Impact of land use type on soil acidity in the highlands of Ethiopia: The case of Fagetalekoma district

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Abstract

Soil acidity is one of the chemical soil degradation problems which affect soil productivity in the Ethiopian highlands. A study was conducted in 2008 with the objective of assessing the status of soil acidity in different land use types in *Fagtalekoma* district, Awi Zone in the Amhara region. The different land use types used for the study were cultivated land, backyard, grazing land and natural forest. Composite soil samples were collected along transects in each of the land use types and analyzed using standard laboratory procedures. Results indicated that cultivated land and grazing land were strongly acidic (pH<5.5), whereas natural forest and backyard land uses were moderately acidic (pH = 5.6-6.0). The strong soil acidity on cultivated lands may be due to intensive cultivation without fallow, removal of crop residues, and in appropriate use of chemical fertilizers. Soil acidity on grazing land might be aggravated by overgrazing. Significantly higher soil pH, CEC, and higher Ca and Mg contents were recorded on natural forest soils as compared to other land uses. On the other hand, significantly lower exchangeable acidity was obtained on backyard and natural forest as compared to other the two land uses. Higher organic matter and total nitrogen contents were observed on the natural forest, whereas higher available phosphorous and potassium were recorded on the backyard land use, which might be attributed to high return of biomass due to little soil disturbance and high farmyard manure input. In order to address soil acidity problem, use of manure and compost should be encouraged on cultivated lands. Reducing overgrazing by improving land management options is necessary to rehabilitate acidic grazing land soils.

Key words: Acidity, land management, land use, soil.

Introduction

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. For this reason, recent interest in evaluating the quality of soil resources has been stimulated by increasing awareness that soil is a critically important component of the earth's biosphere, functioning not only in the production of food and fibre but also in the maintenance of local, regional and worldwide environmental quality (Doran and Parkin, 1994).

On the other hand, feeding the ever-increasing human population is most challenging in developing countries because of soil degradation. Soil acidity is one form of chemical degradation of soils. The main problem of acid soils is the high acidity and low amount of exchangeable calcium (Chopra and Kanwar, 1999) and it is considered to be one of the most important factors that affect the soil chemical fertility. Soil acidity affects productivity of the soil through its effect on nutrient availability and toxicity by some elements like aluminum and manganese. The four major causes for soils to become acid are rainfall and leaching, acidic parent material, organic matter decay and harvest of high yielding crops and crop residues (Johnson, 1914).

This challenge will continue as population pressure increases and degradation of soil resources is aggravated for example in the highlands of Ethiopia. Reversing this trend lies in the enhancement of sustainable development of the agricultural sector. However, the basis of sustainable agricultural development is good soil quality. The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use aggravates the degradation of soil physicochemical and biological properties (Saikhe *et al*., 1998; He *et al*., 1999). In Ethiopia, soil acidity is a problem that has not been addressed in depth. It is observed that most of these soils are found in the highlands receiving high rainfall (Paoulos, 2001). The Ethiopian highlands are one of the hotspots on the African continent with regard to food production and in the struggle to preserve the natural resource base (FAO, 2004, 2005). The Ethiopian highlands cover 95% of the cropped area and support almost 85% of the

Ethiopian population. Yields of the major cereal crops, particularly barley, are as low as 5 t ha^{-1} partly as a result of soil acidity (Paoulos, 2001).

The management of soil acidity requires precise information about the extent of the problem as well as its spatial distributions across the range of the land management practices as well as land use systems. Therefore, this study was conducted with the objectives of identifying and quantifying the extent of soil acidity in different land uses and to investigate the effect of soil acidity on plant nutrients in different land uses.

Materials and methods

The study area

Geographically the study area is located at *Gafera* and *Gullazmach kebeles* in are not damaged due to religious considerations. The *woreda* occupied total areas of 34,207 ha of which, 78% is cultivated land in the flats, 12% is forests, woodland and bushes; and 9% is grazing lands in steep slopes. From the total, 0.96% is for other purpose and 0.14% is out off use (BoARD, 2007).

