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Impact of land use and management practice on soil physical and chemical quality indicators of Vertisols at Pawe, Northwestern Ethiopia

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Soil quality is a function of inherent and dynamic properties of soil which determines the sustainability of crop and animal production. Based on this fact, the study was aimed to investigate the effects of land use systems and management practices on soil physical and chemical quality indicators of Vertisol at Pawe district, Northwestern Ethiopia. The result revealed that most of the soil physical and chemical properties were significantly ($p \leq 0.05$) affected by the land uses and respective management practices. The land uses and respective management practices were selected as the cultivated homestead land (CHL), cultivated research farm (CRF), cultivated fertilized land (CFL) and cultivated unfertilized land(CUL) and native vegetation land (NVL) as a control. The cultivated land with application of farm yard manure (FYM) at the homestead area had higher soil porosity, aggregate size, organic matter (OM), total and mineral nitrogen, available phosphorus (AvP), cation exchange capacity (CEC), exchangeable cations, and micronutrients than the native vegetation land. On the other hand, most of these soil physical and chemical properties found to be declined in the research farm, fertilized and unfertilized cultivated lands. Therefore, integrated use of chemical fertilizer, farmyard manure application and reduced tillage are important soil management practices for sustainable agricultural use of soil in the study area.

Key words: Soil quality, vertisol, land use, cultivated land, management practices.

INTRODUCTION

Soil quality in agricultural system depends on the inherent and dynamic nature of soil which determines the soils suitability for sustainable crop production. There are different factors that influence soil quality in agricultural system which include soil type, climate, tillage, crop rotation and type of soil fertilizer and manure (Imaz et al., 2010). In Ethiopia, due to intensive cultivation of soils without proper management practices such as a removal of crop residues from farm lands, low levels of fertilizer application (Nigussie et al., 2015), use of animal manure

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as a source of fuel (IFPRI, 2010) and the absence of appropriate soil and water conservation practices, result in degradation of soil quality. The core constraints in relation to this improper land use management include: depletion of organic matter due to widespread use of biomass as fuel, depletion of macro and micro-nutrients, removal of topsoil by erosion, change of soil physical properties, and increased soil salinity (IFPRI, 2010; Ayele et al., 2013). These will undoubtedly contribute to exacerbate soil quality decline leading to soil degradation, which may ultimately lead to complete loss of land values. Research in different parts of Ethiopia (Kiflu and Beyene, 2013; Nega and Heluf, 2013; Muche et al., 2015; Takele et al., 2015; Wasihun et al., 2015; Abegaz et al., 2016; Tesfahunegn, 2016) confirm that inappropriate agricultural land management has resulted in the deterioration of soil quality.

Cultivations started in Pawe district in 1985 following the National Resettlement Program in Ethiopia. Since then the natural vegetation of this area had gradually decreased due to deforestation by cutting trees and burning the forest area to use the land for cultivation without any management practice. These had undoubtedly contributed to soil quality degradation in Pawe district. In addition, Vertisols are the largest soil group in this area (Viezzoli, 1992) which affect soil's inherent quality for plant growth, have poor soil physical quality due to high smectite clay mineralogy, very hard and crack when dry, sticky and plastic when wet and poor in drainage. On the other hand, they have relatively high inherent fertility while it requires a careful management in order to tap the potential for crop productivity. Assessment of soil quality based on inherent and dynamic aspects of soil system, is an effective method for evaluating the environmental sustainability of land use and management activities (Nortcliff, 2002). In this regard, soil quality changes in the study area were inferred by measuring the relative changes in soil physical and chemical properties upon the conversion of native woody grass land to cultivated lands with different management practices including organic and inorganic fertilization history. Currently, only little scientific information is available on different land uses and its management impacts with regard to magnitude of soil quality changes under sustainable crop production in the country in general and in the Pawe district in particular. Therefore, this study was initiated to investigate the effects of land use systems on soil physical and chemical quality indicators of Vertisol at Pawe areas.

