Effect of different land use systems and soil depths on soil chemical properties alteration in Yerer forests and its surrounding area, at the central highland of Ethiopia

Yadesa Bato (yadesabato2020@gmail.com)
Ambo University
Tamrat Bekele
Addis Ababa University College of Natural Sciences
Sebsebe Demissew
Addis Ababa University College of Natural Sciences

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Abstract

Background Different land-use systems have different potentials to change soil chemical properties either positively or negatively. Hence, scientifically information on the soil chemical properties dynamics under different land-use systems is crucial for best land management practices, and to avoiding ecological negative impacts of it for sustainable development. The study aimed to evaluate the effect of different land-use systems and soil depths on selected soil chemical properties in Yerer forest and its surrounding area, central Ethiopia. The land-use systems included natural forest, four exotic tree plantation species (Eucalyptus globules, Cupressus lusitanica, Grevillea robusta, and Pinus patuala), grassland, grazing land, and agricultural cropland .

Results The analysis of variance (ANOVA) for the majority of soil chemical properties of OC, TN, Avial. P, soil pH, EC, CEC, and exchangeable bases (Ca, Mg, K, Na) were showed that significant variations among land-use systems ($P<0.0001$). The highest mean values of OC (3.487% DM), TN (0.313% DM), Avail.P (31.515 mg/kg of soil), CEC (33.634 meq/100gm soil), Exch. Ca (17.126 cmol(+)/kg soil), Exch. Mg (5.369 cmol(+)/kg soil), and Exch. K (3.597 cmol(+)/kg soil) were observed under natural forest than others of land-use systems. The results also showed that the lowest mean values of OC (1.472% DM), TN (0.130%DM), soil pH (5.377), CEC (18.983 meq/100gm soil), Exch. Ca (9.931 cmol(+)/kg soil), Exch. K (1.197 cmol(+)/kg soil), and Exch. Na (0.206 cmol(+)/kg soil) were recorded under agricultural cropland than other land-use systems. The highest mean values of EC (3.474ds/m), and Exch. Na (0.604 cmol(+)/kg soil) were observed under Eucalyptus globules plantation forest. The overall mean values of OC, TN, Avail.P, CEC, Exch. Mg, Exch. Ca, Exch. K, and Exch. Na accumulation at the topsoil layer was higher than that of the subsoil layer except for soil pH and EC.

Conclusion In general, the majority of soil chemical properties under agricultural cropland and Eucalyptus globules plantation forest were poorer than the soils subjected to other land-use systems which indicated that changes in land use system were significantly affected soil chemical properties.

1. Background

Land use defined as the human activities, arrangements, and inputs that apply to the use of land such as industrial zones, residential zones, and agricultural fields, while, land cover is the biophysical conditions that cover on the ground surface, like crops, forest, and grassland (Di Gregorio and Jansen 1998, FAO 2000). The land-use change is the main component of environmental change in every region that alters biodiversity, soil properties, and water resources interims of quality and quantity and these in combine which affects the ecosystem functions and climate (Foley et al. 2005, Newbold et al. 2015). The world's forests contribute to essential ecosystem services such as carbon uptake; maintain high biodiversity, improved soil properties and water quality (Hansen et al. 2013; Riebeek, 2011). The loss of forest cover and biodiversity due to anthropogenic activities is a growing concern in many parts of the world (Singh et al. 1997; Hegde and Enters 2000). Even though deforestation, forest degradation, and forest fragmentation are a global phenomenon, but they are severe in the tropical region. Approximately half of the tropical closed-canopy forest has been removed and the land converted to other land-uses (Wright, 2005). Plantation forests have been a significant element of land-use change. The world-wide relatively the annual expansion rate of plantation forest area is predicted to be approximately 2% (FAO, 2005; van Dijk & Keenan, 2007). The reasons for the expansion rate of plantation forest area can result from the demand of the world's increasing population for domestic and industrial wood products (Berthrong et al., 2009).

Across sub-Saharan Africa countries, natural resources remain central to rural people's livelihoods (Roe et al. 2009). Due to the cause of anthropogenic force can exert pressure on the natural resources, thereby influencing spatial and temporal scale changes on landscape resources (Roe et. al. 2009). Land-use change is rapid in developing countries due to biophysical and socio-economic reasons. Ethiopia has lost the majority of natural forest resources, especially during the 20th century. On the other hand, reforestation and afforestation programs have helped to reverse the decline of the natural forest resource cover and its results of a shortage of wood products, fuelwood, charcoal, construction materials, and soil degradation (Lalisa et. al. 2009). At the same time, afforestation and reforestation programs have led to increasing forest area coverage in some regions and reducing the national net forest loss by lowering human pressure on natural forests. The expansion of plantation land use type with different species has significantly contributed to an increase in total forest plantation coverage area from an estimated 190,000 ha in 1990 to approximately 972,000 ha in 2010 (Jaleta, 2016). Reforestation in primary and secondary forest lands accounts for about half of the total increased area of plantations (FAO 2005). Plantation forests have the potential to alter the biogeochemical cycles of the ecosystem as a consequence of changes in tree species composition when compared with other adjacent natural forests (Aborisade & Aweto, 1990; Wall & Hytönen, 2005; Freier et al., 2010).

Land-use change is due to the removal of forests and conversion of grasslands to arable land use. The changes in forests to grazing land and agriculture lands are one of the most concerns in environmental degradation and climate change (Wali et. al. 1999). In general, the conversion of natural forest and grassland to grazing land and agricultural system leads to depletion of soil organic matter pools (Lal 1997, Benbi et al 2003). Land use strongly influences soil properties and unsuitable practices lead to the degradation of soil and environmental quality. Hence, understanding land-use history is essential to realize the magnitude and trend of changes in soil properties (Kettle et.al. 2000). Changes in land use type and soil management can have influenced many soil physical and chemical properties (Lalisa, et.al. 2010, Tellen et.al. 2018). Bekele et al. (2006) showed that afforestation of farmland with exotic trees increased total N, exchangeable K^+, and exchangeable Ca^{2+} in surface soils.

Yerer Mountain forest is one of the protected dry montane forests in central Ethiopia. Rapid population growth requires additional farmlands for food crop production by converting forests and pasture lands to the cropland to address their basic needs. In the study area, on one hand, forest and pasture areas have decreased significantly, while cultivated cropland areas have increased with intensively continuous cultivation, and on the other hand, plantation forests establishment have intensively expanded in large-scale from year to year in both reforestation and afforestation programs with fast-growing and short rotation of exotic species by governmental sector and local communities. Though, the change of land-use systems may cause significant changes in soil chemical properties in the study area. Changes in land use systems significantly alter the soil's physical, chemical and biological composition and qualities (Mulugeta et al. 2004, Bekele et al. 2006; Fantaw et al. 2008, Lalisa, et.al. 2010, Tellen et.al. 2018). However, different scholars or researchers were reported to contradict ideas on the impact of exotic tree species plantation on environmental change particularly on soil chemical properties change as increases (positive), decreases (negative), or negligible (neutral) effect.

To understand the effect of human activities on the soil environment by land-use system change is fundamental to understanding global change and sustainable development. However, information on the effect of land-use systems on soil properties in the Yerer Mountain forest and its surrounding area is still too scanty to recommend the optimal sustainable management and utilization of land resources for the future in the area. With this background, the present study was taken up to evaluate the effect of different land-use systems and soil depth on soil chemical properties change, and to provide additional current scientifically information to build literature surrounding the effect of land-use systems on soils, particularly debate on the effect of exotic tree plantation species, thereby, based on the quantified evaluation results the study to recommend the positive effects would be accentuated or appreciated but the negative effects would be avoided or mitigated. The study aimed to examine the dynamics of soil chemical properties under different land-use systems and soil depths in Yerer forest and its surrounding area of central highland Ethiopia.

