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Research Paper

Assessment of Soil Acidity and Determination of Lime Requirement under Different Land Uses in Gumer District, Southern Ethiopia

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Abstract

The study was initiated to assess the level of soil acidity and lime requirement of four types of land uses (forest lands, grazing lands, cultivated lands, and Eucalyptus tree plantation) and in replications from 0-20 cm soil depth. Lime requirement was evaluated by exchangeable acidity and buffer solution methods. The data were analyzed by SAS software, version 9.1. The study revealed that soils of cultivated and Eucalyptus lands were very strongly acidic with mean of pH 4.8 and 5.0, whereas soils of grazing lands were strongly acidic with pH 5.5 and forest lands were moderately acidic with pH 5.7and 5.6 in both kebeles, respectively. Meaningfully higher pH, OM, TN, CEC, exchangeable Ca^{2+}, and Mg^{2+} were noted under forest lands as compared to the remaining land uses. However, meaningfully lower exchangeable acidity (EA) (1.06) and percentage acid saturation (PAS) (5.18) were obtained in the forest lands than in the other land uses. Significantly higher available P (2.54) was noted in the grazing land, followed by natural forest (1.77) land for Berchernamocheya kebele, and higher available P was recorded under forest (2.50), followed by grazing land (2.37) for Badnayegor kebele. Significantly higher exchangeable K^+ (1.29) and Na^+ (0.63) were observed in grazing land for Badnayegor and Berchernamocheya Kebeles, respectively. The results of the lime requirement revealed that using the SMP buffer solution method recorded 4.1-11.3 t/ha while using the exchangeable acidity method recorded 1.3-6.7 t/ha across the land uses for both kebeles. Based on lime requirement determination methods, the amount of lime required highly varies among the land uses. The investigation showed that soil acidification is a serious problem in the study areas. Thus, integrated land management needs to be practiced to overcome the problem of soil acidification and achieve sustainable agricultural production.

1. Introduction

Different land uses have various influences on soil deprivation on physicochemical properties (Alelgn et al., 2021). Assessment of soil quality indicators related to updated soil nutrient management practices is a suitable and primary indicator for sustainable agricultural land management (Agbede, 2010; Wang et al., 2010). Such an assessment is used to understand nutrient availability in soils. This knowledge can determine whether definite land uses are suitable for a given crop production system or not (Wang et al., 2010).

Soil acidification is one of the fundamental chemical soil degradation problems limiting crop production and productivity in various parts of Ethiopian highlands receiving high rainfall. The problem is also intensifying

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in scope in most other Ethiopian highlands, severely limiting crop production. For instance, in most barley, wheat, and faba bean growing areas of central and southern Ethiopian highlands, agriculturalists have shifted to the production of acid-tolerant crops such as oats rather than acid-sensitive crops (Wassie & Boke, 2009; Chimdi et al., 2012). Challenges of soil acidification are mainly related to acid soil forming exchangeable aluminum (Al3+) and exchangeable Hydrogen (H+) and low availability of exchangeable basic cations. In acidic soil areas, exchangeable bases are easily removed through leaching and crop harvest (Lenka et al., 2007; Ermias et al., 2016).

Most of the Ethiopian agricultural lands are affected by soil acidity and need appropriate amendment options including the application of liming material (Birhanu et al., 2014; Behera & Shukla, 2015; Bikila, 2019; Mesfin et al., 2020). Therefore, soil acidity is a serious concern calling for urgent consideration in most Ethiopian highlands because of its impact on crop yields and soil fertility (Chimdi et al., 2012; Chimdi, 2014; Kidanu & Chimdi, 2018). Even though soil acidity is recognized as an issue requiring urgent thoughtfulness in most Ethiopian highlands, there is very limited information about the impact of land uses on the level of acidity and the magnitude of lime required to neutralize soil acidity and other acidity-associated soil physicochemical properties in Gumer district. Hence, the current research was initiated with the specific objective of assessing the degree of soil acidification and the level of lime needed to reclaim acidification under three land uses.

2. Materials and Methods

2.1.Description of the study area

The current investigation was undertaken in the Gumer District of Gurage Zone, Southern Nations-Nationalities, and People's Regional State. The district is located 220 kilometers south of Addis Ababa on the main road to Jimma, and 65 kilometers from Wolkite, the capital of Gurage Zone (Figure 1). It is found at 7º8′4″- 8o00′6″ latitude North and 37º8′9″- 38º2′00″ longitudes East.

2.1.1. Topography and climate.

Topographically, the study district is composed of a flat plain (7%), and average slope (35%), and the extremely sloppy area covers 58% of the district. The altitude of the study site ranges from 2,600 to 3,170 masl and falls in the highland agro-climatic zone. According to Ethiopian Meteorological Agency, the average annual rainfall of the area is 1001- 1400 mm, with a bimodal rainfall pattern. The main rainy season ranges from June to September and the short rain period covers the months from February to April. The genuine rainy season ranges from June to the end of September. The mean maximum and minimum annual temperature of the study area varies between 17.5ºC and 10.1ºC, respectively (National meteorological agency, 2017).

