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Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia

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Abstract

Land use change particularly from natural ecosystem to agricultural lands in general and to crop cultivation under poor management practices in particular are among the major causes of decline in soil fertility followed by land degradation and low agricultural productivity. Achieving scientific information thereof is vital for planning management strategies; this study assessed the effects of land use on soil physicochemical properties describing soil fertility under three land use types (natural forest, grazing and cultivated land) in Guto Gida District of Oromia Region, Western Ethiopia. The natural forest land was used as a control to assess status of soil properties resulting from the shift of natural forest to other land uses. Disturbed and undisturbed surface soil samples (0-20 cm) were collected from each land use type and examined for their analysis of soils physicochemical properties. The study pointed out the difference between different land use type on soil water content, pH, Cation exchange capacity (CEC), organic carbon (OC), total nitrogen (TN), available phosphorus (P), and exchangeable bases. Correlation analysis also showed highly significant and insignificantly positive relationship of soil pH with exchangeable Mg^{2+} and Ca^{2+} ions but significantly with extractable Fe^{3+}, Mn^{2+} ions and PAS of the soils *among the land uses. Relative to forest land*, when the percent OC contents in cultivated and grazing lands depleted respectively, by 54.62 and 49.89%, *the percent Al saturation in cultivated land increased by* 65.62% and 28.57% in grazing land. Land use changes also caused a decline in CEC, PBS, exchangeable bases and increased BD and Clay content exhibited poor soil physical conditions and deterioration of soil fertility.

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Introduction

The management of tropical soils is crucial to address the issues of food security, soil degradation and environmental quality including the global carbon cycle. Sustaining soil and environmental qualities is the most effective method for ensuring sufficient food supply to support life (Soares *et al*., 2005). In an effort to this end, soil scientists developed the concept of soil quality to describe the fitness of soils to perform particular ecosystem functions and management. Maintaining soil quality mainly depends on the knowledge of the physicochemical properties of a given soil.

The assumption of the sustainability of agricultural ecosystems also depends to a great extent on the maintenance of soil physicochemical properties. Its feasibility is based on the knowledge of the effects of management practices on soil properties, and how they affect soil-crop-water relations (Heluf and Wakene, 2006). Therefore, characterization and/or evaluation of soil properties is a master key for describing and understanding the status and qualities of the major nutrients in soils (Geissen *et al*., 2009). Assessing soil physicochemical properties are used to understand the potential status of nutrients in soils of different land uses (Wondowosen and Sheleme, 2011). This knowledge can ascertains whether the specified land use types are useful for a given production system and used to meet plants requirement for rapid growth and better crops production (Shishir and Sah, 2003).

Over the past several decades, the conversion of native forest to agricultural land use has accelerated and featured in the development of Ethiopian landscapes and has apparently contributed to the widespread occurrence of degraded land across most part of the country. However, different land use practices have a varied impact on soil degradation and on both physical and chemical property of soil. Study by Wakene and Heluf (2003) have examined the impacts of different land uses on soil qualities and the study indicated, the rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions.

Assessing land-use-induced changes in soil properties is essential for addressing the issue of agro ecosystem transformation and sustainable land productivity. The selection of suitable indicators with well established ecological functions and high sensitivity to disturbances is of paramount importance. In this regard, soil organic carbon(SOC) is important for the overall carbon reservoir of the biosphere and plays a preponderant role in the global biogeochemistry cycle of major nutrients and it has been used extensively by authors to monitor land-cover and land-use change patterns (Koutika *et al*., 2002; Sisti *et al*., 2004). Though they are sensitive to land-use changes, soil organic C and N have been proposed by some worker as indicators for assessing the effect of land use management (Alvarez and Alvarez, 2000). Thus, it is a key source of soil nutrients for plant growth and soil structural stability, as well as carbon stock levels (Sisti *et al*., 2004). However, its dynamics and composition are influenced by land-use changes, agricultural and management practices (Stevenson, 1994 and Barthes *et al*., 1999).

Knowledge about an up-to-dated status of soil physical and chemical properties of different land use systems plays a vital role in enhancing production and productivity of the agricultural sectors on sustainable basis. However, practically oriented basic information on the status and management of soil physicochemical properties as well as their effect on soil quality to give recommendations for optimal and sustainable utilizations of land resources remains poorly understood. Therefore, this study was conducted with specific objectives to assess and explore the status of soil physicochemical characteristics of three different land use systems of representative area of Western Oromia Region. The results of this study are expected to add value to the up-to-date scientific documentation of the status of soil fertility and soil quality of different land uses of the study area and other similar agro-ecological environments in the country.

