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RESEARCH ARTICLE

Assessing Soil Fertility Influenced by Land Use in Moche, Gurage Zone, Ethiopia

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Abstract

One of the main reasons for Ethiopia's declining agricultural production is land use change under poor soil management practices. Hence, in order to evaluate the effects of various land use types on certain soil qualities, research was done on the soils of Cheha district, Gurage zone in Ethiopia's central highlands. Four different land use types (LUTs) (cultivated, enset, eucalyptus, and wild forest) were used for this study to assess and analyze their response to soil fertility. A total of 48 soil samples (24 undisturbed and 24 disturbed) was collected from the selected LUTs and two different soil depths (SDs) (0-20 and 20-40 cm) with three replications for the laboratory analysis. The results showed that most of the properties of soil physicochemical properties of soil were significantly affected by LUTs, SD, and the interactions. The result showed that the highest sand (43%), silt (46.5%), and clay (30.30%) fractions were observed under forest land (FL), enset farmland (ENFL), and cultivated land (CUL), respectively. Concerning the SD, higher silt (40.9%) and clay (28.3%) were found in the subsurface soils. Except for CUL, textural classes of all LUTs were loamy. The highest (1.37 g cm^{-3}) bulk density was observed under the subsurface soils of CUL and the lowest (1.06 g cm^{-3}) was in the surface soils of FL and ENFL. In contrast to bulk density, total porosity was highest (60.1%) under surface soils of FL and ENFL and the lowest (48.3%) value was observed under subsurface soils of CUL. The combination of two factors influenced the soil pH. The highest value (6.54) and lowermost (4.82) values were found under the surface soils of ENFL and subsoils of EUCL, respectively. Comparatively, the uppermost (7.48%) and lowermost (3.55%) values of organic matter were recorded under the surface soils of FL and subsoils of EUCL. The uppermost (0.37%) and lowermost (0.17%) values of total nitrogen were registered under surface soil and subsoils of FL and EUCL, respectively. The uppermost (22.69 mg kg^{-1}) value of Av.P was registered under superficial soils of ENFL and the lowermost (5.02 mg kg^{-1}) was obtained under a subsurface layer of EUCL. The uppermost (37.96 $cmol_{(+)}$ kg^{-1}) and lowermost (11.90 $cmol_{(+)}$ kg^{-1}) of CEC values were observed under the surface soils of FL and subsoils of EUCL. The uppermost value of exchangeable acidity (1.85 $cmol_{(+)}$ kg^{-1}) was recorded under soils of EUCL. This study showed that different LUTs and SDs have substantial impacts on the status of soil fertility. Soils of FL and ENFLs were relatively more fertile. Increasing eucalyptus tree cover on arable land and intensive farming severely impacted soil fertility which may have increased soil acidity. Appropriate land use and a variety of soil fertility management practices are crucial to address soil fertility loss and acidity issues.

Keywords: Land use types, Soil fertility status, Soil physiochemical properties.

Introduction

Sustainable agricultural production has attracted attention worldwide due to soil degradation caused by inappropriate land use and poor management (Selassie and Ayanna, 2013). Soil quality can be rapidly degraded by inappropriate agricultural practices and land cover changes (Heluf *et al*. 2014; Arshad *et al*. 2010). The type of land use and the rate at which a land use type expands are believed to be affected by rapid population growth (Duguma *et al.* 2010). This could affect the soil properties of a given land if natural land uses are changed to artificial ones or vice versa. Additionally, intensified agricultural development could lead to severe degradation of land due to the loss of the natural environment. Ethiopia's economy depends heavily on agriculture, with 41% of GDP, 84% of exports, and 80% of employment coming from the sector (EEA, 2017) Ethiopian agriculture, however, is threatened by soil erosion, depletion

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of organic matter, and soil nutrient removal (Elias, 2017). Due to land shortages in densely populated areas of the country, forest lands were converted into agricultural land in order to meet food demand (Beshir *et al.* 2015).

Different types of land use in Ethiopia have been investigated to evaluate the effects on soil properties (Yitaferu *et al.* 2013; Lemenih *et al.* 2005; Adugna and Abegaz, 2016). Some have compared the natural forest and woodland with artificial land uses (Yitaferu *et al.* 2013; Lemenih *et al.* 2005). Forest plantations and natural forests were also studied in terms of soil properties (Jahed *et al.* 2014). The soil properties of conserved areas, cultivated soils, plantations, and natural forests have been compared by some researchers. A comparison has been made between Eucalyptus' effect on soil properties before and after harvesting by Hailu *et al.* (2014). During the past five decades, Ethiopia's central highlands have experienced significant land use changes from natural to artificial ecosystems (Jaleta *et al.* 2016). Eucalyptus has rapidly adapted to the artificial ecosystem throughout Ethiopia's central highlands by taking over grasslands, woodlands, riverside wetlands, cultivated land, and degraded land (Fisseha *et al.* 2011; Jenbere *et al.* 2012). Farmers have been benefitted from eucalyptus, since it supplies household fuel wood, improves their income, contributes to the culture of the community, and provides environmental benefits (Lemenih *et al.* 2010). However, many people are still reluctant to accept its planting because they are concerned about its effects on water consumption, nutrient competitiveness, soil erosion, and land degradation (Kebebew and Ayele, 2010; Jagger and Pender, 2003).