2.1.2. Farming system and soil types

Agriculture is the main source of revenue in the Gumer District. The district comprises a largely diversified farming system that includes field crop production (which includes Enset, Eucalyptus tree, barley, bean, pea, and wheat as the main economic activities and livestock rearing (cattle, goat and sheep) as the second most important economic activity in the district. The major vegetables grown in the area are potato, cabbage, garlic, onion, endive, beetroot, carrot, and many more. The data obtained from FAO (1991) shows the soil type in the district is mainly Cambisols and Plinthosols.

2.1.3. Site selection and soil sampling technique

Purposive field surveillance and reconnaissance survey and selection techniques were undertaken before selecting the study site. Among the sixteen districts of Gurage Zone, Gumer District was purposively selected; this was because of susceptibility to land degradation and soil acidity in most of the highland areas of the district. The presence of representative land uses and topographical situation were the criteria used to identify the study site. Accordingly, cultivated land, eucalyptus plantation land, natural forest land, and grazing land were selected from Brchernamocheya and Badnayegor kebeles and considered for the study. A soil sample was collected from each land use with a random and uniform collection of representative soils. Replication of nearly 1 kg representative soil from the top surface (0-20 cm) of every land use was collected, dried, sieved, prepared, labeled, and transported for laboratory analysis. By doing so, 24 composite soil samples were collected from the selected land uses of the two Kebeles.

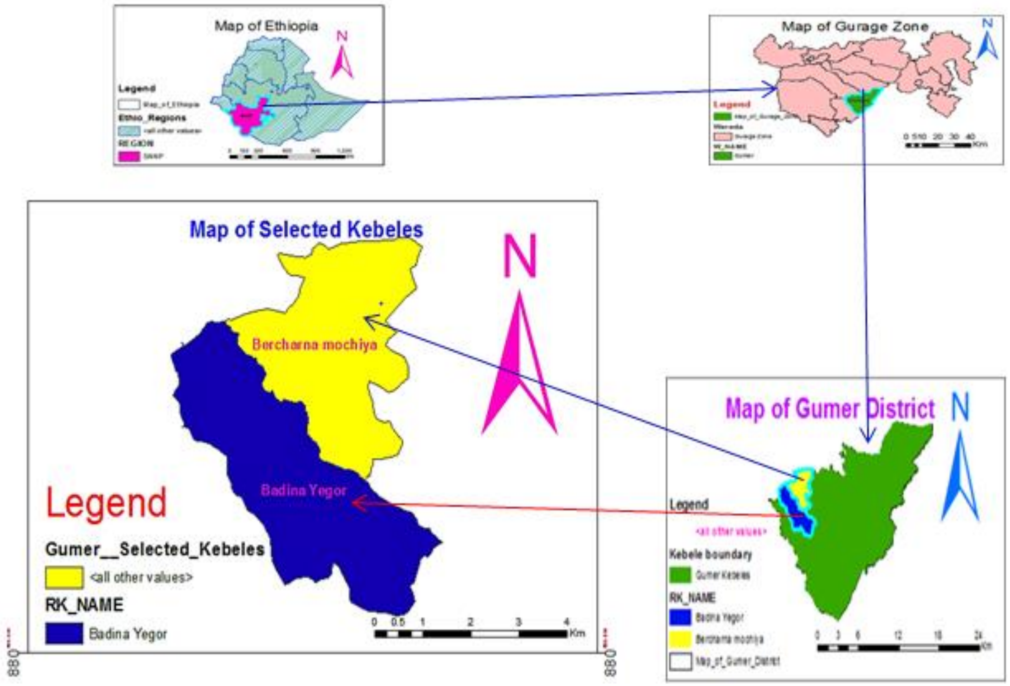

Figure 1: Location map of the study area

Additionally, for the determination of soil bulk density, undisturbed 24 soil samples were taken from each land use in replication using a core sampler. Conversely, soil samples were grounded to pass a 0.5-mm size sieve for analysis of total N and OC. A randomized complete block design was conducted with three replications.

2.2. Soil Laboratory Analysis

The analysis of soil samples was carried out at Wolkite Soil Laboratory Center using regular laboratory procedures and methods for the determination of lime requirement.

2.2.1. Evaluation of selected soil parameters

Soil texture was measured through the Bouyoucos hydrometer method, which can be written (Day (1965). Soil bulk density was determined using the core sampler method. An average value of soil particle density of 2.65g cm-3 was considered for the calculation of total soil porosity. Total porosity was estimated from bulk and particle densities as described by Brady and Weil (2016).

Soil pH was measured using a digital pH meter as a suspension of a 1:2.5 soil-water ratio (Van Reeuwijk, 2002). Cation exchange capacity (CEC) and exchangeable bases were extracted by 1M of NH4COCH3 at (pH 7) as described by Chapman (1965). The extracts of exchangeable Ca^{2+} and Mg^{2+} as well as Na^+ and K^+ were measured using atomic absorption spectrophotometer flame photometer, respectively (Chapman, 1965). The CEC was determined from the displaced NH_4^+ through distillation followed by titration. Exchangeable acid was determined by saturating the soil with 1N KCl solution and titrating it with NaOH as described by McLean (1965). A neutral 1N KCl solution was used to leach exchangeable H^+ and Al^{3+} ions from the soil. After the determination of Organic carbon, using wet digestion, soil organic matter was calculated from organic carbon (OM=1.724 * %OC)as described by Walkley & Black (1934). Soil Total N was measured using the Kjeldahl digestion procedure as designated by Jackson (1958). The available P was determined by using the Olsen method (Olsen et al., 1954). Soil percent base saturation (PBS) was calculated by taking the ratio of the sum of basic exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+) ions to CEC as a percentage. Effective CEC, PBS, and PAS were calculated as follows:

$$PBS = \frac{Ex.base(Ca + Mg + K + Na)ions}{CEC} * 100 \qquad (1)$$

$$ECEC = (Ex.bases(Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}) + Ex.A \qquad (2)$$

$$PAS = \frac{Ex.acidity}{ECEC} * 100 \qquad (3)$$

$$Ex.A = (\mathrm{EX.H^{+}} + \ \mathrm{Ex.Al^{3+}}) \qquad (4)$$

2.2.2. Methods used for lime requirement (LR) determination

The methods that were used for the lime requirement determination for this research were exchangeable acidity with the unbuffered neutral salt solution method and the SMP buffer solutions method. Shoemaker, McLean, and Pratt buffer for the lime requirement was employed using the buffer solutions method as developed by Shoemaker, McLean, and Pratt (SMP) buffer solution (Shoemaker et al., 1961). The SMP buffer method measures the change in pH of a buffer triggered by soil acidity and alteration in buffer pH is a quantity of lime requirement of soil. After determination of the prepared buffer pH, soil samples were determined by using SMP buffer solutions, at Wolkite Soil Testing Center, and the lime requirement was assessed by referring to a published table, linking buffer pH to aimed pH.

2.2.3. Extraction of exchange acidity method

Exchange acid is the total exchangeable H+ and Al3+ adsorbed on a soil exchange complex. The exchangeable acidity above pH 5.5 is very low or even absent since exchangeable acidity is present appreciably only at pH < 5.5. The soil exchangeable acidity was determined as designated by Shoemaker et al. (1961). The mathematical model developed by Kamprath (1984) was used to calculate LR determination.

$$LR, CaCO3\left(\frac{kg}{ha}\right) = \frac{\frac{cmolEA}{Kgsoil} * 0.2m * 1000m^{2} * BD\left(\frac{mg}{m^{3}}\right) * 100}{200} \qquad (5)$$

Where: EA = Exchangeable acidity and BD = Bulk density

2.2.4. Data Analysis:

Data generated from laboratory analysis were subjected to analysis of variance (ANOVA) using Statistical Analysis System (1999) version 9.1.

3. Results and Discussion

3.1.Soil Physical Properties

The analytical result showed that all soil textures changed highly significantly ($p < 0.01$) in Badnayegor and Berchernamocheya kebeles except the silt portion in Badnayegor *kebele*, which significantly ($p < 0.05$) varied between land uses (Table 1). In all land uses of Berchernamocheya *kebele*, a sand portion was high (52.33- 32.33%) tailed by a silt portion (39.33 - 24.67%) and a clay portion (28.83- 16.67%). However, in Badnayegor *kebele*, sand, silt, and clay fractions ranged from 55.67 - 41.0%, 36.33 to 26.0%, and 30.0% - 15.33% respectively, in all land uses (Table 1). Relatively, the sand fraction was the largest proportion in all land uses of the two *kebele*s.

The current finding is corroborated by the findings of Abbasi et al., (2007) and Tessema (2008). The authors state that the disparity of soil texture between land uses implies the effects of land uses on soil properties triggered by different utilization and management system of land uses (Abbasi et al., 2007; Tessema, 2008). In Berchernamocheya *kebele*, soil textural class of cultivation land (CL), EL, GL, and NF were loam, clay loam, sandy clay loam, and sandy loam, whereas in Badnayegor *kebele,* textural class of cultivation land (CL), EL, GL) and NF was sandy clay loam, clay loam, sandy loam and loam (Table 1). Changes in textural class among land uses resulted from amendment in management practices and pedogenic practices at the study area.

3.2.Soil bulk density and total porosity

The analysis of variance depicted that land uses significantly ($P < 0.01$) affected bulk density (BD) in both *kebele*s. Numerically, the highest BD was found under the grazing lands (1.41 g/cm^{3} and 1.44 g/cm^{3}) followed by cultivated lands (1.38 g/cm^{3} and 1.34 g/cm^{3}). However, the lowest value of BD (1.21g/ cm^{3} and 1.17 g/cm^{3}) was detected under NF followed by the soil under EL (1.28 g/cm^{3} and 1.18g/cm^{3}) for Berchernamocheya and Badnayegor *kebele*s, respectively.