Materials and methods

The study area

Geographically Guto Gida District is located in the Oromia Regional State, Western highlands of Ethiopia (Fig. 1) lying between 08^{o} 59'and 09^{o} 06` N latitude and $37^{o}$ 51`and 37^{o} 09`E longitude at an altitude of 1650 meters above sea level (masl). The study site is suited at a road distance of 310 km from the capital, Addis Ababa. According to the Ethiopian agro-climatic zonation (MOA, 1998), the study area falls in the highland (*Baddaa)* and mid altitude *(Badda Darree)*. The ten years (1996-2007) climatic data from Nekemte Meteorological Station recorded an average annual rainfall 1780 mm which is characterized by unimodal rainfall pattern and its annual mean minimum and maximum monthly temperatures lies between 13.75 and 27.65 ^{o}C (Fig. 2). According to FAO, (1990) classification, the soil class of the study area is Nitosols and topographically characterized by mountainous and gentle sloping landscape. Subsistence agriculture is the main livelihood of the community and crop-livestock mixed farming system is predominant. The major crops commonly grown in the study area are coffee (*Coffee arabica)*, *teff (Eragrostis tef),* barley *(Hordeum vulgare)*, maize (*Zea mays),* potato *(Solanum tubersoum) and* hot pepper (*Capsicum frutescence*). Crop production are based on rainfed agriculture and harvested usually once in a year.

Data source and analysis of soil samples

In order to have general information about the land forms, land uses, topography and vegetation cover, a preliminary survey and field observation using the topographic map (1:50,000) of the study area was carried out during the year of 2010. Accordingly, three major representative land uses (natural forest, grazing and cultivated) lands were selected based on their history and occurrence. The natural vegetation of the study area is characterized by Indigenous natural forest and canopies, where as rainfed crop cultivation bounded by scattered settlements in the cultivated land and communal and private grazing land were the characteristic features of the land use types. The composite top soil (0-20 cm) samples from representative site of each land use in three replicates were collected, air dried, ground and passed through a 2 mm sieve for analysis. Analysis of soil samples were carried out at Chemistry laboratory of Ambo University and Holleta Soil Research Laboratory Center based on their standard laboratory procedure.

Soil particle size distribution was analyzed by the Bouyoucos hydrometer method as described by Day (1965). The soil-water holding capacity (WHC) values were measured at -1/3 bar for field capacity (FC) and -15 bar for permanent wilting point (PWP) using the pressure plate apparatus method (Klute and Dirksen, 1986). Specific surface area was determined using ethylene glycol equilibrium method as described by Dipark and Sarkar (2003). Soil bulk density (Db) was measured from undisturbed soil samples collected using a core sampler which was weighed at field moisture after drying the pre-weighed soil core samples to constant weight in an oven at 105 ^{o}C as per the procedures described by (1965). Particle density (Dp) was determined by the pycnometer method (Devis and Freitans, 1984). Total porosity was estimated from the bulk and particle densities as described as:

Total porosity (%) = (1- Db/Pd) x 100

Where Db bulk density in (g cm^{-3}) and Pd particle density (g cm^{-3})

The pH of the soil was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5, soil: liquid ratio (Baruah and Barthakur, 1997). Organic carbon (OC) content was determined by the dichromate oxidation method (Walkely and Black, 1934). Total N was determined using the micro-Kjeldahl digestion, distillation and titration procedure as described by Bremner and Mulvaney (1982). Available P was analyzed using Bray-II method and colorimetrically using vanadomolybedate acid as an indicator and its concentrations was measured using spectrophotometer at a wave length of 880 ηm. Extractable (Fe^{3+} and Mn^{2+}) were extracted using diethylenetriamine pentaacetic acid (DTPA) as described by Lindsay and Norvell (1978) and their contents were determined using atomic absorption spectrophotometer (AAS).