In terms of sustainability, enset plays an important role in securing carbon and nutrients, protecting soils and controlling macroclimates, soil formation and water cycles (Senbeta *et al.* 2022). In another study, status of total nitrogen (0.23%), organic matter (2.41%), available phosphorus (8.52 mg kg^{-1}) and bulk density (1.22 g cm^{-3}) in enset crop soil was higher than that of arable land (Kibebew *et al.*, 2022). However, the effects of land use types on soil, comparing the effects of natural forest and enset farm with the artificial land use (cultivated land and Eucalyptus woodlots) were less studied in the central highlands of Ethiopia and elsewhere. To support developing land use management alternatives, it is helpful to understand the impacts of different land use types on soil attributes. In order to evaluate the effects of various land use types on certain soil qualities in Ethiopia's central highlands, this study aimed to identify the effects of different land use types.

Materials and Methods

Description of the Study Area

The trial was carried out in Moche kebele (village), Cheha district, Gurage zone, central Ethiopia, which is found at 8° 00′ 18.9″-8° 15′ 28.53″ N and 37° 35′ 46.48″-38° 03′ 59.59″ E and the elevation 900-2812 meter above sea level (m.a.s.l) (Bereket *et al.*, 2018; CWANRMO, 2020). The mean annual rainfall is about 1265.7 mm and the temperature ranges between 20 to 27°C (NMA, 2021). Cheha district is situated 180 km from Addis Abeba (the capital).

The topography of the district is characterized by plains, hills, steep slopes, very steep slopes, gentle slopes, very flat slope (i.e., 60% plains and flat slopes, and 40% steep or mountainous) (CWPCEDO, 2020). Moche kebele is located on the upper slope of the top sequence (CASCAPE, 2015). The agro-ecology of the district is 20% highlands (2300–3200 m.a.s.l), 78% midlands (1500–2300 m.a.s.l) and 2% lowlands (500–1500 m.a.s.l) (Bereket *et al.*, 2018; Kibebew *et al.*, 2022). The area receives a bimodal rainy season, i.e., about 70–90% of the total annual rainfall that takes place from June to October and a small rainy season from March to May.

Soils in the Cheha district are dominated by Chromic Luvisols, well-drained, very deep (>2 m), red color, well-structured, sandy clay loam to clay soils with a general increase in clay contents from topsoil to subsoil. The soil color of the area ranged from red to reddish brown (high elevation areas) through light brown (midland areas) to dark (lowland areas) (CASCAPE 2015).

The major crops grown in the area root and tubers, including enset (*Enset ventricosum*), potato (*Solanum tuberosum*), fruits (banana, citrus, papaya, mango and avocado), stimulants such as khat(*Catha edulis*) and coffee (*coffee arabica*), onion (*Allium cepa*), wheat (*Triticum aestivum*), barley (*Hordem vulgare*) teff (*Eragrotis tef*) and maize (*Zea mays*).

Description of the Land use Type (LUT) and Soil Sampling

To choose the sampling site, earlier soil sample gathering, field notes, and preliminary assessment of the sites were carried out by visit and visual observation (Table 1). Four different land use types, namely, cultivated land (CL) (annual crop or cereals), enset farmland, Eucalyptus plantation (*Eucalyptus globulus*), and natural forest dominated by *Juniperus procera* were selected for the experiments. The necessary information was collected from farmers about the chosen land types' past and present land use. Selected land uses were categorized into different blocks following natural slope variation: upper slope (15–25%) lower (3–8%) and middle (8-15%). Soil samples were gathered at two specific pits (0 to 20 cm and 20 to 40 cm) from every LUT and three slope positions (lower, middle and upper). Using the diagonal soil sample taking method, 15-20 subsamples (spots) were randomly taken from every LUT and two respective depths within three slope positions to make one representative merged soil pattern. Overall 24 merged soil samples (four LUTs*three replications (slope position)*two depths) were collected from the selected LUTs for the analysis of soil physicochemical properties (soil particle distribution, exchangeable acidity, pH, exchangeable calcium, exchangeable sodium, magnesium, exchangeable potassium, available phosphorus, and CEC).

Soil Analysis

Soil analysis was done in the laboratory by following the proper protocols as mentioned by several researchers. Soil texture by using the hydrometer method (Day, 1965), bulk density by dividing the oven dry mass (105°C) by the volume of the core, soil organic carbon (OC) (Walkley and Black method) (Nelson and Sommers, 1982), total nitrogen (TN) (Kjeldhal method) (Bremner, 1996), soil pH by a pH meter, electrical conductivity, exchangeable cations (Ca^{2+}, K^+, Mg^{2+}, and Na^+) determined using 1 M ammonium acetate at pH of 7.0 (Grant, 1982), cation exchange capacity (CEC) by summing up the charge concentrations of Ca^{2+}, K^+, Mg^{2+}, and Na^+, available potassium (K) by flame photometer with dissolved 0.3728 g of dried KCl in one liter of extracting solution (Mehlich, 1953), exchangeable sodium percentage (ESP) by dividing exchangeable sodium by soil CEC and multiplying by 100, available sulfur of the soil by the Mehlich-3 multinutrient extraction method (Mehlich, 1984) and available phosphorus by the Bray 2 method (Bray and Kurtz, 1945).

Statistical Analysis

The analysis of variance (ANOVA) was applied to determine variations in soil parameters among land use types. Treatment means comparison was determined using the least significant difference (LSD) at 0.05 level of significance (Gomez and Gomez, 1984). For the analysis of data, the SAS software (version 9) was used.

