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Assessement 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 physicochemical properties of soils of Bedele area were investigated to reveal the effect of different land uses (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. The surface soil color when dry was dark brown (7.5YR 3/4) for the grazing land and reddish brown (5YR 4/4) for the cultivated field. The surface horizons of the grazing and cultivated lands were clay loam and loam in texture, respectively. Bulk density of surface horizons was recorded 1.23 g cm^{-} and 1.25 g cm^{-3} under the grazing land and cultivated field. Based on soil pH (H_20), the soils under both land uses qualify for strongly acidic (pH 4.50-5.25) throughout the entire depth of the respective profiles. The higher CEC (25.00 cmol(+) kg^{-1}),was observed in the grazing land whilst the lower CEC (21.00 cmol(+) kg^{-1}) was recorded in the cultivated field when the surface horizons were considered. For similar layers the higher exchangeable acidity (10.86 cmol(+) kg^{-1}) was observed under the cultivated field whilst the lower (9.62 cmol(+) kg^{-1}) was recorded under the grazing land. The percent base saturation was less than 25% in both land uses. The higher OC (4.06%) and total N (0.356%) were observed under the grazing land whereas the lower OC (3.09%) and total N (0.343%) were obtained under the cultivated field at their surface horizons. The highest available P (4.2 mg kg^{-1}) for Olsen method and (6.68 mg kg^{-1}) for the Bray II were observed under the grazing land whereas the lower available P (both Olsen and Bray II methods) were recorded on the cultivated field at surface horizons. Available Fe and Mn were below the toxic level to plant growth in the different land uses. As the intensity of soil degradation was severe under the cultivated field, 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 and Grazing Land.**

I. 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 Agaancy, 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 continuous exploitation of the agricultural resources by anthropogenic activities has put tremendous pressure on Ethiopia's natural resources in general and the soil in particular (Wakene, 2001). 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. The influences of such anthropogenic practices have strongly affected especially the highland parts of the country where intensive cultivation due to population pressure causes serious degradation of soil resources (Eylachew, 1999). As a result, 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.

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. The decline of soil productivity in most cultivated soils has been attributed to loss of plant nutrients through plant removal, erosion and leaching and deterioration of soil physical conditions (Thomas, 1989). In Ethiopia, poverty and malnutrition attributed to the mismanagement of soil, water and plant resources are threatening the life and livelihoods of millions of its people.

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. But the elaboration and implementation of detailed development plans that include designing appropriate soil management strategies for improved agricultural

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production and soil conservation through proper land use and soil management practices are dependent on the availability of information on physicochemical and biochemical properties of the soil resources.

Even though knowledge on soil physical and chemical properties plays a vital role in enhancing production and productivity of the agricultural sector on sustainable basis, 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

II. 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.

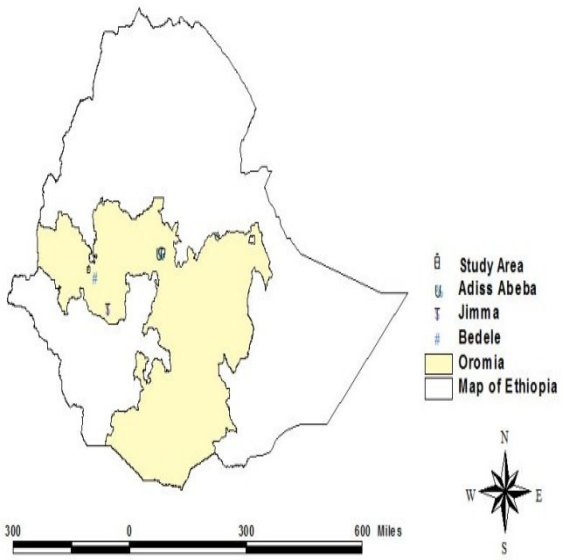

Figure 1. Location map of the study area.

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 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.