2. Results

2.1. Effect of land-use systems on soil chemical properties

2.1.1. Soil Organic C, Total N, C: N ratio and Available P

Soil Organic Carbon (%OC)

The analysis of variance for organic carbon concentration of the soil revealed a significant difference horizontally as a function of land-use systems ($p <$ 0001). The overall mean value of the organic carbon concentration under the eight different land-use systems (natural forest, four different exotic tree species plantation forest, grassland, grazing land, and cropland) was varied between 1.472 to 3.487%. Among the land-use systems (LUS) the highest concentration of organic carbon was observed in the natural forest, whereas in contrary the lowest concentration of organic carbon was observed in agricultural cropland (Table 1, and Fig. 2).

Table 1
Least Significant Mean values of soil chemical properties of different land-use systems

Land-use systems	OC (%DM)	Total N (%DM)	C:N ratio	Avail. P (mg/kg of soil)	PH-H_2O (1:2.5)	EC (ds/m)	CEC (meq/ 100 gm)
Natural forest	3.487^{a}	0.313^{a}	11.382^{a}	31.515^{a}	6.200^{ba}	1.783^{c}	33.634^{a}
Eucalyptus globules	2.029^{c}	0.173^{ed}	11.865^{a}	3.119^{e}	5.480^{d}	3.474^{a}	25.780^{cb}
Cupressus lusitanica	2.287^{cb}	0.197 ^{cd}	11.749^{a}	2.449^{e}	5.414^{d}	2.335^{cb}	21.258^{ed}
Grevillea robusta	3.135^{a}	0.261^{b}	12.030^{a}	5.823^{ed}	5.704^{dc}	2.416^{b}	23.237 ^{cd}
Pinus patuala	2.504^{cb}	0.216^{cbd}	12.076^{a}	20.319^{b}	5.986^{bc}	2.354^{b}	29.227^{b}
Grassland	2.579^{b}	0.226^{cb}	11.859^{a}	14.875^{cb}	6.486^{a}	1.966^{cb}	28.967^{b}
Grazing land	2.159^{cb}	0.184 ^{cd}	11.944^{a}	11.892 ^{cd}	5.996^{bac}	1.878^{cb}	27.455^{b}
Agricultural Crop land	1.472^{d}	0.130^{e}	11.482^{a}	6.516^{ed}	5.377^{d}	3.072^{a}	18.983^{e}
LSD	0.5397	0.0496	1.4198	8.3053	0.4913	0.57	3.4954
CV	24.6116	26.1264	13.482	77.1264	9.43996	26.4991	15.02171
St.dev.	0.93582	0.08746	1.8358	13.4652	0.64089	0.84437	6.00528
SIGN	0.0001***	0.0001***	ns	0.0001***	0.0001***	0.0001***	0.0001***

Figure-2. The mean values of soil OC, TN, and avail. P under different land-use systems (LUS)

Total nitrogen (%TN)

Statistically, the total nitrogen content of the soil showed a significant variation as a function of land-use systems ($p < 0.0001$). The overall mean value of the total nitrogen levels in all different land-use systems (natural forest, four different exotic tree species plantation forests, grassland, grazing land, and cropland) varied between 0.13 to 0.216% ranges. Among the land-use systems, the maximum and minimum mean values of total nitrogen percent were recorded in natural forest and agricultural cropland in order of 0.313% and 0.130%, respectively (Table 1, and Fig. 2).

Carbon to Nitrogen(C: N) ratio

The C: N ratio shall determine by dividing the value of organic carbon to the total nitrogen corresponding to each soil sampling depths. The overall ANOVA analysis result revealed that there was a non-significant ($p < 0.05$) influenced by any land-use systems and soil depth variations. The overall mean value of the

C: N ratio under eight different land-use systems (natural forest, four different exotic tree species plantation forest, grassland, grazing land, and cropland) were felled between 11.382 to 12.076 ranges (Table 1).

Available phosphorus

The main natural source of phosphate in many soils is from the breakdown of organic matter. The analysis of variance for available phosphorus revealed that there were very highly significant differences ($P < 0.0001$) among treatments of land-use systems. The overall available phosphorus concentration level under different land-use systems (natural forest, four different exotic tree species plantation forests, grassland, grazing land, and cropland) was observed in the range between 2.449 to 31.515 mg/kg of soil. Among the land-use systems (LUS), the maximum and minimum available phosphorus concentration were recorded in natural forest and Cupressus lusitanica plantation forest, respectively (Table 1, and Fig. 2).

Table 1. Least Significant Mean values of selected soil chemical properties of different land-use systems

2.1.2. Soil pH, EC (ds/m), and CEC

Soil pH /Soil reaction

Soil reaction or soil pH is one of the soil chemical properties that used to measure the acidity or alkalinity of a soil which ranges from 0 very acid to 14 very alkaline. The analysis of variance for soil pH revealed that a significant difference as a function of land-use systems ($p < 0.0001$), but no significant variation in between vertical gradients of soil depth at ($p < 0.05$). The overall mean value of pH in the soil under the different land-use systems (natural forest, four different exotic tree species plantation forests, grassland, grazing land, and cropland) were observed in the range between5.377 to 6.486. Among the land-use systems (LUS), the maximum and minimum pH in soil was recorded in grassland, and agricultural cropland, respectively (Table 1, and Fig. 2).

Soil electrical conductivity (EC)

Soil electrical conductivity (EC) is a measure of the number of salts in soil (salinity of soil). The statistical analysis for soil electrical conductivity revealed a significant variation laterally as a function of land-use systems ($P < 0.0001$). The overall mean values of soil electrical conductivity (EC) distribution under different land-use systems were varied in the range of 1.783 to 3.474 ds/m. Among all land-use systems, the maximum and minimum mean values of soil electrical conductivity (EC) concentration were observed in Eucalyptus globules plantation forest, and natural forest, respectively (Table 1, and Fig. 3).

Figure-3. The mean values of soil pH, EC, and CEC under different land-use systems (LUS)

Cation-Exchange Capacity (CEC)

The analysis of variance (ANOVA) for cation exchange capacity (CEC) was revealed that a significant variation among land-use systems ($P < 0.0001$). The overall mean values of Cation-exchange capacity (CEC) distribution under different land-use systems were varied in the range of 18.983 to 33.634 meq/ 100 gm soil. Among all land-use systems, the maximum and minimum mean values of soil Cation-exchange capacity (CEC) concentration were observed in natural forest(33.634), and agricultural cropland (18.983), respectively (Table 1, and Fig. 3).

2.1.3. Soil Exchangeable bases (Na, K, Ca, Mg), and Percent Base saturation (PBS)

Exchangeable cations (Na, K, Ca, Mg)

The common exchangeable base cations are K^+, Ca^{+2}, Mg^{+2}, and Na^+ which held in the soil by organic matter and clay. The analysis of Variance (ANOVA) made for exchangeable cations of Na, K, Ca, and Mg were revealed that significant variations, laterally among land-use systems for the concentration of Na ($P < 0.0001$), K ($P < 0.0001$), Ca ($P < 0.0001$), and Mg ($P < 0.0001$). The concentrations of exchangeable cations were generally in the orders of Ca > Mg > > K > Na in all soil samples of different land-use systems (natural forest, four different exotic tree species plantation forest, grassland, grazing land, and agricultural cropland) were observed. The overall mean values of distribution of exchangeable Ca in the study area were found in the orders of natural forest > grassland > Pinus patuala > grazing land > Grevillea robusta > Cupressus lusitanica > Eucalyptus globules > agricultural cropland, with numerical values of 17.126, 16.028, 14.931, 13.356, 12.557, 11.594, 11.245, and 9.931, respectively. Among all land-use systems, the higher concentration of exchangeable cations of Ca, Mg, and K was observed in the natural forest. The higher concentration of exchangeable cations of Na^+ was recorded in Eucalyptus globules plantation forest (Table 2, and Fig. 4).