Results and Discussion

Physicochemical Soil Properties Influenced By Land Use Type

Distribution of Soil Particle Size

The main effect of sand fraction was highly ($p<0.01$) affected by LUTs and soil depth (SD). But it was not influenced by the interaction of LUTs with soil depth ($p>0.05$). Silt fraction was highly significantly ($p<0.01$) affected by LUTs though it was not affected by SD and the interaction of LUTs with SD ($p>0.05$). However, clay fraction was not significantly ($p>0.05$) affected by LUT, SD, and the interaction of the two factors (Table 2). Considering the two SDs, higher (36.4%) and lower (30.8) sand portions were obtained within the superficial (0–20 cm) and sub-superficial (20–40 cm) soils. In contrast, higher silt (40.9%) and clay (28.3%) and lower silt (39.3%) and clay (24.3%) fractions were found in the sub-superficial and superficial soils, respectively. The current result is agreed with Bekana *et al*. (2022) who showed that the sand fraction was non-significant for soil depths, whereas the clay and silt contents were statistically similar for soil depths. Similarly, Mengistu *et al*. (2017) also described the highest sand fractions under FL than CL, whereas, Habtamu (2018) reported the maximum mean sand content on the surface layer of FL shadowed by the superficial coating of feeding terrestrial. Similarly, Mengistu *et al*. (2017), Abera and Kefeyalew (2017) stated that the clay content increases with increased depth because of cultivation for a long period under CUL. Tufa *et al*. (2019) also found greater silt and clay have been registered in the sub-superficial (20-40 cm) soil whereas, the greater sand content at the superficial (0-20 cm) soil coating is because of clay particle removable and leaching into the subsurface soil through clay migrate method.

The silt content was highest in ENFL (46.5%) and lowest (31.5%) in FL and the highest clay (30.30%) was recorded in CUL compared to the other three LUTs (Table 3). The result is similar to the findings of Fentie *et al*. (2020) who reported higher clay content under CUL in relation to forestry and feeding terrestrial. In all the LUTs, except sand, the contents of clay and silt fractions have been increased with depth. This is because of the downhill movement of clay particles. Except for CUL and subsurface soils, the result shows that the textural lessons of the soils were loam. Even though soil texture was the inherent soil physical properties, LUTs might have contributed indirectly to the change in soil texture due to removal by a pedologic process such as erosion, deposition, and weathering (Hadiro *et al*.,2021).

Table 1: Land use pattern of Cheha district

No	*Land uses*	*Coverage(ha)*	*Percent*
1	Annual crops	17657.5	30.8
2	Perennial crops	27325	47.7
3	Grazing land	613.5	1.0
4	Natural and man-made forest land	9284	16.2
5	Degraded land	60	0.1
6	Potentially uncultivated land	1180	2.1
7	Others	1195	2.1
	Total	57315	

Sources: - CWANRMO, 2020 unpublished annual report.

Table 2: Soil parameters and methods of analysis with respective reference

Parameter	*Physicochemical properties of the soil*	
	Method of analysis	*References*
pH	pH meter	Tekalign (1991)
A.P(mg kg^{-1})	Olsen's method	Olsen *et al.*(1954)
Total N%	Kjeldahl method	Murphy (1968)
OC%	wet oxidation method	Walkley and Black (1934).
Ca cmol(+) kg^{-1}	EDTA method	Chapman, 1965
Mg cmol(+) kg^{-1}		
K cmol(+) kg^{-1}	using flame photometer	Chapman, 1965
Na cmol(+) kg^{-1}		
CEC cmol(+) kg^{-1}	Titration method	Rowell (1994).
Pd(gcm^{-3})	2.65 g cm^{-3}	Hillel D (2003)
Bd(gcm^{-3})	Core sampler method	Hillel D (2003)
Tp%	$ƒ = [(1 - ρb/ρs)* 100]$. ƒ = porosity, ρb = bulk density and ρs = particle density	Hillel D (2003)
Texture	Bouyoucos hydrometric method	Rowell (1994)

Table 3: Main effect of LUTs and SDs on soil particle distribution of the soil

Land use types (LUTs)	*Selected soil physical properties*			
	Soil particle distributions (%)			*Textural class*
	Sand	*Silt*	*Clay*	
CUL	26.50^{b}	43.20^{ab}	30.30^{a}	CL
ENFL	26.20^{b}	46.50^{a}	27.30^{ab}	L
EUCL	38.7^{a}	39.3^{b}	22.00^{b}	L
FL	43^{a}	31.5^{c}	25.5^{ab}	L
$LSD_{(0.05)}$	5.01	5.91	7.87	
Soil depth (SD)				
0-20cm	36.40^{a}	39.30^{a}	24.30^{a}	CL
20-40cm	30.80^{b}	40.90^{a}	28.30^{a}	L
LSD $_{(0.05)}$	3.54	4.18	5.56	
CV (%)	12.06	11.90	24.19	
SE(±)	1.80	1.43	1.30	

Main effect means within a column followed by the same letter are not significantly different from each other at $p< 0.05$. LSD=list significant difference; CV = coefficient of variation; SE = standard error, LUT = land use type; SD = soil depth, CL = clay loam and L = loam.

