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Characterization of Physicochemical Properties of Soils as Influenced by Different Land Uses in Bedele Area in Ilubabor Zone, Southwestern Ethiopia

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Abstract

Important morphological and physic chemical properties of soils of Bedele area were investigated to reveal the effect of different land uses (forest, grazing and cultivated lands) and to provide the baseline data for future research and development. Following site selection and field morphological studies of one freshly opened profile on each land use type, the physicochemical properties of the soils were characterized in the laboratory both on disturbed and undisturbed soil samples collected from each genetic horizon. The results of the study revealed that the soil morphological, physical and chemical properties varied with land uses. For instance, the surface horizons of the forest, grazing and cultivated lands were sandy loam, clay loam and loam in texture, respectively. Among the surface horizon the highest CEC (42.00 cmol(+) kg^{-1}, OC (10.74%) total N (0.667%), available P (5.2 mg kg^{-1}) for Olsen method and (9.51 mg kg^{-1}) for the Bray II, were observed in the forestland whilst the lowest were recorded in the cultivated field. On the other hand, available Fe and Mn were below the toxic level to plant growth in the different land uses while soil pH (H_20), under all the land uses qualify for strongly acidic (pH 4.50-5.25) throughout the entire depth of the respective profile. Generally, the intensity of soil degradation was severe under the cultivated field. Therefore, reducing the intensity of cultivation and adopting integrated soil fertility management could maintain the existing soil condition and replenish the degraded soil chemical properties of the study area.

Keywords: morphology, physicochemical, Bedele, cultivated, forest and grazing land

1. INTRODUCTION

Agriculture is the livelihood of the overwhelming majority of Ethiopians. It is the source of food and cash for those who are engaged in the sector and others (Central Statistical Agency, 2015). It contributes for 43.2% of the gross domestic product, accounts for about 80% of the total export earnings and employs about 85% of the country's labor force (The Ethiopian Macroeconomic Handbook, 2010, Global Forum on Agriculture 29-30 November 2010).With the rapidly increasing population, the pressure on land to meet the demand for food, fuel and fiber has become enormous. Hence, soil is one of the most important and determinant factors that strongly affect agriculture and on which most of the agricultural production and productivity is heavily dependent. Therefore, knowledge on soil is crucial and a prerequisite to meet the many challenges that human beings faces in relation to food production, natural resource management, environmental protection and above all sustainable economic development (Abebe, 1988).

However, the fact that soils in the country have been continuously used for cultivation and grazing purposes for centuries has resulted in disastrous losses of soil nutrient resources(Wakene, 2001).. Traditional farming practices that have been carried out for centuries, absence of appropriate soil and water conservation measures, improper land use system and continuous clearing of forests for cultivation purposes have worsen the situation of soil degradation (EFAP, 1994).The rate of soil degradation is related to the farming systems and/or management practices followed. Physical and chemical characteristics of soils could vary on lands under continuous cultivation or lands that remained uncultivated (virgin land) for a long period of time (Wakene, 2001). Maddonni *et al*. (1999) reported that land use systems affect basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, and other soil morphological, physical and biochemical processes.

Soil fertility is one among several major factors that limit crop productivity and sustainability of a given agricultural sector. In fact, soil fertility depletion is the fundamental biophysical root cause for declining per capita and per unit area food production in the sub-Saharan African countries in general (Sanchez *et al*., 1997) and in Ethiopia in particular. In order to increase agricultural productivity and at the same time maintain the environment on sustainable basis, the root causes of land degradation and depletion of soil fertility (partly indicated above) must be properly addressed and solutions must be sought through scientific research efforts. Hence, the elaboration and implementation of detailed development plans for improved agricultural production and soil conservation through proper land use and soil management practices are dependent on the availability of information on physical and biochemical properties of the soil resources.

In accordance with other highland areas of the country, the Bedele area where this study was conducted is under increasingly rising population pressure suffering from scarcity of land for cultivation and grazing. As a result, the area is increasingly under indiscriminate clearing and burning of the natural vegetation, mainly for cultivation and grazing purposes. The rapid removal of the natural vegetation cover has worsened the condition by increasing soil erosion, runoff water and soil nutrients losses. Therefore, to reverse the disturbance of natural resource, and to maintain sustainable utilization of agricultural resources and potential of the area, it is essential to assess and identify the important physicochemical properties of the soils and generate base line data to guide future research direction and development efforts. But, only little information is available in western Ethiopia in general and around Bedele areas in particular under different land use systems. Therefore, this study was undertaken with the following specific objectives to:

- Characterize the soils of Bedele area based on their major physicochemical properties as affected by different land uses, and
- To produce data base of physic-chemical condition of the study area

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted around Bedele area, which is located in Illubabor zone of Oromia Regional State, southwestern Ethiopia (Figure 1). It lies between 8^0 20’-8^0 35’ N and 36^0 15’-36^0 30’ E at about 480 km road distance south-west of Addis Ababa. The area has an altitude ranging from 1920 to 2012 meters above sea level (mas1) and humid agro ecology. Ten-year (1998-2007) weather information collected at Bedele Meteorology Station revealed that Bedele area has a uni-modal rainfall pattern and mean annual rainfall of 1969 mm. The rainy season extends from April to October and maximum rain is received in the months of June, July, August and September with the mean monthly rainfall exceeding 300mm. The annual average, mean minimum and mean maximum air temperatures are 18.3, 11.9 and 24.7 ^{0}C, respectively.

The soils of southwestern Ethiopia are in general classified as Nitosols according to the FAO/UNESCO or Alfisols according to the USDA soil classification systems (Mesfin, 1998). The area is covered with variety of crops and species of natural vegetation. The dominant crops in the area are maize, teff, sorghum, finger millet and haricot bean. The major land use types are cultivated land/cropland, forest land and grazing land. Bedele area has a total land area of 114,057 hectares of which 43,380, 7838 and 10,120 hectares are cultivated, forest and grazing land, respectively

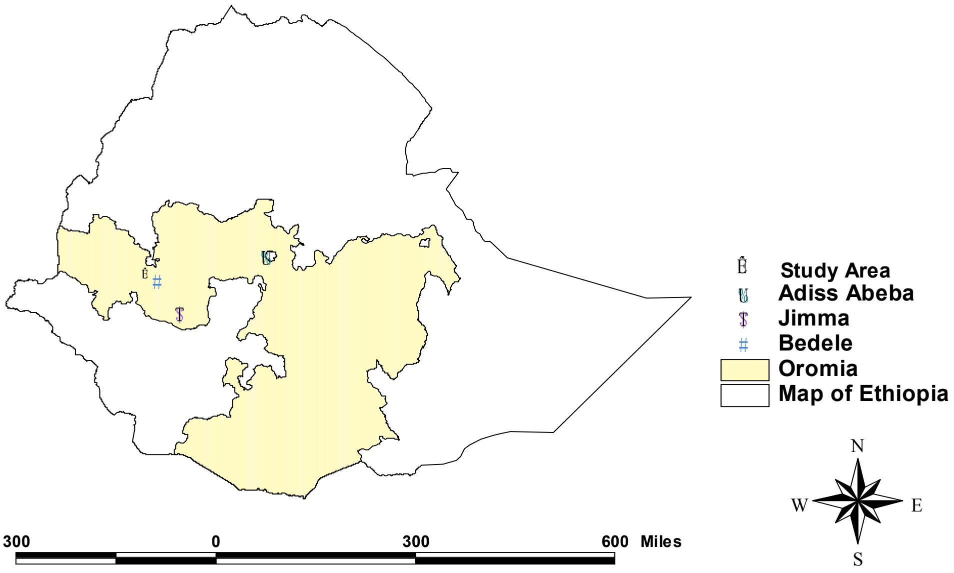


Figure 1. Location map of the study area.

