The Impact of Different Land Use Systems on Soil Quality of Western Ethiopian Alfisols

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ABSTRACT

The success of soil management to maintain soil quality depends on an understanding of how soils respond to agricultural use and practices over time. As a result, the important soil quality indicators were investigated under different land use systems to provide base line data for future research in western Ethiopia. The different land use systems were the cultivated land, abandoned land, and the virgin land. One soil profile was opened in each land use system for field descriptions and laboratory studies in 2000. The soil physical properties such as structure, bulk density, total porosity and soil water characteristics showed notable variations due to different land use system, particularly in A-horizon. The highest bulk density (1.57 Mg m^{-3}*) was recorded at abandoned land, whereas the lowest was (1.16 Mg m*$^{-3}$*) in virgin land in the surface horizon. Similarly, soil pH (*H_2O*) was 5.23 in cultivated land as compared to 6.23 in virgin land.* The amount of depleted OC and TN from the abandoned land was 79 and 76%, respectively. *Likewise, the different forms of P were influenced by different land use systems. The available P was found to be highest, 25.52 and 43.05 mg kg*$^{-1}$ *in Olsen, and Bray-II extraction methods, respectively, in abandoned land as compared to 1.90 and 4.78 mg kg*$^{-1}$ *in the virgin land, because the abandoned land had received P fertilizer during the past three decades.* The depletion of CEC from the abandoned and the cultivated lands was 69.44 and 52.76%, respectively, as compared to the CEC of A-horizon in the virgin land. *The essential micronutrients were also influenced due to different land use systems except for Mo that was trace in all the land use systems. In general, intensive mechanized tillage practices along with continuous use of acid forming inorganic fertilizers on acidic Alfisols has degraded most of the important soil quality indicators. Therefore, reducing the intensive mechanized tillage practices and use of integrated inorganic and organic fertilizers could replenish the degraded soil quality for sustainable agricultural production in the study area.*

Key phrases*: Abandoned land, Alfisols, Land use systems, Soil quality, Virgin land*

1. INTRODUCTION

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. For this reason, recent interest in evaluating the quality of our soil resources has been stimulated by increasing awareness that soil is a critically important component of the earth's biosphere, functioning not only in the production of food and fiber but also in the maintenance of local, regional and world wide environmental quality (Doran and Parkin, 1994). On the other hand, feeding the ever-increasing human population is most challenging in developing countries because of soil degradation. For instance, in Sub-Saharan African countries, soil fertility depletion is the fundamental biophysical cause for declining per capita food production (Sanchez et al., 1997). This challenge will continue as population pressure increases and degradation of soil resources is aggravated. Reversing this trend lies in the enhancement of sustainable development of the agricultural sector; however, the basis of sustainable agricultural development is good soil quality. Since maintenance of soil quality is an integral part of sustainable agriculture.

The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use aggravates the degradation of soil physicochemical and biological properties (Singh et al., 1995; Saikhe et al., 1998a; He et al., 1999). In line with these, Maddonni et al. (1999) reported that land use affects basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration, and other similar physical and biochemical processes.

In Ethiopia, soil degradation due to inappropriate land use system is threatening the livelihood of millions of people. Similarly, large areas of land at Bako Agricultural Research Center, western Ethiopia, are abandoned within less than three decades of continuous cultivation. Although, the knowledge of important soil quality indicators is vital for replenishing and maintaining soil fertility, little information is available in western Ethiopian Alfisols. Therefore, the study was undertaken to investigate the important soil quality indicators under different land use systems to provide base line data for future research.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Geographically the study area is located at Bako Agricultural Research Center in East Wollega Zone of Oromia National Regional State, western Ethiopia, 260 km west of Addis Ababa. It lies at 9^0 6' N and 37^0 09' E, at 1650 meters above sea level. The long-term weather information (1961-2001) revealed that the area has a unimodal rainfall pattern, and annual total rainfall was 1244 mm. The rainy season covers April to October, and maximum rain is received in the months of June, July and August. The mean minimum, mean maximum and average air temperatures were 14.1, 27.9 and 20.6 ^{0} C, respectively. The soil type of the study area is Alfisols (Udalf). Its vernacular name is "Biyyee Diimaa" meaning red soil. The geological history showed that the area is characterized by Tertiary and Quaternary age rhyolite and basalt volcanics (Anon., 1996). The major annual and perennial crops grown in the study area are maize (*Zea mays* L.), sorghum *(Sorghum bicolor* L. Monch.*)*, teff *(Eragrostis tef* (Zucc.*)* Trotter), hot pepper *(Capsicum frutescence* L.*)*, sweet potato *(Ipomoea batatas* Lam*)*, haricot bean (*Phaseolus vulgaris* L.*),* mango *(Mangifera indica* L.*)*, banana (Musa spp.), coffee (*Coffe arabica L.*), and sugarcane *(Saccharum officinarum* L.*)*