Table 2
Least Significant Mean values of soil chemical properties of different land-use systems

Land-use systems	**Exch. Na (cmol(+)/kg soil)**	**Exch. K (cmol(+)/kg soil)**	**Exch. Ca (cmol(+)/kg soil)**	**Exch. Mg (cmol(+)/kg soil)**	**BS (%)**
Natural forest	0.394^{b}	3.597^{a}	17.126^{a}	5.369^{a}	77.939^{ba}
Eucalyptus globules	0.604^{a}	1.965^{b}	11.245^{dc}	3.578^{b}	70.912^{b}
Cupressus lusitanica	0.270^{cd}	2.460^{b}	11.594^{dc}	2.912^{b}	80.830^{a}
Grevillea robusta	0.344^{cb}	2.192^{b}	12.557^{bc}	3.513^{b}	79.775^{ba}
Pinus patuala	0.302^{c}	2.454^{b}	14.931^{ba}	4.754^{a}	76.351^{ba}
Grassland	0.286^{c}	1.988^{b}	16.028^{a}	3.422^{b}	73.323^{ba}
Grazing land	0.325^{cb}	2.571^{b}	13.356^{bc}	3.210^{b}	74.528^{ba}
Agricultural Crop land	0.206^{d}	1.197^{c}	9.931^{d}	3.469^{b}	77.796^{ba}
LSD	0.0748	0.6533	2.5335	0.9762	9.9159
CV	24.5341	31.7769	21.2664	28.943	14.534
St.dev.	0.14922	1.19929	4.16678	1.3721	13.222
Sign	0.0001^{***}	0.0001^{***}	0.0001^{***}	0.0001^{***}	ns

Figure-4. The mean values of soil exchangeable bases (Na, K, Ca, Mg) under different land-use systems

The distribution of exchangeable cations of Mg in Eucalyptus globules, Grevillea robusta, agricultural cropland, grassland, grazing land, and Cupressus lusitanica in the order of 3.578, 3.513, 3.469, 3.422, 3.210, and 2.912, respectively, without significant difference among them statistical. However, the concentration level of exchangeable Mg under natural forest (5.369), and Pinus patuala (4.754) were significantly different from the other land-use systems.

Table 2. Least Significant Mean values of selected soil chemical properties of different land-use systems

The distributions of exchangeable cations of K in the study land-use systems were observed: grazing land > Pinus patuala > Cupressus lusitanica > Grevillea robusta > grassland > Eucalyptus globules plantation forest > agricultural cropland, which numerical values of 2.571, 2.460, 2.454, 2.192, 1.988, 1.965, and 1.197, respectively, without significant difference among them statistical. However, the concentration level of exchangeable K under natural forest was significantly differenced from the other land-use systems.

Percent base saturation (PBS)

Percent base saturation (PBS) is determined by dividing total exchangeable bases (Ca, Mg, K, and Na) to the CEC of the soil and multiplies by 100. The analysis of variance (ANOVA) for percent base saturation revealed a non-significant difference with horizontal as a function of land-use systems, (at $p < 0.05$). In the study area, the mean values of Percent base saturation (PBS) in all land-use systems (LUS) were recorded more than 70%. Among all land-use systems (LUS) the minimum and maximum Percent base saturation (PBS) were observed in Eucalyptus globules (70.912%), and Cupressus lusitanica (80.830%) plantation forests, respectively (Appendix Table 2).

2.2. Effect of soil depth on soil chemical properties

The analysis of variance revealed that the soil OC, Total N, Avail. P, soil pH, CEC, Exch. Ca, Exch. Mg, Exch. Na, Exch. K and BS% were significantly affected by soil depth. Statistically, the analysis of variance for organic carbon concentration, available phosphorus, Exch. Na, Exch. K, Exch. Ca, and BS% were revealed that significant variations vertically as a function of soil depths ($P < 0.0001$). The overall mean values of OC, Total N, Avail. P, Exch. Na, Exch. K, Exch. Ca, and BS% concentration under all different land-use systems (natural forest, Eucalyptus globules, Cupressus lusitanica, Grevillea robusta, and Pinus patuala, grassland, grazing land, and cultivated cropland) across vertical gradients at top layer were higher than the subsoil layer depth (Table 3, and Appendix Table 3).

Table 3

Least Significant Mean values of soil chemical properties under different land-use systems and soil depths

Soil Depth	OC (%DM)	Total N (%DM)	C:N ratio	Avail. P (mg/kg of soil)	pH-H_2O (1:2.5)	EC (ds/m)	CEC (meq/ 100 gm)	Exch. Na (cmol(+)/kg soil)	Exch. K (cmol(+)/kg soil)	Exch. Ca (cmol(+)/kg soil)	Exch. Mg (cmol(+)/kg soil)
Top Soil layer (0–20 cm)	2.891	0.252	11.637	16.171	5.802	2.224	27.312	0.3925	2.755	14.735	4.194
Sub-Soil layer (20–40 cm)	2.023	0.173	11.96	7.956	5.859	2.595	24.824	0.29025	1.852	11.958	3.363
Sign.	0.0001***	0.0001***	ns	0.0001***	ns	0.0115*	0.0059**	0.0001***	0.0001***	0.0001***	0.0012**
Keys: *, **, ***, and ns = significant at P < 0.05, high significant at P < 0.01, very high significant at P < 0.001, and nonsignificant at P > 0.05, respectively.											

The statistical analysis of variance (ANOVA) for soil electrical conductivity (EC), Cation exchange capacity (CEC), and exchangeable Mg (Exch. Mg) were revealed that significant variations between soil depths (P < 0.05). The overall mean value of soil Cation exchange capacity (CEC), and exchangeable Mg (Exch. Mg) concentration under land-use systems at the topsoil layer were higher than the subsoil layer. However, the analysis of variance for soil pH and C: N ratio was revealed that the nonsignificance variations in between vertical gradients of soil depth at (p < 0.05). The overall mean value of soil pH, electrical conductivity (EC), and C: N ratio concentrations under land-use systems at the top layer were lower than the subsoil layer. In all land-use systems, the level of soil pH, electrical conductivity (EC), and C: N ratio trend between topsoil (0–20 cm) and subsoil (0–40 cm) layers were not uniformly distributed in the area (Table 3, and Appendix Table 3).

Table 3. Least Significant Mean values of selected soil chemical properties of different land-use systems Vs soil depth-wise

3. Discussion

3.1. Effect of land-use systems on soil chemical properties

3.1.1. Soil Organic C, Total N, C: N ratio and Available P

Organic carbon (OC) enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. Organic matter has an important influence on soil chemical properties, soil fertility status, plant nutrition and biological activity in the soil (Brady and Weil, 2002). The organic carbon concentration levels were observed in the order of: natural forest > G. robusta > grassland > P. patuala > C. lusitanica > grazing land > E. globules > agricultural cropland. The overall maximum mean value of the organic carbon concentration was observed beneath the natural forest (3.487%DM), and Grevillea robusta plantation forest (3.135%DM) statistical without significant differences between them, but significant difference from the rest six land-use systems. This probably due to the higher accumulation of soil organic matters (SOM) by adding litters to soils from different heterogeneity plant species with the high rate of biomass production, and better carbon nutrient release or mineralize to the soils through decomposition. Similar results have been reported by Michelsen et. al. (1996), Mulugeta et. al. (2004), Bekele et. al. (2006) that the higher soil organic carbon concentrations observed in the natural forest than different exotic tree plantation forests in different regions of Ethiopia.