Table1. Mean values of selected soil physical properties

Land uses	**Berchernamocheya kebele**					**Badnayegor kebele**				
	Percentage (%)					**Percentage(%)**				
	Sand	**Clay**	**Silt**	**Tx. C**		**Sand**	**Clay**	**Silt**	**Tx. C**	
CL	44.33^{a}	21.0^{b}	34.67^{ab}	L		46.33^{b}	28.33^{a}	25.33^{b}	SL	
EL	32.33^{b}	28.33^{a}	39.33^{a}	CL		41.0^{c}	30.0^{a}	29.0^{ab}	CL	
GL	47.0^{a}	28.33^{a}	24.67^{c}	SCL		55.67^{a}	18.33^{b}	26.0^{b}	SL	
NF	52.33^{a}	16.67^{c}	31.0^{cb}	SL		48.33^{b}	15.33^{b}	36.33^{a}	L	
LSD (0.05)	9.6	4.3	7.11			4.61	4.61	7.69		
CV%	11.59	9.72	11.64			5.12	10.65	13.99		
Land uses	**BD/gcm^3**	**TP (%)**				**BD/gcm^3**	**TP (%)**			
CL	1.38^{a}	48.05^{b}				1.34^{a}	49.56^{b}			
EL	1.28^{ab}	51.69^{a}				1.18^{b}	55.59^{a}			
GL	1.41^{a}	46.78^{b}				1.44^{a}	45.53^{b}			
NF	1.21^{b}	54.47^{a}				1.17^{b}	55.97^{a}			
LSD (0.05)	0.14	5.31				0.13	19.03			
CV%	4.08	4.04				5.51	5.15			
		cmol(+) kg^{-1}					**cmol(+) kg^{-1}**			
Land uses	**pH (H_2O)**	**EA**	**Ex. Al**	**Ex. H**	**PAS**	**pH (H_2O)**	**EA**	**Ex. Al**	**Ex. H**	**PAS**
CL	4.80^{b}	3.80^{ab}	2.82^{a}	0.98^{b}	45.96^{a}	5.0^{b}	3.4^{ab}	2.54^{b}	0.86^{a}	26.53^{a}
EL	4.87^{b}	5.25^{a}	3.29^{a}	1.96^{a}	34.19^{a}	4.93^{b}	4.91^{a}	3.91^{a}	0.99^{a}	37.45^{a}
GL	5.53^{a}	2.04^{cb}	1.06^{b}	0.88^{b}	9.69^{b}	5.53^{a}	2.27^{cb}	1.29^{bc}	0.97^{a}	11.09^{b}
NF	5.67^{a}	1.06^{c}	0.30^{b}	0.76^{b}	5.18^{b}	5.63^{a}	1.29^{c}	0.27^{c}	1.03^{a}	6.24^{b}
LSD (0.05)	0.27	1.96	1.58	0.73	12.73	0.27	1.52	1.35	0.77^{ns}	12.41
CV%	2.71	24.2	24.78	26.0	18.46	2.68	27.23	25.79	22.51	13.79
	Meq/100g soil					**Meq/100g soil**				
	Ca	**Mg**	**Na**	**K**		**Ca**	**Mg**	**Na**	**K**	
CL	3.33^{b}	0.69^{b}	0.25^{b}	0.23^{b}		7.67^{cb}	2.09^{b}	0.09^{b}	0.26^{c}	
EL	6.0^{b}	3.33^{b}	0.19^{b}	0.44^{b}		4.33^{c}	3.0^{b}	0.10^{b}	0.73^{b}	
GL	10.0^{a}	7.33^{a}	0.63^{a}	1.07^{a}		9.0^{ab}	7.67^{a}	0.43^{a}	1.29^{a}	
NF	11.0^{a}	7.33^{a}	0.36^{b}	0.99^{a}		12.33^{a}	6.0^{a}	0.32^{a}	0.74^{a}	
LSD (0.05)	3.92	3.01	0.26	0.52		3.77	2.54	0.17	0.32	
CV%	27.45	14.27	19.45	20.71		24.00	17.75	18.29	17.71	

N.B. *The mean values in the table that are followed by the same letter are not significantly different from each other at P < 0.05, GL= grazing land, CL= cultivation land, EL= Eucalyptus land, NF= Natural forest, CV= Coefficient of variation, LSD= least significant difference, EA= exchangeable acidity, Ex. Al= exchangeable Al, Ex. H= exchangeable H, PAS=Percentage acid saturation.*

The possible reason why the BD was higher in GL and CL as compared to NF and EL could be attributed to the compaction effect of livestock during free grazing, deforestation, and consequent tillage practices that might have resulted in worsening soil structure, which in turn leads to soil compaction (Muche et al., 2015). The lowest soil OM available in the cultivation land can also subsidize the highest BD. In addition to this, the current finding is in line with Wakene and Heluf (2003), who stated that the highest BD detected in unrestricted land was caused by soil compaction and deprivation of OM. According to ratings by Hazelton and Murphy (2007), soil BD is rated as very low (<1 g/cm^3), low (1-1.3 g/cm^3), medium (1.3-1.6 g/cm^3), high (1.6 -1.9 g/cm^3) and very high (>1.9 g/cm^3).

Table 2. Mean values of selected soil chemical properties.

Land uses	**Berchernamocheya *kebele***				**Badnayegor *kebele***			
	Meq/100g soil				**Meq/100g soil**			
	TEB	**ECEC**	**CEC**	**PBS**	**TEB**	**ECEC**	**CEC**	**PBS**
CL	4.51^{c}	8.31^{c}	24.28^{c}	18.57^{c}	10.12^{b}	13.52^{b}	28.07^{b}	36.22^{a}
EL	9.96^{b}	15.22^{b}	30.03^{b}	33.17^{b}	8.17^{b}	13.08^{b}	32.67^{b}	26.33^{a}
GL	19.03^{a}	21.08^{a}	30.13^{b}	63.16^{a}	18.39^{a}	20.66^{a}	42.07^{a}	43.71^{a}
NF	19.65^{a}	20.71^{a}	35.0^{a}	56.49^{a}	19.39^{a}	20.68^{a}	43.27^{a}	44.81^{a}
LSD (0.05)	2.87	2.67	3.67	10.39	4.09	4.17	7.90	23.08^{ns}
CV%	11.48	8.69	6.49	12.94	15.51	13.03	11.49	23.33