2.2. Land Use systems and Soil Sampling

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Three land use systems were considered for the study. These were the cultivated land, abandoned land, and virgin land. One soil profile was opened from each land use system for field descriptions and laboratory analysis in 2000. The cultivated land and the abandoned land have been under intensive cultivation with mechanized tillage equipment since the 1970's. The latter became out of use from crop production in 1999. The soil profile representing the cultivated land is located at 9^0 05' 16" N and 37^0 02' 42" E,while the abandoned land is at 9^0 05' 57" N and 37^0 02' 23" E. Both these land use systems have received 75 kg N and 33 kg P ha^{-1} in most of the years under maize and sorghum cropping. The sources of N and P were urea and diammonium phosphate, respectively. The land identified as the virgin land has no recorded cropping history and is under open wood and shrubs. The soil profile representing the virgin land is located at 9^0 06' 16" N and 37^0 02' 33" E. Soil samples were collected from each soil profile and horizon of the different land use systems. The soil profile description and horizon designation were determined according to FAO guidelines (Anon., 1990). Soil color (dry and moist) was determined using the Munsell color chart (Munsell Color Company, 1975).

2.3. Soil Physicochemical Analysis

The soil samples collected from each horizon were air dried and passed through 2-mm sieve for the determination of most of the soil quality indicators; however, the soil samples for organic carbon, total N, and total P analyses were ground to pass 0.5-mm size sieve. Bulk density was estimated from undisturbed soil of 56 and 42-mm diameter and height, respectively. Particle density was determined by the pycnometer method and particle size distribution was determined by hydrometer method. The soil-water potential value was measured at -1/3 bar for field capacity (FC) and -15 bars for permanent wilting point (PWP) with pressure plate apparatus, while available water holding capacity was obtained by subtracting PWP from FC. Soil moisture content at sampling was determined by the gravimetric method. Total porosity was estimated from the bulk and the particle densities as: $Total\ Porosity\% = \left(1 - \frac{Bd}{Pd}\right) \times 100$

Where Bd = bulk density, and Pd = particle density

The pH of the soil was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5, soil: liquid ratio, and the liquid was water and 1M KCl solution. The exchangeable bases were extracted with 1M ammonium acetate at pH 7, whereas cation exchange capacity (CEC) was determined according to Chapman (1965). The exchangeable acidity was determined by saturating the soil samples with 1N KCl solution and titrating with NaOH. The organic carbon was determined by the wet digestion method. Total N was determined with Kjeldahl method (Jackson, 1958). The available P was determined with both Olsen and Bray II methods (Olsen et al., 1954; Bray and Kurtz, 1945), whereas the inorganic P fractions were successively extracted as described by Chang and Jackson (1957). The total P was extracted with an aqua regia digestion. The different forms of P that were extracted with different methods were measured according to Murphy and Riley (1962). The available Fe, Mn, Zn and Cu were extracted with DTPA (Lindsay and Norvell, 1978) whereas the available B was extracted by hot water as described by Bingham (1982). Available Mo was extracted with NH_4OAC EDTA.

3. RESULTS AND DISCUSSION

3.1. Soil Morphological Characteristics

The morphological characteristics of the land use systems are presented in Table 1. The soil depths of the different land use systems varied. The deepest soil profile was observed in the cultivated land. Although, the cultivated land and the abandoned land were under similar management for the past three decades, the latter came out of crop production in 1999. This implies that soil depth is one of the important soil quality indicators in determining the response of soil to intensive land use. The variation in soil depth under the different land use systems is most likely attributed to the variation in micro-relief and slope that influence soil formation and development through its effects on erosion and infiltration. However, argillic B-horizons were well developed in all the land use systems.