Among the land-use systems in the study area, the minimum value of organic carbon concentration was observed in agricultural cropland (1.472%DM) and followed by Eucalyptus globules plantation forest (2.029%DM). The difference could be attributed due to the addition of lower organic matter to the soil via litter inputs and fractions of litter types by losses of organic matter through harvesting of woody and crops biomass from sites, continuous cultivation that aggravates organic matter oxidation lead to losing carbon from the soil in CO_2 form. The results were in agreement with the findings of Wakene (2001), Dhaliwal and Singh (2003), Mulugeta et. al. (2004), Lalisa et.al. (2010), Mulugeta (2014), Wasihun et. al. (2015), and Tellen et.al. (2018) whose reported less organic carbon in the cultivated land and Eucalyptus plantation forest soils than others land-use systems.

The total nitrogen concentration levels distribution trend horizontal as a function of land-use systems were registered in the order of natural forest > G. robusta > grassland > P. patuala > C. lusitanica > grazing land > E. globules > agricultural cropland. The highest mean value of total nitrogen content was observed in natural forest (0.313%DM) and followed by Grevillea robusta plantation forest (0.261%DM), statistically with significant differences between them. This may be attributed to the long–term accumulation of above and below-ground organic matter inputs from litterfall, root turn over mineralization by actions of soil microbes, and N fixation by symbiotic in leguminous plant species diversity in natural forest and other soil microorganisms. This argument is supported by the significant strong positive correlation (r = 0.947) between the total nitrogen and organic carbon. Similar studies were also reported as the higher total nitrogen content was observed in the natural forest than other land-use systems in different areas (Michelsen et. al. 1996, Mulugeta et. al. 2004, Bekele et. al. 2006, Mulugeta 2014, Tellen et.al. 2018). On the contrary, the lowest mean value of total nitrogen content was observed in agricultural cropland (0.130%DM) and followed by Eucalyptus globules plantation forest (0.173%DM), statistical without significant differences between them. The reasons for the lower total nitrogen contents may be attributed due to the loss of nitrogen either to the atmosphere by evaporation or leached down through the soil by water. Because there is no real store of available nitrates in the soil as nitrates are released from organic matter breakdown or fertilizers unless they are used by plants. Similar studies reported that lower total nitrogen concentrations were observed under agricultural cropland, and Eucalyptus plantation forest than the other land-use systems in different regions of Ethiopia (Michelsen et. al. 1996, Mulugeta et. al. 2004, Lalisa et.al. 2010).

The overall mean value of the C: N ratio in all land-use systems were statistically not significant differences between them. The C/N ratio was significantly narrowed from 11.382 in the natural forest soils to 12.076 in the Pinus patuala plantation forest soils. The lowest value of the C: N ratio was observed in the natural forest. This may be attributed by the factor of increase nitrogen nutrient inputs with a high rate of nitrogen fixation by different leguminous plant species diversity having a relatively higher protein and nutrient contents in the natural forest that leads to the lower C: N ratio, due to their fast decomposition rate and release of nitrogen to the soil. Faster decomposition of leaf litter enhances the transfer of fresh carbon to mineral soil (Polglase et al., 2000). Similarly, different workers have been reported the lower C: N ratio under different native plant species diversity (Abebe, 1997; Tadesse 2000, and Yadesa, et.al. 2010). The highest value of the C: N ratio (12.076) was observed in Pinus patuala plantation forest. This may be attributed due to lower nitrogen content in the litters of organic matters which results in a higher C: N ratio, and slow decomposition rate. Plant residue with a low C/N ratio (high nitrogen content) decompose more quickly than plant residue with a high C/N ratio (high carbon content) and do not increase soil organic matter accumulation levels as quickly (Janssen 1996, Bengtsson et al. 2003; Springob and Kirchmann 2003).

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. In the study area the concentration of available phosphorus levels were found in the order of natural forest > P. patuala > grassland > grazing land > agricultural cropland > G. robusta > E. globules > C. lusitanica land-use systems. The available phosphorus concentration mean values were ranged between 2.449 and 31.515 mg/kg of soil. The overall available phosphorus concentration in natural forest (31.515 mg/kg of soil) was found to be higher than other land-use systems. This might be attributed due to a combination of low nutrient demand by natural forest woody plants as compared with different exotic trees species plantation forests, and better phosphorus nutrient release or mineralize to the soils by different heterogeneity plant species diversity during organic matters decomposition. This argument is supported by the analyzed simple linear correlation relationships between available phosphorus was positively correlated with the soil organic carbon ($r = 0.547$). This result is in agreement with the findings of Michelsen et. al. (1996), Nsabimana, et.al. (2008), Mulugeta (2014) whose observe the higher concentration of available phosphorus in the natural forest than others land-use systems. The lower mean values of available phosphorus concentration were recorded in Cupressus lusitanica (2.449), and Eucalyptus globules (3.119) plantation forests statistical without significant differences between them. This may be attributed due to fast-growing tree plantations species were associated with a more intense uptake of nutrients from the soil than slow-growing forest species, and the loss of organic matters by rotational harvesting and took away from the site. Michelsen et al. (1993); and Lisanework & Michelsen (1994) were noted that phosphorus (P) concentration limiting plant growth and leaf litter decomposition under C. lusitanica and E. globulus plantations in Ethiopian.

3.1.2. Soil pH, EC (ds/m), and CEC

The present study results showed that soil pH significantly varied with land-use systems. The overall mean value of soil pH level distribution in different land-use systems was observed in the order of grassland > natural forest > grazing land > P. patuala > G. robusta > E. globules > C. lusitanica > agricultural cropland. Among the land-use systems, the maximum mean value of pH (6.486) was observed in grassland and followed by natural forest (6.200) without significant difference between them. This might be attributable to the higher litter deposition from the aboveground and below ground which gone under decomposition by the action of micro-organisms and subsequent mineralize to releases basic cations to the soil in both land-use systems. This argument is agrees with the simple positive correlation relationships between soil pH with soil organic carbon ($r = 0.4322$), cation exchange capacity (CEC) ($r = 0.6494$), exchangeable cations of Ca($r = 0.5918$), Mg($r = 0.26062$), and K($r = 0.3253$) in the soils. Similar studies results were reported by Michelsen et al. (1993), Michelsen et. al. (1996), and Nsabimana et al., (2008), for soils of higher pH level under natural forest than others land-use systems. Similarly, the higher soil pH under grassland than other land-use systems was reported by Kaur and Toor (2012).

The lower mean values of soil pH were recorded in agricultural cropland, Cupressus lusitanica plantation, and Eucalyptus globules plantation forests in the orders of 5.377, 5.414, and 5.480, respectively, statistical without significant differences between them. The main reasons for the lowest value of soil pH in the agricultural cropland probably due to poorly managed cultivation; use of chemical fertilizers including urea, DAP, and potash, inappropriate use of ammonium-based fertilizers, intensive use of herbicides such as roundup which contain high amounts of cations that helps to neutralize the negative charges i.e. a higher concentration of H^+ (lower pH) will neutralize the negative charge in soils, and soil erosion. Balesdent et al (2000) and Tejada and Gonzalez (2009) have found that cultivation on farmlands led to the soil acidity increase. Other researchers have also observed the lower soil pH in cultivated farmland than other land-use systems (Nega and Heluf 2013, Tellen, et.al. 2018). Similarly, the decrease in soil pH under the Cupressus lusitanica, and Eucalyptus globules plantation forest could be due to the fast-growing exotic plantation forest was acidify the soil in nature by accumulating basic cations in the forest biomass, increasing production of organic acids from decomposing litter and by increasing cation leaching. The fast-growing exotic tree species forest that consumes high water for biomass production may increase solute concentrations and the mineralization of organic sulfur in the soil which leads to decrease soil pH. Similar studies were also reported that a decline in soil pH under the fast-growing exotic trees plantation forests (Jobbágy and Jackson, 2003; Mishra et al., 2003, Sanchez et al., 2003, Nsabimana et al. 2008, Tegenu et. al. 2008, and Tellen, et.al., 2018).

