oven dried at 105°C for 24hrs.²³ The gravimetric soil moisture content (SM %) was calculated following the method described by Cuenca.²⁴ Soil organic carbon (SOC%) was determined according to the Walkley and Black method.²⁵ The pH of the soil samples was measured in water and potassium chloride suspension in a 1:2.5 (soil: water ratio) potentiometrically using a glass- calomel combination electrode.²⁶ Total Nitrogen (TN %) was determined using the Kjeldahi method.²⁷ Cation exchange capacity (CEC) of the soil samples was also determined after extracting the soil samples by ammonium acetate (1N NH₄OAC) at pH 7.

Laboratory results were analyzed using General Linear Model (GLM) procedure of SPSS version 16.0 for windows (SPSS Inc., Chicago, USA). Analysis of variance (ANOVA) was employed to test the degree of variations. Tukey's Honest Significance Difference (HSD) test was also used when the mean separation showed statistically significant differences ($p < 0.05$).

Results and discussion

Soil physical properties

Soil textural fractions (%), bulk density (gcm⁻³) and soil moisture content (SMC %): Soil textural fractions of sand, silt and clay significantly varied with land use types ($p < 0.001$, $p = 0.003$ and $p = 0.001$, respectively, Table 2). Except silt, the other soil textural fractions (sand, $p = 0.041$ and clay, $p = 0.002$) showed significant variation with soil depth in the study area (Table 2). The combined effect of land use type and soil depth on sand and clay textural fractions were also significant ($p = 0.012$, $p = 0.02$, respectively, Table 2). Sand fraction was higher in EBCSTS (Table 3) than in CBCVTS land use types. Clay and silt fraction were also higher in CBCVTS (Table 3) than in EBCSTS. Considering soil depth, higher amount of sand fraction was observed under 0-15cm of EBCSTS and 15-30cm of CBCVTS, while higher clay takes 0-15cm of CBCVTS and 15-30cm of EBCSTS land use types, respectively. The higher clay at 0-15cm soil depth on CBCVTS might be due to intensive and continuous cultivation which may reduce downward movement of clay particles within the soil profile. This finding is in agreement with findings of Jaiyeoba.²⁸ The higher sand fraction on CBCVTS was due to selective removal of clay fraction by erosion.²⁹⁻³⁴ Since the area is endowed with higher amount of rain fall, surface erosion is common. Similarly, higher amount of sand fraction under EBCSTS land use types was due to removal of clay fraction through leaching from the soil surface.² The tendency of increase in clay fractions with soil depth under the EBCSTS could also be related with the abundance of root channels (macro-pores) favoring the downward migration of fine clay fractions below 15cm.² While the clay fraction moves downward (15-30cm), the sand content remains high at the surface (0-15cm) under EBCSTS of land use types.

Soil bulk density has shown significant variation with land use type ($p = 0.016$, Table 2) and soil depth ($p = 0.002$, Table 2). The combined effect of land use types and soil depth has also shown a significant interaction effect on soil bulk density ($p < 0.001$, Table 2). Bulk density was lower in soil under the EBCSTS than in CBCVTS (Table 3). This was due to continuous addition of soil organic residues on the surface soil layer.^{2,6,35,36} In CBCVTS, the continuous tillage operation and thereby lowering of soil organic carbon (SOC) might have contributed

for increased soil bulk density.^{6,13,29,31,37-40} With respect to soil depth, the weight of overlying soil and the availability of less soil aggregates have increased the soil bulk density on both land use types.^{13,29,41,42}

Gravimetric SMC (%) also showed significant variations with land use types ($p < 0.001$, Table 2) and soil depth ($p < 0.001$, Table 2). A higher SMC (%) was observed under EBCSTS than CBCVTS land use types. This was due to the presence of higher SOC (%) and hence formation of stable soil aggregate in EBCSTS.^{4,6,29,36,43} Concurrently, higher SMC (%) was observed at 15-30cm across land use types (Table 3). Moreover, since there are perennial and annual crops in the EBCSTS land use type, litter fall and some residues always protect the soil from direct sun light and hence this reduces moisture evaporation from the soil.^{2,40,34,44}