Table 1. Selected morphological characteristics of Alfisols under different land use systems

			Color			Consistency*		
Land Use	Depth (cm)	Horizon	Moist	Dry	Structure$^+$	Dry	Moist	Wet
	0-20	Ap	2.5YR 3/4	2.5YR 3/4	MCSB	Hd	Fr	SP
Cultivated	20-70	Bt1	2.5YR 3/6	10YR 4/6	MCSB	Hd	Fr	SP
	70-120	Bt2	2.5YR 4/6	2.5YR 4/6	WFSB	Hd	Fr	SP
	120-200$^+$	Bt3	2.5YR 4/6	2.5YR 3/6	MCSB	Hd	Fr	SP
	0-16	Ap	5YR 3/2	5YR 3/3	MCSB	Hd	Fr	SP
Abandoned	16-40	Bt1	2.5YR 3/6	5YR 4/6	MMSB	Hd	Fr	SP
	40-125	Bt2	2.5YR 3/4	2.5YR 4/6	WMAB	Hd	Fr	SP
	125-200$^+$	C	-------	-------	-------	-----	------	------
	0-13	A	10YR 2/2	5YR 3/2	MMC	Shd	Fr	SSP
Virgin	13-30	Bt1	7.5YR 3/4	5YR 3/3	MMSB	Hd	Fr	SP
	30-140	Bt2	2.5YR 2.5/4	2.5YR 3/6	MCSB	Hd	Fr	SP
	140-165$^+$	BC	-------	-------	-------	-----	------	-------

$^+$ MCSB =moderate coarse subangular blocky, WFSB = weak fine subangular blocky, MMSB = moderate medium subangular blocky, WMAB = weak medium angular blocky, MMC = moderate medium crumb, * Fr = friable, Hd = hard, SP = sticky and plastic, Shd = slightly hard, SSP = slightly sticky and plastic, ------- = not determined

Similarly, there were color variations among the different land use systems at the surface horizons. The very dark brown color of moist surface horizon of the virgin land as compared to the dark reddish brown of the cultivated and the abandoned lands were attributed to differences in soil organic matter contents. On the other hand, there were few color variations among the land use systems in the B-horizons. This implies that soil color is highly influenced by soil organic matter in the A-horizon that significantly decreased with depth and was highly affected by intensive cultivation as presented in Table 6. The dark yellowish brown and dark red color in B-horizons of the different land use systems is probably due to the presence of Fe oxides in the Alfisols. There were also differences in soil structure among the different land use systems. The moderate coarse sub-angular blocky structure in the cultivated and abandoned land as compared to moderate medium crumb at the surface horizon of the virgin land was due to the intensive cultivation for the past three decades with mechanized tillage machinery. This finding is in agreement with work done elsewhere. For instance, Saini and Grant (1980) reported as intensive tillage practices affected soil structure. The consistency of the virgin land at the surface horizon was different from the other land use systems. Although, consistency is an inherent soil characteristic, the presence of high organic matter in the virgin land surface horizon changed its consistency.

3.2. Soil Physical Properties

There were textural variations among the different land use systems particularly in the surface horizons. In the subsurface horizons, however, slight differences was noticed. The clay percentage increased whilst the sand decreased from the surface to the subsurface horizons in all land use systems (Table 2). Texture is an intrinsic soil property, but intensive cultivation contributed to the variations in particle size distribution at the surface horizons of the cultivated and the abandoned lands. This could be due to the removal of soil particles through sheet and rill erosion, and mixing of the surface and subsurface horizons during deep tillage activities.

Table 2. The soil texture, bulk density, and total porosity under different land use systems

Land Use	(cm) Soil Depth	% Sand	Silt	Clay	Textural Class	Mg m^{-3} Bulk density	Particle density	% Total porosity
Cultivated	0-20	36	30	34	CL	1.22	2.55	47.84
	20-70	38	22	40	C	1.09	2.71	36.26
	70-120	26	20	54	C	1.15	2.54	54.72
	120-200^{+}	28	10	62	C	1.25	2.52	50.40
Abandoned	0-16	60	10	30	SCL	1.57	2.46	36.20
	16-40	44	6	50	SC	1.40	2.46	43.09
	40-125	34	10	56	C	1.41	2.50	43.60
	125-200^{+}	42	26	32	SCL	-----	2.59	----
Virgin	0-13	44	30	26	L	1.16	2.26	49.78
	13-30	42	18	40	C	1.25	2.32	48.77
	30-140	34	21	45	C	1.28	2.34	48.9
	140-165^{+}	38	14	48	C	-----	2.41	-------