MATERIALS AND METHODS

Description of the study area

Geographically, the study area is located in Pawe district (11° 18´ 40" to 11º 19´ 29" north latitude and from 36º 24´ 26" to 36º 25´ 27" east longitude) Metekel Zone, Northwest Ethiopia (Figure 1). The district covers an area of about 150,000 ha and the altititude varies from 1,000 to 1,200 m above sea level (masl) with much of the area falling in nearly flat to gently undulating topography. it is slightly undulating towards the Beles River. The geology of the area consists of metconglomerate and quartzite of the Precambrian basement complex (Mengesha et al., 1996). The dominant soil types in the Pawe district are broadly categorized as Vertisols, which account for 40–45% of the area (Viezzoli, 1992).

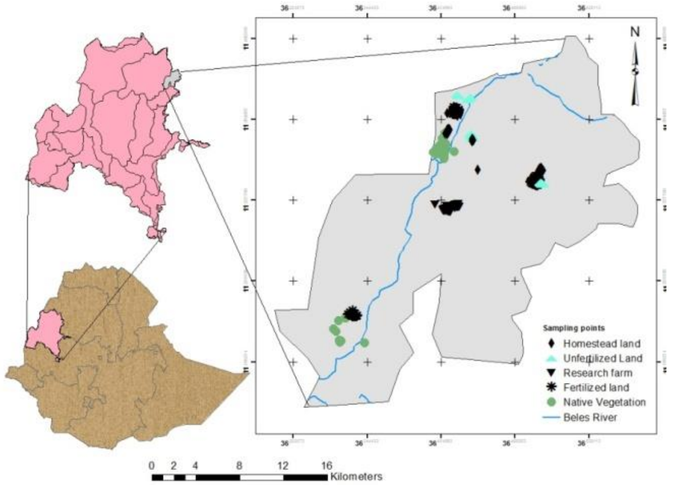

Figure 1. Location map of the study site, Pawe district, Northwestern Ethiopia.

The climate of the study area is hot humid with annual mean temperature of 25ºC. It is characterized by a unimodal rainfall pattern with annual mean of 1587 mm.

Land use and management practices

The natural vegetation in Pawe districts consists of thick shrub, scattered trees and different grass species were currently survived from deforestation along the sides of Beles main river and its sub tributaries. The majority of the farming system is oriented towards grain production which depends on the use of oxen for land preparation. Cultivation of crops without much application of fertilizer is also a common practice in the study area. However, local farmers usually use farm yard manure (FYM) as soil management at nearby homestead fields. In contrary to the most farmers cultivate crops without much application of chemical fertilizers, the research station fields in the study area use different acid forming fertilizers and mechanized farming for land preparation. Therefore, this study considered the effect of tillage, fertilizer and farmyard manure application management practice in cultivated lands with comparison of natural forestland.

Field survey, site selection and soil sampling

Field observation and soil sampling were carried out with the help of topographic map of the district. Prior to the actual field work, preliminary soil survey and field observations were carried out using the topographic map (Scale 1:50,000) produced by the Ethiopian Mapping Authority (1994). However, the information about the actual soil condition and management practices of specific sites was gathered by observation of the actual soil condition and interviews with farmers and local agriculture experts. The sampling

Table 1. Effects of land use and soil depth on selected soil physical properties of Vertisols at study area.

Land use	Sand (%)	Silt (%)	Clay (%)	Textural class	BD (g cm^{-3})	PD (g cm^{-3})	Porosity (%)	FC (%)	PWP (%)	AWHC (%)
NVL	13.83	17.34	68.83	Clay	1.19^{a}	2.44	51.35^{a}	45.15^{a}	33.58^{ab}	11.57^{b}
CHL	11.50	18.67	69.83	Clay	1.12^{b}	2.45	54.29^{a}	48.80^{a}	35.16^{a}	13.64^{a}
CFL	10.67	17.50	71.83	Clay	1.22^{a}	2.43	50.69^{b}	44.36^{ab}	34.01^{ab}	10.36^{c}
CRF	8.17	20.83	71.00	Clay	1.21^{a}	2.45	49.78^{b}	38.26^{c}	29.67^{b}	8.60^{d}
CUL	7.67	21.50	70.83	Clay	1.24^{a}	2.49	50.06^{b}	40.13^{bc}	31.12^{ab}	9.01^{d}
LSD (0.05)	NS	NS	NS		0.05	NS	2.89	4.2952	4.4595	0.914
0-15	9.87	19.47	70.67	Clay	1.14^{b}	2.44	53.17^{a}	43.41	32.47	10.94^{a}
15-30	10.87	18.87	70.27	Clay	1.25^{a}	2.46	49.30^{b}	43.27	32.94	10.33^{b}
LSD (0.05)	NS	NS	NS		0.04	NS	1.75	NS	NS	0.59