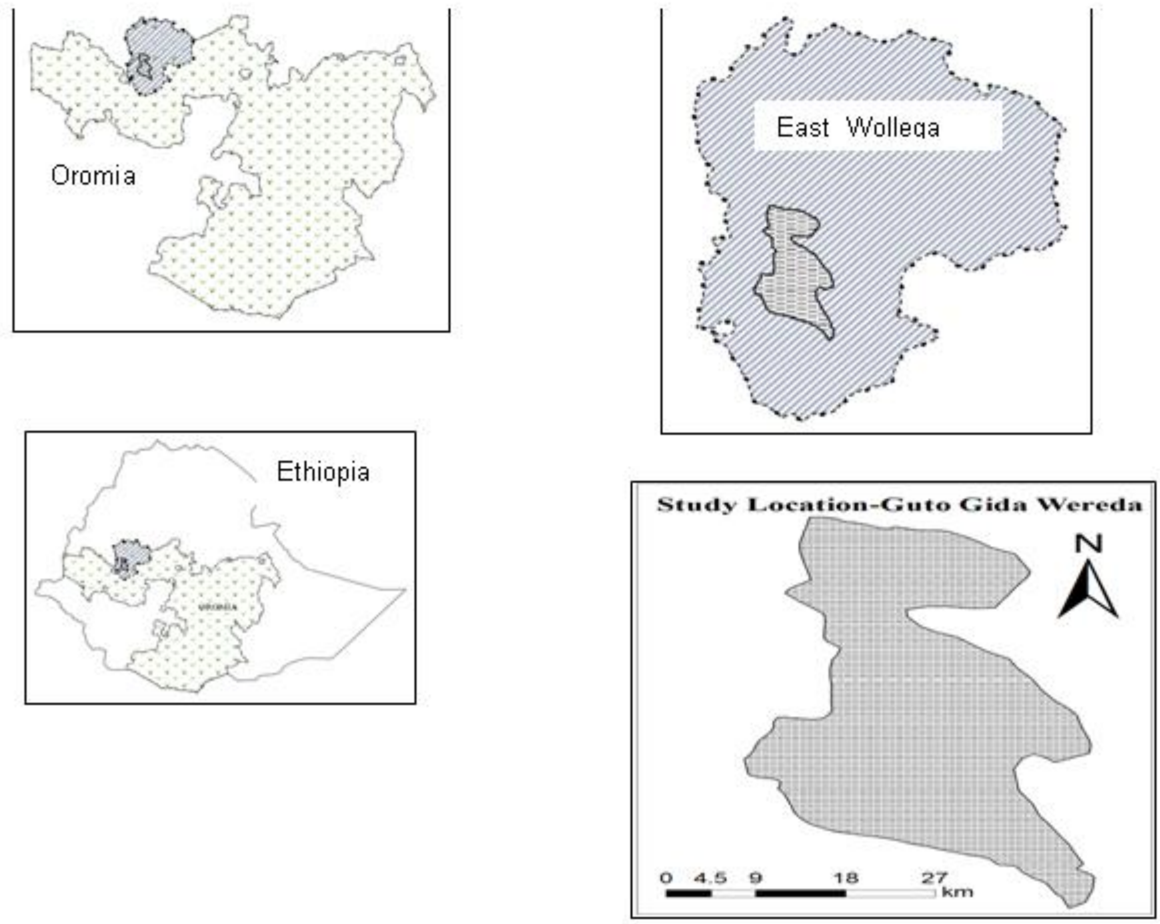

Fig. 1. Location map of the study site.

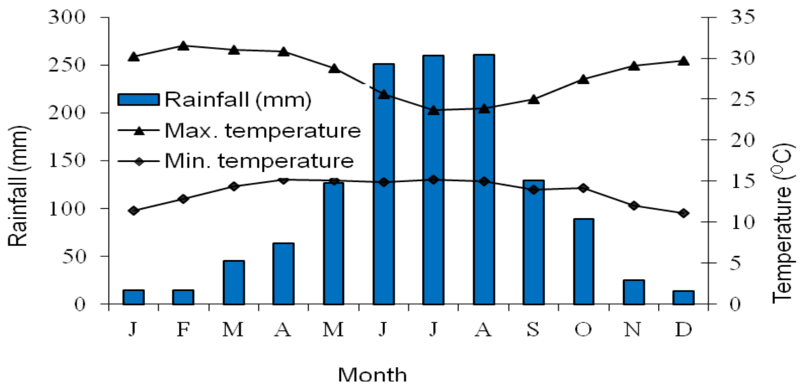

Fig. 2. Mean monthly rainfall and mean maximum and minimum temperatures of the study areas based on records at the Nekemte Meteorological Station.

Exchangeable bases (Ca, Mg, K and Na) were extracted with 1 M NH_4OAc at pH 7. The extracts of Ca and Mg were analyzed using AAS while K and Na were determined by flame photometer. To determine the cation exchange capacity (CEC), the soil samples were first leached with 1 M ammonium acetate (NH4OAc), washed with ethanol and the adsorbed ammonium was replaced by Na (Chapman, 1965). Then, the CEC was measured titrimetrically by distillation of ammonia that was displaced by Na. Total exchangeable acidity was determined by saturating the soil samples with 1M KCl solution and titrated with 0.02M HCl as described by Rowell (1994). From the same extract, exchangeable Al in the soil samples was titrated with a standard solution of 0.02M HCl. The percent base saturation (PBS) of the soil samples was calculated from sum of the base exchangeable cations (Ca, Mg, K and Na) as percentage of CEC.

Data analysis

Pearson's simple correlation coefficient was executed using Statistical Analysis System (SAS) version 9.00 (SAS, 2004) to reveal the magnitudes and directions of relationship between different parameters of soil properties within and among land use types.

Results and discussion

Status of soil properties of different land uses

Selected soil physical characteristics of the experimental site are given in Table 1. The textural class of the top (0-20 cm) soils of all the land use types was clay, indicating the similarity in parent material; however, higher clay content was recorded in the cultivated land. Negative and insignificant relationship of clay with sand ($r = -0.64$, $P > 0.05$) and silt ($r = -0.95$, $P > 0.05$) fractions were observed from the output of the correlation matrix. Silt to clay ratio in the (0-20) cm depth was low and varied from 0.68, 0.47 and 0.30 for soils of forest, grazing and cultivated lands, respectively (Table 1). Higher clay fraction and lower silt to clay ratio recorded in the cultivated land attributed to the impacts of deforestation and farming practices.