	(mg kg^{-1})	**cmol(+) kg^{-1}**				**(mgKg^{-1})**	**cmol(+) kg^{-1}**			
Land uses	**Av.P**	**OC**	**OM**	**TN**	**C: N**	**Av. P**	**OC**	**OM**	**TN**	**C: N**
CL	1.09^{c}	1.35^{c}	2.33^{c}	0.14^{b}	9.59^{ab}	1.36^{b}	1.40^{d}	2.42^{d}	0.20^{b}	7.19^{b}
EL	0.32^{d}	2.17^{b}	3.77^{b}	0.24^{b}	9.02^{ab}	0.63^{b}	2.47^{c}	4.27^{c}	0.21^{b}	11.56^{a}
GL	2.54^{a}	1.55^{c}	2.69^{c}	0.21^{b}	6.29^{b}	2.37^{a}	3.37^{b}	5.78^{b}	0.46^{a}	7.37^{b}
NF	1.77^{b}	5.93^{a}	10.2^{a}	0.51^{a}	11.71^{a}	2.50^{a}	5.47^{a}	9.40^{a}	0.50^{a}	10.9^{a}
LSD (0.05)	0.59	0.57	0.99	0.11	4.07	0.80	0.45	0.78	0.05	1.93
CV%	18.05	10.94	11.12	20.79	17.02	17.81	7.55	7.59	8.24	11.08

Land uses	**BpH**	**LRSMP t/ha**	**LREA t/ha**	**BpH**	**LRSMP t/ha**	**LREA t/ha**
CL	5.63^{a}	11.3^{a}	5.1^{ab}	5.73^{c}	10.2^{a}	4.55^{ab}
EL	5.80^{a}	9.7^{a}	6.7^{a}	5.80^{cb}	9.5^{ab}	5.72^{a}
GL	6.17^{a}	6.0^{a}	2.8^{cb}	6.10^{ab}	6.6^{cb}	3.29^{cb}
NF	6.33^{a}	4.7^{a}	1.3^{c}	6.40^{a}	4.1^{c}	1.5^{c}
LSD (0.05)	0.74	7.1	2.58	0.33	3.02	1.9
CV%	4.73	24.15	17.41	2.92	21.1	

N.B. *Means within a column followed by the same letter are not significantly different from each other at P < 0.05, BpH = Buffer pH, LRSMP= Lime requirement determination method as Shoemaker, McLean, and Pratt, LREA= Lime requirement determination method by extraction of exchange acidity, Av. P= Available P, OC= Organic carbon, OM= Organic Matter, TN= total N, PBS= percentage base saturation, CEC= Cation exchange capacity, TEB= total exchangeable bases, ECEC= effective cation exchange capacity, ns = non-significant.*

Soil total porosity (TP) is a signal of the degree of compaction in the soil. Analysis of variance reveals significant ($P < 0.01$) differences in TP among land uses for Badnayegor and Berchernamocheya *kebele*s. The highest TP (54.47% and 55.97%) was detected in natural forest land followed by EL (51.69 and 55.59 %). In contrast, the lowest mean values (46.78% and 45.53%) of TP were registered under grazing lands followed by CL (48.05% and 49.56%) for Berchernamocheya and Badnayegor *kebele*s, respectively (Table 1). Alterations in TP among land uses might be due to high soil OM and lowest BD of natural forest lands and low OM content and high compaction due to the flattening effect of livestock during unrestricted foraging in grazing land. Factors that affect BD have also a direct effect on TP.

The results of the current study are in agreement with Gebrelibanos and Mohammed (2013), who asserted that the high TP in the soil of natural forests is accredited to higher OM, as TP is affected by the level of soil OM and BD (Habtamu et al. 2014). According to the ranking of FAO (2006), soil TP (< 2%) was classified as very low,(5-10%) low, (10-15%) medium, (15-40%) high, and (> 40%) very high. Based on this rating, the TP of all land uses was found to be very high (> 40%). Higher TP implies better aggregation and provides good aeration for microorganisms and an opportunity for crop production.

3.3.Soil chemical parameters

Soil pH was highly significantly ($P < 0.01$) affected by land uses. Comparison of the mean pH value of cultivation and eucalyptus lands with grazing and natural forest lands indicates statistically significant differences in Berchernamocheya and Badnayegor *kebele*s. However, there were no significant differences between EL and CL as well as between GL and NF lands of the two *kebele*s (Table 1). Relatively the highest (5.67) and the lowest (4.8) pH were documented in the natural forest and CL of Berchernamocheya *kebele* respectively. On the other hand, relatively the highest (5.63) and the lowest (4.93) pH were verified under the natural forest and EL of Badnayegor *kebele* respectively (Table 1). Low pH in CL and EL could be due to high tillage frequency and high rates of annual rainfall that resulted in different forms of soil erosion, removal of plant residues after harvesting of plants, and leaching of basic cations. The current findings are consistent with previous findings that indicate soil pH was significantly lower in the soil of CL when compared to uncultivated soils (Malo et al., 2005). Consistent with the current study, Gebeyaw (2015) also observed a significant alteration in pH value among land uses and showed lower pH in the soil of cultivation land. According to Jones (2003), soil pH rated for Berchernamocheya *kebele*, mean pH for CL, EL, GL, and NF were respectively, 4.80, 4.87, 5.53, and 5.67 and the rating ranged from very strong acid for CL to moderate acid for NF. Similarly, for soil pH rating for Badnayegor *kebele*, the mean pH value for CL, EL, GL, and NF was respectively 5.0, 4.93, 5.53, and 5.63, and rating ranges from very strongly acidic for CL to moderate acidic soil for NF (Table 1).