2.2. Site Selection, Sampling and Profile Description

Field observation and visual reconnaissance soil survey of the area were made to determine representative soil of the study area. Accordingly, representative soil profile sampling sites were selected to represent three different land use systems (forest, grazing and cultivated lands). Three soil profiles were then opened one each under the three different land use systems and soil samples were collected depth wise from each genetic horizon for characterization of their physicochemical properties.

The field identified as the forest land has no cropping history. Currently, the field is under disturbed mixed natural forest. The dominant woody plants in the site are *Acacia species, Croton macrostachyus, Ficus sycomorus, Ficus capensis and Prunus africanus*. The soil profile representing this field is located at 8^0 27’ 3” N and 36^0 23' 56" E and it is identified as P1.

The field identified as grazing or pasture land is currently under grasses and open wooded shrubs that are used for grazing. The land has been under intensive grazing for a long period of time. The field has no cropping history for the last thirty years as per the information obtained from the farmer owning the field. The area is covered with different grass species. The soil profile representing this field is located at 8^0 27’ 4” N and 36^0 23’ 6” E and it is identified as P2.

The cultivated field (crop land) has been under cultivation with oxen drawn plow for more than thirty years and planted for different annual crops. During the study period, the field was cultivated for teff crop. Mono-cropping has been the dominant cropping practice. Farmers used crop rotation practice when the fertility of the land has been exhausted due to mono-cropping. To maintain soil fertility, farmers have been applying chemical fertilizers such as P and N at the rates of 46 kg P_2O_5 ha^{-1} and 18 kg N ha $^{-1}$ for both maize and teff annually since 1995 when extension package program was launched around Bedele. The soil profile opened representing this field is located at 8^0 23' 3" N and 36^0 23' 6" E and it is identified as P3.

The soils that are at present under different land use systems are presumed to have similar morphological, physical and chemical properties prior to disturbance by different land use systems. On each site selected as a representative sampling area, a fresh soil profile of a 2 x 1.5 x 2 m depth, width and length, respectively, was opened. Within a profile, soil sampling depth was based on the depth of pedogenic horizons of the profile. Soil profile description was made following the FAO Guidelines for profile description (FAO, 2006) and soil samples were taken from every identified genetic horizon. A total of twelve disturbed and nine undisturbed soil samples were taken from the three pedons horizon-wise. Undisturbed core samples were collected for the determination of bulk density, soil water content at field capacity and permanent wilting point. The soil samples were bagged, labeled and transported to the laboratory for preparation and analysis following standard laboratory procedures.

2.3. Soil Analysis

The status of selected physicochemical properties of soils under the different land use systems were investigated through laboratory analysis of soil samples collected from the three profiles. Accordingly, soil color (dry and moist) was determined using the Munsell color chart (Munsell Color Campany, 1975). Particle size distribution (soil texture) was analyzed by the modified Buoyoucos hydrometer method (Buoyoucos, 1951). Bulk density was determined from undisturbed soil samples collected in core samplers of known dimension and finally calculated as the mass of the oven dry soil per unit volume of the soil including the pore spaces (Blake, 1965). Particle density was determined by the pycnometer method as described by Blake (1965).

The soil water content at field capacity (FC) and permanent wilting point (PWP) were measured using the pressure plate apparatus; while the available water holding capacity was obtained by subtracting the value of water content at PWP from FC (Klute, 1965). Soil moisture content at sampling was determined using the gravimetric method from the ratio of the weight of water lost due to oven drying to the weight of oven dried soil. Total porosity was obtained from the values of bulk density (Db) and particle density (Dp) as:

$$\text{Total porosity (\%)} = \left(1 - \frac{Db}{Dp}\right) \text{ x } 100$$

The pH of the soil was measured potentiometerically using glass electrode pH meter in the supernatant suspension of 1:2.5 soil to H_2O and 1M KCl solution. Soil organic carbon was determined by the wet oxidation method as described by Walkey and Black (1934). Determination of total N of the samples was performed by the Kjeldahl method as described by Jackson (1958).

Exchangeable basic cations (Ca, Mg, K and Na) were extracted with 1M ammonium acetate at pH 7. Exchangeable Ca and Mg were determined from this extract with atomic absorption spectrophotometer while exchangeable K and Na were determined from the same extract with flame photometry. Cation exchange capacity (CEC) of the soil was determined from ammonium acetate saturated samples that was subsequently replaced by Na from a percolated NaCl solution after removal of excess ammonium by repeated washing with alcohol.

Exchangeable acidity (Al and H) was determined by saturating the soil samples with KCl solution, filtering and titrating with NaOH as described by Mclean (1965), whereas effective cation exchange capacity (ECEC) was determined by the summation of exchangeable bases and exchangeable acidity. Percent base saturation (PBS) was computed from the sum of exchangeable bases and CEC as:

$$\text{PBS} = \frac{\text{Sum of exchangeable bases (cmol(+) kg}^{-1}\text{)}}{\text{CEC (cmol(+) kg}^{-1}\text{)}} \text{ x } 100$$

The CEC of the clay fraction was calculated from the soil CEC as:

$$\text{CEC (cmol(+) kg}^{-1}\text{) clay} = \frac{\text{CEC (cmol(+) kg}^{-1}\text{) soil x \% clay}}{100}$$

Available sulfur was extracted with barium chloride in 1:5 soil: water ratio and finally measured by calorimeter as indicated by Tekalign and Haque (1991). Available P was determined both by the Olsen (Olsen *et al*., 1954) and the Bray (Bray and Kurtz, 1945) extraction methods. Total P was extracted by the aqua regia digestion technique followed by color development using vanado-molybdate acid method (Olsen and Sommers, 1982). The P extracted by the different methods was determined colorimetrically with the molybdate ascorbic acid procedure (Murphy and Riley, 1962). Percent organic matter (OM) was obtained from percent organic carbon (OC) as:

$$\%OM = \%OC \times 1.724$$

Available Fe, Mn, Zn and Cu were extracted from the soil samples with DTPA as described by Lindsay and Norvell (1978), whereas available B was extracted by hot water as described by Bingham (1982). All micronutrients extracted with different methods were measured by atomic absorption spectrophotometer.