Bulk Density

The highest bulk density (1.37 g cm^{-3}) was detected under the subsoils of CUL and the lowest (1.06 g cm^{-3}) was recorded on the surface soils of FL and ENFL (Table 3). Using Hazelton and Murphy's (2007) bulk density classification, >1.9 gcm^{-3} was classified as extremely high, 1.6–1.9 gcm^{-3} as medium, 1.3–1.6 gcm^{-3} as medium and 1–1.3 gcm^{-3} as very low. This might be due to often a tendency for bulk density values to rise with depth, as the effects of cultivation and organic matter content reduce and the reason for the lowest bulk density on surface soils of FL and ENFL could be the highest OM content. Another reason may be excessive plowing, which frequently quickly slackens the plowed soil coating, whereas compressing the coating underneath and depletion of OM increases bulk density (Negasa *et al.*, 2017). In addition, raindrops underground during a prolonged period of unbroken farming were also contributing to the rise of bulk density since raindrops influence soil compactness by breaking it down (Wubie *et al.*, 2020). Jaleta (2020) found a similar result that showed the highest bulk density was found in the CUL at both Abechikeli Mariam and Aferfida Georgis, Achefer district, northwestern Ethiopia. Also, Tufa *et al.* (2019) and Weldesemayat and Nandita (2020) found that the highest BD on CUL than the adjacent land uses (forest, grass, grazing land, and Eucalyptus woodlot) and the lowest value was obtained from under soils of forest land.

Total Porosity

Total porosity (ƒ) was significantly affected ($p<0.05$) by an interaction of LUTs and SDs (Table 3). The highest (60.1%) and lowest (48.3%) values of ƒ were recorded in the upper layer of FL and ENFL and subsoil CUL soil of the experimental site.

When soil porosity increases, it means the soil has greater aggregation, better-growing conditions, and can aerate well enough to support microorganisms. The higher result of ƒ shows relatively FL and ENFL were well aerated and suitable for plant root penetration and microorganisms under the site's soils. The result of the present study is in line with the result reported by Weldesemayat and Nandita (2020) who described the highest and lowest total porosity under natural forest and agricultural (cultivated) lands compared to other adjacent lands (bamboo forest and degraded forest). In contrast to ρb, total porosity was decreased with SD under all LUTs. Achalu (2019) finding also indicated low OM content caused a decrease in ƒ in the CUL and subsurface soils in the Nitosols of the Bako area. The reason for the highest mean value under FL and ENFL might be relatively higher OM content, a household refusal for ENFL, and microbial activities. Generally, this trial indicated that the overall porosity of the soil of Moche has been affected by different land use types and depths.

Soil Reaction (pH-H_2O)

The soil pH-H_2O (1:2.5 soil to water ratio) value has been highly affected by LUTs ($p<0.01$), SD ($p<0.01$) and the interaction of LUTs by SDs ($p<0.05$) (Table 4). The highest pH(6.54) was recorded in the uppermost and lowest (4.82) registered underneath the top or sublayer soils of ENFL and EUCL, respectively. The higher pH value in ENFL might be a result of the application of house refuse, wood ashes, and manure that cause a higher value of the exchangeable base.

This result agrees with the result of Fentie *et al.* (2020) who obtained the highest pH value underneath the ENFL. Similarly to a current study, Belay *et al.* (2021) reported lower pH values underneath the soil of eucalyptus and cultivated areas in the western Gurage watershed, south-central Ethiopia. Plants might be taking more basic cations than usual as soils in eucalyptus plantations were more acidic. Likewise, Blay *et al.* (2021) and Kibebew *et al.* (2022) also found the lowermost value and strong acidic pH under soils of CUL. This is because of anthropogenic factors like the removable essential nutrients during crop harvesting and erosion from the CUL. In general, when the SD increases the value of the pH decreases in all types of land use. This is because as SD increases, the soil's organic matter content decreases, leading to the decrease of soil pH from top to down layer.

Organic Carbon (OC)

Organic carbon is significantly ($p < 0.05$) affected by the interaction effects of LUTs with SDs. The highest OC was reported in FL at the surface and lowest in EUCL at the subsurface level (Table 5). According to Hillel (2003), more organic carbon content in the topsoil of forest land makes soils loose, porous, and well-aggregated, thereby reducing bulk density. This implies that the forest soils have no excessive compaction or restriction to root development. Greater soil OC content (%) was observed in the case of forest land due to the presence of more litter fall, and decomposition of a large amount of root biomass and dead roots in the case of forest land compared to eucalyptus land. The value of soil OC decreased with depth in each land use, possibly due to the presence of less biomass and biologically active microorganisms for decomposition in the lower depth of the soil profile. The current result is in line with the findings of Isreal et al. (2018) who reported that forest land had the highest organic carbon (4 and 2.8%) whereas eucalyptus land (2.5 and 2.1%) had less on the surface and subsurface, respectively.