In the present finding, the mean values of electrical conductivity (EC) of soil were found numerical between 1.783 and 3.474 deciSiemen per meter (dS/m) ranges. According to the current finding the mean value of electrical conductivity (EC) of soil levels across land-use systems was found in the order of E. globules > agricultural cropland > G. robusta > P. patuala > C. lusitanica > grassland > grazing land > natural forest. The maximum mean value of electrical conductivity (EC) was observed in Eucalyptus globules plantation forest (3.474) and followed by agricultural cropland (3.072) without significant differences between them. For the higher value of EC under Eucalyptus globules plantation forest may be attributed due to the lower soil moisture content that related with soluble salts accumulate in the upper soils rather than leached down, high evaporation rate due to open canopy and low infiltration rate in combine resulting to dissolved salts are left behind to accumulate in the soils, salts originate from the disintegration (weathering) of minerals and rocks, soils with an accumulation of exchangeable sodium are often characterized by poor tilth and low permeability making high EC. This argument is supported by the positive correlation between the electrical conductivity (EC) and exchangeable sodium, Na (r = 0.202), and negatively correlated with organic carbon (r = -0.466). This result is in agreement with the findings of Michelsen et al. (1996). However, for the high level of EC in agricultural cropland probably due to tillage intensity and land management practice, cropping system and nature, salt accumulation from commercial fertilizers, chemical contamination (from herbicide, insecticide and fungicide use by farmers), erosion, runoff, animal manures (usually high tunnels), and compost were contributed to raise EC. Similar studies were reported that higher values of EC in agricultural cropland soils than others of land-use systems (Dhaliwal and Singh 2003, Gol Ceyhun, 2009, Kaur and Toor, 2012).

The minimum mean value of electrical conductivity was observed in the natural forest (1.783) than the other land-use systems. The lower level of EC under natural forest probably attributed due to the higher accumulation of organic matters (litter deposition) that decomposed and release higher exchangeable cations (K, Ca, Mg) to the soils, which lead to reducing the salinity level and lowering the values of electric conductivity in the soils. This explanation is supported with the negative correlation between electrical conductivity and exchangeable cations K(r= -0.400), Ca(r = -0.532), Mg(r = -0.173), and organic carbon (r = -0.466). This finding is in agreement with similar study report by Michelsen et al. (1996), and Gol Ceyhun, (2009) who had reported that the lower mean value of electrical conductivity under natural forest than other land-use systems.

The mean values of CEC in the study area were found between 18.983 and 33.634 meq/100 gm of soil ranges. The overall mean value of soil CEC level distribution in different land-use systems was recorded in the order of natural forest > P. patuala > grassland > grazing land > E. globules > G. robusta > C. lusitanica > agricultural cropland. Among the land-use systems the highest concentration of cation exchange capacity (CEC) was registered in natural forest (33.634). This probably influenced by the high amount of organic matter accumulation, and high soil pH in the natural forest soils that lead to higher CEC. This means the CEC of soils is affected mainly by the amount and degree of decomposition of the organic matter. In general, the higher soil organic matter (SOM) is resulting the higher the CEC. Because most of the CEC is originates from the amount of SOM decomposition rate that entirely pH-dependent. This argument is supported by a significant positive correlation between the soils CEC and OC (r = 0. 644), and pH (r = 0.649). The CEC is positively correlated with pH; therefore, acid soils have a lower potential of CEC. The present result is agreement with the findings of Michelsen et al. (1996), Dhaliwal and Singh (2003), Mulugeta et al. (2004), Nsabimana et al. 2008, Habtamu et.al. (2008), and Tellen and Yerima (2018) were observed the highest cation exchange capacity (CEC) values in natural forest than others of land-use systems in different areas.

The lowest concentration value of cation exchange capacity (CEC) was observed in agricultural cropland (18.983) and followed by Cupressus lusitanica plantation forest (21.258), Grevillea robusta plantation forest (23.237), and Eucalyptus globules plantation forest (25.780). The occurrence variation may be attributed due to the low additions of organic matters or litters deposition in the agricultural cropland which results in low libration of exchange cation nutrients (Ca, Mg, Na, K) to the soil by decomposition. Similar to the present findings, other researchers were reported the lower values of CEC in mechanized farming (MF) by Mulugeta et al. (2004), Selassie et al. (2015), and Molla and Yalew (2018).

3.1.3. Soil Exchangeable bases (Na, K, Ca, Mg), and Base saturation percent

The main ions associated with CEC in soils are the exchangeable cations calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) are generally referred to as the base cations (Rayment and Higginson 1992). As the function of land-use systems, the concentration of exchangeable cations was generally in the order of Ca > Mg > > K > Na in all different land-use systems. These agree with the principle stated as the energy of the adsorption sequence of: Ca > Mg > K > Na. The highest concentration of exchangeable cations of Ca, Mg, and K, were observed in the natural forest in the order of 17.126, 5.369, and 3.597 cmol(+)/kg soil, respectively. These probably attributed due to the higher accumulation of soil organic matters (SOM) by adding of woody plant litters and understory herbaceous plant residues to soils from different heterogeneity plant species with the high rate of biomass production and those undergone decompositions, thereby, liberate cations nutrients of Ca, Mg, and K to the soils. These results are in agreement with the findings of Michelsen et.al. (1993), and Tellen, et.al. (2018). Similarly, Nsabimana et al. (2008) were observed the higher concentration of exchangeable cations of Ca, and Mg under Mixed native species (MNS) forest than other exotic tree species plantation forests in southern Rwanda.

Additional reasons for the higher concentration of exchangeable cations of Ca, Mg, and K, in the natural forest, maybe due to reduced losses of cations nutrients from the soil by leaching out withholding positively charged ions (cations) by electrostatic force, reduced runoff and soil erosion via upper surface cover approach with litters, and low cations nutrients demand by natural forest trees species might contribute to the higher of cations nutrients under natural forest. These explanations are supported with the positive correlation between the organic carbon and exchangeable cations in the soils K(r = 0.576), Ca(r = 0.677) and Mg(r = 0.426). The present findings were agreed with Molla and Yalew (2018) and Kokeb et. al. (2015). In general, a similar observation was reported by Michelsen et. al. (1996) concerned with the higher cations nutrients under natural forest than other exotic tree species plantation forests in the highland of Ethiopia.

The highest concentration of Na was observed in Eucalyptus globules plantation forest (0.604 cmol(+)/kg soil) than the other land-use systems. The overall mean values of the distribution of exchangeable Na in the study area were found in the orders of Eucalyptus globules > natural forest > Grevillea robusta > grazing land > Pinus patuala > grassland > Cupressus lusitanica > agricultural cropland. For the highest concentration of the exchangeable Na + in Eucalyptus globules plantation forest may be due to the effects of high soil compaction that result with high bulk density, and lower soil moisture content could be facilitated to the soluble salts accumulate in the upper soils rather than leached down. Additionally, the accumulation of exchangeable sodium salts is probably originated from the disintegration (weathering) of minerals and rocks. Similar observations were reported by Michelsen et. al. (1993), Michelsen et. al. (1996) that the higher exchangeable sodium under Cupressus lusitanica, Eucalyptus globules, Eucalyptus grandis, and Eucalyptus saligna plantation forests in the highland of Ethiopia.

