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Conversion in Land-Use Alter Soil Physiochemical Properties in the Highland of Western Ethiopia

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Abstract: Information on the effects of various land-use types on selected soil physicochemical properties is critical for the sustainable use of soil resources. As a result, this study was carried out to assess the Conversion in Land-Use Alter Soil Physiochemical Properties in the Highland of Western Ethiopia. The main aim of this study is to evaluate the effects of different land use types and soil depth on soil's physical and chemical properties. A total of 45 composite soil samples were collected from forest, grass, eucalyptus plantation, cultivate and grazing lands using three soil depths (0-15cm, 15-30 and 30-45 cm) and three replications. Analysis of variance was used to test the mean differences in soil physicochemical properties. Sand and clay mean values were highest in grazing and forest, respectively. The mean bulk density of the soils ranged between 1.10 and 1.61gcm^{-3}, and the mean total porosity ranged between 39.37 and 58.49%, indicating lower soil compaction. The mean field capacity ranged from 34.21 to 42.93% whereas the permanent wilting point ranged from 19.79 to 27.87% and the mean water holding capacity ranged between 14.07 and 16.21%. The mean pH ranged from 4.92 to 5.55, with mean OM values ranging from 0.64 to 5.91% while the mean values of total N ranged from 0.04 to 0.31%. The mean value of available P ranged from 2.10 to 7.26mg kg^{-1}. Conversion of land use types harms soil properties, particularly overgrazing, eucalyptus plantation and cultivation of deforested land. Therefore, the deteriorated physiochemical properties of the soils should be amended with application different source of nutrients and sustainable management practices.

Keywords: Eucalyptus Plantation, Grazing Lands, Land Use Types, Physicochemical Properties, Soil Depth

1. Introduction

A combination of biological and technical anthropological activities that serve economic and social goals is referred land use. It is the arrangements, activities and involvements that people begin in a specific land to produce, modify, or sustain it [1]. As a result, agricultural practice requires a basic understanding of land use [2]. Soil supply has played an important role in sustaining local, regional and global environmental quality [3]. In Ethiopia, where there is a high population density and heavy reliance on agricultural activities, the growth of the human population is most inspiring. This is a terrible threat in which soil properties are severely affected, resulting in land degradation and hampered soil resource sustainability [4].

The main causes of land degradation in Ethiopia are agricultural practices on steep soil with inadequate soil conservation management, erratic and torrential rainfall patterns, insufficient recycling of residues in the soil, deforestation, and overgrazing [5]. Furthermore, because of the interaction effect of cultivation practices and slopes, the landscape has a similar effect on soil quality and depth. Thus, every effort should be made to maintain the physical, biological and socioeconomic environment for the production of food crops, livestock, wood, and other goods using natural resources in a sustainable manner. Generally, soil nutrients are influenced by land use and soil conservation practices [6].

The surface of earth has changed due to anthropogenic changes in land use, with notable changes in physical, chemical and biological properties of the soils [7]. Some of the critical attentions in extensive range design for effective and sustainable use of soil resources include evaluating soil properties, determining soil management options and also its productivities. Changes in physical, chemical and biological properties of the soils are known to occur when land-use types such as forest land, cultivated land, grassland and grazing land are converted [8]. Therefore, information about

the effects of land-use types and soil depth on soil physical, chemical and biological properties are critical for taking measures to ensure the lasting sustainability of soil resources. As a result, the study was carried out with change in soil physical and chemical properties attributable to land-use and soil depth variation in the study area.