Soil chemical properties

Soil reaction (pH, H₂O) and cation exchange capacity (CEC meq/100g soil): Soil pH value showed highly significant ($p < 0.001$, Table 2) variation among land use types. Considering land use types, relatively higher soil pH values were recorded under EBCSTS. The higher soil pH values were probably due to the presence of higher values of exchangeable bases in EBCSTS land use types. Exchangeable bases like Ca²⁺ and Mg²⁺ could accumulate due to household refuses, wood or biomass ash and animal manures usage. Moreover, by-products from *enset* processing might also be a contributing factor for the higher soil pH values as it burned inside EBCSTS farms. *Enset* is the common type of food item in the study area and has some by-products after its preparation in the farm. For the purpose of clearing their farm, farmers sometimes set fire and burn this by-product and create some sort of ash. Misra et al.,⁴⁵ reported that household refuses and wood ash provides considerable amount of Ca²⁺, Mg²⁺ and K⁺ and enhances the pH values of the soil. The lowest value of pH under the CBCVTS (12.5% reduced, Table 4) might be due to depletion of basic cations either by plant root extraction⁴⁶ or leaching⁴⁷ coupled with crop biomass removal by farmers. Moreover the presence of run-off erosion, long term effect of chemical fertilizer application and the higher microbial oxidation in CBCVTS could also contributed to the lower values of soil pH. This in turn partly enhances the amount of Al³⁺ and H⁺ in soil solutions.⁴⁶⁻⁴⁸ Generally, the pH values observed in the study area are within the ranges of acidic (5.34 and 6.1 for CBCVTS and for EBCSTS, respectively) as indicated by Tekalign.⁴⁹ This result agrees with the studies of Alemayehu and Sheleme¹⁴ who reported that highest pH values under *enset* land than cereal land uses in Central and Southern Ethiopia, respectively. Similar results were also reported by Amusan et al.,⁵⁰ from Nigeria that, a significant lower soil pH was recorded from frequently tilled cropping land as compared to other land use types. Though differences were not significant ($p < 0.05$, Table 2), soil pH showed tendency of increasing with soil depth (Table 4).

Cation exchange capacity has shown a significant variation along land use types ($p < 0.001$) and soil depth ($p = 0.001$, Table 2). Considering land use types, relatively higher (15.31%) CEC values (Table 4) were recorded on EBCSTS than CBCVTS land use type. This was probably due to the presence of higher soil organic carbon within EBCSTS. In addition, clay fraction also contributes for the presence of higher CEC in EBCSTS. Clay is a negatively charged particles that commonly absorb and hold positively charged ions and provides protection against depletion of nutrients through its colloidal aggregates.^{1,14,48} On the other hand, the presence of higher clay content in CBCVTS would not guarantee higher CEC.⁵¹ Boke⁵² showed long-

term continuous tillage practices could also contribute for the lower values of CEC in CBCVTS. These results were in agreement with pervious findings of Negassa, Boke.^{51,52}

CEC (meq/100g soil) tended to decrease along soil depth on both land use types. The highest CEC was recorded at 0-15cm soil depth on both land use types. On CBCVTS, CEC at 0-15cm was 9.5% higher than CEC at 15-30cm soil depth. Similarly on EBCSTS, CEC at 0-15cm was 2.23% higher than 15-30cm soil depth. The main reason for higher CEC at 0-15cm soil depth was the addition of some organic matter inputs like dead plant roots, litter fall and remains of crops after harvesting.² Since clay textural fractions were higher on CBCVTS land use types, sealing of soil pores and compaction is highly expected and thus, nutrients responsible for the higher CEC are unable to move down to 15-30cm soil depth. Concerning the degree of variability between soil depths, higher variability was recorded on CBCVTS (9.5%). Only 2.23% variability was recorded on EBCSTS land use types. The minimum variability of CEC on EBCSTS was partly attributed due to conservation tillage practices which allows minimum soil disturbance. This is in agreement with the results of Habarurema and Steimer.⁵³

Soil organic carbon (SOC %) and total nitrogen (TN, %): SOC significantly varied with land use types ($p < 0.001$) and soil depth ($p < 0.001$, Table 2). SOC was higher in soil under EBCSTS (80 %) than in CBCVTS (Table 4), (Figure 5). The higher SOC was due to the presence of lower organic carbon turnover rate as a result of minimum soil disturbance, less water erosion occurrence and accumulation of higher amounts of organic matter on the top soil surface.⁵⁴⁻⁵⁶ The lowest SOC in CBCVTS could be due to low organic matter inputs coupled with reduced physical protection (due to high soil disturbance) by the soil. This result is in agreement with the findings of Tilahun & Assefa. The practice of removing crop residues from CBCVTS land use types for either animal feed or fuel wood reduced SOC. Variation in SOC

content with soil depth was observed under both land use types. Based on the overall mean, SOC decreased with soil depth on both land use types (Table 4), (Figure 5). Many researchers He et al., Grigorich et al., Abera et al.,^{40,57,58} reported reduction of SOC with soil depth. The variation observed was very wide on CBCVTS land use types under both soil depths (0-15 and 15-30cm). The upper 0-15cm depth of CBCVTS was 49.31% lower in SOC than EBCSTS of similar depth. Similarly, the lower soil depth (15-30cm) under CBCVTS has shown a 58% reduction in SOC (%) as compared to EBCSTS land use types.