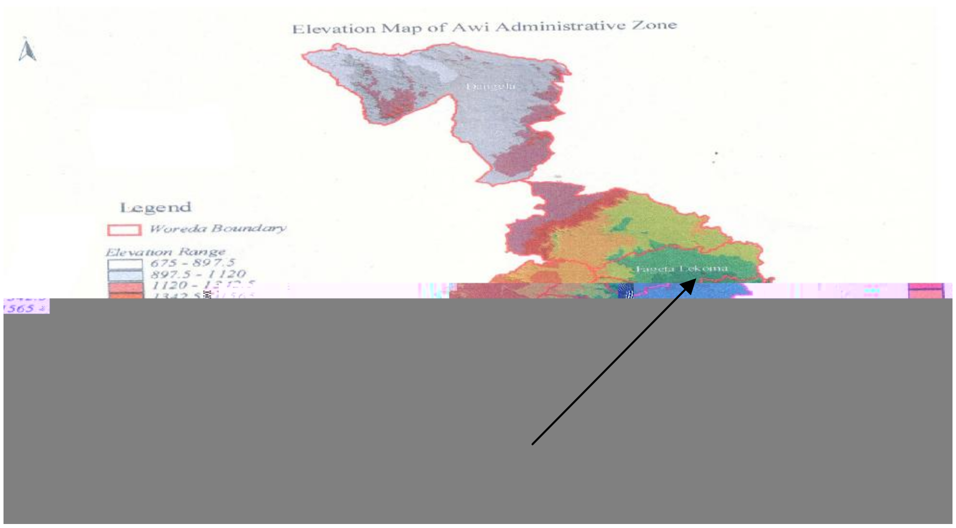

Figure 1. Elevation map of *Awi* Administrative Zone (Source: BoFED, 2004).

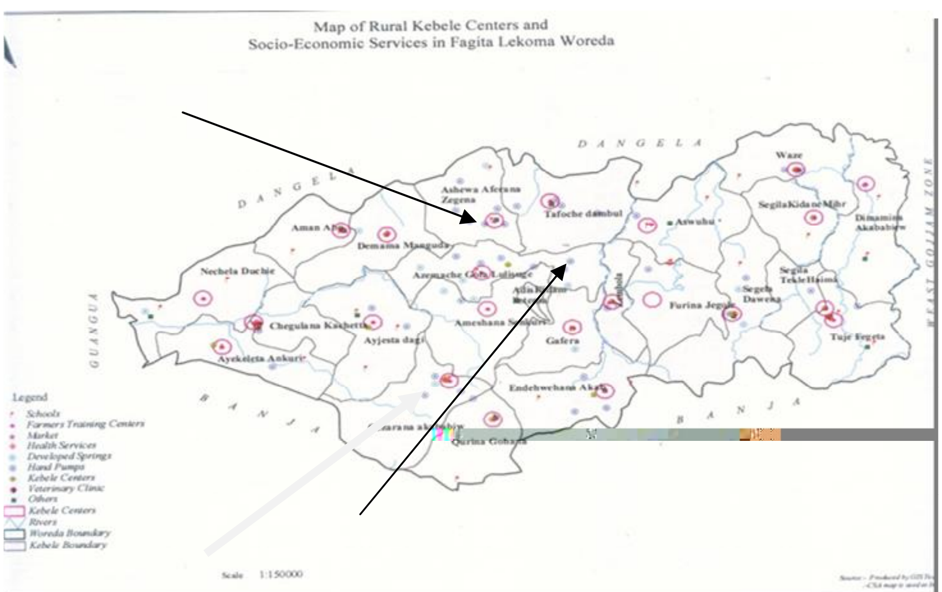

Figure 2. Map of rural *Keble* centres and socio-economic services in *Fagtalekoma* district (Source: BoFED, 2004).

Experimental procedures

Selection of kebeles, land use types and soil sampling

Before the start of the study reconnaissance survey was conducted in 2008 during off season and two sample *kebeles* and land use types were selected using purposive sampling technique. During surveying, the general geography of the area was identified. The criteria used to select the sample *kebeles* were: presence of high incidence of soil acidity problem as per the information from the district office of agriculture and presence of different land use types and its representativeness. Based on these criteria two *kebeles* (*Gullazmach* and *Gaffer*) were selected. Then, four land use types (cultivated, backyard, grazing land and natural forest) were systematically selected within each *kebele* on the basis of similarity in soil type, slope and altitude. Land use types that were bordering each other with in the respective land use types were selected for soil sampling.

According to farmers', cultivated and backyard land use systems were under intensive cultivation for more than 30 years. Besides, backyard plots got special treatment from application of farmyard manure and compost. Grazing lands were under grazing for at least the past 30 years. The cultivated land use type has received Urea and DAP fertilizers in most of the past years under barley and tef cropping systems. The forest land use type had no recorded cropping history.