3. RESULTS AND DISCUSSION

3.1. Site Characteristics and Soil Morphological Features

3.1.1. Site Characteristics and Soil Classification

The soils of the area are generally classified as Ultisols and are dominantly developed from basalt parent material. The physiographic position of the pedons opened for the description of cultivated field and forest land were located at the upper slope, whereas the pedon on the grazing land was located at the summit of the land form. Topography of the surrounding land form of all the three land use types was characterized by rolling plain. The slope gradient of the profile representing the cultivated field and the forest land was about 5%, whereas for the grazing land it was 2%. The slope form of the grazing land and cultivated field was convex, whereas the forest land had linear/straight slope. During soil sampling, all the profiles under the three land uses were nearly dry throughout their depths and well drained. Moderate sheet and rill erosion was observed on cultivated field, whereas slight sheet erosion was observed on the grazing and forest lands.

In the present study, the pedons representing the three land uses are classified as Acrisols. According to FAO (2006), soils that have argic horizons starting from the bottom of the first horizon, base saturation less than 50% in the major part between 50 and 100 cm depth and CEC of clay less than 24 cmol(+) kg^{-1} within 50 cm from the upper limit of argic horizon are classified as Acrisols. The equivalent USDA classification is Ultisols for all the three pedons representing the different land uses.

3.1.2. Soil Morphological Features

3.1.2.1. Soil Color

The color of the surface horizons showed variability in relation to different land uses (Table 1). The colors of the surface layers when moist were very dark brown (7.5YR 2.5/3) for the forest land, dark reddish brown (5YR 3/4) for the grazing land and dark reddish brown (5YR 3/3) for cultivated field. Whereas, the color of the subsurface horizons of the forest land ranged from very dark brown (7.5YR 2.5/3) to dark reddish brown (2.5YR 3/4) for moist soil, the color of the subsurface horizons of the grazing land ranged from dark reddish brown (5YR 3/2) to dusky red (10R 3/3) and, the subsurface soil horizons of the cultivated field was dark reddish brown having same hue (2.5YR) with slight variation in value and chroma (2.5/3 to 3/6) in color (Table 1).

Redness of the soil horizons in the three land uses increases with depth from the surface to the bottom of the subsoil. This could be attributed to the decline in the contents of organic matter (OM) with depth and good drainage conditions of the profiles. The redness of the soil with depth might also indicate the presence of iron oxides in the subsurface horizons as explained by Murphy (1959) for similar observations in some soils of Ethiopia. The very dark brown soil color at the surface horizon of the forest land could be attributed to the relatively higher OM content as compared to the other land uses. Therefore, in the study area soil color showed variations with soil depth within a profile and among the different land uses which may be associated with the differences in the content of OM and perhaps iron oxides.

3.1.2.2. Soil Structure

The structure of the soils under different land uses showed slight variation (Table 1). The structures of the surface horizons of the forest, grazing and cultivated lands were moderate, fine crumb; strong, medium angular blocky; and strong, fine sub angular blocky, respectively. The strong, fine subangular blocky structural type observed in the cultivated field could be due to tillage practices and the moderate, fine crumb structure of the forest land could be due to the relatively high OM content. Generally, the slight variation observed in soil structure among the soils under differing land uses could be mainly due to the differences in the OM contents in the soils (Table 5). The higher OM content at the surface horizons of the forest land was credited for resulting in aggregation of mineral particles into compound particles or crumbs (MMRAI, 1998).

3.1.2.3. Soil Consistence

The dry consistence of the soil at the forest land was slightly hard at the surface horizon and slightly hard to moderately hard at the subsurface horizons (Table 1). The grazing land soil was moderately hard at both the surface and subsurface horizons (Table 1). The soil of the cultivated field was hard at the surface horizon and hard to slightly hard at the subsurface horizons (Table 1). The slight variation of dry consistence at the surface horizons of the soils under different land uses could be attributed to differences in soil OM and clay content that are in agreement with MMRAI (1998). The moist soil consistence of the different land uses was friable at the surface and subsurface horizons (Table 1).

The wet consistences of the forest, grazing and cultivated land soil were slightly sticky and slightly plastic at the surface horizon while it ranged from slightly sticky and slightly plastic to sticky and plastic, moderately sticky and moderately plastic to sticky and plastic and moderately sticky and moderately plastic at the subsurface horizons of forest land, grazing land and cultivated land, respectively (Table 1). The slight changes in consistence from the surface to subsurface horizons are reflections of the difference in the contents of clay and organic matter. Accordingly, the relatively higher organic matter and lower clay contents at the surface than in the subsoil horizons resulted in slightly sticky and slightly plastic wet consistence of the soils under the different land uses (Table 1). This is in agreement with the findings of Baird and Charles (1992).

3.2. Soil Physical Properties

3.2.1. Soil Texture

The texture of the soils under different land use systems showed variation in the surface horizons (Table 2). Accordingly, the surface horizon of the forest, grazing and cultivated lands is sandy loam, clay loam and loam, respectively in texture. Land uses might have contributed indirectly for changes in particle size distribution particularly in the surface horizons as a result of removal of clay through sheet and rill erosion and eluviations, and mixing up of the surface and sub surface horizons during tillage activities as reported by Wakene (2001). In the subsurface horizons, uniform textural class (clay) was observed both within a profile and between the three soil profiles each representing different land uses.

Table 1. Some morphological features of Bedele area soils as influenced by different land uses

Depth (cm)	Horizon	Boundary*	Color		Structure	Consistence		
			Moist	Dry		Dry	Moist	Wet
Forest land: Acrisols								
0-26	A	cs	7.5YR 2.5/3	7.5YR 3/3	mfc	sh	fr	sssp
26-70	Bt1	cs	7.5YR 2.5/3	5YR 4/4	mmsb	sh	fr	sssp
70-120	Bt2	gs	5YR 3/3	2.5YR 3/4	mmab	mh	fr	msmp
120-180^{+}	Bt3	-	2.5YR 3/4	2.5YR 4/4	Wcab	mh	fr	Sp
Grazing land: Acrisols								
0-23	A	cs	5YR 3/4	7.5YR 3/4	smab	mh	fr	sssp
23-52	Bt1	gs	5YR 3/2	2.5YR 3/4	smab	mh	fr	msmp
52-100	Bt2	ds	10R 3/2	10R 3/4	wmsb	mh	fr	msmp
100-190^{+}	Bt3	-	10R 3/3	10R 3/6	wfsb	mh	fr	sp
Cultivated field: Acrisols								
0-25	Ap	cs	5YR 3/3	5YR 4/4	sfsb	h	fr	sssp
25-65	AB	gs	2.5YR 2.5/3	2.5YR 3/3	mmsb	h	fr	msmp
65-125	Bt1	ds	2.5YR 2.5/3	2.5YR 3/4	sfsb	sh	fr	msmp
125-190^{+}	Bt2	-	2.5YR ¾	2.5YR 3/6	wmsb	sh	fr	msmp

*cs = Clear and smooth; gs = Gradual and smooth; ds = Diffuse and smooth; fr = Friable; smab = Strong, medium angular blocky; smsb = Strong, medium sub angular blocky; wmsb = Weak, medium sub angular blocky; wfsb = Weak, fine sub angular blocky; mmsb = Moderate, medium sub angular blocky; wcab = Weak, coarse angular blocky; sfsb = Strong, fine sub angular blocky; mfc = Moderate, fine crumb; mmab = Moderate, medium angular blocky; h = Hard, sh = Slightly hard; sssp = Slightly sticky and slightly plastic; msmp = Moderately sticky and moderately plastic; sp = Sticky and plastic

However, the relative proportions of the different soil separates (sand, silt and clay) showed variations within the different layers of the same profile in all of the three land uses. In addition, the relationship between the different particle sizes and soil depth was consistent in almost all soil profiles and nearly all soil separates. Accordingly, the contents of clay increased linearly with depth from 13 to 59%, 33 to 63% and from 25 to 77% in the forest land, grazing land and cultivated field, respectively (Table 2). Conversely, both the sand and silt fractions decreased with soil depth in all land uses consistently with the exception of the silt fraction on the cultivated field, which showed inconsistent trend.