Organic Matter (OM)

Organic matter content was significantly ($p<0.05$) influenced by the interaction of LUTs with SDs. Considering the collaboration response of LUTs by SDs, the highest (7.48%) value of OM content was registered under superficial (0-20 cm) soil of FL followed by ENFL (7.11%) and the lowest (3.55%) OM content was registered at the sub superficial (20–40 cm) soil of EUCL (Table 5). According to EthioSIS (2014), OM is rated very low (2%), low (2–2%), optimum (3–6%), and high (7–8%). Based on these ratings, except for the top soils

Table 4: Interaction effects of LUT by SD on bulk density and total porosity of the soil

Land use type (LUT)	*Bulk density gcm^{-3}*		*Total porosity (%)*	
	Soil depth		*Soil depth*	
	0-20cm	*20-40cm*	*0-20cm*	*20-40cm*
Cultivated	1.14b^{c}	1.37^{a}	56.70^{bc}	48.30^{d}
Enset	1.06^{d}	1.14^{c}	60.10^{a}	56.86^{b}
Eucalyptus	1.10^{cd}	1.23^{b}	58.37^{ab}	53.70^{c}
Forest	1.06^{d}	1.09^{cd}	60.10^{a}	59.0^{ab}
LSD(0.05)	0.08		3.05	
CV (%)	4.3		3.08	
SE(±)	0.02		0.84	

Interaction effect within a column specific soil parameter followed by the same letter(s) are not significantly different from each other at p < 0.05; LSD = least significant difference; CV = coefficient of variations SE = standard error.

of ENFL and FL the range of OM qualifies optimum range but the surface soils of ENFL and FL qualify as the high range. Under soils of all LUTs, OM content decreased with increasing with SD. The cause for the higher mean value of OM content on the surface soils might be higher plant leaf, litter, root biomass, and microbial activities that involve in the decomposition process than the subsurface layer. This outcome is in line with the findings of Eyayu and Mamo (2018) and Mulugeta (2018) who reported the highest OM content on the top layer of FL and enset land is increased compared to adjacent land. The organic matter content of the eucalyptus land is less than the ENFL, this is because on the ENFL, the decomposition rate of enset residue is faster than on eucalyptus leaves (Jaleta, 2020).

Total Nitrogen (TN)

Analysis of variance demonstrated that the TN was highly affected by LUTs ($p<0.01$), SD ($p<0.01$) and their interaction ($p<0.05$). Considering the interaction of LUTs by SDs, the highest TN (0.37%) was obtained at the superficial (0– 20 cm) soils of the FL followed by the ENFL (0.35%) at the same depth (Table 5). In contrast, the lowest TN (0.17%) value was detected in the sub-superficial (20 to 40 cm) soils of the EUCL. The current result is in line with Mengestu *et al.* (2017), Sudarshan *et al.* (2018) and Tufa *et al.* (2019) who recorded the highest value of TN on the top soils of forest land that is because of the high amount of organic matter on forest land as a result of leaves and stem residues. As per the ranking of total nitrogen, >0.5% very great, 0.25 to 0.5% great, 0.15 to 0.25% average, 0.05 to 0.15% little and <0.05% as very little (Hazelton and Murphy, 2016). According to the N status rating, surface soils (0–20 cm) of FL and ENFL were considered high, and the rest were under average (0.15–0.25%).

Carbon to Nitrogen Ratio (C:N)

Carbon to nitrogen ratios of the soils was not significant ($p>0.05$) for LUTs, soil deepness, and their interactions (Table 7). The value of C:N on different LUTs was 11.68, 11.65, 11.54, and 11.51 under CUL, FL, ENFL, and EUCLs, respectively.

Available Phosphorous (Av.P)

Av.P was significantly ($p<0.05$) affected by the interaction of LUTs with SDs (Table 5). The highest Av.P (22.69 mg kg^{-1}) and the lowest (5.02 mg kg^{-1}) amount was obtained at the top soil (0–20 cm) of ENFL and the subsoil layer of EUCLs, respectively (Table 5). The current study's findings showed that LUTs influenced Av.P except in the top soils of ENFL and FL. The lowermost value of Av.P content underneath EUCL and CULs was probably due to low soil pH value and the highest exchangeable acidity and aluminum value under EUCL which may result in fixation problems. The reason for the higher Av.P content under ENFL with the rest LUTs could be due to the decomposition effect of enset residue that leads to a conducive environment for microbial activity that increases soil pH (Kibebew *et al.*, 2022). This is in line with Bereket *et al.* (2018) who indicated the highest value of Av.P underneath enset farmsteads, followed by maize and grassland soils.

The Av.P decreased with increasing depth under soils of all LUTs. This is agreed with the result of Eyayu and Mamo (2018) which showed the decrease in Av.P by 3.75% with increasing SD. Lower soil pH value in the subsurface soils, soil acidity, depletion of nutrients by crop, and decline in soil OM with depth might be the cause of the reduction of the av. P status in the layer of the subsoil of the studied area. According to Hazelton and Murphy (2016), soil available P rated as <5 mg kg^{-1} very little, 5 to 9 little, 10 to 17 middle, 18 to 25 great, and >25 great. Based on the above rating, soils of CUL and EUCL were qualified low, FL and subsoils of ENFL were qualified medium and surface soils of ENFL were qualified high status.

Cation Exchange Capacity (CEC)

The status of the cation exchange capacity (CEC) of the soils was highly ($p<0.01$) influenced by LUTs and SDs interactions