The lowest concentration of exchangeable cations of Na, K, and Ca, were recorded in agricultural cropland in the order of 0.206, 1.197, and 9.931 cmol(+)/kg soil, respectively. However, the minimum mean value of exchangeable Mg was recorded in Cupressus lusitanica plantation forest (2.912 cmol(+)/kg soil). This could be due to the low addition of organic matters from external factors and the removal of crop residuals from the cropland by harvesting maybe contribute to lower addition of the cations nutrients of Na, K, and Ca to soils. Another explanation for the lowest concentration of exchangeable Na, K, and Ca in agricultural cropland probably due to continuous intensive tillage and cropping systems were facilitate to lower bulk density, lower CEC, higher porosity, and higher infiltration rate in soils could lead simply these cations nutrients of Na, K, and Ca were leached out down to the soil depth by water. In a similar way, Lalisa et. al. (2010), and Molla and Yalew (2018) were observed that the highest concentration of exchangeable Ca in cereal farmland than other land-use systems.

Among the land-use systems, the highest mean value of percent base saturation (80.830) was observed in Cupressus lusitanica plantation forest. This probably due to the amount and nature of clay particles contents and low concentration of CEC, and low pH level in soils could be contributed to the existence of higher percent base saturation (PBS) under Cupressus lusitanica plantation forest than others land-use systems. Because of the amount and type of clay minerals are responsible factors for CEC in that both clay and colloidal organic matters (COM). This argument is supported by a significant negative correlation between the soils PBS and CEC (r = -0.300) and between PBS and pH (r = -0.050). Similarly, Fassil and Charles (2009) were suggested that clay and colloidal organic matters are negatively charged and can act as anions; as a result, these two materials have the ability to absorb and hold positively charged ions (cations). These findings are in agreement with a similar study report by Nsabimana, et.al. (2008), who had reported the higher percent base saturation (93.7%) under Cupressus lusitanica plantation forest among others plantation forests in southern Rwanda.

The lowest mean value of percent base saturation (70.912) was recorded in Eucalyptus globules plantation forest. This probably due to the lower addition of organic matters that undergone decomposition and liberate low cations nutrients of Na, K, Ca, and Mg to soils that lead to lower percent base saturation under Eucalyptus globules plantation forest than the others land-use systems. This explanation is supported by the positive correlation between percent base saturation and organic carbon (r = 0.262). The percent base saturation (%BS) levels were distributed in similar values without significant difference among the LUS of Grevillea robusta plantation, agricultural cropland, Pinus patuala plantation, grazing land, grassland in the order of 79.775, 77.796, 7.351, 74.528, and 73.323, respectively. The variation of the percent base saturation (PBS) means values among different land-use systems may be due to the variation of amount, and nature of organic matters addition, and degree of decomposition to release cation nutrients to soils. Similar observations were reported by Mulugeta et. al. (2004), Nsabimana, et.al. (2008), and Lalisa et.al., (2010), who reported different percent base saturation (%BS) levels under different land-use systems.

3.2. Effect of soil depth on soil chemical properties

Concerning to vertical gradient of soil depth the higher mean values of organic carbon (2.891%DM), total nitrogen (0.252%DM), available phosphorus (16.171 mg/kg of soil) concentration were recorded in the upper part of the soil layer at 0-20cm depth than in the lower subsoil layer at 20-40cm depth. The organic carbon, total nitrogen, and available phosphorus concentration levels distribution trend across soil depths were decreased gradually from the topsoil layer to the subsoil layer in all land-use systems. This explanation may be due to the higher organic matter inputs to the topsoil layer from plant litters, crop residues, commercial fertilizers, and animal waste materials than the subsoil layer. This is in agreement with previous studies (Michelsen et. al. 1993, 1996, Abebe, 1997; Tadesse 2000; Mulugeta et. al., 2004, Yadesa et.al., 2010, Kaur and Toor, 2012, Sugihara 2014).

The study results indicated that the lower overall mean values of the C: N ratio (11.637), pH (5.802), and electrical conductivity (EC) (2.224) were observed at topsoil layers than that of the subsoil layers. For the higher value of C: N ratio levels at topsoil is probably due to the highly decomposed organic matter releases higher N- levels on the topsoil than the subsoil layers, thereby, the lowering C: N ratio occurred at topsoil layer. Similar to this finding, Abebe (1997) and Tadesse (2000) also found a lower C/N ratio at the topsoil than in the subsoil layers under different native woody plant species diversity on farmland. The higher values of EC at topsoil are probably due to the addition and accumulation of organic matters at the topsoil surface than subsoil surface that liberates exchangeable cations, thereby, reducing soil EC at the subsoil layer. On the other hand, the pH levels distribution trend in soil was increased gradually from topsoil to subsoil layers in Eucalyptus globules plantation, Cupressus lusitanica plantation, Pinus patuala plantation forest, grazing land, and agricultural cropland of land-use systems in the study area. The result of the higher value of soil pH at subsoil than topsoil layers probably due to the leaching of more soluble soil minerals and basic cations from topsoil to subsoil layer. Similarly, Michelsen et al. (1996) and Mulugeta & Olsson, (2008) was reported that the increment of pH values from topsoil to subsoil layers in Eucalyptus globules and, Pinus patuala plantation forest land-use systems in the Ethiopian Highlands.

With regarding a vertical gradient of soil depth the overall higher mean value of exchangeable cations of Na, K, Ca, Mg, and percent base saturation (%BS) concentrations were observed at the topsoil layers than the subsoil layer with significance difference. The distribution of exchangeable cations of Na, K, Ca, Mg, and percent base saturation (%BS) concentration were decreased vertical from the topsoil layer to the subsoil layer in all land-use systems. These probably due to the effect of higher organic matters depositions or accumulation from litters of woody, herbaceous residuals, animal manures, and crops residuals on farmlands that undergone decomposition and mineralized cations nutrients of Na, K, Ca, and Mg to soils then CEC play the roles to retain the released cations at topsoil from the decomposed organic matter rather than translocating them to the subsoil layer. Cations, such as K^+, Na^+, and Ca^{2+}, can be adsorbed onto soil or organic colloids, making the cations available for plant uptake by preventing cation leaching from the system (Brady and Weil 2007). Similar studies results have been reported by Michelsen et. al., (1996), Mulugeta et al. (2004), Mulugeta and Olsson (2008) that the majority of exchangeable cations nutrient concentrations were declined as soil depth increase, except exchangeable Na in some land-use systems in different areas.

4. Conclusion

Yerer Mountain natural forest is one of the remnants protected forests among the designated protected forests in Ethiopia for environmental protection purposes. The natural forest losses occur continuously, on the other hand, the extent of exotic tree plantation forest in monoculture form in reforestation and afforestation programs has increased in the study area by private, enterprises, and governmental sectors for multiple purposes. The historical changes in land-use systems, land-use intensity, and land management practices by the human intervention have altered the characteristics of soil chemical properties across the horizontal as a function of land-use systems, and vertical layers as a function of soil depth. Under similar environmental conditions, the different land-use systems have a strong significant effect on soil chemical properties either positively or negatively.