CL = Clay loam, C = Clay, SC = Sandy clay, SCL = Sandy clay loam, L = Loam

The highest bulk density in the surface horizon of the abandoned land was 26.11 and 22.29% greater than that of the virgin and the cultivated lands, respectively (Table 2). Similarly, the bulk density of the abandoned land in the B-horizon was greater than the bulk densities of the other land use systems. The highest bulk density in the abandoned land is attributed to the soil compaction and organic matter degradation as a result of continuous and intensive cultivation with heavy farm machinery. This result is in harmony with the research findings reported by Girma (1998). The highest bulk density noted under the abandoned land could limit root growth, gas exchange and availability of less mobile essential plant nutrients, such as P and K (Dolan et al., 1992).

Table 3. Soil water characteristics under different land use systems

Land Use	(cm) Soil Depth	% θ	(mm/m) FC	PWP	AWHC
Cultivated	0-20	27.8	335.05	238.40	116.65
	20-70	32.0	340.00	244.06	90.94
	70-120	30.8	360.52	275.88	84.64
	120-200^{+}	--------	384.38	301.00	83.38
Abandoned	0-16	19.3	275.22	173.80	101.42
	16-40	22.0	317.66	226.38	91.28
	40-125	23.3	355.74	243.79	111.95
	125-200^{+}	----	-----	-----	----
Virgin	0-13	39.2	403.91	303.30	100.11
	13-30	30.0	347.77	266.63	81.12
	30-140	32.0	472.74	266.46	129.03
	140-165^{+}	-------	------	-------	--------

θ = Soil water content at sampling, FC = field capacity, PWP = permanent wilting point, AWHC = Available water holding capacity

The lowest and the highest total porosity were observed in the abandoned and the virgin lands, respectively, (Table 3). These results showed that land use systems significantly affect soil porosity because intensive cultivation without appropriate soil management results in organic matter degradation and soil compaction. The results obtained from this study are in agreement with the findings reported by other researchers (Singh et al., 1995; Maddonni et al., 1999). Soil water content at sampling (θ) was the highest at the surface horizon of the virgin land but the lowest for the abandoned land. Similarly, in the subsurface horizon of the abandoned land, θ was inferior to the other land use systems. Moreover, the lowest field capacity (FC) and permanent wilting point (PWP) were observed in the surface horizon of the abandoned land whereas the highest was recorded from the surface horizon of the virgin land (Table 3). This is attributed to significant variation in organic matter contents among the land use systems. The FC and the PWP increased with depth for the cultivated and the abandoned lands as a result of the increasing trends of clay content with profiles depth. The amount of water retained at PWP was high because of high organic matter content in the surface horizon of the virgin land..

3.3. Soil Chemical Properties

In all the soil profiles of the different land use systems, soil pH measured in water was higher by about 1-2 units than the respective pH values measured in KCl solution (Table 4). The low soil pH with KCl determination indicates the presence of substantial quantity of exchangeable hydrogen ion. According to Mekaru and Uehara (1972) and Anon. (1993), high soil acidity with KCl solution determination showed the presence of high potential acidity and weatherable minerals. The soil pH (KCl) consistently increased in the abandoned land whereas decreased in the virgin land with increasing profile depth. Similarly, soil pH (H_2O) were also significantly affected due to different land use systems. The highest and the lowest were recorded at the surface horizons of the virgin and the cultivated lands, respectively.