The results of the present finding also observed, soils of different land use systems but of same area with same soil type and textural class differed in some other soil physical conditions (Table 1). These differences are mainly due to the fact that soil physical properties changes with the change in land use systems and its management practices. Results of the correlation analysis revealed the negatively insignificant association of specific surface area with sand and clay fractions. This negative correlation may attribute to the inverse relationship of the clay fraction with surface area. This is in agreement with the finding of Dekimpe *et al.* (1979) who reported the inverse relation of surface area with particle size. In this study, soils from cultivated land relatively had lower surface area than grazing and forest lands. This may be due to lower soil organic matter(SOM) and higher Fe and Al oxides contents in soils of cultivated land tends to lower surface area than in the remaining land uses. Oxides of Fe and Al are important cementing agents and reduce total surface area of the soil of cultivated land more than the remaining land uses.

The correlation matrix showed significant positive relationship ($r = 0.99$, $P < 0.01$) between Permanent wilting point (PWP) and field capacity (FC). Results of the present study demonstrated, soils under different land uses differed in their water content both at FC and PWP. The variation in water content both at FC and PWP may be due to differences in their sand, silt and clay fractions. However, it is lower and higher in forest and cultivated lands, respectively (Tables 1 and 4). The lower FC, PWP and AWC in forest land was due to lower moisture contents which reduces available water capacity of the soils of forest land through its adverse effects on both FC and PWP, however, the higher values of FC, PWP and AWC of the cultivated land may be due to its higher clay contents. This is in agreement with the finding of Emerson (1995) who concluded increase in clay content increases both the FC and the PWP. Changes in soil-water level and its possible effect on

AWC, FC and PWP indicate that, the soil water retention properties of the study area has been disturbed by changes in land use type. This could be attributable to the variations in soil organic matter (SOM) and clay contents of land uses (Ebtisam, 2007).

Table 1. Selected soil physical properties of experimental soils

Land uses	parameters										
	Sand (%)	Silt (%)	Clay (%)	Textural class	BD (g cm^{-3})	PD (g cm^{-3})	TP %)	FC (%)	PWP (%)	AWC (%)	SSA ($m^2 g^{-1}$)
FL	22.5	31.25	46.25	Clay	2.40	1.19	51	34.7	24.9	9.8	220.3
GL	17.5	26.25	56.25	Clay	2.54	1.29	50	35.7	25.0	10.7	251.1
CL	20.0	18.50	61.50	Clay	2.63	1.58	34	62.8	42.6	20.2	195.9

FL = forest land; GL= grazing land; CL = cultivated land; BD= bulk density; PD =particle density; TP= total porosity; FC= field capacity; PWP= permanent wilting point; AWC= available water capacity; SSA= specific surface area

Table 2. Organic matter, total N, available P and extractable Fe and Mn oxides

Land uses	Parameters							
	OC (%)	TN (%)	C/N ratio	Av P Bray II (mg kg^{-1})	Av P Olsen (mg kg^{-1})	TP (mg kg^{-1})	Ex. Fe (mg kg^{-1})	Ex. Mn (mg kg^{-1})
FL	4.65	0.23	20.21	7.40	6.80	975.6	0.17	0.11
GL	2.33	0.14	16.64	5.20	2.01	908.0	0.23	0.16
CL	2.11	0.13	16.23	5.00	1.70	553.4	1.14	0.89

FL = forest land; GL= grazing land; CL = cultivated land OC = organic carbon; TN = total nitrogen; Av P = available phosphorus; TP = total phosphorus; Ex Fe = extractable iron; Ex. Mn = extractable manganese

Table 3. Soil pH, exchangeable cations and exchange properties of soils studied.

Land use types	soil properties													
	pH	Ex.Ca	Ex. Mg	Ex. K	Ex. Na	TEB	CEC	ECEC	Ex. Al	Ex. A	PAl S	PAS	PBS	%$CaCO_3$
--------------------------------- (cmol(+) kg^{-1})-------------------------------------														
FL	5.25	7.43	1.25	0.51	0.47	9.66	28.20	12.48	1.40	2.82	11.22	22.59	34.22	0.16
GL	5.15	5.13	1.14	0.46	0.41	7.14	22.20	10.85	3.10	3.71	28.57	34.19	32.61	0.15
CL	4.56	2.94	0.43	0.39	0.38	4.14	19.20	14.66	9.62	10.52	65.62	71.75	21.56	0.12