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 two different land use systems (grazing and cultivated lands). Two soil profiles were then opened one each under the two 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 grazing or pasture land is currently under grasses and open wooded shrubs that are used for grazing. 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 P1. On the other hand, 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. 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 P2.

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. 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 eight disturbed and six undisturbed soil samples were taken from the two pedons horizon-wise. 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 two profiles.

2.3.1. *Analysis of Soil Physical Properties*

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

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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:

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

2.3.2. *Analysis of Soil Chemical Properties*

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:

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

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

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

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:

$$\text{\%OM} = \text{\%OC} \times 1.724$$

III. 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 was 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 and grazing fields were about 5% and 2%, respectively whereas, the slope form of both fields were convex., During soil sampling, both representative profiles were nearly dry throughout their depths and well drained. Moderate sheet and rill erosion was observed on cultivated field, while slight sheet erosion was observed on the grazing.

In the present study, the pedons representing the two 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*

The color of the surface horizons showed variability in relation to different land uses (Table 1). The colors of the surface layers when dry, was dark brown dark brown (7.5YR 3/4) for the grazing land and reddish brown (5YR 4/4) for the cultivated land. On the other hand, the color of the subsurface horizons of the grazing land ranged from dark reddish brown (2.5YR 3/4) to dark red (10R 3/6) when dry whereas, 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) .

Redness of the soil horizons in the two 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. 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.

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

Depth (cm)	Horizon	pH (1: 2.5)		ΔpH	EA*	Exch. Al	CEC	ECEC	CEC clay
		KCl	H_2O		---------- (cmol(+) kg^{-1}) ----------				
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

*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

The structure of the soils under different land uses showed slight variation (Table 1). The structures of the surface horizons of the grazing and cultivated lands were strong, medium angular blocky; and strong, fine sub angular blocky, respectively. The strong, fine sub-angular blocky structural type observed in the cultivated field could be due to tillage practices. 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 was credited for resulting in aggregation of mineral particles into compound particles or crumbs (MMRAI, 1998).

The dry consistence of the soil at the grazing land soil was moderately hard at both the surface and subsurface horizons and 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 consistence of the grazing land soil was slightly sticky and slightly plastic at the surface horizon, while it ranged from moderately sticky and moderately plastic to sticky and plastic at the subsurface horizons (Table 1). On the other hand, the cultivated field had slightly sticky and slightly plastic at the surface horizon and moderately sticky and moderately plastic consistence at the subsurface horizons (Table 1). The slight changes in consistence from the surface to subsurface horizons are reflections of the difference in the contents of clay and OM. 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*

The texture of the soils under different land use systems showed variation in the surface horizons (Table 2). Accordingly, the surface horizon of the grazing and cultivated lands is 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 two soil profiles each representing different land uses.

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 two land uses. Accordingly, the contents of clay increased linearly with depth from 33 to 63% and from 25 to 77% in the 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 higher and lower soil particle density (2.61 g $cm^{-3}$and 2.45cm^3) was recorded at the Bt_1 and Bt2 horizons of the grazing land (Table 2). Generally, particle density, as influenced by different land uses varied from 2.52 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. 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,

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the lower bulk density (1.23 g cm^{-3}) was recorded under grazing land whilst the higher (1.25 g cm^{-3}) was recorded under the cultivated field. The higher bulk density (1.25 g cm^{-3}) recorded at the surface horizon of the cultivated field may be attributed to the intensive cultivation history (tillage practices) and the relatively low organic matter content. In both 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).

Concerning total porosity, the higher (51.20%) and lower (51.17%) total porosity were obtained on the grazing and cultivated field, respectively whereas, it was linearly on decreasing order from the surface to the bottom layers of the respective profiles (Table 2). This total porosity distribution is in opposite to clay proportion distribution rather signifying the influence of balk density on total porosity distribution (Table 1 and 2).