Table 5: Interaction effects of LUT by SD on pH, OC, OM, TN, and av.P of soil

Land use types (LUTs)	*pH*		*OC*		*OM*		*TN*		*Av.P*	
	SD (cm)		*SD(cm)*		*SD(cm)*		*SD (cm)*		*SD(cm)*	
	0-20	*20-40*	*0-20*	*20-40*	*0-20*	*20-40*	*0-20*	*20-40*	*0-20*	*20-40*
CUL	5.54^{b}	5.13^{bc}	2.79^{b}	2.27^{cd}	4.78^{b}	3.91^{cd}	0.23^{b}	0.19^{cd}	9.27^{de}	7.4^{e}
ENFL	6.54^{a}	5.15^{bc}	4.11^{a}	2.28^{cd}	7.08^{a}	3.95^{cd}	0.35^{a}	0.19^{cd}	22.69^{a}	16.97^{b}
EUCL	5.28^{bc}	4.82^{c}	2.55^{bc}	2.01^{d}	4.39^{bc}	3.47^{d}	0.22^{bc}	0.17^{d}	7.57^{e}	5.02^{f}
FL	5.64^{b}	5.45^{b}	4.29^{a}	2.14^{d}	7.39^{a}	3.70^{d}	0.37^{a}	0.18^{d}	12^{c}	10.6^{cd}
$LSD_{(0.05)}$	0.54		0.36		0.63		0.03		2.19	
CV (%)	5.71		7.89		8.05		8.28		10.92	
SE(±)	0.11		0.01		0.21		0.01		1.16	

Interaction effect within a column followed by the same letter(s) are not significantly different from each other at p< 0.05; LSD = least significant difference; CV = coefficient of variation; SE = standard error; OM = organic matter; OC = organic carbon; TN = total nitrogen; av.P = available phosphorus and pH = power of hydrogen LUT = land use type, CUL = cultivated land, ENFL = enset farm land, EUCL = eucalyptus land, FL = forest land and SD = soil depth.

(Table 6). The highest CEC (37.96 cmol$_{(+)}$ kg^{-1}) was obtained at the topsoil of the FL, while the lowest (11.90 cmol$_{(+)}$ kg^{-1}) was detected in the subcoating of the EUCL (Table 6). It is generally true that clay and colloidal OM can absorb and maintain positively charged ions. Accordingly, soils containing high clay and OM contents have high CEC. The cause for the highest value of CEC on the top layer (0-20 cm) of FL is probably due to higher OM content, the existing pH range, low erosion on the surface of the forest, and prevention the basic cations from erosion. This is in line with the result of Belay *et al*. (2021) who obtained the highest value of CEC on the surface soils of FL. In the study conducted by Mulugeta (2018), the highest CEC value was recorded on soils of FL rather than the adjacent other LUTs (cultivated, grazing, and grasslands) and it was due to the presence of high OM under FL and also the findings of Woldemariam *et al*. (2020) indicated that the CEC of soil was higher in FL related with the adjacent grazing and CULs. Similar to the results of many authors, considering the interaction effects of LUT by SD, the current study indicated that the values of CEC were affected by LUT and SDs.

The advanced cation exchange capacity was registered in forest land with advanced organic matter. Under CUL the value of cation exchange capacity was increased with SD. This could be due to the migration of basic cations and the incorporation of OM during tillage practices (Mathewos *et al*., 2022). As indicated by Landon (1991) the topsoil having a cation-exchange capacity of <5 (cmol$_{(+)}$ kg^{-1}) is classified as very little, 5-15 (cmol$_{(+)}$ kg^{-1}) little, 15-25 (cmol$_{(+)}$ kg^{-1}) intermediate, 25-40 (cmol$_{(+)}$ kg^{-1}) great and >40 (cmol$_{(+)}$ kg^{-1}) very great. Based on these rating, the status of CEC of has been qualified from low to high. The top and bottom soil layers of FL and surface soils of ENFL were qualifying for high, the top soils of EUCL and the sublayer soils of ENFL and CUL were qualified medium, and the top and bottom soil layers of CUL and EUCL were qualified in low range. The reason for the low CEC on soils of EUCL might be the high uptake nutrient demand and depletion of positive cations by eucalyptus trees (Belay *et al*., 2021). A great CEC is deliberated as advantageous as it donates to the ability of soils to maintain plant nutrient cations. Based on the above result of CEC growing of eucalyptus plantations on the lands that could be used for crop growing may compute with basic cations and affect the status of soil fertility and crop productivity. In addition, deforestation and conversion of land from forestry to cropland starved of good management magnifies soil decrease. Consequently, the current trial's finding showed that the FL and ENFL cation exchange capacity was significantly higher than other adjacent LUTs and relatively more fertile than soils of CUL and EUCL.

Percent Base Saturation (PBS)

PBS was not significantly (p>0.05) influenced by LUTs, SDs and with their interaction.

Basic Exchangeable Cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})

Exchangeable Calcium (Ex.Ca^{2+})

Replaceable Ca significantly (p<0.01) influenced the LUT and SD interactions (Table 6). The highest calcium (12.2 cmol$_{(+)}$ kg^{-1}) was observed at the superficial (0 to 20 cm) soil layer of the FL, and the lowest (4.26 cmol$_{(+)}$kg^{-1}) was recorded at the sub-superficial coating of the EUCL. This result agrees with those obtained by Daniel (2020) who reported that forest land had the highest exchangeable calcium (20.5 and 21.5 meq/100 g soil), while Eucalyptus woodlot soils had the lowest (17.5 and 17.15 meq/100 g soil) in both upper and lower layers, respectively the status of exchangeable Ca under soils of the studied area qualified under low to high