*Means within a column and the same factor followed by same letter are not significantly different from each other at $p > 0.05$. NS = Not significant; LSD = Least significant difference.

sites were selected based on the land use system and management practices which are expected to affect soil physical and chemical quality. Accordingly, soil samples were collected from five land uses (NVL, CHL, CFL, CUL and CRF) in the Vertisols dominant area of Pawe district. From each sampling sites, three composite soil samples were augured at 0-15 and 15-30 cm depths and taken to the laboratory for analysis. For determination of bulk density and aggregate size distribution undisturbed soil samples were also separately taken from the selected sites.

Soil sample preparation and analysis

The disturbed soil samples that were collected from the study area were air dried, crushed and passed through 2 mm mesh sizes and analyzed in the soil laboratories of Pawe and Deberzeit agricultural research centers. Total porosity was calculated from the bulk and particle density. Soil texture was determined using the Bouyoucos hydrometer method, soil bulk density (BD) by the core method and aggregate size distribution by the dry sieving method (Jaiswal, 2003).The soil water contents at field capacity (FC -1/3 bar) and permanent wilting point (PWP -15 bars) were determined using the pressure plate apparatus and the plant available water holding capacity (AWHC) of the soils was calculated as the difference between the water contents at FC and PWP (Klute, 1965). Soil pH was measured using a digital pH-meter in 1:2.5 soils to water ratio (Peach, 1965). The soil OC content was determined by Walkley and Black method. Total nitrogen(TN) was determined by the micro-Kjelda CHL digestion, while NH_4^+ and NO_3^- were determined by steam distillation of ammonia (NH_3), using heavy MgO for NH_4^+ and Nevada's Alloy for NO_3^- (Bremner and Keeney, 1965). Available P was determined using the Bray II extraction method as described by Bray and Kurtz (1945). Exchangeable cations (Ca, Mg, K and Na) and Cation exchange capacity were determined after leaching the soil samples with 1 M ammonium acetate solution at pH 7 (Chapman, 1965). The micronutrients (Fe, Mn, Zn and Cu) were determined by extracting the soils with the DTPA method as described by Lindsay and Norvell (1978).

Data analysis

The soil analysis data were subjected to analysis of variance (ANOVA) using SAS software (9.3) to assess the significance of differences in soil parameters due to land uses and soil depths. Correlation coefficient (r) was also computed to determine the magnitude and relationship between selected soil quality indicators.

RESULTS AND DISCUSSION

Physical soil quality indicators

The data shows that there were no differences in textural classes among the land use system and corresponding management practices (NVL, CHL, CRF, CFL and CUL). Accordingly, the soils in the study area were clayey in texture; with the clay fraction accounting for more than 50% of the soil separates. Relatively higher sand contents were observed under the native vegetation followed by homestead lands, whereas relatively higher clay contents were observed under the remaining cultivated lands (Table 1). This indicated that the long-time cultivation process could be contributed to increase the clay size soil separates through the process of ploughing and other management practices. Adugna and Abegaz (2016) also suggested that the lower content of sand and higher content of clay fractions in the cultivated land may be attributed to the process of ploughing, clearing, and the levelling of farming fields. The soil bulk density (BD) and total porosity values were significantly ($p \leq 0.05$) different for the land use types and the corresponding management practices (Table 1). Numerically, it was ranged from 1.12 in the CHL to 1.24 g cm^{-3} in CUL. Contrary to BD, total porosity was highest (54.29%) in the CHL while it was the lowest (49.78%) in the CRF. The observed lowest BD in CUL and highest total porosity figures in the CHM are largely attributed to its highest soil OM content due to continuous application of FYM. On the other hand, the lowest total porosity in CRF and the highest BD in CUL are attributed to the continuous and intensive cultivation of the soil without much application organic and inorganic fertilizer inputs in UCL and heavy farm machinery compaction in CRF.