Soil bulk, particle density and total porosity

In this study insignificant negative correlation of soil bulk density (r = -98, P > 0.05) and particle density (r = -0.82, P > 0.05) with total porosity was observed (Table 4). Bulk density in cultivated land was higher than adjacent soils of the natural forest and grazing lands, respectively by 24.68 % and18.35%. The lower and higher bulk density of the soils of forest and cultivated lands attribute to the high SOM, porosity and less disturbance of the land under forest land. Compaction of soil surface caused by intensive field traffic and deforestation also increases the soil bulk density in the cultivated land. Basically, increase in SOM lowers bulk density while compaction increases bulk density. Soils having low and high bulk density respectively exhibit favorable and poor soil physical conditions (Hajabbasi *et al.*, 1997; Patil and Jagdish, 2004). Significant negative correlation (r = -0.99, P<0.05) between particle density and CEC was observed (Table 4). Soil particle density varied with the land use type and recording the highest and lowest in the soils of cultivated and forest land, respectively. In this study, soil particle density in cultivated land increased by 8.75 and 3.42% than forest and grazing lands. The lower particle density of the forest land as compared to grazing and cultivated lands is due to trapped air and higher contents SOM in forest land. The presence of iron oxide and heavy minerals in soil increases the average value of particle density but SOM on surface soils lowers it.

This was confirmed by Li *et al.* (2007) who found lower particle density values when the rates of compost addition increased in the soil.

The total porosity was negatively but significantly correlated with Extractable Fe (r = -0.99, P < 0.01) and Mn (r = -0.99, P < 0.01) (Table 4). This negative correlation attributed with acidity of the soil which increases the concentration of toxic substances like Mn and Fe ions in the soil solution. Experimental data revealed a reduction of 17% total porosity due to shift of forest land to cultivated lands. A decrease in total porosity in the soils of cultivated lands as compared to natural forest and grazing land attributed to a reduction in pore size distribution and it is also closely related to the magnitude of SOM loss which depending on the intensity of soil management practices. For instance, soil of cultivated land is highly subjected to compaction and subsequently decreased porosity than soils of forest and grazing lands. Higher particle density and/or bulk densities and a concomitant lower porosity due to change in land use also reported by Caron (1992) and Celik (2005) which are in agreement with the results of the present study. Differences in vegetation type and cropping systems may results variation in soil physicochemical characteristics (Ogunkunle and Eghaghara, 1992). Because cropping systems may leads to erosions and leaching of soil nutrients which in turn adversely affect the physicochemical properties of the soils (Oguike and Mbagwu, 2009).

Organic carbon, total nitrogen and carbon to nitrogen (C: N) ratio

When comparison are made between the land use types, experimental data of present study recoded higher percent organic carbon (OC) content for natural forest and lower for cultivated land. The higher percent OC content in natural forest land and lower in cultivated land, respectively, attribute to plant litter fall which abundantly returned to soil surface enhancing the fraction of percent SOM in soils of forest land and the presence of high concentration of iron oxide and clay fraction lowers percent OC in cultivated land. Relative to forest land, percent OC contents in soils of cultivated and grazing lands depleted by 54.62 and 49.89%, respectively (Table 2). The depletion of soil OC was higher in cultivated land than grazing land. This is attributed with the fact that, cultivation increases soil aeration which enhances decompositions of SOM and most of the percent SOM produced in soils of cultivated land removed with harvest causing for its reduction in values of OC content which in turn an increased in soil bulk density and decreased soils total porosity. The conversion of forest land to cultivated land has been associated with reduction in percent SOM content of the top soil. As per the rating of nutrients suggested by Tekalign (1991), the soil OC can be categorized as high in the soils of natural forest and moderate in soils of grazing and cultivated lands. Studies by Lal, (1996); Mandiringana *et al.* (2005) and Michel *et al.* (2010) indicated the decrease of soil OC content due to shifting of natural forest to grass, fallow and to cultivated. Across the land uses, distribution of total N followed same patterns to soil OC distribution. It was highest in forest land and lowest in the cultivated land. As compared to soils of forest land, total N content in cultivated and grazing lands, respectively, depleted by 43.482 and 99.13%, (Table 2) but as suggested by Tekalign (1991), the total N in all land use types rated as high. Differences in OC and total N between natural forest and the remaining land uses could arise from the reduction in OM inputs due to removal of biomass during cultivation and grazing. Conversion of natural forest to different land uses causes a decline of SOM and total N in the top soil layer of the present study. The decline in OC and total N due to land use change concurs with the findings of (Jaiyeoba, 2003; Heluf and Wakene (2006); Abbasi *et al.*, 2007). Exposure of the top soil to rainfall brings about erosion, rapid decomposition of soil OM and intense leaching of basic nutrients rendering the soil infertile and the agricultural production unsustainable. Numerically, distribution of C: N followed similar patterns to OC and total N distributions except slight variation within the land uses. Relative to forest land, soils of the cultivated land recorded narrow C: N ratio. Aeration during tillage and increased temperature that enhance mineralization rates of OC than organic nitrogen could probably be the causes for the lower level of C: N ratio in cultivated land.