Table 6: Interaction effects of LUT by SD on exchangeable Ca and CEC on the soil

	Ca (cmol$_{(+)}$kg^{-1})		*CEC(cmol$_{(+)}$kg^{-1})*	
LUT	*Soil depth (cm)*		*Soil depth (cm)*	
	0-20	*20-40*	*0-20*	*20-40*
CUL	5.23^{d}	8.30^{ab}	13.83^{c}	17.55^{c}
ENFL	10.30^{a}	8.10^{abc}	27.89^{b}	24.17^{b}
EUCL	5.53^{dc}	4.26^{d}	16.63^{c}	11.90^{c}
FL	12.20^{a}	9.17^{b}	37.96^{a}	27.17^{b}
LSD$_{(0.05)}$	2.72		5.22	
CV (%)	22.21		15.16	
SE(±)	0.49		1.47	
	p value			
LUTs	0.002^{**}		0.0001^{***}	
SD	0.35^{NS}		0.025^{*}	
LUT*SD	0.03^{*}		0.026^{*}	

Interaction effect within a column and followed by similar letter(s) have not significantly different from each other at p< 0.05; Ca = calcium and CEC = cation exchange capacity range. Ca in surface soils of FL and ENFL were high and the sub-layer soils of EUCL had low status of exchangeable Ca.

Exchangeable Magnesium (Ex.Mg^{2+})

Exchangeable magnesium content was significantly different ($p<0.01$) by the main effect of SD (Table 7). It was not significantly influenced by LUT and their interaction. The cause for the decrease in the value of Mg with SD might be the reduction of OM content with SD.A higher (2.56 $cmol_{(+)}kg^{-1}$) value of Mg was detected on the surface than in subsurface soils (1.98 $cmol_{(+)}kg^{-1}$). The cause for the decrease in the value of Mg with SD might be the reduction of OM content with SD. This result is similar to the finding of Yadeta *et al*. (2019), who found high amount of replaceable Mg under enset fields.

Exchangeable Potassium (Ex.K^+)

Replaceable K content was significantly ($p<0.01$) influenced only by LUTs (Table 7). The highest (3.36 $cmol_{(+)}kg^{-1}$) value was obtained in the ENFL and the lowest one (0.91$cmol_{(+)}$ kg^{-1}) in the CUL. The highest K content in the ENFL could be interrelated with the decomposition of enset leaves residue and wood ash in the study area. The current result is in consistent with the findings of Fentie *et al*.(2020)who indicated the tendency for enset farmland to have the highest concentration of K followed by grassland and then maize fields. Muhammad *et al*. (2017) recorded the different concentrations of K in the leaf samples of various species of enset and mentioned that enset had more K than *Enset brucei* and *E. abyssinica*. The level of replaceable K is rated as 0-0.2 very little, 0.2-0.3 low, 0.3–0.7 moderate, 0.7-2 greater, and >2 $cmol_{(+)}kg^{-1}$ (Hazelton and Murphy, 2007). Based on these ratings very high (3.36$cmol_{(+)}kg^{-1}$) K was recorded under the soils of ENFL.

Exchangeable Sodium (Ex.Na^+)

The status of Na was highly influenced ($p<0.01$) by LUTs and SDs (Table 5). The highest Na content (0.88 $cmol_{(+)}$ kg^{-1}) was reported in the FL and the lowest (0.52 $cmol_{(+)}$ kg^{-1}) was in the CUL. Generally, underneath CUL except for Ca the value of the rest three basic cations was recorded as the lowest mean value. The major reasons for low Na in the CUL are low recycling of plant deposits in the soil, very little application of element stimulants, constant harvesting and soil destruction, which reduces the basic cations (Belay *et al*., 2021). A higher status of Na was observed on subsoil (0.83 $cmol_{(+)}$ kg^{-1}) than the surface (0.64 $cmol_{(+)}$ kg^{-1}) soil layer. This is agreed with Mengistu *et al*. (2017) who obtained the highest and lowest replaceable Na under surface soils of FL and CULs. Similarly, Eyayu and Mamo (2018) described the higher replaceable Na in the subsurface soils. As indicated by FAO (2006), the rating of sodium is<0.1$cmol_{(+)}$ kg^{-1}) very little, 0.1–0.3 little, 0.3-0.5 moderate, 0.5-1 great and >1 very great. Hence, the status of Na on the soils of Moche was characterized as high.

Exchangeable Acidity (Ex.A)

The result showed that replaceable acidity was significantly ($p<0.01$) influenced by the main effects of LUTs and SDs (Table 8). The highest mean value of exchangeable acidity was obtained under EUCL (1.85$cmol_{(+)}kg^{-1}$) and CUL (1.33 $cmol_{(+)}kg^{-1}$). Regarding the soil depth, highest value (1.29 $cmol_{(+)}kg^{-1}$) of replaceable acidity was recorded under the subsoil layer than on the surface (1.04 $cmol_{(+)}kg^{-1}$). The highest status of replaceable acidity under EUCL showed the acidifying consequence of the eucalyptus tree. The existence of a high level of soil response on the eucalyptus farmstead is being accredited to the absorption of further basic cations into the biomass of the trees and littler invest through its foliage droplet (Bereket *et al*., 2018). The current

Table 7: The main effects of LUTs and SDs on exchangeable basic cations, C:N and PBS on the soils