Previous studies reported that land use systems had significantly affected BD and soil porosity because of intensive cultivation without appropriate soil management which resulted in OM degradation and soil compaction (Bahrami et al., 2010, Bezabih et al., 2016). However,

Table 2. Aggregate size distribution (%) and mean weight diameters under different land use system on Vertisols of study area.

Land use/use	Aggregate size (mm)*								
	> 5	**2-5**	**1-2**	**0.5-1**	**0.15- 0.5**	**0.125-0.15**	**0.053-0.125**	**≤ 0.053**	**MWD**
Vertisols									
NVL	16.94^{a}	42.98^{ab}	26.34	6.57^{ab}	2.62^{bc}	1.68^{b}	1.64^{b}	1.24	4.11^{ab}
CHL	21.42^{a}	43.89^{a}	23.78	4.59^{b}	1.87^{c}	1.62^{b}	1.50^{b}	1.33	4.44^{a}
CFL	15.99^{ab}	36.97^{b}	28.71	10.14^{ab}	3.71^{b}	1.58^{b}	1.67^{b}	1.24	3.83^{bc}
CRF	$9.72b^{c}$	26.62^{c}	29.83	17.91^{a}	9.47^{a}	2.47^{a}	2.57^{a}	1.41	2.94^{c}
CUL	8.09^{c}	41.64^{ab}	31.71	10.50^{a}	3.13^{b}	1.77^{b}	1.72^{b}	1.44	3.49^{d}
LSD (0.05)	6.68	6.78	NS	4.69	2.66	0.52	0.50	NS	0.50
Depth (cm)									
0-15	14.80	37.56	28.14	10.30	4.24	1.86	1.81	1.29	3.77
15-30	14.06	39.28	28.00	9.58	4.09	1.79	1.83	1.37	3.75
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

application of manure to the soil counteracted soil compaction by decreasing soil compatibility and improved porosity (Shirani, 2002), had impacted on soil quality by improve root growth, nutrient and air balance and water retention (Jamil et al., 2016).

Water contents at FC, PWP and AWHC were significantly ($p \leq 0.05$) affected by land use types and soil management practices (Table 1). The observed results generally showed that the soil water contents at all three conditions were highest in the CHL while lowest in the CRF. This was attributed to the improved OM and total porosity of the soils in the CHL and declined in the remaining cultivated lands. Yuksek et al. (2010) also reported that as the amount of organic materials decrease, soil water retention at FC, PWP and AWHC of the soil decrease as well.

The aggregate size distributions was also significantly ($p \leq 0.05$) affected by land use and management practices at all aggregate size classes except the 1-2 mm and ≤ 0.053 mm which has not affected by soil depth (Table 2). The CHL and NVL lands had a good soil structure as a result of having the greater proportion of macro aggregates (> 1 mm) and a lower proportion of micro-aggregate (≤ 1 mm) (Table 2). In contrast to homestead land, the percentage of macro- aggregates (> 5, 2-5 and 1- 2 mm) and the calculated mean weight diameter (MWD) decreased in the research farm while the micro- aggregates(0.5-1, 0.15-0.5, 0.125-0.15, 0.053-0.125 and ≤ 0.053 mm) increased as a result of using heavy farming machinery and intensive cultivation in the research farm. This indicated that the lower OM contents in the cultivated lands have hastened the decomposition of humus and the deterioration of soil aggregates while in homestead land, the application of FYM might be responsible for increased OM content and the stabilization of aggregates as well as higher MWD. In agreement with this result Bidisha et al. (2010) observed that cultivation without fertilization or manuring over control soil showed abundant micro aggregates.