Similar to SOC, there was a significant variation in total nitrogen (TN %) among land use type ($p < 0.001$) and soil depths ($p < 0.001$, Tables 2). Higher (48.9%) TN (%) was recorded on EBCSTS land use types (Table 4), (Figure 6). The higher TN (%) was attributed partly to higher addition on organic matter in the form of litter from the agroforestry system. Moreover, house waste disposal as well as manure has also contributed for the highest value of TN. There was also significant positive correlation ($r = 0.92^{**}$) and ($r = 0.60^*$) between organic carbon and total nitrogen at 0-15cm and 15-30cm depth (Figure 6), respectively. This shows that the contribution of OC to total N is high.⁵⁹⁻⁶¹ This research strongly agreed with the findings of Boke⁵² who obtained relatively higher content of total nitrogen from EBCSTS land use types. Considering soil depth, higher amount of TN was recorded on the top surface of both land use types (0-15cm Table 4, Figure 6). Higher TN (70.91%) was observed on EBCSTS at 0-15cm than 0-15cm of CBCVTS land use types. Similarly, at 15-30cm soil depth, 14.29% higher TN was recorded on EBCSTS than CBCVTS land use types (Table 4), (Figure 6). This result agrees with studies by Yifru et al., Lalisa et al., Yimer et al.,^{58,60,61} who found a decreasing trend of TN content with increasing soil depths in Central Highlands of Ethiopia. The higher TN at the soil surface (0-15cm) directly related with the SOC addition on the soil surface.

Table 2 Summary of ANOVA for SMC (%), BD (g/cm³), SOC (%), soil textural fractions (Sand, Silt and Clay, %), Total Nitrogen (%), Soil reaction (pH) and Cation Exchangeable Capacity (CEC) (pmm)

Source of Variation	df	SMC		BD		SOC		Sand		Silt		Clay		TN		pH		CEC	
		MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P	MS	P
LU	1	343.68	<0.001	10.04	0.016	7.6	<0.001	1386.75	<0.001	252.1	0.003	456.33	0.001	0.05	<0.001	6.48	<0.001	143.66	<0.001
SD	1	49.13	<0.001	10.553	0.002	6.63	<0.001	310.1	0.041	10.1	0.53	432	0.002	0.05	<0.001	0.05	0.74	56.3	0.001
LU*SD	1	20.67	0.661	0.88	<0.001	3.24	0.12	420.1	0.02	18.75	0.39	261.33	0.012	0.76	0.001	0.05	0.75	19.63	0.45
Error	44	105.82		0.006		1.63		69.74		24.66		37.86		0.01		0.46		33.44	
Total	48																		

LU, land use; SD, soil depth; SMC, soil moisture content; BD, bulk density; SOC, soil organic carbon; TN, total nitrogen; Ph, soil reaction; CEC, cation exchange capacity

Table 3 Soil textural fractions (%), bulk density (BD cm⁻³) and Soil Moisture Content (SMC %) in relation to land use types and soil depth (cm) (Mean±SE)

Land use types	Soil depth (cm)	Soil textural fractions			Bd (g/cm ³)	SMC (%)
		Sand (%)	Silt (%)	Clay (%)		
CBCVTS	0-15	42.8(±2.10) ^a	27.2(±1.49) ^a	30.0(±1.29) ^b	0.84(±0.02) ^a	11.7(±2.31) ^a
	15-30	45.7(±1.77) ^b	27.0(±1.60) ^a	27.3(±1.49) ^a	1.40(±0.03) ^b	15.0(±2.92) ^b
	Overall	44.25(±1.94) ^A	27.1(±1.55) ^B	28.65(±1.39) ^B	1.12(±0.03) ^A	13.4(±2.62) ^A
EBCSTS	0-15	61.5(±2.36) ^a	22.3(±1.45) ^b	16.2(±1.17) ^c	0.79(±0.02) ^b	18.4(±3.23) ^a
	15-30	50.5(±3.18) ^c	22.7(±1.16) ^b	26.8(±2.71) ^a	1.10(±0.02) ^a	21.1(±3.32) ^b
	Overall	56.0(±2.77) ^B	22.5(±1.31) ^A	21.5(±1.94) ^A	0.95(±0.02) ^B	19.75(±3.28) ^B

The overall means followed by the same letter (s) across columns and rows are not significantly different (P<0.05) with respect to land uses types and soil depths. CBCVTS, cereal based conventional tillage system; EBCSTS, enset based conservation tillage system

Table 4 Soil pH (1:2.5), CEC (meq/100g of soil), TN (%) and SOC (%) in relation to land use types and soil depth (cm) of the study area (Mean±SE).