The generally high clay content in the soils of the study area under the different land uses is the reflection of the basaltic parent material on which the soils were formed that weathers to fine textured soils as compared to the acidic igneous rocks and many of the sedimentary rocks. In addition, it is the result of high intensity of weathering which the areas have experienced as it is evident from the very high rainfall and the moderately to strongly acidic soil reaction with pH values of around 5.0. The increase in clay content with soil depth in all the soil profiles further indicates its translocation from the surface layers and accumulation at the subsurface horizons in the development of argillic (Bt) horizons in the soils under all land uses.

3.2.2. Soil Particle and Bulk Densities

The highest soil particle density (2.61 g cm^{-3}) was recorded at the Bt_1 horizon of the grazing land whereas; the lowest (2.35 g cm^{-3}) was obtained at the surface horizon of the forest land (Table 2). Generally, particle density, as influenced by different land uses varied from 2.35 to 2.56 g cm^{-3} in the surface soil horizons with the highest particle density observed in the surface horizon of the cultivated field. The lowest particle density at the surface horizon of the forest land may be attributed to higher organic matter content than that of the soils under the grazing land and the cultivated field. Generally, however, the observed values of particle density in the soils of the study area are lower than the average values of similar mineral soils world-wide, which is considered to be about 2.65 g cm^{-3} (Brady and Weil, 2002).

The bulk density of soil showed variation among the different land uses (Table 2). Among the surface horizons, the lowest bulk density (1.03 g cm^{-3}) was recorded under the forest land whilst the highest (1.25 g cm^{-3}) was recorded under the cultivated field. In all the three land uses, bulk density increased consistently with increasing depth from surface to the bottom horizons. This is apparently due to decrease in organic matter contents with depth, less aggregation, less root penetration and more compaction of the subsurface soils due to the weight of the overlying layers of soils as reported by MMRAI (1998).

3.2.3. Total Porosity

Among the surface soil horizons, the highest total porosity of (56.20%) was obtained on the forest land and the lowest (51.17%) was noted on the cultivated field (Table 2). In the soils considered in the study, total soil porosity decreased linearly from the surface to the bottom layers of the respective profiles with the largest reduction of (8.20%) being observed in the soil of the forest land. The highest total porosity registered under the forest land and the decline in total porosity values with depth in all soils are the reflections of the high organic matter content in the forest and the surface soil horizons and the increasing bulk density values with depth of the soils.

3.2.4. Soil Moisture Retention Characteristics

Soil water content at FC decreased with depth within the profiles from the surface to the bottom horizons under all the three different land uses (Table 2). This may be due to the decreasing trend of OM content and subsequent increase in bulk density with profile depth observed in all the three land uses. Conversely, water content at PWP increased with depth for all the three land uses. This could be attributed to the increasing trends of clay content with profile depth in the three land uses. In line with that of FC, AWHC of soils under all the three land uses decreased with depth from the surface to the bottom horizons. This could be due to decreasing trend of silt with depth in the forest and grazing lands, which is in agreement with Foth (1990) who indicated that available water in many soils is closely correlated with the content of silt.

3.3. Soil Chemical Properties

3.3.1. Soil Reaction (pH)

Considering the soil profile under the three land uses, soil pH measured in KCl solution was lower by about 1.17-1.38 units than their respective pH value measured in water (Table 3). The decrease in soil pH when measured in KCl solution indicates that appreciable quantity of exchangeable hydrogen (H) has been released into the soil solution through exchange reaction with potassium (K) in the KCl solution. Anon (1993) related the decrease in pH (increase in soil acidity) due to measurement of pH in KCl solution to high potential acidity of the soil system.

Based on soil pH (H_2O), the soils under the three land uses qualify for strongly acidic (pH 4.50-5.25) reaction as per the limits set by Sahlemedhin (1999) throughout the entire depth of the respective profiles. Considering the surface layers (Table 3 and Figure 2), the highest pH (H_2O) value was recorded in the forest land (pH: 5.17) followed by the grazing land (pH: 5.05) and the lowest (pH: 4.92) was observed in the cultivated field soil. The pH values measured in both H_2O and KCl solution of the soils under the three land uses increased slightly but linearly with increasing soil depth.

The relatively higher soil pH (H_2O) observed in the forest land followed by the grazing land could be partly due to the presence of relatively higher total exchange bases (Table 5) and higher cation exchange capacity (Table 3) than in the soil on the cultivated field. This may further indicate that land use systems such as cultivation and continuous use of inorganic fertilizers decreased soil pH (increased soil acidity), particularly at the surface horizon of the cultivated land. This finding is in agreement with the findings of Mokwaunye (1978), Kang and Osinama (1985) and Wakene and Heluf (2003) who reported that use of acidifying mineral fertilizers and intensive cultivation that enhanced leaching of basic cations and oxidation of organic matter reduced soil pH.

3.3.2. Cation Exchange Capacity

There was great variation in cation exchange capacity (CEC) of the soils under the different land uses in both the surface and subsurface layers of the profiles. Considering the surface horizons, the highest CEC value of 42.0 cmol(+) kg^{-1} was observed under the forest land followed by 25.0 cmol(+) kg^{-1} on the grazing land, whereas the lowest 21.0 cmol(+) kg^{-1} of soil was recorded for the cultivated field (Table 3 and Figure 3). In all the three different land uses, CEC decreased consistently from the surface to the subsurface horizons in accordance to the OC content (Table 5). The decrease in CEC with depth could be due to the strong association between organic matter and CEC as it is also evident from the fact that the highest CEC among the soil profiles studied was obtained in the forest land soil, which also contained the highest organic matter. The depletion of organic matter because of continuous cultivation had reduced the CEC of the soil under the surface horizon of the cultivated field, which is in line with several previous findings (Gao and Chang, 1996; Wakene, 2001).

The highest effective cation exchange capacity (ECEC) (17.28 cmol(+) kg^{-1} soil) was observed on the surface horizon of the forest land followed by that of the grazing land (13.89 cmol(+) kg^{-1} soil), whereas the lowest ECEC (13.6 cmol(+) kg^{-1} soil) was recorded in the cultivated field surface horizon (Table 3). In accordance with CEC, the ECEC also decreased consistently from the surface horizons to the subsurface horizons within the profiles of the grazing land and forest land, whereas the trend on the cultivated field was not consistent.