To collect soil samples, transects were laid out in a 100 m x 100 m land to determine the plot in each land use systems. Along the transect walk 20 m x 20 m plot with three replications was used for soil sampling. In each plot soil samples were collected at the four corners and the centre of the plot from the depth of 0-20 cm with soil auger in March 2008. The five samples from each plot were mixed to form one composite sample. Totally, 24 composite samples were collected from the two *kebeles* and four land use systems per *kebele*.

Laboratory analysis

The soil samples collected from each land use type were air dried and passed through 2-mm sieve to determine the soil physical and chemical parameters. Soil samples for organic matter, total N, and available P determination were ground to pass 0.5-mm size sieve. Soil texture was determined with hydrometer (McDonald *et al*., 1994). The pH of the soil was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5 soils: liquid ratio where the liquid were water and 1M KCl solution (Pam and Brian, 2007). Exchangeable bases were extracted with 1M ammonium acetate at pH 7 and cation exchange capacity (CEC) was determined with 1M ammonium acetate (Abbott, 1989). Exchangeable acidity was determined by saturating the soil samples with 1N KCl solution and titrating with NaOH (Abbott, 1989). Organic matter, total N, and available P contents were determined using Wakley and Black (Skjemstad *et al*., 2000), Kjeldahl (Jackson, 1958) and Olsen (Olsen *et al*., 1954) methods, respectively. Soil sample analysis was done in Jun 2008.

Data analysis

Statistical analyses were performed to test the influence of land use type on soil parameters in general and soil acidity in particular using one-way analysis of variance (ANOVA). Mean comparisons were made using the least significant difference (LSD) test at $P<0.01$ and 0.05. ANOVA was done using SAS statistical software.

Results and discussion

Soil acidity in different land use systems

Soil pH ranged from 5.13-5.24 on cultivated land to 5.73-6.14 on forest land using water, while it ranged from 3.8-4.07 on cultivated land to 4.59-4.93 on forest land using KCl in *Gullazmach* and *Gaffera kebeles,* respectively. In all the different land use types soil pH measured in water was higher by about 1.05-1.33 units than the respective pH values measured in KCl solution (Table 1). The low soil pH with KCl determination indicates the presence of substantial quantity of exchangeable hydrogen and aluminium ions. According to Mekaru and Uehara (1972) and Anon (1993), high soil acidity with KCl solution determination shows the presence of high potential acidity and weatherable minerals. There are different parameters that can indicate the status of soil acidity. Among these parameters pH indicates active (solution) acidity. There was great difference in soil acidity indicator parameters between the two *kebeles*.

Soil pH (active acidity) was significantly ($p<0.01$) affected by the different land use types where in both *kebeles* the highest and the lowest pH (using H_2O solution) were recorded for the forest and cultivated land use types, respectively (Table 1). Higher soil acidity in cultivated land showed that intensive cultivation, removal of crop residues and continuous use of acid forming inorganic fertilizers on acid soils might have aggravated soil acidity (Table 1). Similarly, over grazing might be responsible for leaching of basic cations that can lead to acidity of the area in grazing land use types. These results were in agreement with the reports of many research findings (Baligar *et al*., 1997; Blamey *et al*., 1997; Wakene and Heluf, 2006).

Table 1. Soil acidity indicator parameters in different land uses at *Gullazmach and Gaffera kebeles* in 2008.

	Gullazmach kebele					*Gaffera kebele*				
Land use	pH (H_2O)	pH (KCl)	ΔpH	EA (cmol$_c$ kg^{-1})	AS (%)	pH (H_2O)	pH (KCl)	ΔpH	EA (cmol$_c$ kg^{-1})	AS (%)
Cultivate	5.24^{c}	4.07^{b}	1.18	3.02^{a}	29.7	5.13^{b}	3.80^{b}	1.33	4.56^{a}	32.35^{a}
Grazing	5.41^{bc}	4.30^{ab}	1.10	3.20^{a}	20.8	5.64^{a}	4.57^{a}	1.09	1.54^{b}	10.87^{b}
Backyard	5.59^{b}	4.54^{ab}	1.05	0.56^{c}	3.49^{b}	5.72^{a}	4.58^{a}	1.14	1.20^{bc}	9.11^{b}
Forest	6.14^{a}	4.93^{a}	1.21	0.41^{c}	1.07^{b}	5.73^{a}	4.59^{a}	1.14	0.71^{c}	2.66^{c}
CV (%)	1.67	5.02		7.52	43.4	2.57	3.01		15.81	1

Means followed by the same letter are not significantly different at $P<0.05$. EA = Exchangeable acidity, AS = Acid saturation percentage (exchangeable acidity/ECEC).