Soil chemical quality indicators

The effects of land use and the corresponding management practice on soil chemical quality indicators (Tables 3 and 5). The result revealed that most of soil chemical quality indicators; pH, OM, TN, Av.P, exchangeable cations, CEC and micronutrients were significantly ($p \leq 0.05$) affected by soil management practice in the study area. Based on the result, the soil pH was ranged from 6.71 in NVL to 6.07 in CRF. This could be due to the ameliorating effect of FYM on soil acidity by reducing the activity of aluminum ions in CHL and the continuous use of acid forming fertilizers (urea and DAP) and depletion of basic cations in the CRF. Similarly, Wakene and Heluf (2003) also attributed the lowest pH values recorded in the soils of the Bako Research Station due to intensive cultivation and use of acidifying inorganic N and P fertilizers.

The soil organic matter content of of the study area was significantly ($p \leq 0.01$) varied from 2.25% in the CUL to 3.82% in the CHL. In addition, the soil under NVL also had relatively higher OM values (2.91%) next to the CHL in study area. According to Tekalign (1991), the amount of OM recorded in the CFL and CUL cultivated lands of the study area were found to be low, whereas the remaining cultivated lands and NVL in the study area had moderate OM content. Similarly, Bidisha (2010), recorded low organic carbon for unfertilized soil compared to the fertilized and manure amended soil. With regard to soil depth, the amounts of OM in the subsurface (15-30) soils were lowered 34.66, 45.44, 26.44, 20.32 and 14.08% under the NVL, CHL, CFL, CRF and CUL respectively as compared to their respective surface (0-15 cm) soils in

Table 3. Main effects of land use and soil depth on some chemical properties of Vertisols in the study area.

Landuse/use	**pH**	**EC (dS m^{-1})**	**OM (%)**	**Total N (%)**	**C:N**	**NO$_3^{-1}$**	**NH$_4^+$**	**AvP**
							(mg kg^{-1})	
NVL	6.71^{a}	0.58^{b}	2.91^{b}	0.132^{b}	12.78	15.63^{ab}	6.73^{bc}	3.48^{b}
CHL	6.70^{a}	0.89^{a}	3.82^{a}	0.169^{a}	13.21	19.75^{a}	10.63^{a}	18.91^{a}
CFL	6.40^{b}	0.45^{bc}	2.56^{bc}	0.118^{b}	12.96	14.73^{ab}	7.72^{bc}	2.97^{b}
CRF	6.07^{c}	0.33^{c}	2.64^{cb}	0.127^{b}	12.04	18.52^{ab}	8.01^{ab}	2.82^{b}
CUL	6.28^{b}	0.41^{bc}	2.25^{c}	0.110^{c}	11.86	13.38^{b}	5.22^{c}	2.31^{b}
LSD (0.05)	0.20	0.17	0.633	0.033	NS	5.950	2.72	7.09
Depth (cm)*								
0-15	6.46	0.59^{a}	3.35^{a}	0.15^{a}	12.87	21.26^{a}	8.58	8.89^{a}
15-30	6.40	0.48^{b}	2.32^{b}	0.11^{b}	12.27	11.55^{b}	6.74	3.31^{b}
LSD (0.05)	Ns	0.10	0.40	0.02	NS	3.76	NS	4.48

*Main effect means within a column of the same factor followed by the same letter are not significantly different from each other at $P > 0.05$.

the study area. This could be due to the mechanical tillage practice in the research farm uniformly mixing the surface and the subsurface soil. However, under the CHL, the OM was accumulated in the surface soil because the use of traditional tillage practices had significantly mixed the surface and subsurface soils.

The total N contents of the soils in the study area were also varied from 0.110% in the CUL to 0.169% in the CHL. According to Tekalign (1991), the status of total N of the soils in the study area was moderate under the CHL, NVL and CRF and low in the CUL. The OM showed strong association with total N (r = 0.92**) and mineral N contents (NO$_3^-$ (r = 0.81**) and NH$_4$+ (r = 0.64**) (Table 4). Thus, the result revealed that land use and management practices that increased soil OM content, also increase the N contents of soils.