Table 2. Selected physical properties of Bedele area soils under the influence of different land uses

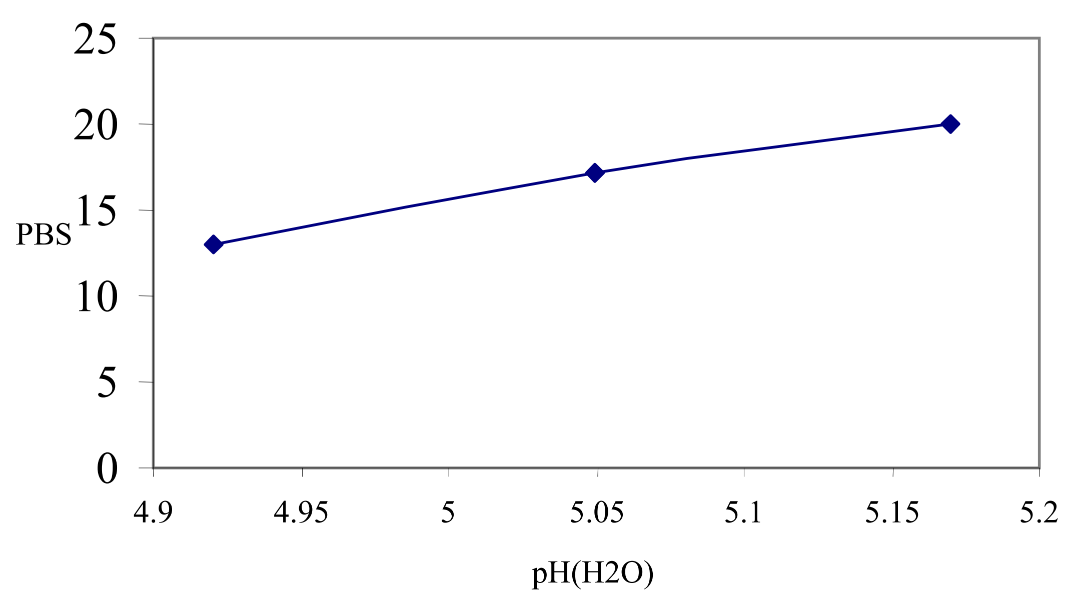
Depth (cm)	Horizon	Particle size (%)			*Tex. class	Dp (g cm^{-3})	Db (g cm^{-3})	TP (%)	Water content (%)		
		Sand	Silt	Clay					FC	PWP	AWHC
Forest land: Acrisols											
0-26	A	53	34	13	SL	2.35	1.03	56.20	27.6	10.2	17.4
26-70	Bt1	25	34	41	C	2.37	1.12	52.70	25.3	10.9	14.4
70-120	Bt2	23	24	53	C	2.50	1.30	48.00	23.2	12.1	10.1
120-180^{+}	Bt3	25	16	59	C	2.46	-	-	-	-	-
Grazing land: Acrisols											
0-23	A	31	36	33	CL	2.52	1.23	51.20	25.7	10.4	15.3
23-52	Bt1	31	26	43	C	2.61	1.28	51.00	24.6	11.4	13.2
52-100	Bt2	22	21	57	C	2.45	1.34	45.30	23.5	13.7	9.8
100-190^{+}	Bt3	23	14	63	C	2.56	-	-	-	-	-
Cultivated field: Acrisols											
0-25	Ap	45	30	25	L	2.56	1.25	51.17	24.3	10.3	14.00
25-65	AB	33	32	35	CL	2.57	1.32	48.60	23.8	11.6	12.2
65-125	Bt1	19	34	47	C	2.46	1.34	45.50	23.7	11.9	11.8
125-190^{+}	Bt2	7	16	77	C	2.49	-	-	-	-	-

*SL = Sandy loam; C = Clay; CL = Clay loam; L = Loam; Dp = Particle density; Db = Bulk density; TP = Total porosity; FC = Field capacity; PWP = Permanent wilting point; AWHC = Available water holding capacity.

Table 3. Soil reaction (pH), Exchangeable Al and cation exchange capacity of Bedele area soils under the influence of different land uses

Depth (cm)	Horizon	pH (1: 2.5)		ΔpH	EA*	Exch. Al	CEC	ECEC	CEC clay
		KCl	H_2O		------------ (cmol(+) kg^{-1}) -----------				
Forest land: Acrisols									
0-26	A	3.82	5.17	1.35	9.41	7.25	42.0	17.28	5.46
26-70	Bt1	3.85	5.23	1.38	9.33	7.14	22.5	13.83	9.23
70-120	Bt2	3.91	5.24	1.33	8.11	6.78	15.4	11.46	8.16
120-180^{+}	Bt3	3.92	5.24	1.32	3.29	2.33	15.0	5.60	8.85
Grazing land: Acrisols									
0-23	A	3.80	5.05	1.25	9.62	7.62	25.0	13.89	8.25
23-52	Bt1	3.85	5.09	1.24	8.58	7.08	20.0	12.24	8.60
52-100	Bt2	3.88	5.16	1.28	8.09	6.77	16.5	11.35	9.41
100-190^{+}	Bt3	3.92	5.17	1.25	4.35	3.02	16.2	6.34	10.21
Cultivated land: Acrisols									
0-25	Ap	3.75	4.92	1.17	10.86	9.62	21.0	13.60	5.25
25-65	AB	3.98	5.11	1.22	10.46	9.06	17.4	14.11	6.09
65-125	Bt1	4.01	5.23	1.22	8.35	6.94	15.8	11.40	7.43
125-190^{+}	Bt2	4.03	5.25	1.22	4.83	3.23	15.3	7.86	11.78

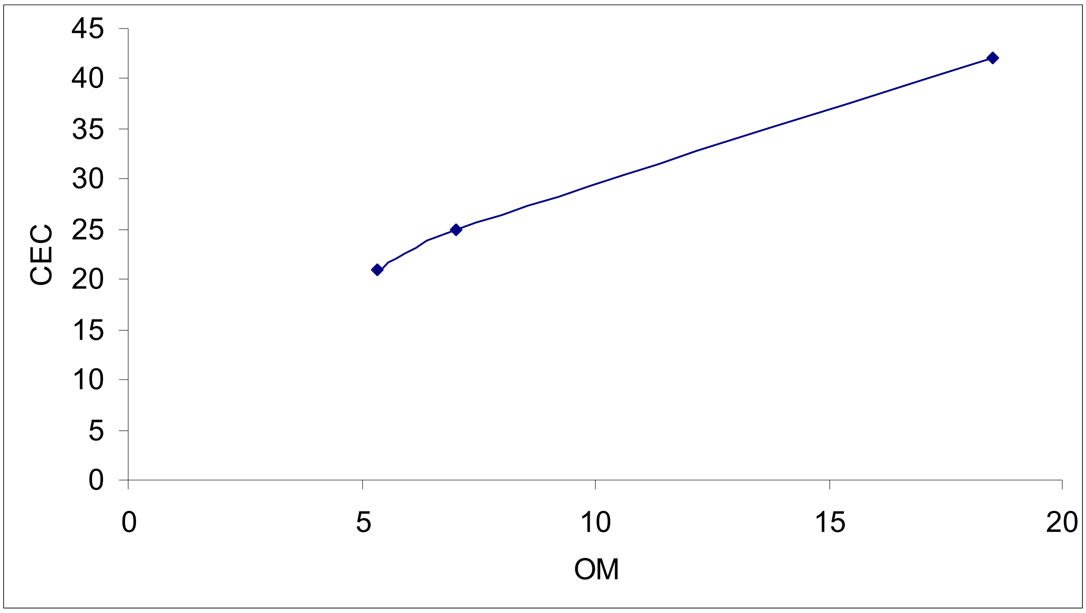
*EA = Exchangeable acidity; Exch. Al = Exchangeable aluminum; CEC = Cation exchange capacity; ECEC = Effective cation exchange capacity; ΔpH = pH (H_2O) – pH (KCl)



P1 = Forest land; P2 = Grazing land; P3 = Cultivated land; PBS = Percent base saturation
Figure 2. Relationship between pH and percent base saturation in the surface soil horizons.