2. Materials and Methods

2.1. Description of the Study Area

The research was carried out in the Western highland of Oromia. The area is 652 km from Addis Ababa (the capital city of the country). Geographically, it is located between 8°29'30"-8°32'30"N latitude and 34°44'30"-34°47'00"E longitude, with an altitude ranging from 1627 to 2149 m.a.s.l. It has a total land area of 1474.87ha. The land features of the study area is undulated topography. As [9] soil classification system the study area is dominated with Nitisols types of the soil. The economic activities of the local communities of the study area are based on mixed farming system whereas coffee is the dominant cash crop in most part of the study area [10].
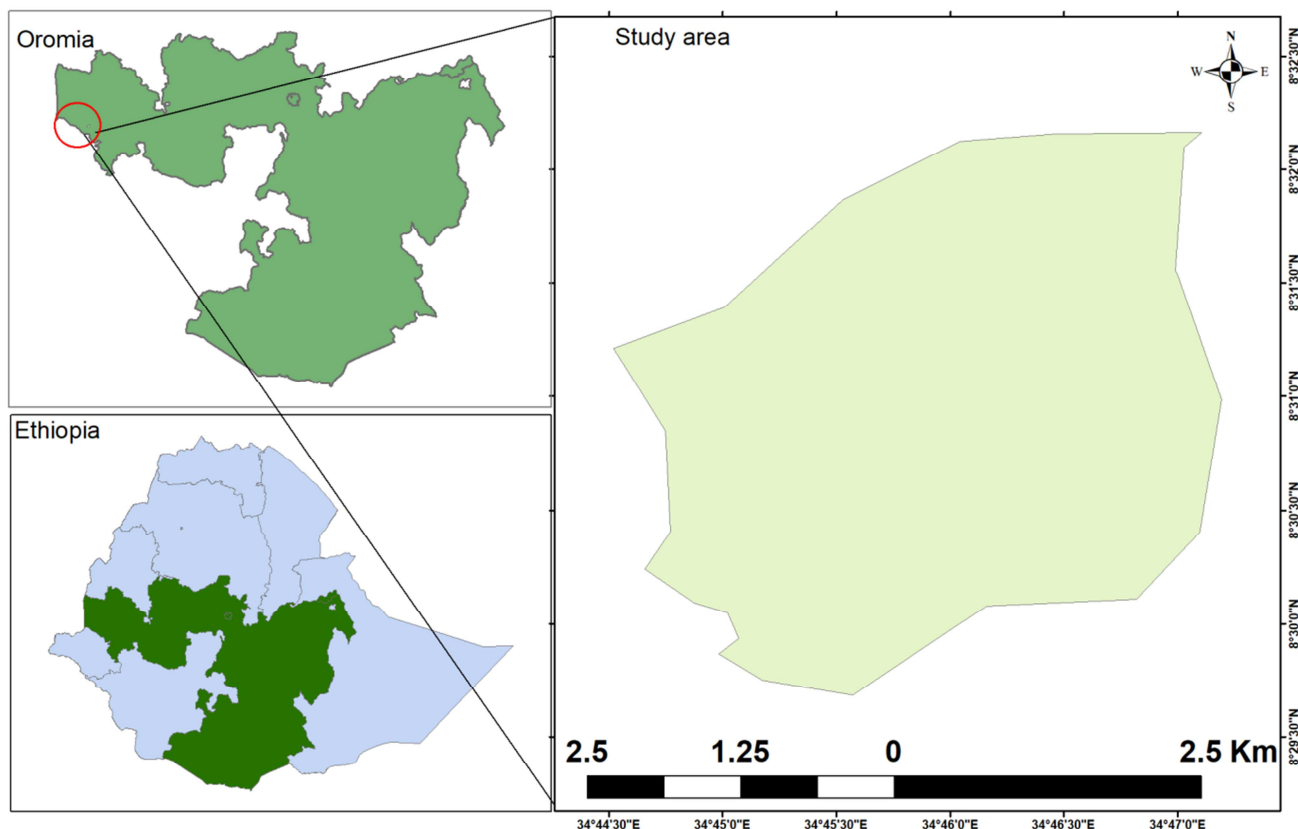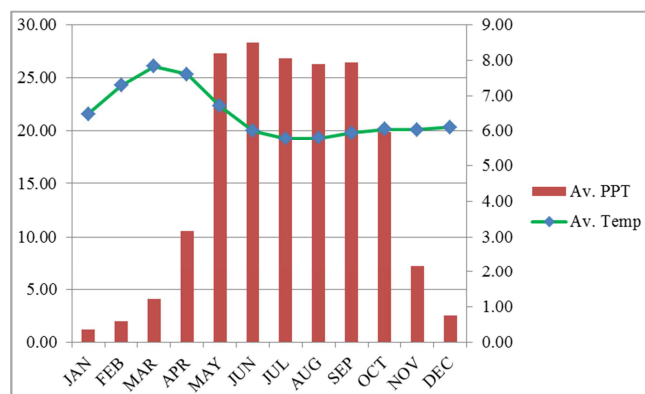

Figure 1. Map of the study area.

Figure 2. Mean monthly temperature and precipitation of the study area recorded from the year 2000-2020 GC. Source: National Meteorological Agency.