The concentration of available P with Bray II extraction method was ranged from 2.31 in the CHL to 18.91 mg kg-1 in the CUL (Table 3). The relatively high availability of P in the CHL could be associated with the added FYM on this cultivated land which reduce P fixation by masking the fixation sites on the soil colloids. On the other hand, the low availability of P in the natural vegetation land and other cultivated lands could be related to the inherent P deficiency of Vertisols as insoluble Ca and/or Mg phosphates complex through reactions with the relatively high clay contents. As a result, available P was positively and significantly associated with the OM (r = 0.80**) and pH (r = 0.51*) and negatively associated with the clay contents (r = -0.57**) (Table 4).

In general, the result of OM, TN, mineral N' and Av. P under the CRF, CFL and CUL cultivated lands showed overall change towards the direction of loss of their quality compared to the soils attributes of the adjacent NVL and CHL. Furthermore, these chemical properties generally declined in CUL as compared to CFL. However, Continuous use of sole inorganic fertilizers lead to various harmful effects on the soil environment, and reducing the productivity of the soil by affecting soil health in terms of physical, chemical and biological properties (Surekha et al. 2013). Several research work in different parts of Ethiopia indicated a depletion risk in pH, OM, TN and Av.P contents under cultivated lands (Emiru and Gebrekidan (2013), Kiflu and Beyene (2013), Takele et al (2015), Mucheet al(2015), Adugnaand Abegaz (2016), Tesfahunegn (2016)). This might be due to continuous intensive cultivation with frequent tillage, application of acid forming fertilizers practice, overgrazing, erosion and removal of crops and crop residues with poor soil management practices.

Exchangeable cations (Ca, Mg, K, Na) were affected by land use and management practices in the study area. The highest exchangeable Ca, Mg and K values were observed in the CHL followed by in the NVL, whereas the lowest exchangeable values were observed in the CRF. The CEC values of the soils in the study area were also highest (49.44 cmol (+) kg^{-1}) in the homestead land followed by 43.78 cmol kg^{-1} in the NVL and lowest (27.13 cmol (+) kg^{-1}) in the CRF (Table 5). The depletion of CEC from the CRF, CFL and CUL were 38.03, 19.27 and 23.78%, respectively, as compared to the CEC in the NVL. The highest Exchangeable cations and CEC values obtained in the CHL could be related to high OM from continuously applied FYM and stable soil structure that decrease loss of cations by soil erosion. On the other hand, the lowest values in the CRF could be due to continuous use of the inorganic fertilizer that enhanced loss of base cations through leaching, erosion and crop harvest. Based on the ratings of FAO (2006), exchangeable Ca and Mg of soils in the NVL and CHL were very high and that of the CFL, CUL and CRF were high in the study area. However, the status of exchangeable K of the soils in the study area was high (0.94 cmol(+) kg^{-1}) and very high (1.46 cmol(+) kg^{-1}) in

Table 4. Pearson's correlation matrix for various soil physical and chemical parameters.