The narrow C:N ratio in soil of cultivated land concurs with the study of Abbasi *et al.* (2007) who concluded higher microbial activity and more CO_2 evolution and its loss to the atmosphere in the top (0-20 cm) soil layer resulted to the narrow C:N ratio.

Table 4. Pearson`s Correlation coefficient (r) among selected soil physicochemical properties.

	pH	TP	Ex.Ca	Ex.Mg	Ext.Fe	Ext.Mn	CEC	PAS	PBS	PD	BD	PO	FC	PWP
TP	0.99**													
EX.Ca	0.92	0.92												
Ex.Mg	0.99**	0.99*	0.91											
Ext.Fe	-0.99*	-0.99	-0.88	-0.99*										
Ext.Mn	-0.99*	-0.99	-0.88	-0.99*	0.99**									
CEC	0.83	0.84	0.98	-0.83	-0.79	-0.79								
PAS	-0.99*	-0.99*	-0.95	-0.99	0.98	0.98	-0.88							
PBS	0.99**	0.99*	0.91	0.99**	-0.99*	-0.99*	0.82	-0.99						
PD	-0.87	-0.87	-0.99	-0.86	0.82	0.83	-0.99*	0.91	-0.86					
BD	-0.99	-0.99	-0.96	-0.99	0.98	0.98	-0.89	0.99*	-0.99	0.92				
PO	0.99*	0.99	0.88	0.99*	-0.99**	-0.99**	0.78	-0.98	-0.96	-0.82	-0.98			
FC	-0.99	-0.99	-0.87	-0.99	0.99	0.99*	-0.77	0.98	-0.99*	0.82	0.89	-0.98		
PWP	-0.99	-0.98	-0.86	-0.98	0.99*	0.98*	-0.76	0.97	-0.99	0.80	0.97	-0.99*	0.99**	
AWHC	-0.99*	-0.99*	-0.90	-0.99*	0.99	0.99	-0.81	0.98	-0.99*	0.84	0.98	-0.99*	0.99*	0.99*

*, ** and *** significant at 0.05, 0.01and 0.001 probability levels respectively.(Ext. Fe = extractable Fe ,Ex Mn =extractable Mn, Ex.Ca = exchangeable Ca Ex. Mg = exchangeable Mg, TP = total P, CEC= cation exchange capacity, PBS= percent base saturation, PAS = percent acid saturation , PO = porosity, BD = bulk density, FC = field capacity, PWP = permanent wilting point, AWHC = available water holding capacity)

Available and total phosphorus of the experimental soils

Result of the present finding indicate positively insignificant correlation (r = 0.68, P > 0.05) between available P and total P. The available P content in the top soils of each land use varied from 5.0-7.4ppm using Bray method and 1.7- 6.8ppm using Olsen method. In both methods the value was lower in cultivated land and higher in forest lands (Table 2). For soils of forest, grazing and cultivated lands, values of available P obtained using Bray method was higher than Olsen method, respectively by 8.11, 61.35 and 66% (Table 2). As per the rating suggested by Jones (2003), the available P of soils of all land uses were qualifying for very low range, however, numerically better in the forest land (Bray method). This is may be because of the forest vegetation with their larger biomass, absorb larger amount of available P and the lower available P in grazing and cultivated land may be due to lower SOM status and domination of the HPO_4^{2-} anion in strongly acidic soils than $H_2PO_4^-$ anion (Mishra *et al.*, 2004). Unlike to soils of forest lands, grazing intensity and continuous cultivation can negatively affect soil nutrient levels. Result of this study is consistent with Paulos (1996) finding who observed variations in available P contents in soils are related with the intensity of soil soil disturbance, the degree of P-fixation with Fe and Ca ions. Similarly, Tekalign and Haque (1987); Dawit *et al.* (2002b) reported SOM as the main source of available P and the availability of P in most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion. The distribution of total P content followed a similar pattern to available P distributions and ranged from 553.4 to 975.6 mg kg^{-1}. As per the ratings of Landon (1991), medium total P content was observed in all land use types. However, numerically higher in natural forest and lower in soils of cultivated land.

The value implies that, conversion of forest land to cultivated land causes for the decline for the distribution of soil total P.