Table 4. The soil acidity status under different land use systems

Land Use	Depth (cm)	pH (H_2O)	pH (KCl)	ΔpH	TEA*	EAl*
	0-20	5.23	3.45	1.78	0.64	0.52
Cultivated	20-70	5.22	4.12	1.10	0.52	0.40
	70-120	5.38	3.36	1.02	0.08	trace
	120-200$^+$	5.68	4.99	0.69	0.08	trace
	0-16	5.26	3.80	1.46	0.52	0.32
Abandoned	16-40	5.29	4.04	1.25	0.40	0.24
	40-125	5.31	4.35	0.96	0.68	trace
	125-200$^+$	5.55	4.56	0.99	0.08	trace
	0-13	6.34	4.97	1.37	0.04	Trace
Virgin	13-30	6.04	4.44	1.60	0.16	Trace
	30-140	6.43	4.23	2.20	0.28	0.14
	140-165	5.61	4.34	1.27	0.20	trace

ΔpH = pH H_2O-pH KCl, * = (cmol(+) kg^{-1} soil, TEA = Total exchangeable acidity, EAl = Exchangeable Al

The increasing trend of soil acidity and appearance of EAl under the cultivated and the abandoned lands showed that intensive cultivation and continuous use of acid forming inorganic fertilizers on acid soils aggravates soil acidity. The results are in agreement with the reports of many research findings (Baligar et al., 1997; Blamey et al., 1997).

There was great variation in cation exchange capacity (CEC) of the soils under the different land use systems both in A and B-horizons. The depletion of CEC from the abandoned and the cultivated lands was 69.44 and 52.76%, respectively, as compared to the CEC of A-horizon in the virgin land (Table 5). The CEC was decreased almost consistently from the surface to the subsurface horizons in the cultivated and the virgin lands, whereas the trend in the abandoned land was similar throughout the profile. The decrease in CEC with depth is attributed to a decrease in organic matter content. Therefore, the depletion of organic matter as a result of intensive cultivation has reduced the CEC under the abandoned and the cultivated lands and that is in concurrence with several previous findings (Mesfin 1980; Gao and Chang, 1996).

Table 5. The exchangeable bases of Alfisols under different land use systems

		(cmol(+)/kg of soils					(%)
Land Use	Depth (cm)	Na	K	Ca	Mg	CEC	PBS
	0-20	0.19	0.26	4.59	1.83	17.0	40
Cultivated	20-70	0.21	0.18	3.40	1.08	15.4	32
	70-120	0.21	0.22	3.49	1.42	13.0	41
	120-200$^+$	0.20	0.21	2.59	1.42	13.8	32
	0-16	0.22	0.27	2.30	1.08	11.0	35
Abandoned	16-40	0.23	0.17	2.54	1.42	12.8	34
	40-125	0.08	0.26	2.99	2.25	12.0	47
	125-200$^+$	0.16	0.29	2.64	2.58	11.6	49
	0-13	0.21	1.23	16.41	4.50	36.0	62
Virgin	13-30	0.23	0.34	10.88	3.42	26.8	55
	30-140	0.19	0.50	7.36	2.86	17.7	60
	140-165$^+$	0.65	0.29	4.84	1.92	16.4	47

PBS = Percent base saturation

Exchangeable K varied markedly due to differences in land use systems. The highest exchangeable K was recorded from the surface horizon of the virgin land as compared to the cultivated and the abandoned lands surface horizons. Similarly, the exchangeable K in the sub-surface horizons was greater for the virgin land while the distribution of K was similar for the cultivated and the abandoned lands (Table 5). The results were in contrast to the common belief that Ethiopian soils are rich in K for the cultivated and the abandoned lands. However, it was in agreement with Alemayehu (1990) who reported low K concentration for Nitisols of the then Wollega state farms, western Ethiopia. Many research results supported the findings, since weathering, intensive cultivation and use of acid forming inorganic fertilizers on acid soils affect the distribution of K in the soil systems and enhance its depletion (Baker et al., 1997; Saikh et al., 1998b).

Similarly, the exchangeable Ca concentration in the A horizon of the virgin land was seven and four times greater than that of the abandoned and the cultivated lands, respectively. The distribution of exchangeable Ca was tended to decrease from surface to subsurface horizons for the virgin and the cultivated lands, whereas it tended to increase for the abandoned land (Table 5). The concentration of exchangeable Mg was also highest in the virgin land and decreased from the surface to the sub-surface horizons, but increased for the cultivated and the abandoned lands' subsurface horizons. The increasing trend of Ca and Mg concentration with depth in the abandoned land could be due to the leaching effect that was aggravated by intensive cultivation and organic matter degradation. Moreover, soil erosion and abundant crop harvest for the past three decades contributed for the depletion of Ca and Mg in the cultivated and abandoned lands. This is in agreement with the findings of different investigators who indicated that continuous cultivation and use of acid forming inorganic fertilizers deplete exchangeable Ca and Mg (Saikh et al., 1998b; He et al., 1999; Aitken et al., 1999).