Matrix	pH	OM	N	AvP	EA	Ca	Mg	K	Na	CEC	Cu	Fe	Mn	Zn	FC	PWP	AWC	BD	CLAY	SILT	SAND	MWD
H	1																					
OM	0.43*	1																				
N	0.44*	0.93**	1																			
AvP	0.60**	0.78**	0.73**	1																		
EA	-0.45**	0.03	0.07	-0.18	1																	
Ca	0.83**	0.29	0.25	0.42*	-0.24	1																
Mg	0.71**	0.19	0.18	0.46**	-0.46**	0.63**	1															
K	0.68**	0.70**	0.68**	0.87**	-0.28	0.48**	0.51**	1														
Na	0.51**	-0.01	0.02	0.21	-0.22	0.41*	0.23	0.36*	1													
CEC	0.80**	0.41*	0.40*	0.65**	-0.28	0.78**	0.83**	0.68**	0.33	1												
Cu	0.01	0.37*	0.29	0.40*	-0.06	-0.11	0.21	0.22	-0.34	0.11	1											
Fe	0.08	0.14	0.03	-0.15	-0.13	0.01	-0.03	-0.04	0.1	-0.08	-0.01	1										
Mn	0.52**	0.74**	0.67**	0.66**	0.06	0.3	0.31	0.64**	0.07	0.52**	0.23	0.13	1									
Zn	0.55**	0.72**	0.67**	0.93**	-0.25	0.34	0.45*	0.83**	0.2	0.62**	0.26	-0.1	0.64	1								
Fc	0.75**	0.27	0.22	0.51**	-0.32	0.76**	0.88**	0.62**	0.35	0.80**	0.09	-0.06	0.37	0.46	1							
PWP	0.56**	0.08	0.04	0.27	-0.22	0.60**	0.79**	0.40*	0.25	0.61**	0.37*	-0.08	0.19	0.28	0.93**	1						
AWC	0.77**	0.51**	0.47**	0.72**	-0.36*	0.70**	0.65**	0.77**	0.36*	0.81**	0.78**	0	0.53**	0.60**	0.68**	0.35	1					
BD	-0.36*	-0.92**	-0.88**	-0.61**	0.01	-0.21	-0.15	-0.59**	0.09	-0.35	-0.60**	-0.21	-0.71**	-0.58**	-0.19	-0.01	-0.46**	1				
Clay	-0.17	-0.16	-0.19	-0.19	0.04	-0.12	-0.06	-0.08	0.42	-0.2	-0.05	-0.06	-0.27	-0.26	0.02	0.12	-0.17	0.29	1			
Silt	-0.07	0.08	0.09	-0.06	0.12	-0.05	0.09	0.06	-0.31	-0.05	-0.06	-0.19	0.06	0.02	0	0.05	-0.1	-0.1	-0.08	1		
Sand	0.69**	0.05	0.09	0.18	-0.42*	0.69**	0.66**	0.29	0.33	0.61**	0.35	0.19	0.08	0.22	0.65**	0.55**	0.55**	-0.06	-0.21	-0.21	1	
MWD	0.2	0.67**	0.54**	0.46**	-0.36*	0.67**	0.70**	0.43*	0.36	0.77**	0.54**	-0.15	0.18	0.4	0.68**	0.52**	0.66**	-0.12	-0.04	-0.07	0.55**	1

*,** Significant at 5 and 1% levels, respectively.

the CHL and the remaining lands had medium exchangeable K. Based on the ratings of Hazelton and Murphy (2007), the values of CEC under all land uses in the Vertisols are categorized as high level. With regards to soil depth, the higher values of exchangeable cations and CEC generally were recorded at the surface (0-15 cm) soil than subsurface (15-30 cm) soil. This decreased in CEC value in the subsurface layer, with the parallel declined in OM content is to be expected. The possible reason for the higher concentrations of exchangeable cations and CEC with higher OM could be related the decomposition of organic material (plant residue and FYM) to release K, Ca and Mg into the soil and makes soil less susceptible to erosion (Fageria, 2009).

The value of PBS was highest(80.04%) in the CHL while it was lowest (68.28%) in the CFL. This could be related to its higher OM content as compared to the other cultivated lands which leads to a greater in CEC than the increase in exchangeable bases regulating in the reduction of PBS. On the other hand, the CFL, CUL and CRF had lowered OM as compared with CHL which led in to decrease the CEC but increased PBS. It is because naturally the exchangeable bases in the Vertisols clay are high. The PBS in the Vertisols is greater than 50 and often close to 100% with Ca and Mg occupying more than 90% of the exchange sites (FAO, 2001).