3.3.3. Exchangeable Acidity

Considering the surface horizons, the highest exchangeable acidity (10.86 cmol(+) kg^{-1}) was observed under the cultivated field followed by the grazing land (9.62 cmol(+) kg^{-1}) (Table 3). Exchangeable Al contributed 85, 79 and 77% of the total exchangeable acidity of the soils under the cultivated field, the grazing and forest land, respectively, on their respective surface horizons. The highest exchangeable acid saturation (51.7%) and exchangeable Al saturation (45.8%) were obtained in the cultivated field, while the lowest exchangeable acid saturation (22%) and Al saturation (17.3%) were recorded in the forest land soil when the surface horizons were considered. This could be due to cultivation and continuous use of inorganic fertilizers in the cultivated land coupled with leaching of bases due to high rainfall. This is in agreement with the findings of Blamey *et al.* (1997) who concluded that intensive cultivation and continuous use of inorganic fertilizers were the root cause of soil acidity. Nair and Chamuah (1993) indicated that the presence of more than 1 mg kg^{-1} of exchangeable Al can significantly bring toxicity to plants. According to same, the critical level of exchangeable Al is 60% saturation of the exchange complex.



P1 = Forest land; P2 = Grazing land; P3 = Cultivated land; CEC = Cation exchange capacity
Figure 3. Organic matter (OM) and CEC in the surface horizons of the soils under the different land uses.

3.3.4. Exchangeable Bases

3.3.4.1. Exchangeable Potassium and Sodium

Exchangeable sodium was trace in all the land uses (Table 4). This could be due to effective leaching loss of sodium as a result of high amount of annual rainfall (1969 mm) at the area. The result obtained in the present study is in line with the opinion of Landon (1991) who indicated that soil sodicity is not expected in soils of high rainfall areas of tropical environments.

Exchangeable potassium (K) showed some variation due to differences in land uses (Table 4). Considering the surface soil horizons, the highest exchangeable K (0.69 cmol(+) kg^{-1}) was observed in the forest land followed by the grazing land (0.60 cmol(+) kg^{-1}). Exchangeable K decreased consistently with increasing depth within the profile of the forest land, but in the soils of the grazing and cultivated lands, it decreased inconsistently with increasing depth (Table 4). According to the critical level of 0.38 cmol(+) kg^{-1} exchangeable K set by Barber (1984), the contents of exchangeable K observed in the surface horizons of the soils under the three different land uses are above this critical level and were therefore optimum for crop production.

High intensity of weathering, intensive cultivation and use of acid forming inorganic fertilizers have been reported to affect the distribution of K in soil system and enhance its depletion (Saikh *et al*., 1998b). Mokwaunye (1978) indicated that the K content of a soil depends on the climatic condition and degree of soil development, the intensity of cultivation and the parent material from which the soil is formed.

Table 4. Exchangeable bases and base saturation of Bedele area soils as influenced by different land uses

Depth (cm)	Horizon	Exchangeable bases (cmol(+) kg^{-1})						PBS
		Ca	Mg	K	Na	Ca:Mg	TEB*	
				Forest land: Acrisols				
0-26	A	3.50	3.58	0.69	Trace	0.98	7.87	20.0
26-70	Bt_1	0.73	3.45	0.32	Trace	0.21	4.50	21.7
70-120	Bt_2	0.66	2.39	0.30	Trace	0.28	3.35	15.4
120-180$^+$	Bt_3	0.52	1.51	0.28	Trace	0.34	2.31	15.4
				Grazing land: Acrisols				
0-23	A	1.36	2.31	0.60	Trace	0.59	4.27	17.1
23-52	Bt_1	1.04	2.25	0.37	Trace	0.46	3.66	18.3
52-100	Bt_2	0.73	2.14	0.39	Trace	0.34	3.26	19.7
100-190$^+$	Bt_3	0.73	0.83	0.43	Trace	0.88	1.99	12.3
				Cultivated land: Acrisols				
0-25	Ap	1.20	0.97	0.58	Trace	1.237	2.746	13.0
25-65	AB	1.82	1.31	0.52	Trace	1.389	3.650	19.4
65-125	Bt_1	2.34	0.26	0.45	Trace	9.000	3.045	19.8
125-190$^+$	Bt_2	1.27	1.07	0.49	Trace	1.187	3.030	18.7

*TEB = Total exchangeable bases; PBS = Percent base saturation

3.3.4.2. Exchangeable Calcium and Magnesium

The surface horizons of the grazing and forest lands showed the highest exchangeable calcium (Ca) and magnesium (Mg) as compared to their respective subsurface horizons while in the cultivated field, the highest exchangeable Ca was obtained at the subsurface layer of 65-125 cm and 25-65 cm depth, respectively (Table 4). Considering the surface horizons of the three different land uses, the highest exchangeable Ca content (3.50 cmol(+) kg^{-1}) and Mg content (3.58 cmol(+) kg^{-1}) were observed under the forest land, and whereas the lowest exchangeable Ca (1.20 cmol(+) kg^{-}1) and Mg content (0.97 cmol(+) kg^{-1}) were in surface horizon of the cultivated field.

The highest exchangeable Ca and Mg observed in the surface horizons of the grazing and forest lands could be due to the relatively higher OM content on the surface horizons of these soils. On the other hand, the lowest exchangeable Ca and Mg recorded in the surface horizon of the cultivated field as compared to the forest and grazing lands could be due to removal in crop harvest, high leaching as a result of continuous cultivation and OM decomposition. This is in agreement with the findings of different investigators (Baker *et. al*., 1997; Wakene, 2001; Wakene and Heluf, 2003) who indicated that cultivation enhances leaching of Ca^{2+} and Mg^{2+} especially in acidic tropical soils. Mokwaunye (1978) indicated that continuous cultivation and inorganic fertilizer application resulted in declining of soil pH and caused loss in basic cations, especially under the intensive cropping of inherently poor soils where the deficiencies of Ca and Mg are common. According to Landon (1991) the critical level of exchangeable Ca and Mg for optimum crop production is 0.2 cmol(+) kg^{-1} and 0.5 cmol(+) kg^{-1}, respectively, hence the surface and subsurface horizons of the soils under the three land uses contained optimum levels of exchangeable Ca and Mg.