2.2. Site Selection, Soil Sampling and Analysis

The area around the Dambi Dollo University of the western highland of Oromia was selected for this study because it has more severe issues with soil erosion and land degradation, both of which harm the physicochemical properties of soil under various land-use types.

Soil samples were collected from five land use types (cultivated land, grazing land, eucalyptus plantation land, grassland, and forest land) within three soil depths from each land use. The representative soil samples with three replications were taken by a simple random sampling technique from the 0-15, 15-30 and 30-45cm soil depth. In a zigzag method, disturbed soil samples were collected from three soil depths.

The collected soil samples were securely bagged, tagged and sealed before being delivered to the soil laboratory for

preparation and analysis. Before the examination, they were air-dried at room temperature, ground with a mortar and pestle, and forced through a 2 mm screen in the laboratory for all soil parameters except soil OC and N which were then passed through a 0.5 mm screen. Finally, the soil samples were analyzed using standard analytical procedures for selected physicochemical parameters.

The physical properties of the soils which were determined in the laboratory include particle size distribution, bulk density, field capacity and permanent wilting point whereas; total porosity and available water holding capacity were computed. Soil particle size distribution was determined by the hydrometer method [11] and from that result, the soil textural classes were determined while bulk density was determined from undisturbed soil samples following the core sampling method [12]. Finally, soil total porosity was calculated from the values of bulk density and the average particle density of mineral soil (2.65g cm$^{-3)}$ as:

$$TP\ (\%) = (1 - \left(\frac{BD}{PD}\right) * 100 \qquad (1)$$

Where; BD is bulk density, PD is particle density and TP is Total Porosity.

The soil moisture content was determined at field capacity (-0.33 bars) and permanent wilting point (-15 bars) matric potentials by subjecting undisturbed core samples to pressure plate apparatus as described [13]. The difference between the water contents at field capacity and the permanent wilting point was used to compute the possible water-holding capacity.

$$AWC = \text{Water content at FC} - \text{Water content at PWP} \quad (2)$$

Where AWC is Available Water Capacity, FC is field capacity and PWP is the permanent wilting point.

Soil pH, organic carbon, total nitrogen, available phosphorous, exchangeable bases (Ca, Mg, K, and Na), cation exchange capacity, and micronutrients (Fe, Mn, Zn, and Cu) were studied. Organic carbon was used to calculate organic matter, while the percentage of base saturation was calculated using the sum of exchangeable bases and cation exchangeable capacity. Accordingly, the pH of the soil was determined in H_2O using a 1:2.5 soil-to-water ratio [13]. The organic carbon in the soils was determined using the wet digestion method [14]. The total nitrogen was determined using the micro-Kjeldahl digestion, distillation, and titration method, while the available phosphorus was determined using the conventional Olsen extraction method [15]. Cation exchange capacity was determined at a soil pH of 7 following displacement using the 1N ammonium acetate method, and it was then determined titrimetrically by distilling ammonium that had been displaced by sodium [16]. The exchangeable bases in the soil were determined using the leachate of 1M (NH_4OAc) solution at pH 7. An atomic absorption spectrophotometer was used to measure exchangeable Ca and Mg, while a flame photometer was used to measure K and Na [17]. The extractable micronutrients Fe, Mn, Zn, and Cu were extracted from soil samples using DTPA, as [18]

described. Atomic absorption spectrometry was used to measure the concentrations of all extracted micronutrients.

The following parameters were computed from the result of the chemical analysis:

$$OM(\%) = OC * 1.724 \qquad (3)$$

$$C: N \text{ ratio} = OC(\%)/TN(\%) \qquad (4)$$

$$\text{Sum of Ex. Bases} = Ex. Ca + Ex. Mg + Ex. K + Ex Na \quad (5)$$

$$PBS = \frac{\text{Sum of Ex.Bases}}{CEC} * 100 \qquad (6)$$

Where OM = organic matter, OC = organic carbon, TN = total nitrogen, C: N = carbon to nitrogen ratio, PBS = the percentage of base saturation and CEC = cation exchangeable capacity.

2.3. Statistical Analysis

The analysis of variance (ANOVA) was used to test differences in soil physical and chemical properties across land-use types and soil depths after collecting and organizing all of the data. Using SAS software version 9.4, Duncan's Multiple Range Test was used to separate means for statistically different parameters with a probability of 5% ($p \leq 0.05$) [19].