From the results, pH (H_2O) of cultivated land at both *kebeles* and grazing land at *Gullazmach* kebele were strongly acidic according to USDA (1999) (Table 1). Grazing land and natural forest in *Gaffera kebele* and backyard land at both *kebeles* were in moderate category. But the natural forest land in *Gullazmach kebele* was slightly acidic (Table 1). Factors such as climate (temperature, rainfall and precipitation), seasonal variations of dry and rainy season, topography and morphological factors may be responsible for the increment of acidity. Further investigation should be carried out to identify the major and minor factors in acid soil formation in this area. The natural soil acidity in cultivated land of both *kebeles* and grazing land use types of *Gullazmach kebele* is aggravated by poor soil and range management.

There was a highly significant ($p<0.01$) discrepancy between land use types on exchangeable acidity as well as acid saturation percentage in both *kebeles* (Table 1). The two parameters are very good indicators of extent of potential or reserve acidity of the soil. Exchangeable acidity indicates the presence of excess Al and H^+ ion on the soil colloid as compared to total cation exchange capacity of the soil (Table 1). This is because the basic cations are leached out of the top soil layer (Tables 2 and 3) cultivated and grazing land uses. So, in the cultivated land use type there was a significantly ($p<0.01$) high exchangeable acidity and acid saturation percentage. This needs ameliorative measures. In this land use type Al toxicity may be a problem for crop production.

Acid saturation percentage and exchangeable acidity were not significantly ($p<0.01$ and $p<0.05$) different between cultivated and grazing lands use types in *Gullazmach kebele* (Table 1). This may be due to the highly destructive overgrazing that leads depletion of basic cations in the grazing land use type in this *kebele*. On the other hand, there was significant ($p<0.05$) variation between cultivated and backyard land use types in exchangeable acidity and acid saturation percentage in the same *kebele* (Table 1). This may be explained by the fact that exchangeable basic cations are not depleted and acidic cations are not left over because of good soil management in backyard land use type as compared to cultivated land in *Gullazmach kebele*. Grazing land in *Gullazmach kebele* was almost double in exchangeable acidity and acid saturation percentage as compared to the same land use system of *Gaffera kebele* (Table 1). This might be due to the high destructive overgrazing practice and collection of cow dung for energy consumption in *Gullazmach kebele* than *Gaffera kebele*. In terms of the soil acidity indicators, natural forest and backyard land were higher than the two land uses. There was no significant ($p<0.05$ and $p<0.01$) variation between forest and backyard land use types in exchangeable acidity and acid saturation percent.

Generally, soil acidity was low in natural forest and backyard land use types compared to the other land use types in both *kebeles* (Table 1). The reason may be farmers apply compost and farmyard manure that can add organic matter to their backyard. The low soil acidity in the natural forest and backyard may be attributed to accumulation of organic matter due to little soil disturbance (in natural forest), high manure and organic waste input (in backyard) as compared to the cultivated and grazing lands and hence decrease soil acidity on this land uses.

Soil acidity and plant nutrients

Highly significant ($p<0.01$) differences were observed in exchangeable Mg and Ca content between the land use types in *Gullazmach* and *Gaffera kebele* (Tables 2 and 3). On the other hand, significantly ($p<0.01$) higher exchangeable Ca and Mg were recorded in the forest land use type in *Gullazmach kebele,* while higher exchangeable cations were recorded in the same land use types in *Gaffera kebele* except exchangeable Na (Tables 2 and 4). Significantly higher ($p<0.01$ and $p<0.05$) exchangeable K content was recorded in the backyard land use type in *Gullazmach kebele* (Table 2), but not in *Gaffera kebele* (Table 3). Significantly higher ($p<0.01$ and $p<0.05$) exchangeable Na was recorded in the grazing land use type in *Gullazmach kebele* (Table 2). In *Gaffera kebele* there were no significant ($p<0.01$ and $p<0.05$) variations between land use types in exchangeable Na content (Table 3). The cation exchange capacity was also significantly different across the land use types in both kebeles (Tables 2 and 3).