Soil extractable iron and manganese contents

In this study highly significant and positive relationships(r = 1.00, P < 0.01) was observed between extractable Fe and Mn ions. Their concentration respectively, lies in the range of 0.17-1.14 and 0.11-0.89 (cmol(+) kg^{-1}). The value was in the strongly acidic soils of cultivated land followed by grazing and forest lands (Tables 2 and 4). The relatively higher concentrations of Fe^{3+} and Mn^{2+} ions in soils of cultivated land attributed to intensive rainfall which exposes soils to excessive leaching of exchangeable basic cations, and causes the predomination of excessive toxic substances like Al^{3+}, Fe^{3+} and Mn^{2+}ions in to the soil. The variations in contents of extractable ions across the land uses may be due to the influences of various factors such as soil texture, CEC, P level in soil affects the availability of micronutrients. Moreover, higher solubility, availability and plant uptake of micronutrient (Fe^{3+} and Mn^{2+}) in soil acidic conditions have reported by Han *et al.* (2007). In this study it refers to cultivated land. As per the critical rating recommended by Jones (2003), the contents of DTPA extractable Fe was found to be low in all land use types and extractable Mn was low in forest and grazing lands where as marginal in the cultivated land. The relatively excess extractable (Fe^{3+} and Mn^{2+}) contents under strongly acidic soils of cultivated land as compared the remaining land uses might be due to crop harvest and high percent exchangeable acidity that were aggravated by continuous cultivation with very low input of farming system enhances the contents of extractable (Fe^{3+} and Mn^{2+}) ions in the soil. The result observed in this study concur with the finding of Wakene and Heluf (2003) who reported the depletion of micronutrients due to changes in land use practices.

Soil reaction and exchangeable cations (Ca, Mg, K and Na)

Output of the correlation analysis showed significantly higher positive (r = 0.99, P < 0.01) and insignificantly positive (r = 0.92, P > 0.05) relationship of soil pH with exchangeable Mg^{2+} and Ca^{2+} ions. However, it was negatively significant (r = -0.99, p < 0.05) with extractable Fe^{3+}, Mn^{2+} ions and PAS of the soil. Experimental data indicated the reduction of soil pH due to land use changes from forest to cultivated land. Higher (5.25) soil pH-H_2O values in forest land while lower value (4.56) was recorded in cultivated land (Tables 3 and 4). As per the rating indicated by Jones (2003) the soil pH values observed under different land use types were found to be varying from very strongly acidic for cultivated soil to strongly acidic soil reaction for forest and grazing lands. The lower value of soil pH under the cultivated land may be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution lowers its soil pH value. Moreover, the acidic nature with low soil pH obtained from all the representative land uses may be attributed to the fact that, soils were derived from weathering of acidic igneous granites and leaching of basic cations such as K, Ca and Mg from the surface soil (Frossard *et al.,* 2000). Similarly, basic exchangeable (Ca, Mg, K and Na) ions decreases from soils of forest, grazing and to cultivated lands. Exchangeable Ca was dominant in the exchange sites of the soil colloidal materials of the three land uses; this was followed by Mg, K and Na ions in that order. As per the ratings of FAO (2006), the basic exchangeable cations (Ca, Mg, K and Na) contents in the soils of all land uses were medium. Variations in exchangeable bases among the land use types were insignificant (Table 4). This may be due to same clayey textural classes of the soils. Changes in land use type from forest land to cultivated land have resulted in a decline of exchangeable Ca and Mg contents by 60.43 and 65.65% respectively. Compared to forest land the relatively lower concentrations of exchangeable Ca, Mg, K and Na contents recorded in soils of cultivated could be attributed to continuous losses in the harvested parts of plants and leaching of basic cations from top soils of cultivated land Similarly (Dudal and Decaers, 1993; He *et al.*, 1999) revealed that, domination of soil by extractable acidic Al^{3+} and Fe^{2+} ions as well as adsorption of the cations by higher content of clay in their top soils of cultivated land resulting relatively lower contents of Ca and Mg ions in the soil. The relatively lower concentration of exchangeable K and Na contents in the cultivated and the grazing lands than in the forest land might be due same reason explained for Ca and Mg ions. In this study, deforestation and continuous cropping mainly contributed to depletion of basic cations and CEC on the cultivated land as compared to the adjacent forest land. Study by Heluf and Wakene (2006) revealed that, variations in the distribution of exchangeable bases depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed.