3. Results and Discussions

The results of the descriptive analyses revealed that the selected physicochemical soil properties differed numerically across land-use types and soil depth. Low clay content was found in almost all surface soils from various land use types, while subsurface soil had a low sand percentage. While high values of total porosity, water content at field capacity, permanent wilting point and available water holding capacity were recorded in surface soils under all land use types, the soil bulk density of the study area showed the same trends with clay percentage. Organic matter, total nitrogen, available phosphorous and cation exchange capacity were all higher in the surface layers than in the subsurface soil. Subsurface soil had high pH, percentage of base saturation and exchangeable bases (Ca, Mg, K, and Na) values. In other cases, high levels of soil micronutrients (Fe, Mn, Zn, and Cu) were recorded in surface soil of the study area.

High sand percentage values were recorded under grazing land, while high clay percentage values were observed under forest land in the current study area. According to USDA soil textural classification, the soil texture of the study site was classified as clay soil for the forest, cultivated, and grasslands, and clay loam for grazing and eucalyptus plantation lands. Furthermore, low soil bulk density and high total porosity values were found in forests and grasslands. Water content at field capacity, permanent wilting point and available water holding capacity show nearly the same trends with the total porosity of studied soils. The chemical properties of the soil such as pH, organic carbon, total nitrogen, available phosphorous, exchangeable cations (Ca, Mg, K, and Na),

CEC and PBS were higher in values under forest and grassland than in other adjacent land use types of the study area. The pH of the soil in the study area ranged from 4.92 to 5.60, indicating that it was a very strong acid to moderate acid [20]. Soil micronutrient (Fe, Mn, Zn, and Cu) were found to be higher in eucalyptus plantations and cultivated land than in the forest, grass and grazing land in the study area (Tables 1, 2 & 3).

***Table 1.** Mean (±SEM) of selected soil physical properties across land uses and soil depths.*

LUT	Depth	Sand	Silt	Clay	BD	TP	FC	PWP	AWHC
	0-15	32.67±0.88	15.67±0.88	51.67±0.33	1.16±0.02	56.10±0.88	42.93±0.98	27.87±0.95	15.06±0.50
FL	15-30	28.00±0.58	18.00±1.00	54.00±0.58	1.26±0.03	52.58±1.12	40.02±0.06	24.11±0.56	15.90±0.53
	30-45	22.00±0.58	13.00±1.15	65.00±0.58	1.42±0.01	46.42±0.44	37.34±1.05	22.16±0.62	15.18±1.03
	0-15	31.67±1.20	19.33±1.45	49.00±0.58	1.10±0.01	58.49±0.22	41.96±0.98	26.74±0.95	15.22±0.50
GR	15-30	27.33±0.33	20.33±1.45	52.33±1.45	1.18±0.01	55.60±0.55	39.05±0.06	22.98±0.56	16.06±0.53
	30-45	21.33±1.45	20.00±1.53	58.67±2.19	1.28±0.07	51.82±2.55	36.37±1.05	21.03±0.62	15.34±1.03
	0-15	40.00±0.58	27.33±1.76	32.67±1.20	1.42±0.02	46.54±0.88	40.80±0.98	26.28±0.95	14.52±0.50
EL	15-30	36.33±0.67	26.33±1.20	37.33±1.20	1.49±0.02	43.77±0.87	37.89±0.06	22.52±0.56	15.36±0.53
	30-45	33.67±0.33	26.67±1.45	39.67±1.20	1.53±0.03	42.39±1.12	35.21±1.05	20.57±0.62	14.64±1.03
	0-15	32.67±1.20	26.67±0.33	40.67±0.88	1.51±0.03	42.89±1.31	40.87±0.98	25.50±0.95	15.37±0.50
CL	15-30	30.33±0.67	24.67±0.88	45.00±0.58	1.57±0.01	40.75±0.38	37.96±0.06	21.74±0.56	16.21±0.53
	30-45	22.00±1.00	28.67±1.20	49.33±0.88	1.61±0.00	39.37±0.13	35.28±1.05	19.79±0.62	15.49±1.03
	0-15	42.67±0.88	23.00±1.15	34.33±0.88	1.32±0.05	50.06±1.75	39.80±0.98	25.73±0.95	14.07±0.50
GZ	15-30	40.00±1.15	22.00±1.00	38.00±1.53	1.49±0.03	43.65±1.01	36.89±0.06	21.97±0.56	14.91±0.53
	30-45	35.67±0.33	24.67±1.33	39.67±1.20	1.55±0.01	41.64±0.33	34.21±1.05	20.02v0.62	14.19±1.03

Where LUT= Land use types, FL= Forest land, GR= grassland, EL= Eucalyptus land, CL= Cultivated land, GZ = Grazing land, BD = bulk density, TP= Total Porosity, FC= Field Capacity, PWP= permanent wilting point, AWHC = Available water holding capacity.