Land use types	Soil depth (cm)	Soil pH (1:2.5)	CEC (meq/100g of Soil)	TN (%)	SOC (%)
CBCVTS	0-15	5.24(±0.15) ^b	39.1(±1.23) ^b	0.55(±0.02) ^b	1.46(±0.33) ^c
	15-30	5.34(±0.15) ^b	35.7(±2.69) ^a	0.35(±0.02) ^a	1.04(±0.25) ^d
	Overall	5.29(±0.15) ^A	37.4(±1.96) ^A	0.45(±0.02) ^A	1.25(±0.02) ^A
EBCSTS	0-15	6.03(±0.22) ^a	41.3(±1.17) ^a	0.94(±0.03) ^b	2.88(±0.30) ^a
	15-30	6.16(±0.24) ^a	40.4(±1.102) ^b	0.40(±0.01) ^a	1.62(±0.53) ^b
	Overall	6.1(±0.23) ^B	40.9(±1.10) ^B	0.67(±0.02) ^B	2.25(±0.33) ^B

The overall means followed by the same letter(s) across columns and rows are not significantly different (P<0.05) with respect to land uses and soil depths. ACLU, annual crop land use; AGFLU, agroforestry land use

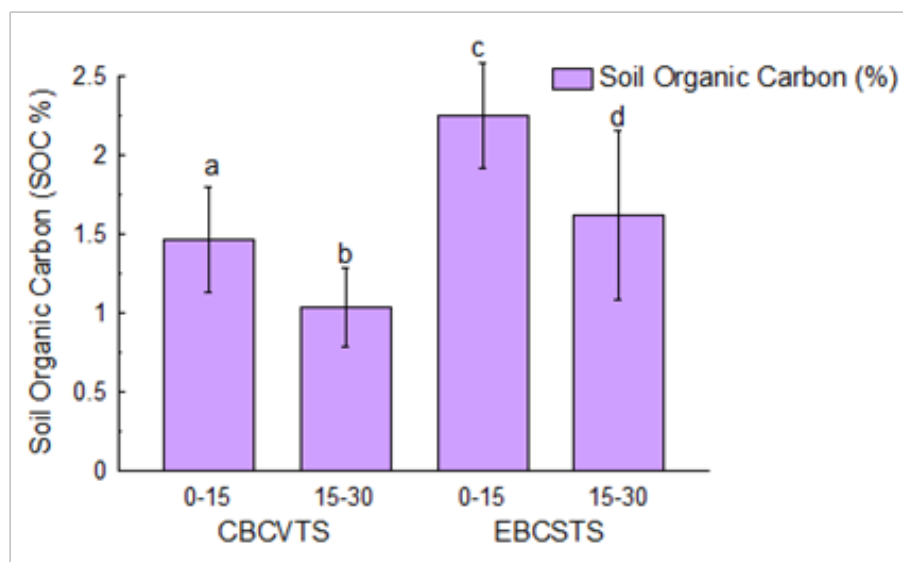


Figure 5 Soil Organic Carbon (SOC %) trend along soil depth and land use types.

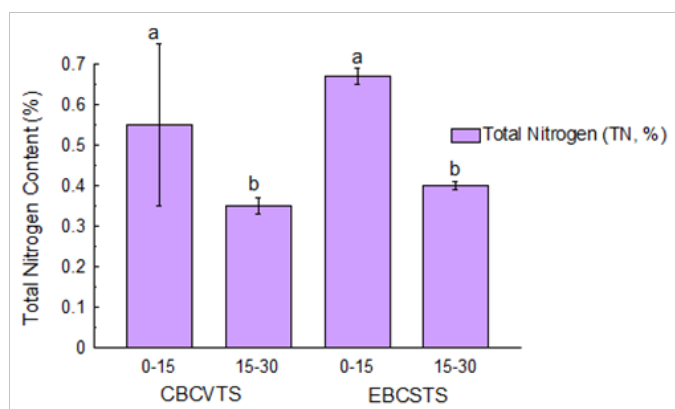


Figure 6 Soil total nitrogen (TN %) trend along soil depth and land use types.

Conclusion

Soil management through adoption of either *enset* based conservation tillage (EBCSTS) or cereal based conventional tillage system (CBCVTS) was the principal anthropogenic factor that causes variations in soil qualities. Understanding the effect of these land use types on soil property changes is quite important for the prediction of soil behavior and its response to different management options. On the bases of land use types, there were markedly differences in soil quality between EBCSTS and CBCVTS. The possible explanation for the difference includes the effect of tillage or the combined effect of tillage and crop on the soil properties. The result of this study implies that EBCST land use type has potential to improve soil quality. The observed improvements were most likely due to addition of organic matter from *enset* crop and presence of less soil disturbance in the agroforestry system. Therefore, EBCSTS is a good management option for rehabilitation and improvement of soil qualities as compared to CBCVTS in the study area. Finally, further research work should be conducted through comparing the soil data generated from agroforestry based conservation tillage and cereal based conventional tillage with that of natural system and making the crops subjected to both tillage types.

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None.

Conflict of interest

The author declares no conflict of interest.

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