3.4.Exchangeable acidity (EA) and Percent Acid saturation (PAS)

The analysis of variance revealed EA and PAS varied highly significantly ($P < 0.01$) through land uses in both *kebele*s. The mean EA values for CL, EL GL, and NF lands were (3.8, 5.25, 2.04, and 1.06 cmol(+) kg^{-1}), and (3.4, 4.91, 2.27, and 1.29 cmol (+) kg^{-1}) for Berchernamocheya and Badnayegor *kebele*s, respectively (Table 1). The highest EA value was attained from EL (5.25 cmol (+) kg^{-1}) and (4.91 cmol (+) kg^{-1}) and the lowest EA value was acquired from NF lands (1.06 cmol (+) kg^{-1}) and (1.29 cmol (+) kg^{-1}) for Berchernamocheya & Badnayegor *kebele*s, respectively (Table 1). The mean PAS values for cultivated land, EL, GL, and NF land were (45.96, 34.19, 9.69, and 5.18 cmol (+) kg^{-1}) and (26.53, 37.45, 11.09, and 6.24 cmol (+) kg^{-1}) for Berchernamocheya and Badnayegor *kebele*s respectively (Table 1). The highest PAS value was achieved from cultivation land the PAS (45.96 cmol (+) kg^{-1}) and the lowest (5.18 cmol (+) kg^{-1}) value was achieved from NF land of Berchernamocheya *kebele*. Likewise, the highest PAS attained from EL (37.45 cmol (+) kg^{-1}) and the lowest (6.24 cmol (+) kg^{-1}) PAS value was achieved from NF land of Badnayegor *kebele*.

3.5.Exchangeable bases

The analysis of variance depicted that mean values of exchangeable cations (Ca^{2+}, Mg^{2+}, $Na^{+,}$ and K^+) were highly significantly ($P < 0.01$) different across land uses for Badnayegor *kebele* while Ca^{2+} and Mg^{2+} and Na^+ and K^+ were highly significantly ($P < 0.01$ and $P < 0.05$ respectively) diverse for Berchernamocheya *kebele*. The highest mean values of exchangeable bases Ca^{2+} and Mg^{2+} (11.0 and 7.33) were recorded in the soil of NF land and Na^+ and K^+ (0.63 and 1.07) were recorded in the soil of GL. The lowest mean values of exchangeable bases Ca^{2+}, $Mg^{2+,}$ and K^+ (3.33, 0.69, and 0.23) were recorded in the soil of CL, and Na^+ (0.19) was recorded under eucalyptus land for Berchernamocheya *kebele*, respectively. Similarly, the highest mean values of exchangeable cations Ca^{2+} (12.33) in NF land and Mg^{2+}, $Na^{+,}$ and K^+ (7.67, 0.43, and 1.29) were registered under GL, whereas the lowest mean values of exchangeable cation Ca^{2+} (4.33) were registered under Eucalyptus land, and Mg^{2+}, Na, and K^+ (2.09, 0.09 and 0.26) were recorded under CL for Badnayegor *kebele* respectively (Table 1). The relatively high exchangeable (Ca^{2+} and Mg^{2+}) observed in soils of NF land might be due to the presence of relatively higher soil OM and low exposure to soil erosion under NF lands. However, lower exchangeable Ca^{2+} and Mg^{2+} were observed in soils of CL and EL soils, which resulted from lower pH and soil OM as well as due to continuous removal of Ca^{2+} and Mg^{2+} with crop harvest from topsoil. The present finding was in covenant with Aboytu (2019) who showed that soil acidification limits the availability of essential nutrients from the top soils. The impact of high soil acidification results in a deficiency of available Ca, P, and Mo and domination of soluble Al, Mn, and other acid-forming metallic ions (Getachew & Sommer, 2000).

3.6.Cation exchange capacity and percent base saturation

The analysis of variance revealed that soil CEC was highly significantly ($P < 0.01$) affected by land uses at the two kebeles. Accordingly, the highest (35.0 cmol (+) kg-1) CEC value was observed in NF soil, followed by GL (30.13), while the lowest (24.28) in CL soil, followed by EL (30.03) for Berchernamocheya kebele. The highest (43.27) CEC value was observed in NF land soil, followed by GL (42.07), whereas the lowest (28.07) was recorded in CL, followed by EL (32.67) for Badnayegor kebele (Table 2). A possible reason for the highest and lowest CEC in NF land and CL respectively might be due to high soil OM in FL land but low level of OM and high leaching of basic cations from cultivation land. This finding was in agreement with the findings of Bore & Bedadi (2015), who stated that the decline in soil properties is mainly due to the transformation of native forest and range land into cultivated land. According to Hazelton and Murphy (2007), the CEC of soils in CL was medium (24.28) & high (28.07) for Berchernamocheya and Badnayegor kebeles respectively; CEC in EL soil was high for both kebeles. High CEC was revealed in grazing land (30.03) and NF land (35.0) for Berchernamocheya, and very high CEC was confirmed in grazing land (42.07) & NF land (43.27) for Badnayegor kebeles (Table 2).