The organic carbon (OC) and the total N (TN) was highly affected by the different land use systems particularly in the surface horizons. The OC and the total N was decreased consistently from the surface to the subsurface horizons in all of the land use systems (Table 6). The amount of depleted OC and TN from the A horizon of the abandoned land compared with the virgin land was 79 and 76%, respectively, which was 24 and 23% greater than that reported by Solomon et al (2002) from southwestern Ethiopian soil that was subjected to traditional oxen plowing for 25 years. Similarly, Wakene (2001) reported the depletion of OC and TN by 43 and 30%, respectively, from the farmland of Bako area, western Ethiopia, which was cultivated for 40 years with oxen. This implies that intensive cultivation with mechanized tillage machinery significantly depleted OC and TN as compared to traditional tillage equipment with oxen plowing

Table 6. Organic carbon, and total N of Alfisols under different and use systems

		(%)			
Land Use	Depth (cm)	OC	OM	TN	C:N
Cultivated	0-20	1.95	3.36	0.13	15.0
	20-70	0.99	1.70	0.07	14.0
	70-120	0.80	1.38	0.06	13.0
	120-200$^+$	0.58	0.99	0.05	11.6
Abandoned	0-16	1.24	2.14	0.08	15.5
	16-40	0.72	1.23	0.05	14.4
	40-125	0.61	1.05	0.06	10.2
	125-200$^+$	0.38	0.65	0.04	9.5
Virgin	0-13	5.90	10.14	0.33	17.9
	13-30	2.16	3.71	0.14	15.4
	30-140	1.06	1.82	0.09	12.35
	140-165$^+$	0.55	0.95	0.06	9.2

OC = Organic carbon, OM = Organic matter, TN = Total N

The concentration of available P with both in Olsen, and Bray II extraction methods was very low in the different land use systems, except for the surface horizon of the abandoned land, (Table 7). The highest concentrations of available P in the abandoned land's surface horizon were due to the carry over effects of continuous application of P fertilizer for the past three decades at the rate of 33-kg P ha^{-1}. This result is in line with the findings of Ransmussen and Douglas (1992) and Whitebread et al. (1998). The low available P in the other land use systems could be due to the inherent P deficiency of the Alfisols and/or the presence of P in unavailable forms as presented in Table 7. The inorganic P forms were also significantly affected by land use systems. Among the active inorganic P forms, the Fe-P was the highest in all the land use systems , followed by Al-P in the cultivated and the abandoned lands of the surface horizons. This result suggests that the continuous use of acid forming inorganic fertilizer on acid soils increases P fixation in the form of Fe-P and Al-P.

Table 7. Different forms of P under different land use systems

	(cm)	(mg kg^{-1})							
Land Use	Depth	Olsen	Bray II	Al-P	Fe-P	Ca-P	RSFeP	OAlFeP	Total P
Cultivated	0-20	5.84	10.15	55.5	120.0	35.5	108.50	34.5	1658.50
	20-70	0.94	0.84	19.5	37.0	10.5	97.00	30.5	1560.00
	70-120	0.94	1.32	17.5	46.5	11.0	93.50	30.0	1626.40
	120-200$^+$	1.78	1.61	20.5	77.5	11.5	101.00	26.0	1626.10
Abandoned	0-16	25.52	43.05	88.0	140.0	7.0	54.50	10.5	1203.45
	16-40	0.74	1.14	15.0	38.0	13.5	62.50	15.0	1190.00
	40-125	1.54	1.40	24.5	50.5	4.0	61.00	20.0	1206.40
	125-200$^+$	1.10	1.02	24.0	44.0	6.5	73.00	21.0	1339.85
Virgin	0-13	1.90	4.78	38.5	78.0	62.0	135.00	37.0	1960.00
	13-30	0.40	1.10	20.5	53.0	42.0	135.00	47.0	2050.00
	30-140	0.89	138	24.3	48	37.35	114.5	54.5	2115.00
	140-165$^+$	1.01	1.42	25.0	61.0	29.5	110.0	37.0	2230.00