3.3.4.3. Percent Base Saturation

The percent base saturation (PBS) of the three land uses was below 25% throughout the depths of the profiles

(Table 4). The surface horizons showed lower PBS as compared to their respective subsurface horizons in almost all the three land uses. This could be attributed to leaching of bases from the topsoil to subsoil layers as a result of high rainfall in the study area. The forest land soil contained the highest PBS (20%), whereas the lowest (13.0%) was observed under the cultivated field when the surface horizons were considered (Table 4 and Figure 2).

The lowest PBS observed in the surface soil of the cultivated field as compared to the other land uses could be attributed to continuous cultivation and the use of inorganic fertilizers which caused losses of basic cations under the cultivated field. This is in agreement with the findings of Wakene (2001) and Wakene and Heluf (2003) who indicated that continuous cultivation and use of inorganic fertilizer depleted exchangeable Ca and Mg in soils of Bako area, western Ethiopia.

3.3.5. Organic Carbon and Total Nitrogen

Considering the surface soil horizons, the highest organic carbon (OC) (10.74%) and total nitrogen (TN) (0.667%) were observed under the forest land, whereas the lowest OC (3.09%) and TN (0.343%) were obtained under the cultivated field (Table 5). This indicates that OC and TN were highly affected by different land uses particularly on the surface horizons. The lowest OC and TN contents of the surface layer of the cultivated field could be due to continuous cultivation that aggravated OC oxidation which resulted in reduction of TN.

The lower OC and TN contents of the surface soil horizon of the grazing land compared to the forest land could be attributed to the effect of intensive grazing that reduced the amount of biomass returned to the soil. The highest OC content of the surface layer of forest land could be the result of addition of OM by decay of leaves. This is in agreement with the findings of Dawit *et al.* (2002) who reported soil OM contents of 3.8 and 10.3% at Munesa and 3.8 and 8.5% at Wushwush areas in sub humid Ethiopian highlands for the surface 0-10 cm soil depth of the cultivated and natural forest lands, respectively.

In agreement with OC and TN, C: N ratio also varied markedly due to changes in land uses (Table 5). Considering the surface soil horizons of the three different land uses, the wider C: N ratio (16.09: 1) was recorded under the forest land and the narrow C: N ratio (9: 1) was observed under the cultivated field (Table 5). The wide C: N ratios observed in the soils under study indicated low level of mineralization of OM and low level of release of N to the soil systems. This is in agreement with finding of Thompson and Troeh (1997). In general, a C: N ratio of about 10:1 suggest relatively better decomposition rate and indicate improved availability of N to plants. Wakene and Heluf (2003) reported the highest C: N ratio (17.9: 1) and the lowest C: N (14.7: 1) in the research farm and the farmer's field, respectively.

3.3.6. Total and Available Phosphorus

Considering the surface horizons, the highest concentration of available P (5.2 mg kg^{-1} for the Olsen method and 9.51 mg kg^{-1} for the Bray II method) was recorded in the surface horizon of the forest land followed by (4.20 mg kg^{-1} for Olsen method and 6.68 mg kg^{-1} for the Bray II method) in the grazing land (Table 5). This may be because available P is tied to the OM content of the soil which is also in agreement with Clark *et al.* (1998) who indicated that soil OM influences P availability to crops directly by contributing to P pool. In the present study, the available P content of the top-soils was greater than that of the subsoil's in the three land uses which may be due to desorption of P, greater biological activities and accumulation of OM in the former as indicated by Sharply and Smith (1983).

According to the critical values for Olsen extractable soil P (8.5 mg kg^{-1}) and Bray II extractable soil P (50 mg kg^{-1}) established by Tekalign and Haque (1991) for some Ethiopian soils, the available P content of the soils under the three land uses were below the critical values both in Olsen and Bray II extraction methods. Continuous P removal by crop harvest in the cultivated field and in grasses grazed by livestock in the grazing field are apparently the causes of the relatively low available P in the surface horizons of the soils under the respective land uses. Inherent P deficiency of the soil and the P fixation with Fe and Al as indicated by the favorable acidic soil reactions displayed by the results (Table 3) of the present study may explain the very poor available P contents across the different land uses. Generally, the low available P of the soils could cause one of the major soil fertility limiting factors in the study area. This is in agreement with Blamey *et al.* (1997) who stressed that plant growth on acid soils is limited by toxicity of Al and deficiencies of P.

The highest total P content (1243.7 mg kg^{-1}) was observed under the forest land followed by in the grazing land (1193.1 mg kg^{-1}) and the lowest (1095.2 mg kg^{-1}) was recorded under the cultivated field when the surface soil horizons were considered (Table 5). The highest total P content under the forest land may be due to OM which was higher under the forest land which implies no soil P removal in harvested crops and/or grasses as in the cultivated and grazing lands. This is in line with the findings of Tekalign and Haque (1991) who reported that the total P contents of Ethiopian soils range from 185-1981 mg kg^{-1} and is positively correlated with silt content, OM, and oxides of Fe and Al.

Table 5. Organic carbon, TN, available P, total P, available S and C: N of soils as influenced by different land uses

Depth (cm)	Horizon	OC*	TN	C: N ratio	**Available P (mg kg^{-1})**		TP (mg kg^{-1})	Available S (mg kg^{-1})
		----- (%) ----			**Olsen**	**Bray II**		
Forest land: Acrisols								
0-26	A	10.740	0.667	16.09	5.20	9.51	1243.7	23.31
26-70	Bt_1	2.242	0.241	10.04	2.00	4.12	1090.4	10.60
70-120	Bt_2	1.586	0.170	9.32	1.80	2.62	1079.5	1.48
120-180$^+$	Bt_3	1.302	0.080	16.28	1.00	1.53	1058.6	1.48
Grazing land: Acrisols								
0-23	A	4.06	0.358	13.34	4.20	6.68	1193.1	15.56
23-52	Bt_1	1.995	0.168	11.88	1.19	2.60	1226.7	12.73
52-100	Bt_2	1.382	0.139	9.94	0.90	1.64	1094.1	5.65
100-190$^+$	Bt_3	0.487	0.066	7.38	1.02	1.73	1056.6	4.65
Cultivated land: Acrisols								
0-25	Ap	3.090	0.343	9.00	3.20	4.78	1095.2	13.12
25-65	AB	1.544	0.153	12.05	1.08	2.14	1125.4	5.35
65-125	Bt_1	0.931	0.080	11.64	0.72	1.03	1188.5	3.62
125-190$^+$	Bt_2	0.540	0.051	10.58	0.50	0.98	1092.0	2.28

*OC = Organic carbon; TN = Total nitrogen; TP = Total phosphorus; AS = Available sulfur

3.3.7. Available Sulfur in Soils

Considering the surface soil layers, the highest available sulfur (23.31 mg kg^{-1}) was recorded in the soil under the forest land followed by the grazing land (15.56 mg kg^{-1}) and the lowest (13.12 mg kg^{-1}) was obtained under the cultivated field (Table 5). This implies that the available sulfur was highly affected due to intensive tillage activities, and was in line with the findings of Mclaren and Swift (1977) and Rasmussen and Douglas (1992). However, available sulfur contents in the surface horizons of the three land uses were in the optimum range for crop production as these were above the critical level of available sulfur (6.5 mg kg^{-1}) as indicated by Blair *et al.* (1991).