The value of PBS showed a highly significant ($p<0.01$) difference amongst land uses in Berchernamocheya kebele. However, it showed an insignificant ($p > 0.05$) difference among land uses in Badnayegor kebele. Likewise, numerical variations were observed among the four land uses. Relatively, the highest PBS (63.24%) was observed in grazing land, followed by NF land (56.49%), while the lowest PBS (18.57%) was recorded in CL, followed by EL (33.17%) in Berchernamocheya kebele. The reason for the high PBS content in grazing land in this kebele is probably due to the high total exchangeable bases (TEB) content noted in GL, while the low PBS documented in CL is probably due to the presence of a lower level of total exchangeable bases (TEB) observed in CL, low pH values and soil OM and removal of basic nutrients from topsoil by erosion and crop harvest for the Berchernamocheya kebele (Table 2). The findings of the current study agree with the findings of Jobira (2018) and Kedir (2015), who reported that the highest PBS (57.87%) was measured in GL soil, whereas the lowest (31.23%) was recorded in CL soil.

3.7.Soil organic matter, total N, C: N ratio and available P

The analysis of variance showed that soil OM was very highly significantly ($P < 0.001$) affected by land uses in both kebeles. The highest (10.2 %) and (9.40%) SOM were documented in the soil of NF land, while relatively lowest (2.33 %) and (2.42%) SOM were recorded in the soil of CL for Berchernamocheya and Badnayegor kebeles, respectively. The mean value of SOM increased from CL to GL, EL, and NF lands and from CL to EL, GL, and NF land at Berchernamocheya and Badnayegor kebeles, respectively (Table 2). The highest soil OM recorded in the NF land is due to the fall of plant biomass like leaves, barks, limbs, and other remaining plants and low exposure to soil. Conversely, the lower SOM of CL is probably due to the removal of SOM through oxidation, which is resulted from the mismanagement of cultivated land triggered by intensive cultivation and soil erosion, which then leads to the washout of soil OM. According to Tekalign et al., (1991), (< 0.86) OM is rated as very low, (0.86-2.59 %) low, (2.59-5.17%) medium/moderate, and > (5.17%) high. Based on this rating, the OM for CL, GL Eucalyptus plantation land, and NF land in Berchernamocheya kebele were 2.33%, 2.69%, 3.77%, and 10.2% respectively. The mean values of SOM for Badnayegor kebele were 2.42%, 4.27%, 5.78%, and 9.40% in CL, EP, GL, and NF land respectively. The result indicated that SOM was low under CL of both kebeles, medium under Eucalyptus and GL, and high under NF lands of both kebeles (Table 2).

The total N was very highly significantly ($P < 0.001$) affected by different land uses in both kebeles. The highest mean values (0.51% and 0.50%) of the TN were documented in NF lands, while the lowest (0.14% and 0.20%) were noted in CL of Berchernamocheya and Badnayegor kebeles respectively (Table 2). This might be due to comparatively high SOM content noted in natural FL and low SOM content in CL as well as due to land use change from natural FL to CL, which may trigger the decline of TN content. This result is congruent with the findings of (Dawit et al., 2002). Based on the rating suggested by Barber (1984), the TN content recorded in CL was low for both kebeles, medium in grazing and EL lands in Berchernamocheya kebele and eucalyptus land in Badnayegor kebele, and very high in NF lands at both kebeles (Table 2). The result of the C: N ratio showed significant (P<0.05) and highly significant (P<0.01) variations amongst land uses in Berchernamocheya and Badnayegor kebeles, respectively (Table 2). The highest (11.71) C: N was noted in NF land, followed by CL (9.59), while the relatively lowest (6.29) C: N was documented in GL, followed by EL (9.02) in Berchernamochya kebele. Similarly, the highest (11.56) C: N was documented in EL, followed by NF land (10.9), while the lowest (7.19) C: N was observed in CL, followed by GL (7.37) in Badnayegor kebele (Table 2). Low input of SOC, removal of crop residues from CL, and overgrazing are probably the reasons for a low level of C: N in CL and GL, whereas higher C: N is probably due to higher contents of soil OC and high plant biomass in natural FL. Similarly, previous findings also stated that narrow C: N at the surface soils of CL is probably due to higher microbial activity in the surface 0-20 cm soil layer (Chimdi, 2014). Based on the ratings by Hazelton and Murphy (2007), we have found out that except for natural FL, which was low C: N, for all the remaining land, uses, the C: N was rated as very low at grazing and CL in Berchernamocheya kebele, low at the EP land and natural FL in Badnayegor kebele (Table 2).

Available P was highly significantly (P<0.01) affected by land uses in both kebeles. Relatively, the soil under grazing land was documented with the highest available P (2.54 mg/kg), followed by NF land and CL (1.77 and 1.09mg/kg) respectively; the lowest (0.32mg/kg) was noted in EL in Berchernamocheya kebele. On the other hand, the highest available P was noted (2.50 mg/ kg) in NF land, followed by grazing and CL (2.37 and 1.36 mg/kg) respectively, and the lowest (0.63 mg/kg) was registered in EL in Badnayegor kebele. This result agrees with the finding of Tessema (2008), who reported that low available P in acid soils is due to the inherently high P fixing capacity of the soil. As rated by Barber (1984), the available P was qualifying very low in all land uses in both kebeles; however, it is numerically better in soils of NF land and GL of both kebeles (Table 2).