Land use types (LUTs)	*Exchangeable basic cations ($cmol_{(+)}kg^{-1}$)*			*C:N*	*PBS (%)*
	Mg	*K*	*Na*		
CUL	1.88^a	0.91^b	0.52^c	11.68^a	59^a
ENFL	2.63^a	3.36^a	0.85^{ab}	11.54^a	63^a
EUCL	2.05^a	0.95^b	0.69^{bc}	11.51^a	57.6^a
FL	2.52^a	1.00^b	0.88^a	11.65^a	68.6^a
$LSD_{(0.05)}$	0.75	0.58	0.18	0.24	11.21
Soil depth (SD)					
0-20cm	2.56^a	1.74^a	0.64^b	11.64^a	57.1^a
20-40cm	1.98^b	1.37^a	0.83^a	11.54^a	56.9^a
$LSD_{(0.05)}$	0.53	0.41	0.12	0.17	7.82
CV (%)	26.82	30.30	19.89	1.72	14.67
SE(±)	0.16	0.24	0.05	0.04	2.8

Main effect means within a column followed by the same letter are not significantly different from each other at p< 0.05. LSD=list significant difference; CV = coefficient of variation; SE = standard error, Mg= magnesium; K= potassium; Na= sodium; C: N = carbon to nitrogen ratio, PBS = percent base saturation.

Table 8: The main effects of LUTs and SDs on ExA, ExAl and ExH of soil.

LUTs	*ExA*	*ExAl*	*ExH*
CUL	1.33^{b}	0.69^{b}	0.63^{ab}
EUCL	1.85^{a}	0.90^{a}	1.0^{a}
$LSD_{(0.05)}$	0.33	0.16	0.43
Soil depth (cm)			
0-20	1.04^{b}	0.48^{a}	0.59^{a}
20-40	1.29^{a}	0.57^{a}	0.72^{a}
$LSD_{(0.05)}$	0.24	0.12	0.31
CV (%)	23.2	26.4	30.4
SE (±)	0.13	0.07	0.09
	p value		
LUTs	0.0001^{***}	0.0001^{***}	0.04^{*}
SD	0.04^{*}	0.12^{NS}	0.22^{NS}
LUT*SD	0.97^{NS}	0.63^{NS}	0.89^{NS}

Main response means within a column and followed by the similar letters are not statically different from each other at p< 0.05., ExA = Exchangeable acidity, Ex. Al = exchangeable aluminum and Ex. H = exchangeable hydrogen.

result is in agreement with those obtained by Deressa (2022) who reported the higher replaceable acidity originating in the eucalyptus plantation soil.

Exchangeable Aluminum (Ex.Al)

The results revealed that exchangeable aluminum (Ex.Al) was highly significant ($p<0.01$) by the main effects of LUTs (Table 8). The highest Ex. Al (0.90 $cmol_{(+)}$ kg^{-1}) was recorded under EUCL followed by CUL (0.69 $cmol_{(+)}kg^{-1}$). In regard to SD, the highest value (0.57 $cmol_{(+)}$ kg^{-1}) of Ex Al were registered under the subsoil layer than the surfaces (0.48 $cmol_{(+)}$ kg^{-1}). Higher soil acidity in cultivated land showed that intensive cultivation, removal of crop residues and continuous use of acid-forming inorganic fertilizers on acid soils might have aggravated soil acidity. The current result is in line with the findings of Yadeta *et al.* (2019) who recorded the highest Exchangeable Al (3.2 cmol $_{(+)}kg^{-1}$ soil) in the eucalyptus land and lowest (2.5 cmol $_{(+)}kg^{-1}$ soil) in cultivated land.

Exchangeable Hydrogen (Ex.H)

The result showed that Ex.H was statistically ($p<0.05$) influenced by LUTs however, not influenced by SDs and the interaction of the two factors (Table 8). The higher (1.0 $cmol_{(+)}kg^{-1}$) mean value was obtained under soils of EUCL followed by CUL (0.63 $cmol_{(+)}kg^{-1}$). Similarly, Isreal *et al.* (2018) reported higher exchangeable hydrogen (1.06 $cmol_{(+)}kg^{-1}$) in eucalyptus land whereas lowest was recorded (0.6$cmol_{(+)}$ kg^{-1}) in cultivable land.

Conclusion

The soil analysis results indicated that different LUTs and SDs have an impact on the physical and chemical properties of soils. The findings indicated that the least average value of soil properties like, organic matter, organic carbon, total nitrogen, available phosphorus, pH, cation exchange capacity, calcium, C:N, percentage base saturation, and exchangeable acidity were observed under the soil of EUCL followed by CUL. Conversely, almost all soil chemical properties were the highest under soils of FL followed by ENFL. Regarding soil SDs, the higher average value of organic matter, organic carbon, total nitrogen, available phosphorus, cation exchange capacity, calcium, magnesium potassium, percentage base saturation, C:N, sand content, and pH were found to be on the surface soil (0-20 cm) but the CEC and Ca were increased with depth only under CUL. Contrarily, the silt and clay content values, bulk density, Na, and exchangeable acidity increased with depth from 0-20 cm to 20-40 cm. The FL and ENFL soils had relatively higher fertility levels, whereas the CUL and EUCL soils had relatively low fertility levels. There should be great attention to improve soil nutrient status and managing soil acidity on cultivated lands by the concerned bodies and the farmers. Due to the strong soil acidity problem, there might be the fixation of problem P with Al and the unavailability of essential plant nutrients under soils of CUL. To solve this problem, soil management practice should focus on managing soil acidity problems by applying lime. Increasing the coverage of eucalyptus plantations to arable land may lower soil fertility status by lowering soil pH. So, plantation sites should be far from arable land and the governing bodies need to create awareness among the farmers about the impact of eucalyptus and try to control inappropriate planting sites of eucalyptus trees. It is important to strengthen local norms and awareness of the society to conserve and sustain the natural forests.

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