Al-P = Aluminum bounded P, Fe-P = iron bounded P, Ca-p = calcium bounded P, OP = organic P, TP = total P, AP = available P, RSFeP = Reductant soluble Fe-P, OAl-Fe-P = occluded aluminum iron bounded P

The inactive forms of inorganic P fractions (reductant soluble Fe-P, and occluded-Al-Fe-P) concentrations were highest in the virgin land (Table 7). The lowest concentrations of inactive form of inorganic P fractions, however, were noted under the abandoned land. This could be due to the gradual conversion of inactive forms of inorganic P into active forms of P (Gahoonia and Nielson, 1992). The highest concentration of total P was recorded in the virgin land, whereas the lowest total P was under the abandoned land. The high concentration of total P under the virgin land is attributed to accumulation of organic matter due to little soil disturbance as compared to the cultivated and the abandoned lands.

Significant variation was also observed among the different land use systems in available Fe and Mn concentrations at the surface horizons (Table 8). In spite of variations among the land use systems in available Fe and Mn concentrations, Fe and Mn were at toxicity levels for most plants at the surface horizons (Lindsay and Norvell, 1969). Moreover, the available Fe and Mn decreased consistently within soil profile depths of each land use system. In general, the trend of available Fe and Mn concentrations under the different land use systems were similar. This implies that these two elements have similar chemical behaviors as described by Krauskof (1972). The depletion of available Zn from the cultivated and the abandoned lands was 83 and 68 %, respectively as compared to the virgin land. The depletion of available Zn from the cultivated and the abandoned lands is probably due to abundant crop harvest, organic matter degradation, and sheet and rill erosions that are aggravated by the continuous and intensive cultivation.

Table 8. The status of available micronutrients under the different land use systems

		(mg kg^{-1})				
Land Use	Depth (cm)	Fe	Mn	Zn	Cu	B
	0-20	20.78	56.02	0.32	1.76	0.15
Cultivated	20-70	4.56	10.60	0.08	0.56	trace
	70-120	3.48	13.26	0.12	0.50	trace
	120-200^{+}	2.60	14.06	0.12	0.42	0.03
	0-16	58.08	89.54	0.60	1.56	0.10
Abandoned	16-40	6.68	3.76	0.10	0.38	0.08
	40-125	4.40	5.70	0.08	0.02	0.02
	125-200^{+}	2.68	7.20	0.12	0.10	trace
	0-13	67.76	68.98	1.88	2.34	0.45
Virgin	13-30	21.14	26.28	0.22	2.28	0.27
	30-140	7.39	9.55	0.13	1.00	0.17
	140-165^{+}	3.82	10.12	0.12	0.34	0.02

Mo = was not detected in all the land use systems

The concentration of available Cu was also affected by land use systems (Table 8). The highest available Cu was observed in the virgin land, whereas the lowest was in the abandoned land. The distribution of available copper was consistently decreased form the surface to the subsurface horizons. This is attributed to the strong association of Cu with soil organic matter. Similarly, higher concentration of available B was observed in the virgin land of surface and subsoil horizons. Although the different land use systems contributed to change in available B concentration, the low concentration of available B in all the land use systems could be due to the inherent B deficiency of Alfisols of the study area. Sillanpää (1990) also reported similar results from western Ethiopia. The available Mo was not detected in all of the different land use systems. This implies that the soil of the study area is most probably deficient in Mo.

4. CONCLUSION

Most of the important soil quality indicators were significantly influenced by different land use systems, particularly at the surface horizon. The bulk density, structure, OC, soil pH, CEC, total N, different forms of P, exchangeable bases, and available micronutrients were affected due to intensive cultivation and use of acid forming inorganic fertilizers for the past three decades. Except for the available P, nearly all of the chemical properties of the soil under the abandoned land were very poor as compared to the other land use systems. The virgin land was superior in most of the soil quality indicators. In general, the continuous intensive cultivation and use of acid forming inorganic fertilizers on acid soils for crop production without appropriate soil management has degraded most of the important soil quality indicators. Therefore, reducing intensive cultivation, and integrated use of inorganic and organic fertilizers could replenish the degraded soil quality parameters for sustainable agricultural production and productivity in the study area.

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