The present study results were showed that different land-use systems and soil depth have different potential in their influence on soil chemical properties dynamics. Among the different land-use systems, natural forest land was showed a positive effect on most soil chemical properties. In soil chemical properties, the results revealed that the highest mean values of OC, TN, Avail. P, CEC, Exch. Ca, Exch. Mg and Exch. K was observed under natural forest than others of land-use systems in the area. On the other hand, the lowest mean value of soil EC properties was registered under natural forest than other land-use systems. The study results showed that the lowest mean values of OC, TN, soil pH, CEC, and exchangeable bases (Na, K, and Ca) were recorded under agricultural cropland than other land-use systems. Among the five forest land-use systems the lowest mean values of soil OC, TN, Avail. P and BS% were recorded under Eucalyptus globules plantation forest. However, the highest mean values of EC and Exch. Na was observed under Eucalyptus globules plantation forest than other land-use systems. In general, the majority of soil chemical properties under Eucalyptus globules plantation forest were poorer than the soils subjected to other forest land-use systems. The majority of soil chemical properties were significantly differenced as a function of vertical gradients (soil depth) factor. As a function of soil depth factor, the highest concentration of OC, TN, Avail.P, CEC, Exchangeable bases (Na, K, Ca and Mg), and BS% were observed at topsoil layer than subsoil layer. However, the highest concentration/ amount of soil pH and EC were recorded at the subsoil layer in the area.

Under similar climatic conditions, among exotic tree plantation forests, Eucalyptus globulus plantations forest has a more negative influence on soil chemical properties, which means the majority of soil chemical properties under Eucalyptus globules plantation were poorer than the soils subjected to other land-use systems. The governmental bodies and land-users should be given attention to consider the future positive soils chemical properties change when allocating the land-use to specific land-use systems.

5. Materials And Methods

5.1. Description of the study area

A field study was conducted in the central highland of Ethiopia, Oromia Regional State, Yerer forests and its surrounding area. Yerer forest is one of the remaining mountain montane evergreen natural forest and plantation forests with different exotic tree species which administrated by Oromia Forest and Wildlife Enterprise (OFWE) in the eastern central highland of Ethiopia. The study area is located geographically between 8°52’00”- 8°55’00” N latitude and 38°59’30” – 38°95’15” E longitude, with the altitudinal range between 2000 and 3100 m.a.s.l. The 31 years meteorological data(1988–2019) showed that the mean annual rainfall of the study area is 907.33 mm which characterized by a unimodal rainfall having long dry season (6–8 months), and the mean annual minimum and maximum temperatures were recorded 11.1 ^{0}C, and 29.5^{0}C, respectively National Meteorology Service Agency (2019). The farmers in the central highland of Ethiopia area are practicing “mixed” farming systems (i.e. both crop and livestock production activities).

Figure: 1. Yerer Forest and its surrounding area study site map

Land-use systems

In the Yerer forest and its surrounding area, the major land-use systems are a natural forest, exotic tree plantation species forests, grassland, grazing land, and agricultural cropland. The land-use change started from 1991 and in the past two half decades in the central highlands of Ethiopia, pasture, and forest areas have decreased significantly, while arable cropland has increased proportionally due to the rapid population growth requires additional farmlands for food crop production. In the present study context definition: Natural forest is the forest land that composed primarily of the indigenous (native) tree, shrubs, lianas, climbers, and other herbaceous plant species, which may include both closed forest and open forest. Exotic tree plantation species is described as the forest stands established artificially by non-native tree or shrub species in reforestation and afforestation program for industrial and non-industrial purposes. Grassland is an area where characterized as vegetation land dominated by the nearly continuous cover of grasses (Poaceae) family rather than large shrubs or trees species. Grazing land – is a land covered with grass or herbage and suitable for grazing or feeding by livestock or herbivore. Agricultural cropland is a land covered with temporary crops production both in single or multiple cropping systems, followed by harvest and leave a bare soil period. Recently, plantation activities were carried out by different exotic and native tree species in, and surround the Yerer forest area. The major plantations of exotic tree species are Eucalyptus globulus, Cuppressus lustanica, Eucalyptus camandulensis, Eucalyptus saligna, Pinus patula, and Grevillea robusta; however, the native tree species include Juniperus procera, Hagenia abyssinica, Podocarpus falcatus, Olea europaea subsp.cusp, and Cordia Africana. Yerer Mountain natural forest is consists of a mixed deciduous native forest and established plantation forests, and covers an area of 3254 ha of this 1793 ha is plantation forest, and 1461 ha is covered by natural forest and others.

5.2. Sampling Design

For the present study, eight (8) different land-use systems (LUSs) were selected, namely: natural forest, four exotic tree plantation species (Eucalyptus globules, Cupressus lusitanica, Grevillea robusta, and Pinus patuala), grassland, grazing land, and cultivated cropland. In this study, the eight land-use systems were considered as treatments and the quadrat sample plots in each land-use system were considered as a replication. The systematic sampling design was used to determine the soil chemical properties with transect lines laid in each land-use systems (LUS). Three transect lines were delineated and laid parallel to each other along the altitudinal gradient in each land-use system separately for soil sample collection by using the 50-meter distance between two adjacent transect lines, and between the consecutive interval of quadrat sample plots on a transect line to avoid biased of samples selection.

5.3. Soil sampling procedure, data collection, and sample preparation

For soil data collection of site selection from eight (8) land-use systems (LUS) were considered the relative similarity of each LUS as criteria in their topography, altitude, aspect, slope, and areas free from erosion exposed. For soil data collection the main square sample quadrat of 20 m x 20 m (400 m^2) area was established by systematic sampling techniques with twelve (12) replication quadrats in each land-use system. The soil samples were collected in five replicates of subplots with 1 m x 1 m area within each a main square quadrat by placing four (4) subplots at each corner and one (1) subplot at the center of the main plot. The soil samples were collected close to the center of each subplot (1 m x 1 m area) by using a soil auger in adjusting with the required soil depth layers and by carefully cleaning the equipment at each soil sampling depths, to prevent soil contamination between different soil sampling layers and plots. The soil samples were collected at two soil depth layers; each layer is 20 cm thick at the topsoil layer (0–20 cm) and subsoil layer (20–40 cm) at the center of each sub-plot area.

The collected five soil samples from each main quadrat were bulked /combined concerning their similar depth layer categories and mixed well thoroughly to form a one representative composite soil sample per main plot to reduce variability within the quadrats. Finally, 1 kg of the composited representative soil samples from each quadrat with respect to each depth layer was packed into plastic bags and transport to soil chemical laboratory analysis. The collected representative soil samples were labeled with appropriate information and transport immediately to the soil laboratory of Hawassa University, Wondo Genet College of Forestry and Natural Resources, for sample preparation and laboratory analysis. Before the analysis, the composite soil samples were air-dried, ground and sieved to pass through 2 mm size sieve in preparation for laboratory analysis of most soil chemical properties. The soil samples were further sieved to pass through a 0.5 mm size sieve for the analysis of total nitrogen (Ranst et al., 1999).

Laboratory Analysis of soil chemical properties

The soil chemical properties analysis parameters include organic carbon, total nitrogen, C: N ratio, available phosphorous, soil pH, soil electrical conductivity, Cation exchange capacity, exchangeable bases (Ca, Mg, K, and Na), and Percent base saturation. The soil organic carbon (OC) was determined following the Walkley Black wet digestion method as described by Ranst et al. (1999). The total nitrogen level in the soil was determined following the modified Kjeldahl's digestion, distillation, and titration method as described by Ranst et al. (1999). The C: N ratio was determined by dividing the value of organic carbon to the total nitrogen corresponding to each soil sampling depths. The soil available phosphorus content was determined by following the Olsen procedure (Olsen et, al., 1954). The soil pH was measured by using a digital pH meter in a 1:2.5 soil to water supernatant suspension (Jackson, 1973, Van Reeuwijk 1992). The Electric conductivity of the soil samples was determined by using electrical conductivity meter from 1:1 soil-distill water mixture (20 g of soil in 20 ml distilled water). The cation exchange capacity (CEC) of soils was determined by saturation with 1N sodium acetate followed by replacement of sodium on the exchange complex with 1N ammonium acetate at pH 7 following the procedure described by Chapman (1965). Sodium level was determined by atomic absorption spectrometry (AAS) and CEC expressed as meq/100 g of soils.` The exchangeable bases were extracted with 1M ammonium acetate at pH 7.0. Exchangeable Ca and Mg were measured from the extract with an atomic absorption spectrophotometer; whereas exchangeable Na and K were determined from the same extraction with a flame photometer (Black et, al; 1965). Percent base saturation (PBS) was determined by dividing total exchangeable bases (Ca, Mg, K, and Na) to the CEC of the soil and multiplies by 100.