The highest exchangeable K was recorded from the surface top soil of the backyard land as compared to the cultivated and the grazing lands in *Gullazmach Kebele* (Table 3). According to Marx *et al*. (1997), the exchangeable potassium content in all the land use types is high. This is in agreement with the reports of Yihenew *et al.* (2008) who reported high K status at Yilmana densa district Nitosol and Medum K statsus at Farta district

Luvisol in North West Ethiopia. However, it was in contrary with Alemayehu (1990) who reported low K concentration for Nitisols of the then Wollega state farms, western Ethiopia.

Table 2. Concentration of exchangeable bases in $cmol_c\ kg^{-1}$under different land use types in *Gullazmach kebele* in 2008.

Land use	Exch. Ca		Exch. Mg		Exch. K		Exch. Na	
	Conc.	Level	Conc.	Level	Conc.	Level	Conc.	Level
Cultivated	8.15^{b}	m	2.51^{c}	h	0.92^{b}	h	0.12^{b}	l
Grazing	7.48^{b}	m	2.58^{c}	h	1.27^{b}	h	0.25^{a}	m
Backyard	8.85^{b}	m	5.23^{b}	h	2.62^{a}	h	0.13^{ab}	l
Forest	20.46^{a}	h	15.44^{a}	h	1.45^{b}	h	0.19^{ab}	l
CV (%)	24.92		13.35		23.39		34.39	

Means followed by the same letter are not significantly different at P<0.05. Exch. = Exchangeable, Conc. = Concentration, h = High, m = Medium, l = Low.

Table 3. Concentration of exchangeable bases in $cmol_c\ kg^{-1}$under different land use types in *Gaffera kebele* in 2008.

Land uses	Exch. Ca		Exch. Mg		Exch. K		Exch. Na	
	Conc.	Level	Conc.	Level	Conc.	Level	Conc.	Level
Cultivated	5.56^{C}	m	3.35^{B}	h	$0\ .83^{A}$	h	0.18^{A}	l
Grazing	8.48^{B}	m	3.41^{B}	h	1.20^{A}	h	0.09^{A}	l
Backyard	7.46^{BC}	m	2.86^{B}	h	1.02^{A}	h	0.12^{A}	l
Forest	13.80^{A}	h	10.82^{A}	h	1.47^{A}	h	0.11^{A}	l
CV (%)	13.35		26.23		31.49		48.16	

Means followed by the same letter are not significantly different at P<0.05. Exch. = Exchangeable, Conc. = Concentration, h = High, m = Medium, l = Low.

On the contrary, many research results supported the presence of low exchangeable potassium, since weathering, intensive cultivation and use of acid forming inorganic fertilizers on acid soils affect the distribution of K in the soil systems and enhance its depletion in cultivated lands (Baker *et al*., 1997; Saikh *et al*., 1998).

The exchangeable Ca concentration in the top soil of the natural forest land was higher by 12 $cmol^{(+)}$ Kg^{-1} in *Gullazmach keble* and five to eight $cmol^{(+)}$ Kg^{-1} in *Gaffera keble* than that of the cultivated and the grazing lands, respectively (Tables 3 and 4). The distribution of exchangeable Ca tended to increase in the order of cultivated lands, grazing lands, backyard and forest lands, except in grazing land in *Gullazmach kebele* (Table 3). Exchangeable Ca content in both *kebeles* was medium for all land use types, except in the natural forest land use type which is high (Tables 3 and 4).

There was also significant ($p<0.01$) difference in exchangeable Mg concentration between the land use types in *Gullazmach keble* (Table 3). In all the land use systems exchangeable Mg was in the highest range (Tables 3 and 4). Although exchangeable Mg, K and Ca concentrations were high and medium, their availability may be limited due to the acidity of the soil.

The decreasing trend of exchangeable K, Ca and Mg concentration in the cultivated and grazing land use types could be due to the leaching effect due to intensive cultivation, crop residues removal and organic matter degradation. Moreover, soil erosion, overgrazing and crop harvest removal for the past decades contributed for the depletion of K, Ca and Mg in the cultivated and grazing lands. This is in agreement with the findings of different investigators who indicated that continuous cultivation and use of acid forming inorganic fertilizers depleted exchangeable Ca and Mg (Saikh *et al*., 1998; He *et al*., 1999; Aitken *et al*., 1999).