***Table 2.** Mean (±SEM) of selected soil chemical properties across land uses and soil depths.*

LUT	Depth	pH	OM	TN	C: N	Av. P	Ca
	0-15	5.22±0.05	5.59±0.16	0.29±0.02	11.38±0.48	6.73±0.17	9.52±0.05
FL	15-30	5.37±0.08	3.78±0.22	0.16±0.02	13.66±1.28	4.95±0.17	10.02±0.24
	30-45	5.43±0.07	2.14±0.23	0.11±0.01	10.93±0.69	3.39±0.23	10.40±0.26
	0-15	5.29±0.07	5.91±0.14	0.31±0.00	11.18±0.18	7.26±0.17	9.77±0.57
GR	15-30	5.47±0.02	2.91±0.40	0.18±0.02	9.16±0.36	5.48±0.17	14.17±0.63
	30-45	5.50±0.01	1.60±0.15	0.09±0.01	10.17±0.99	3.92±0.23	14.72±0.33
	0-15	5.18±0.08	2.80±0.13	0.12±0.01	13.68±0.85	5.44±0.17	7.62±0.28
EL	15-30	5.32±0.10	1.33±0.30	0.07±0.01	11.53±0.60	3.66±0.17	8.81±0.24
	30-45	5.55±0.04	0.64±0.23	0.04±0.01	9.94±0.34	2.10±0.23	8.96±0.15
	0-15	4.99±0.07	4.07±0.29	0.25±0.02	9.60±0.15	6.92±0.17	6.77±0.25
CL	15-30	5.26±0.05	1.99±0.11	0.11±0.02	10.56±1.24	5.15±0.17	8.31±0.39
	30-45	5.60±0.08	0.83±0.29	0.04±0.01	12.28±1.78	3.59±0.23	9.31±0.50
	0-15	4.92±0.07	4.14±0.15	0.26±0.02	9.17±0.37	5.23±0.17	8.44±0.19
GZ	15-30	5.30±0.10	2.86±0.25	0.17±0.02	9.84±0.82	3.45±0.17	9.39±0.18
	30-45	5.55±0.04	0.95±0.16	0.06±0.01	9.38±0.59	1.89±0.23	10.43±0.52

***Table 2.** Continued.*

LUT	Depth	Mg	K	Na	SEB	CEC	PBS
	0-15	3.47±0.05	0.85±0.01	0.22±0.00	14.05±0.11	40.51±0.59	34.71±0.46
FL	15-30	3.97±0.24	0.97±0.06	0.26±0.02	15.23±0.57	39.62±0.57	38.43±1.41
	30-45	4.35±0.26	1.06±0.06	0.30±0.02	16.11±0.60	38.45±0.12	41.90±1.50
	0-15	3.72±0.57	0.91±0.14	0.24±0.05	14.64±1.33	50.17±0.71	29.21±2.74
GR	15-30	7.78±0.36	1.90±0.09	0.29±0.03	24.13±1.09	48.53±1.09	49.71±1.74
	30-45	8.60±0.29	2.10±0.07	0.36±0.02	25.77±0.71	39.04±1.33	66.20±3.29
	0-15	1.57±0.28	0.38±0.07	0.06±0.02	9.63±0.66	37.16±0.35	25.95±2.01
EL	15-30	2.76±0.24	0.67±0.06	0.16±0.02	12.41±0.56	36.80±0.56	33.76±1.87
	30-45	2.91±0.15	0.71±0.04	0.18±0.01	12.76±0.35	34.05±0.63	37.53±1.72
	0-15	0.92±0.07	0.23±0.02	0.03±0.01	7.95±0.31	37.96±1.16	21.01±1.31
CL	15-30	2.25±0.39	0.55±0.09	0.12±0.03	11.23±0.90	35.63±0.90	31.49±2.24
	30-45	3.25±0.50	0.79±0.12	0.20±0.04	13.56±1.16	32.34±0.31	41.97±3.93
	0-15	2.39±0.19	0.58±0.05	0.13±0.02	11.55±0.43	40.56±1.20	28.48±0.91
GZ	15-30	3.34±0.18	0.81±0.04	0.21±0.01	13.75±0.41	38.15±0.41	36.08±1.46
	30-45	4.37±0.52	1.07±0.13	0.30±0.04	16.16±1.20	35.94±0.43	44.94±3.02