On the other hand, soil water content at FC and AWHC decreased with depth within the profiles from the surface to the bottom horizons under two different land uses (Table 2). This could be due to decreasing trend of silt and OM, and subsequent increase in bulk density with depth, which is in agreement with Foth (1990) who indicated that available water in many soils is closely correlated with the content of silt. Conversely, water content at PWP increased with depth for both land uses. This could be attributed to the increasing trends of clay content with profile depths.

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
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.

3.3. *Soil Chemical Properties*

3.3.1. *Soil Reaction (pH)*

Considering the soil profile under the two 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 two 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. The highest (5.25) and lowest (4.92) pH (H_2O) values were observed in the bottom and the surface horizons of the cultivated field, respectively (Table 3). Generally, 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 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.

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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}) ----------				
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)

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 higher CEC value of 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). In both 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 higher CEC among the soil profiles studied was obtained in the grazing land soil, which also contained the higher 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). Similarly, effective cation exchange capacity (ECEC) (13.89 cmol(+) kg^{-1} soil) and (13.6 cmol(+) kg^{-1} soil) was recorded in the surface layers of gerezing land cultivated land respectively (Table 3).

On the other hand the CEC of clay showed variation due to differences in land uses (Table 3). Considering the surface layers, the CEC of clay was the higher (8.25 cmol(+) kg^{-1} clay) in the grazing land, whereas the lower (5.25 cmol(+) kg^{-1} in the cultivated land and it is consistently increased with depth within the profile (Table 3).

3.3.3. *Exchangeable Acidity*

Considering the surface horizons, exchangeable acidity of (10.86 cmol(+) kg^{-1}) and (9.62 cmol(+) kg^{-1}) (Table 3) was observed under the cultivated and grazing land, respectively. Exchangeable Al contributed 85% for cultivated land and 79% for grazing land of the total exchangeable acidity of the soils on their respective surface horizons. Accordingly, the highest exchangeable acid saturation (51.7%) and exchangeable Al saturation (45.8%) were obtained in the cultivated field. 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.

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 higher exchangeable K (0.60 cmol (+) kg^{-1}). was observed in the grazing land while in both land uses it is inconsistently decreasing 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 two 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). Similarly, 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 which the soil is formed. But in both land uses the surface horizons contained higher exchangeable K as compared to their respective subsurface horizons of the profiles. This might be attributed to higher nutrient cycling in the surface layers of the soils as compared to the subsurface horizons.

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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*	
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 lands showed the highest exchangeable calcium (Ca) 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 depth (Table 4). Considering the surface horizons of the two different land uses, the higher exchangeable Ca content (1.36 cmol(+) kg^{-1}) was observed under the grazing land, whereas the lower exchangeable Ca (1.20 cmol(+) kg^{-}1) was in the cultivated field. Relatively high exchangeable Ca observed in the surface horizons of the grazing lands could be due to the relatively higher OM content on the surface horizons of this soils. On the other hand, the lower exchangeable Ca recorded in the surface horizon of the cultivated field as compared to the 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+} especially in acidic tropical soils. According to Landon (1991) the critical level of exchangeable Ca for optimum crop production is 0.2 cmol(+) kg^{-1} and hence the surface and subsurface horizons of the soils under the two land uses contained optimum levels of exchangeable Ca.

In line with that of exchangeable Ca, the grazing land soils contained the higher exchangeable Mg in their surface horizons as compared to their respective subsurface horizons. This could be attributed to the relatively higher OM content in their surface horizons (Table 4). On the other hand the low exchangeable Mg observed in the surface horizons of cultivated field could be because of its continuous removal in crop harvest coupled with the high leaching as a result of cultivation, soil erosion and OM degradation. 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. Cultivation enhances leaching of Ca^{2+} and Mg^{2+} especially in acidic tropical soils (Baker *et al*., 1997). Except in the Bt1 horizon of the cultivated field, which contained 0.26 cmol(+) kg^{-1} Mg, the levels of exchangeable Mg in the surface and subsurface horizons of the two land uses were optimum for crop production as per the critical level of exchangeable Mg (0.5 cmol(+) kg^{-1}) suggested by Landon (1991).