3.3.8. Micronutrients

The status of available micronutrients showed variation with differences in land uses (Table 6). Comparing the surface soil horizons, the highest available Fe content (9.43 mg kg^{-1}) was observed under the forest land, whereas the lowest (3.63 mg kg^{-1}) was recorded under the grazing land (Table 6). Available Fe decreased consistently with increasing soil depth within the three land uses. Available Fe was below the toxic level (> 20 to >40 mg kg^{-1} Fe depending on soil texture) to plant growth under different land use systems based on the Fe toxicity level established by Lindsay and Norvell (1978).

Available copper (Cu) also showed variations in response to land uses (Table 6). Considering the surface layers, the highest (0.25 mg kg^{-1}) and the lowest (0.11 mg k^{-1}) available Cu were observed in the forest and the grazing lands, respectively. In all the three land uses the distribution of available Cu decreased almost linearly from the surface to the subsurface horizons. This could be attributed to decreasing of OM with increasing soil depth. This is in agreement with the findings of Haque *et al.* (1992) who concluded that OM enriched surface horizons often contain high concentration of Cu than the lower horizons. In the present study, according to Lindsay and Norvell (1969), the concentrations of available Cu in the surface and subsurface horizons of all land uses were very low for crop production.

Table 6. Status of micronutrients of Bedele area soils as influenced by different land uses

Depth (cm)	Horizon	Available micronutrients (mg kg^{-1})				
		Fe	Cu	Mn	Zn	B
Forest land: Acrisols						
0-26	A	9.43	0.25	12.14	0.11	0.45
26-70	Bt_1	1.33	0.02	10.34	Trace	0.29
70-120	Bt_2	1.05	0.03	8.58	0.03	0.61
120-180$^+$	Bt_3	0.400	0.0233	4.95	0.01	0.48
Grazing land: Acrisols						
0-23	A	3.63	0.11	15.77	0.15	0.42
23-52	Bt_1	1.94	0.06	6.38	0.01	0.46
52-100	Bt_2	1.13	0.02	6.14	0.11	0.42
100-190$^+$	Bt_3	0.42	0.03	2.67	0.13	0.35
Cultivated land: Acrisols						
0-25	Ap	4.83	0.15	17.42	0.05	0.33
25-65	AB	2.16	0.07	6.36	0.05	0.27
65-125	Bt_1	1.81	0.04	5.50	Trace	0.35
125-190$^+$	Bt_2	0.93	0.01	2.48	Trace	0.37

In accordance with that of available Fe and Cu, available manganese (Mn) also showed variation among the three land uses and within layers of the same profile. However, unlike Fe and Cu, the highest available Mn content of 17.42 mg kg^{-1} was observed in the soil of the cultivated field followed by 15.77 mg kg^{-1} on the grazing land whereas the lowest (12.14 mg kg^{-1}) was recorded in the forest land when the soil of the surface horizons were considered (Table 6). In all the different land uses, the concentrations of available Mn decreased consistently and rapidly with increasing soil profile depth. The available Mn of the surface soils were above the critical level to plant growth and also below the toxic level (>48 mg kg^{-1}) to plant growth under different land use systems based on the Mn toxicity level established by Lindsay and Norvell (1969).

Comparing the surface soil horizons, the highest available zinc (Zn) content (0.15 mg kg^{-1}) was observed in the surface soil horizon of the grazing land, whereas the lowest available Zn (0.05 mg kg^{-1}) was recorded in the surface horizon of the cultivated field (Table 6). The lowest available Zn in the surface horizons of the cultivated field as compared to the other land uses could be due to the lower OM content and topsoil Zn removal by erosion which both area aggravated by tillage activities coupled with its continuous removal in crop harvest.

Unlike the other micronutrients, available boron showed less variability under the three land uses both in the surface and subsurface soil horizons (Table 6). The highest (0.45 mg kg^{1}) available boron was observed in the forest land, whereas the lowest (0.33 mg kg^{-1}) was recorded in the cultivated field when surface horizons were considered. The trend of available boron distribution in relation to soil depth was almost inconsistent in all the land uses. Available boron contents in all the land uses were very poor as compared to the critical level of 0.70 mg kg^{-1} as described by Landon (1991). Clay content, pH, organic matter and tillage practices have been reported (Fisseha, 1992) to be the factors that largely influence the solubility and availability of most micronutrients.

4. SUMMARY AND CONCLUSIONS

Three soil profiles representing the three different land uses were opened and soil samples were collected depth wise from each genetic horizon for characterization of their morphological and physicochemical properties.

The results of the present study indicated that most of the physicochemical properties of the Bedele area soils were considerably influenced by the different land uses. Soil physicochemical properties such as soil color, structure, bulk density, CEC, exchangeable bases (Ca, Mg, K and Na), percent base saturation, organic carbon, total nitrogen, available phosphorus, available sulfur and available micronutrients (Fe, Mn, Zn, Cu and B) showed variations in response to differences in land uses. Most of the variations in soil physicochemical properties as a result of differences in the land uses were highly pronounced in the surface soil horizons and most were related to contents of organic carbon.

Moreover, most of the soil physicochemical properties studied showed variation between the surface and subsurface horizons within a profile. For instance, soil bulk density, CEC, OC, total N, available P and available sulfur decreased with depth within the profiles from the surface horizon to subsurface horizons.

The forest land soil was higher in most of the soil physicochemical properties such as CEC, exchangeable bases, OC, total N, available P, available sulfur and micronutrients (Fe, Cu and B) as compared to the grazing land and cultivated field when the surface horizon were considered. The grazing land was higher than the cultivated field, but lower than the forest land in most of the selected soil chemical properties studied. This indicates that the forest land had high biomass production that contributed to its high OC content and characterized by minimum soil disturbance, which accounts for its good physicochemical properties. Continuous cultivation without proper soil management in the cultivated field, on the other hand, enhanced deterioration of soil aggregates, leaching of basic cations, oxidation of OC and degradation of other soil chemical properties, which accounts for its poor soil physicochemical properties as compared to the forest and grazing lands.

The acidic soil reaction observed in the study area as a result of leaching of basic cations has affected the availability of plant nutrients both from the soil and applied fertilizers. Accordingly, the strongly acidic soil reaction (very low pH value), which limit the fertility status of the soil need to be reclaimed using liming to alleviate the acidic soil conditions in order to sustain the agricultural productivity of the soils in the study area. As the intensity of soil degradation was severe under the cultivated field, reducing the intensity of cultivation, adopting integrated soil fertility management could maintain the existing soil conditions and replenish the degraded soil chemical properties of the study area.

Besides, appropriate crop species which are tolerant to acidic soil condition should be adopted. Soil conservation through proper land use and soil management practices should also be considered in maintaining and improving the existing soil physical and chemical properties. Generally, in introducing new agricultural production technologies into areas under different land uses like the present study area, the variation in soil physicochemical properties should be considered for sustainable production and productivity. Soil analysis gives only the level of certain nutrient element in the soil. Therefore, to give conclusive recommendation on soil management for sustainable production and productivity of the soils in the area, plant analysis and field experiment on crop nutrient requirement should be undertaken.

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