5.4. Data Analysis

All quantitative field soil data were analyzed by the General linear model (GLM) analysis of variance (ANOVA) procedure. Statistical difference in soil chemical properties among land-use systems and between soil depth layers was analyzed by a two- way analysis of variance (ANOVA) at $p < 0.05$ significant levels by using Statistical Analysis System (SAS) software (Version 9.4). A least significant difference (LSD) test was employed to assess the mean difference between soil variables. Means comparisons were used to soil properties change interpretation and explanation among eight land-use systems in the study area. Additionally, Pearson’s correlation coefficient was employed to evaluate the relations of various soil chemical variables.

Abbreviations

Av.P
available phosphorous:BS%:Base Saturation percent; C:N:the ratio of carbon to nitrogen; CEC:cation exchange capacity; CV:Coefficient Variation, DM:dry matter; EC:electrical conductivity; Exch. Ca:Exchangeable Calcium; Exch. K:Exchangeable Potassium; Exch. Mg:Exchangeable Magnesium:Exch. Na:Exchangeable Sodium; FAO:Food and Agricultural Organization of the united nations; JCS:Jaccard’s Similarity Coefficient; LSD:Least Significant Mean; LUS:land-use system; m.a.s.l.:Meter above sea level; OC:organic carbon; sign:significant; TN:total nitrogen, and >:greater than.

Declarations

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Availability of data and materials

The data can be available in Additional files and for detail upon please request the Corresponding Author.

Authors’ contributions

All authors played a vital role to accomplish this manuscript. The corresponding author, YB develop the idea of the research, designed the research method, soil samples collection, soil laboratory results organized, statistical analysis, and wrote the manuscript. TB and SD were contributed significant input into the successful completion of the manuscript by supervising the study, consistent and inspiring guidance, valuable suggestions; constructive comments, and reviews on the manuscript preparation.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author Details information

[1] Yadesa Bato is a Ph.D. student at Addis Ababa University, College of Natural Science, Department of Plant Biology and Biodiversity Management, Addis Ababa, Ethiopia. Email address: yadesabato2020@gmail.com; Telephone +251-911994127

[2] Tamrat Bekele (Ph.D., Associate Professor in Plant Ecology) is a senior lecturer and researcher at Addis Ababa University, College of Natural Science, Department of Plant Biology and Biodiversity Management, Addis Ababa, Ethiopia, and he supervises the corresponding author. Email address: tambek07@gmail.com; Telephone +251-911406350

[2] Sebsebe Demissew (Professor in taxonomy and systematics) is a senior lecturer and researcher at Addis Ababa University, College of Natural Science, Department of Plant Biology and Biodiversity Management, Addis Ababa, Ethiopia, and he supervises the corresponding author. Email address: sebseb.demissew@gmail.com; Telephone +251-911247616

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Figures

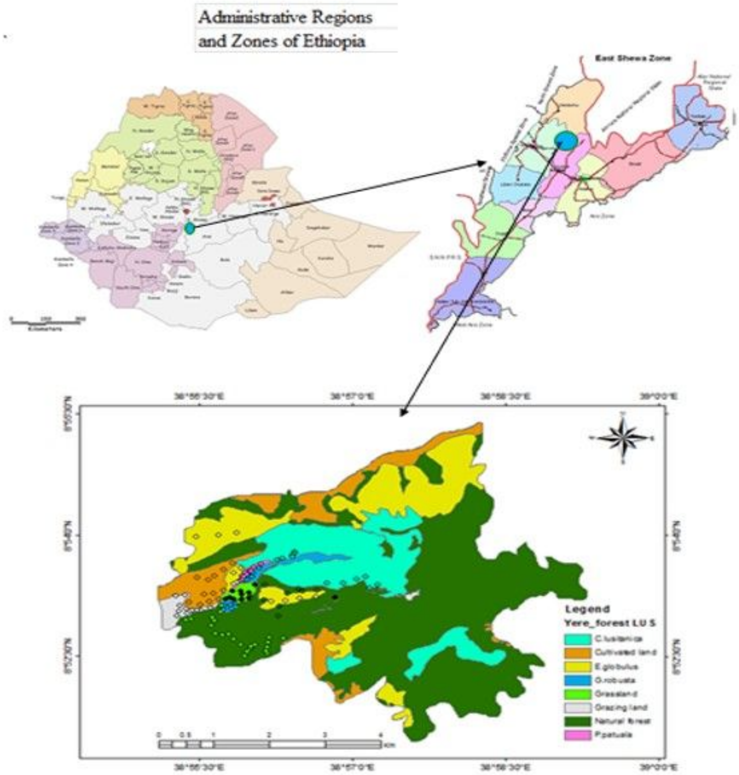

Figure 1

Yerer Forest and its surrounding area study site map

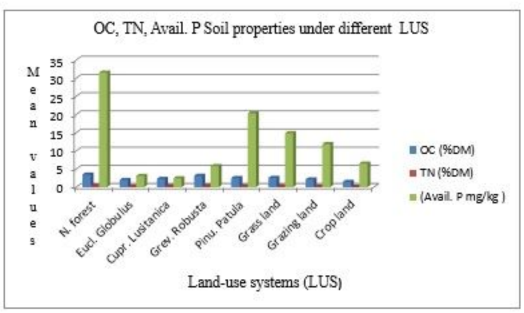

Figure 2

The mean values of soil OC, TN, and avail. P under different land-use systems (LUS)

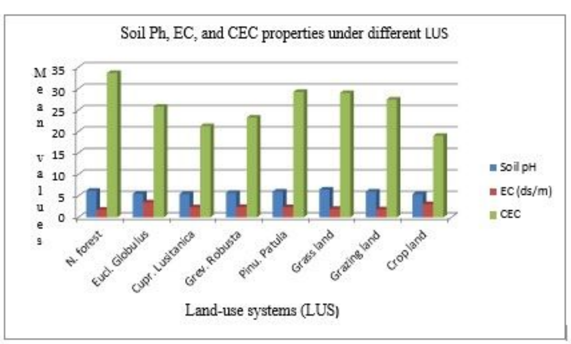

Figure 3

The mean values of soil pH, EC, and CEC under different land-use systems (LUS)

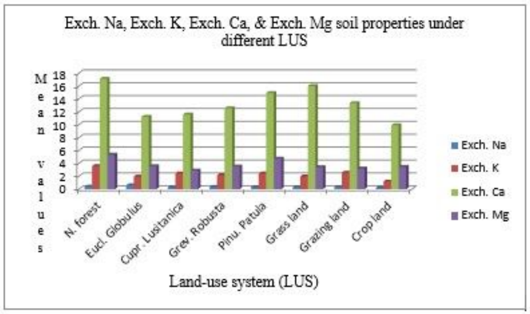

Figure 4

The mean values of soil exchangeable bases (Na, K, Ca, Mg) under different land-use systems

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