Percent base saturation and cation exchange capacity

Output of the correlation matrix showed highly significant ($r = 0.99$, $P < 0.01$) relationship of PBS with pH, total P and exchangeable Mg^{2+} ion and insignificantly positive ($r = 0.82$, $P > 0.05$) with CEC, however negatively significant ($r = -0.99$, $P < 0.05$) relationship with extractable Fe^{3+} and Mn^{2+} ions (Table 4). The PBS of soils, declined from 34.22% in the natural forest land to 32.61 and 21.56% in soils of grazing and cultivated lands, respectively. However as per the ratings recommended by Hazelton and Murphy (2007), the value of PBS of the top soil (0-20) cm depth of all land use types classified as low status of percent base saturation (PBS) values. The trends of the distribution of PBS showed similarity with the distribution of CEC, exchangeable Ca and Mg, since factors that affect these soil attributes also affect the percentage base saturation (PBS). The cultivated land showed lower values of cation exchange capacity (CEC) and percentage base saturation (PBS) suggesting intensive weathering and presence of more 1:1 (kaolinitic) clay minerals in the soil than the remaining land uses. As the PBS increases, the soil pH and the availability of basic nutrient cations to plants also increases (Bohn *et al.*, 2001). Previous research work conducted by Eyelachew (1999) on fertility status of some of Ethiopian soils indicated that, exchangeable bases, especially Ca and Mg ions dominate the exchange sites of most soils and contributed higher to the PBS. The CEC of soils ranged from19.2 cmol (+) kg^{-1}in the cultivated land to 28.2 cmol (+) kg^{-1}in the natural forest land. As per the ratings recommended by Hazelton and Murphy (2007), the CEC value of the top soil (0-20) cm depth of the natural forest land qualifies for high where as grazing and cultivated lands classified as moderate status of CEC value (Table 3). The relatively higher and moderate CEC values recorded, respectively, in forest and the two adjacent land use types may attributed to the fact that soil in forest land accumulate high percent OC and has greater capacity to hold cations thereby resulted greater potential fertility in the soil. Therefore, soil CEC is expected to increase through improvement of the soil OM content. However, deforestation, overgrazing and changing of land from forest to crop land without proper management aggravates soil fertility reduction, like in the cultivated land. The result of the present study concur with the findings of Woldeamlak and Stroosnijder (2003) who reported highest CEC value in soils of forest land and lowest under cultivated land. Similarly, across each land use type, the trend of the values of the CEC of clay follows the same patterns as the CEC of the soils. Higher 34.05% CEC of clay in the soils of forest land followed by 13.89 and 11.52% were observed respectively, in grazing and cultivated lands (Table 3). The variability in the percent CEC of clay across the land use types attributed to the variation in their SOM contents.

Soil exchangeable acidity, percent acid saturation and calcium carbonate

The highest (10.52 cmol(+) kg$^-$) exchangeable acidity in soil of cultivated and the lowest (2.82 cmol(+)kg$^-$) in the soil forest land were recorded (Table 3). The Pearson`s correlation matrix showed negatively significant (r = -0.99, P < 0.05) relationship of PAS with pH and total P and insignificantly negative relationship with CEC, exchangeable Ca^{2+} and Mg^{2+} ions. Highest (71.75%) and lowest (22.59%) PAS were recorded in the soils of cultivated and forest lands, respectively (Table 3). The inverse relationship of exchangeable acidity and Percent acid saturation (PAS) with PBS may attributed to deforestation and intensive cultivation which leads to the higher exchangeable acidity content in soils of cultivated land than the two adjacent land uses. Because the more acid the soil, the greater Al will be dissolved into the soil. Once soil pH is lowered much below 5.5, aluminosilicate clays and Al- hydroxide minerals begin to dissolve, releasing Al-hydroxy cations and Al-H then exchange other cations from soil colloids and fractions of exchange sites occupied by Al-H.

Processes that affect the extent of acidic cations (Al^{3+} and H^+) also affect PAS. For instance, in the present study, the contribution of Al percentage in making soils of cultivated land acidic was 65.62% while11.22 and 28.57% in the soils of forest and grazing lands, respectively (Table 3). At low soil pH oxides of Al and Fe get in to solution and through step wise hydrolysis and releases H^+ ions resulting in to further soil acidification. In this study, higher exchangeable acidity and percent Al saturation were recorded in the soils of cultivated land followed by grazing and forest lands. This is in agreement with the findings Baligar *et al.* (1997) who showed an increase in soil acidity due to land use change following deforestation especially, in the tropics. Results of the present study also recorded negligible percentage of $CaCO_3$ content in the soil of cultivated land (0.12%) than forest (0.17%) and grazing (0.15%) lands. Basically, the severity of acidity of the soil in cultivated land comes from intensive cultivation which results leaching of basic cations from soil solutions. In line with this, the process of evaporation to form carbonates and bicarbonates in the soil solution of such type of land use is faster than the remaining land use systems. As a result; calcium gets precipitated in the form of carbonates and bicarbonates and is rendered low percentage fractions and less soluble form of calcium carbonate in the soil of cultivated land.

Conclusion

In the present study area, practices of exceptional deforestation, overgrazing and intensive cultivation of soils with low inputs over many years. Such practices may disturb soil structure and resulted variations and even deterioration in the soil quality attributes (soil properties) among land use types of same soil type (Nitosol). Nutrients deteriorated land, like cultivated land in this study may indicate risk to the sustainable crop production and soil fertility. Therefore, it is important to sustain natural vegetation and to reinstate intensively cultivated degraded lands through best management practices, for instances improving soil properties by managing the exchangeable Al at optimum level, crop rotation, composting, returning crop residues to the fields and cultivating no more than necessary and adding organic materials are very crucial and shall be considered as important sources to upgrade the soil basic nutrients and increase soil pH of acidic soil to the required level.

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