3.8.Lime requirement(LR) determination with the SMP buffer solution method

The amount of lime required by using the buffer solution method of lime requirement determination (LR_SMP) of the experimental soil was highly significantly (P < 0.01) affected by land uses at Badnayegor *kebele*; however, it is insignificantly affected by land uses at Berchernamocheya *kebele* (Table 2). Accordingly, the highest (10.2 t/ha) value of LR was noted in CL soil, followed by EP land (9.5 t/ha), while the lowest (4.1 t/ha) was documented in NF land soil, followed by GL (6.6 t/ha) at Badnayegor *kebele*. A possible reason for the highest quantity of LR verified in CL and EL is probably due to lower OM content, low pH values, relative existence of substantial quantity of Al and H ions, and low level of basic nutrients. However, a lower quantity of LR was documented in NF and GL soil is probably due to relatively higher OM content, high pH (above 5.5), and high quantity of basic nutrients. The quantity of lime requirement determined by using buffer solution method of lime requirement determination SMP methods to change the current pH value of soils to targeted pH 6.5 was in line with the finding, CL and GL required 14.0 - 15.90 ton/ha of lime to change the soil from 5.13-6.5 by SMP buffer solution method (Birhanu, 2008).

3.9.Lime requirement determination with exchangeable acidity method

The mean values of LR evaluated using the extraction of exchange acidity method were highly significantly (P < 0.01) affected by different land uses in both *kebeles*. The study revealed the highest (6.7 and 5.72) t/ha mean value of LR in EL soil, followed by CL (5.1 and 4.55) t/ha, and the lowest (1.3 and 1.5) t/ha in NF land, followed by GL (2.8 and 3.29) t/ha in Berchernamocheya and Badnayegor *kebeles*, respectively (Table 2). A possible reason for the difference in LR among land uses is probably due to high

OM, high pH values, and lower amount of exchangeable acidic cation (Al^+ and H^+). Low acid saturation was recorded in NF land and GL in the study area requires a relatively low quantity of lime. However, soils under CL and EL require a high quantity of lime probably due to low OM content, lower pH values, a relatively higher quantity of acidic cation (Al^+ and H^+), and high acid saturation. This means that when the soils contain a substantial value of acidic cations, a higher quantity of lime is required to reclaim soil acidity (Desalegn et al., 2017).

3.10. Comparison of lime requirement determination methods

Of the two lime requirement determination methods stated above, lime requirement determination by using the buffer solution method (LR_SMP) was exaggerated (4.1 t/ha to 11.3 t/ha) across the land uses. However, in lime requirement by using the extraction of exchangeable acidity method, the quantity of lime required ranged from 1.3 t/ha to 6.7 t/ha across land uses for the study area. The quantity of lime required by using the extraction of exchangeable acidity method was very low for NF lands (1.3 t, 1.5 t) and GL (2.8 t, 3.29 t) as compared to the amount of lime required by using the buffer solution method, where the quantity of lime required for NF lands (4.7 t, 4.1 t) and grazing lands (6.0 t, 6.6 t) was very high for Berchernamocheya and Badnayegor *kebeles* respectively. Similarly, the quantity of lime required by using the extraction of exchangeable acidity method was very low for CL (5.1 t, 4.55 t) and EL (6.7 t, 5.72 t) as compared to the quantity of lime required by using the buffer solution method for CL (11.3 t, 10.2 t) and EL (9.7 t, 9.5 t), which was very high for Berchernamocheya and Badnayegor *kebeles* respectively (Table 2). Although lime requirement can be determined both through SMP buffer and exchangeable acidity methods, a more suitable method should be identified by validating it under field conditions.

4. Conclusion

The assessment of soil acidity in four land uses showed that very low soil pH (4.8 and 4.87), (5.0 and 4.93); and higher acid saturation (45.96% and 34.2%), (26.53 and 37.45) were recorded in CL and EL for Berchernamocheya and Badnayegor *kebeles*, respectively. The findings of the study also indicated overall variation and loss of soil fertility in CL and EL as compared to NF land and GL. Accordingly, CL and EL soils were also poor in macronutrient contents and fell below TEB (from 4.51 to 13.52), CEC (from 24.28 to 32.67), and PBS (from18.57% to 33.17%). However, relatively higher soil pH (>5.5) and lower acid saturation (from 5.1% to 11.09%) in NF land and GL soils indicated its suitability for better available nutrients. The TEB ranged from (19.03 to 19.65); CEC from (30.13 to 43.27) and PBS from (43.71% to 63.16%) were recorded in the soil of NF land and GL. Based on the evaluation of lime requirement under the four land uses, we have observed that the quantity of lime required varies greatly among land uses. This variation is probably due to low pH values in CL and EL soils, which require a higher quantity of lime than adjacent NF land and GL. Finally, this soil acidity and reduction of basic cations lead to the intensification of risks to agricultural productivity. Immediate and integrated land management interventions are required to overcome soil acidity, improve soil productivity, and achieve viable agricultural crop production. . Application of agricultural lime and organic fertilizers is considered a dominant measure for such acidified cultivated land. Finally, we recommended that further studies are needed on lime recommendation rates in the study area based on locational field experiments.

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