The contents of available micronutrients (Fe, Mn, Zn and Cu) were significantly ($p \leq 0.05$) affected by land use and its corresponding management practices. The highest contents of Cu (6.18 mg kg^{-1}), Zn (1.87 mg kg^{-1}) and Mn (26.05 mg kg^{-1}) were recorded in the CHL and Fe (36.40 mg kg^{-1}) was recorded in the CUL. However, the lowest values of Cu (3.70 mg kg^{-1}) and Zn (0.44 mg kg^{-1}) were recorded under the

Table 5. Main effects of land use and soil management on exchangeable cations, CEC and micronutrients of Vertisols in the study area

Land use	Basic exchangeable cations (cmol(+) kg^{-1})				CEC (cmol(+) kg^{-1})	PBS (%)	Available micronutrients (mg kg^{-1})			
	Ca	Mg	K	Na			Cu	Fe	Mn	Zn
NVL	23.40^{a}	7.22^{ab}	0.51^{b}	0.30	43.78^{b}	71.79^{b}	3.96^{b}	34.07^{a}	14.65^{bc}	0.75^{b}
CHL	24.06^{a}	8.49^{a}	0.94^{a}	0.27	49.44^{a}	68.28^{b}	6.18^{a}	29.44^{ab}	26.05^{a}	1.87^{a}
CFL	21.15^{b}	6.75^{b}	0.45^{bc}	0.23	34.34^{c}	80.44^{a}	3.94^{b}	23.26^{b}	8.94^{c}	0.55^{b}
CRF	15.67^{c}	4.25^{c}	0.35^{bc}	0.14	27.13^{d}	75.23^{ab}	4.43^{b}	35.63^{a}	14.33^{bc}	0.44^{b}
CUL	20.10^{b}	5.70^{bc}	0.32^{c}	0.24	33.37^{c}	78.99^{a}	3.70^{b}	36.40^{a}	18.89^{ab}	0.54^{b}
LSD (0.05)	2.66	1.69	0.19	NS	3.58	10.02	1.44	10.30	8.27	0.71
Depth (cm)*										
0-15	21.78	6.55	0.57	0.25	39.29^{a}	73.31	4.75	32.20	18.99	1.03^{a}
15-30	20.37	6.41	0.46	0.22	36.33^{b}	76.94	4.14	31.32	14.15	0.63^{b}
LSD (0.05)	NS	NS	NS	NS	2.26	NS	NS	NS	NS	0.33

*Means within a column of the same factor followed by same letter are not significantly different at $P > 0.05$. NS = Not significant; LSD = Least of significant difference.

CUL and CRF, respectively. Similarly, the lowest values of Mn (8.94 mg kg^{-1}) and Fe (23.26 mg kg^{-1}) were recorded in the CFL (Table 5). With regards to soil depth, all values of micronutrients were numerically higher in the surface soil (0-15 cm) than in the subsurface (15-30 cm) soil layer (Table 5).

The availability of micronutrient is influenced by accumulation of OM and soil pH. The higher OM in surface soil can form soluble organic complex with most of micronutrients which are mobile and can be lost by leaching. However, the influence of pH on availability of Cu and Zn is less than that of Fe and Mn (Fageria, 2009). Therefore, the higher concentrations of Fe and Mn in the research farm are probably due to its lower pH as compared to the other land uses types. The contents of Fe and Mn in this study decreased with the increase of pH (r = -0.57** and r = -0.48*, respectively) (Table 4). Hence, these results indicated that soil pH is an important chemical property in determining availability of such micronutrients in the soils. In general, all of micronutrients (Fe, Mn, Cu and Zn) in study area are between the toxicity and sufficiency levels as per the rating by Lindsay and Norvell (1978). Therefore, there is no soil quality problem related to these micronutrients.

Conclusions

The results of this study are evidences of the significant changes in the quality attributes of the soils in the study area following the removal or destruction of vegetative cover, low organic input and frequent tillage that led to soil erosion and decline in soil quality. The result revealed good soil quality in terms of water availability, soil aggregate size distribution, bulk densities, OM, total and mineral N' available P, CEC, exchangeable base and micronutrient in continuous manure amended cultivated land as compared to the natural vegetation. However, these physical and chemical indicators in the research farm, fertilized and unfertilized cultivated lands showed overall change towards the direction of loss of their quality compared to the soils attributes of the adjacent native vegetation and homestead land. Therefore, there is a vital need to adopt appropriate soil and plant management practices that reduce soil degradation or maintain soil quality at a desirable level in the study area.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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