3.3.4.3. *Percent Base Saturation*

The percent base saturation (PBS) of the two 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 two 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. Accordingly, the grazing land soil contained the higher PBS (17.1%), whereas the lowest (13.0%) was observed under the cultivated field when the surface horizons were considered (Table 4).

The lowest PBS observed in the surface soil of the cultivated field as compared to the grazing land 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, similar to other parameter, the higher organic carbon (OC) (4.06%) and total nitrogen (TN) (0.358%) were observed under the grazing land, whereas the lower 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. Cultivation appears to have enhanced reduction of OC in the soils by mixing top and subsurface soils that might have created better aeration, well distributed OC, readily available carbon for microbial attack and rapid OM decomposition. Whereas, the relatively high OC an TN of grazing land is due to relatively high biomass production which contributed to high OC content of its surface horizon as compared to the cultivated field. 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

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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 two different land uses, the wider C: N ratio (13.34: 1) was recorded under the grazing 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. And they concluded as, such significant difference between C: N ratios of the different land uses could be attributed to the effects of intensive and continuous cultivation that increased OC oxidation, resulted in reduction of TN. Generally, the C: N ratio showed an irregular variation with depth under the soil profiles of the cultivated field (Table 5). Whereas under the grazing land, the C: N ratio was wider in the surface horizon and decreased with increasing depth within the profile. This could be apparently due to the existence of different conditions of mineralization in the recognized horizons.

3.3.6. *Total and Available Phosphorus*

Considering the surface horizons, the higher concentration of available P (4.2 mg kg^{-1} for the Olsen method and 6.68 mg kg^{-1} for the Bray II method) was recorded in the surface horizon of the grazing land and the lower available P(3.20 mg kg^{-1} for Olsen method and 4.78 mg kg^{-1} for the Bray II method) recorded in the cultivated 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 sub-soils in the two 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). The available P content of the cultivated field decreased with depth from the surface horizons to the bottom horizons, whereas the decrease was inconsistent in the grazing land for both the Olsen and Bray II extraction methods.

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 two 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.

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})	AS (mg kg^{-1})
		----- (%) ----			Olsen	Bray II		
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

The higher total P content (1193.1 mg kg^{-1}) was observed under the grazing land and the lower P content (1095.2 mg kg^{-1}) was recorded under the cultivated field when the surface soil horizons were considered (Table 5). 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.

3.3.7. *Available Sulfur in Soils*

Considering the surface soil layers, the available sulfur recorded were 15.56 mg kg^{-1} and 13.12 mg kg^{-1} in the soil under grazing and cultivated land, respectively (Table 5 and Figure 4). 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 two land uses were in the optimum range for crop production as these were

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above the critical level of available sulfur (6.5 mg kg^{-1}) as indicated by Blair *et al*. (1991). Under both land uses, the available sulfur decreased consistently with soil profile depth from the surface to subsurface horizons. This could be related to the decrease in OM contents (Table 5) within the profile from the surface horizon to the subsurface horizons.

IV. Summary and Conclusions

Three soil profiles representing the two different land uses were opened and soil samples were collected depth wise from each genetic horizon for characterization of their selected morphological and physicochemical properties. Morphological descriptions of the soil profiles were carried out in the field following the FAO guidelines and analysis of soil physical and chemical properties were carried out in the laboratory following standard laboratory procedures.

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 and available sulfur 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 grazing land soil was higher in most of the soil physicochemical properties such as CEC, exchangeable bases, OC, total N, available P and available sulfur as compared to the cultivated field. This indicates that continuous cultivation without proper soil management in the cultivated field, 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 grazing lands.

Therefore, 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. Finally, 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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