On the contrary there was no significant ($p<0.05$) difference in exchangeable Na in all the land use types in *Gaffera kebele* (Table 9). However, at *Gullazmach kebele* there was significant difference in exchangeable Na concentration between cultivated and grazing land. Exchangeable Na concentration was in low level in all the land use types of both *kebeles,* except in grazing land in *Gullazmach kebele* which was in medium level (Table 4). It could be concluded that intensive cultivation and overgrazing increased soil acidity and decreased basic cations concentration. On the other hand this study indicated that reforestation practices would help in decreasing soil acidity and increasing the concentration of exchangeable bases in the soil. In the backyards increased vegetation growth and yield of crops was observed which could be due to the contribution of organic matter maintenance in the soil to decreasing acidity levels and increasing the concentration of exchangeable bases. So to decrease soil acidity and increase exchangeable base it is advisable to apply compost, lime, organic wastes, and farmyard manure and practicing plantation of forests on the boarder of cultivated as well as grazing lands.

Soil organic matter, total nitrogen and soil acidity

There was highly significant ($p<0.01$) difference in total nitrogen and organic matter (OM) content between the natural forest and the other land use types (Table 4). The organic matter content of forest land use types was found to be four times than the cultivated land use types at *Gullazmach kebele*. However, there was no significant difference between the cultivated, grazing and backyard land use types in the same *kebele* (Table 4). Total nitrogen content followed the same pattern (Table 4). In *Gaffera kebele*, however, the highest OM content of 10.88% was recorded in the forest land followed by grazing land (Table 5). These values were significantly ($p<0.01$) different compared to the cultivated and backyard soils. Total nitrogen content of forest land was found to be 0.52% which is significantly ($p<0.01$) higher than all the other land use types (Table 5).

Table 4. Soil organic matter, total nitrogen, available phosphorous and available potassium contents of the soil under different land use types in *Gullazmach kebele* in 2008.

Land use	OM (%)		TN (%)		Available P		Available K	
	Conc.	Level	Conc.	Level	Conc.	Level	Conc.	Level
Cultivated	3.52^{B}	l	0.18^{B}	l	10.65^{B}	l	119.57^{B}	h
Grazing	4.70^{B}	l	0.33^{B}	m	5.75^{B}	l	147.12^{B}	h
Backyard	5.52^{B}	l	0.37^{AB}	m	28.87^{A}	l	482.39^{A}	h
Forest	14.73^{A}	m	0.60^{A}	h	13.94^{B}	l	246.10^{B}	h
CV (%)	20.56		33.1		24.85		23.76	

Means followed by the same letter are not significantly different at $P<0.05$. OM = Organic matter, TN = Total nitrogen, Conc. = Concentration, l = Low, m = Medium, h = High.

Organic matter content (OM) was low in all land use types at *Gullazmach kebele*, except forest land which has high OM content. While at *Gaffera keble* organic matter content was medium in grazing and backyard land use types and high in forest land use type. In both *kebeles*, total nitrogen concentration was high in the forest land use type and medium in the grazing and backyard land use types, but low in the cultivated land use types (Tables 4 and 5). Soil organic matter and total nitrogen contents have direct relation to soil acidity. This implies that in the study area intensive cultivation and total removal of crop residues had significantly depleted soil OM and total nitrogen that led to soil acidity problem. Continuous tillage operation without fallow and collection of crop residues for fuel consumption in the cultivated land may be responsible for the significantly lower organic matter and total nitrogen content. Tillage loosens the soil, improves its aeration, which hastens microbial break down of soil organic matter through respiration. It also increases decomposing of organic matter that may fasten soil acidity. It also increases susceptibility of the soil particles to detachment and removal by water during the erosion process (Roose and Barthes, 2001).

Table 5. Soil organic matter, total nitrogen, available phosphorous and available potassium contents of the soil under different land use types in *Gaffera kebele* in 2008.

Land use	OM (%)		TN (%)		Available P (ppm)		Available K (ppm)	
	Conc.	Level	Conc.	Level	Conc.	Level	Conc.	Level
Cultivated	1.42^{B}	l	0.15^{B}	l	6.61^{B}	l	161.39^{A}	h
Grazing	6.61^{AB}	m	0.30^{B}	m	6.27^{B}	l	206.87^{A}	h
Backyard	5.13^{B}	m	0.27^{B}	m	17.12^{A}	l	85.60^{B}	m
Forest	10.88^{A}	h	0.52^{A}	h	5.30^{B}	l	261.26^{A}	h
CV (%)	27.0		28.9		34.9		31.3	

Means followed by the same letter are not significantly different at P<0.05. OM = Organic matter, TN = Total nitrogen, Conc. = Concentration, l = Low, m = Medium, h = High.

The high concentration of organic matter and total nitrogen under the natural forest land could be attributed to accumulation of organic matter due to little soil disturbance as compared to the cultivated and grazing land and hence decreases soil acidity. Reduced erosion is expected to occur in natural forests, because the canopy formed by the trees, shrubs and under-storey vegetation shields the soil from the erosive energy of raindrops and thereby protecting the soil from splash erosion and surface or sheet erosion, this will again further reduce soil acidity through reducing leaching of basic cations. Water infiltration in the soil is enhanced by both preferential flow along trees roots and accumulation of absorbent humus on the soil surface, thereby significantly reducing the volume, velocity, and erosive and leaching capacity of surface runoff (Jiang *et al*., 1996). However, destructive free grazing practices in grazing land use types and continuous cultivation without fallow in cultivated land use types were responsible for poor physicochemical properties of the soil.

Therefore, poor organic matter and total nitrogen content might be due to poor nutrient management in cultivated land and over grazing in grazing land types. This finding was in agreement with Mullar - Harvey *et al*. (1985) who report that less biomass return results in less soil OM and total nitrogen content in the cultivated and grazing lands. Shariff *et al*. (1994) also reported that the most evident impact of grazing in the rangeland ecosystem is removal of the major part of above ground biomass by livestock. Therefore, the input of aboveground litter to the soil decreases. Any reduction in litter inputs may have important consequences for soil nutrient conservation and cycling.

According to Williams (2003), the OM content in all the land use types at both *kebles* was below optimum which is 11-20%, except the forest land use types. The OM content for the forest land use type was in the optimum range which was 14.73 and 10.88% for *Gullazmach* and *Gaffera kebles*, respectively. The other land use types had low OM content (1.1-6.61%) as compared to the OM content requirement of most crops. According to Williams (2003), the lower OM content category is 0-10%. High decomposition rate of OM aggravates acidification of the soil in cultivated land use types, but decomposition of OM was low in natural forest (Tables 4 and 5).

Available phosphorous, potassium and soil acidity

There was significantly ($p<0.01$ and $p<0.05$) higher variation between backyard and other land use systems in available P and K concentrations (Tables 4 and 5). Significantly ($p<0.01$ and $p<0.05$) higher available P was recorded in backyard land use at both *kebeles*. There was also variation in available P and K concentrations between the two *kebeles* (Tables 4 and 5). Available P concentration decreased in the order of backyard (28.87 ppm), natural forest (13. 94 ppm), cultivated (10.65 ppm), and grazing (5.75 ppm) in *Gullazmach kebele*. There was no significant difference in available P in the other land use types. The higher concentration of these nutrients in the backyard land use may be due to the deposition of organic wastes and farmyard manure and the carry over effects of continuous P fertilizer application. Availability of phosphorous and potassium may be affected due to soil acidity in cultiv

There was significant ($p<0.01$) variation in available K between the land use types (Tables 4 and 5). High available K concentration was observed in the backyard land use type in *Gullazmach Kebele,* but it was significantly lower in *Gaffera kebele* (Tables 4 and 5). The other land use types had statistically similar available K concentrations (Tables 4 and 5). Available K concentration for all the land use types was high, except for the backyard land use type in Gaffera kebele (Tables 4 and 5). This indicates that potassium nutrition is not a problem in that specific area.

Conclusion and recommendation

This study assessed soil acidity status in different land use systems. The results revealed that soils in all of the land use systems were generally acidic (pH<7) in the study area. Nearly all of the soil acidity indicators under the cultivated and grazing lands were very poor as compared to the other land use systems. This might be due to the continuous intensive cultivation, overgrazing, and removal of crop residue and cow dung.

Cultivated and grazing lands were also poor in macronutrients. This indicates that available nutrients might be depleted due to soil erosion, harvest of crops and crop residues and leaching which can be aggravated by repeated tillage without fallow. On the other hand, the high acidity in the cultivated and grazing land might affect the availability of these nutrients. Therefore, reducing intensive cultivation, integrated use of inorganic and organic fertilizers and lime application could replenish the degraded soil quality for sustainable agricultural production and productivity in the study area. Over grazing also causes chemical degradation of lands, therefore, controlled grazing or cut and carry system should be practiced to alleviate soil acidity problems in such land use systems.

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