Where LUT= Land use types, FL= Forest land, GR= grassland, EL= Eucalyptus land, CL= Cultivated land, GZ = Grazing land, OC= Organic carbon, OM = Organic matter, TN = total nitrogen, C:N= carbon to nitrogen ration, Av.P= Available Phosphorous, CEC= Cation Exchangeable Capacity, PBS = percentage of base saturation

Table 3. *Mean (±SEM) of selected soil micronutrients across land uses and soil depths.*

LUT	Depth	Fe	Mn	Zn	Cu
	0-15	25.38±0.65	45.37±1.32	3.79±0.04	1.95±0.04
FL	15-30	22.01±0.90	42.17±1.15	3.57±0.13	1.84±0.02
	30-45	19.80±1.72	40.07±0.90	3.24±0.23	1.67±0.01
	0-15	21.89±1.01	42.71±0.58	3.79±0.07	1.84±0.03
GR	15-30	21.14±0.64	41.00±1.99	3.70±0.09	1.79±0.04
	30-45	19.97±0.41	40.21±1.63	3.37±0.15	1.70±0.03
	0-15	27.69±0.53	49.76±0.78	5.53±0.11	3.02±0.05
EL	15-30	26.34±0.67	47.70±1.15	4.46±0.28	2.70±0.02
	30-45	23.49±0.91	45.73±0.70	4.16±0.30	2.67±0.02
	0-15	28.38±0.86	49.90±1.13	5.28±0.19	2.74±0.04
CL	15-30	25.96±0.45	47.22±0.73	4.79±0.14	2.53±0.07
	30-45	23.72±0.55	45.18±0.91	4.19±0.26	2.04±0.07
	0-15	26.65±0.78	48.51±1.02	4.80±0.06	2.70±0.08
GZ	15-30	23.44±0.80	44.51±0.92	4.42±0.13	2.39±0.07
	30-45	19.82±0.64	43.61±0.44	4.05±0.30	1.91±0.14

3.1. Effects of Land-Use Types, Soil Depth and Their Interaction on Soil Physical Properties

In the current study site, there was a significant difference (p<0.05) in soil particle distribution among different land-use types (Table 4). The clay percentage of forest land > grassland > cultivated land > grazing land > eucalyptus plantation land whereas the sand percentage of grazing land > eucalyptus plantation land > cultivated land > forest land > grassland. The horizontal, vertical and lateral movement of soils caused by various agents such as erosion and management activities may cause differences in soil particle distribution among different land-use types. In agreement with this finding [21] reported a significant difference in particle size distribution between different land-use types due to different erosion statuses and tillage activities. In general, the variation of soil texture among land-use types indicates that the effects of land-use types on soil properties are caused by different land-use utilization and management systems [22, 23].

In the other case, there was a statistically significant (p<0.05) difference in sand and clay content within soil depth (Table 4). High sand and clay percentage values were recorded in surface and subsurface of the soils, respectively. Clay percentage values were higher in subsurface soil than in surface soil. This could be due to the vertical movement of fine soil material. In line with this result, [24-27] reported higher clay content in subsurface horizons than in surface soil under different land-use types due to preferential removal of clay particles and downward movement into the subsurface soil layer via the clay migration process. Finally, the interaction of land use types and soil depth significantly (p<0.05) affects the sand and clay content of the soils in the current study area. In terms of this effect, the highest (42.67%) and lowest (22%) values of sand were observed in surface soil of grazing and forest land, respectively, while the lowest (37.67%) and highest (65%) values of clay were recorded in surface soil of eucalyptus plantation and subsurface of forest land, respectively.

The statistical analysis of soil bulk density reveals a significant difference (p<0.05) among the land-use types of the study area. Soil bulk density values were found to be high (1.56 g cm^{-3}) and low (1.18 g cm^{-3}) in cultivated land and grassland, respectively (Table 4). The high value of organic matter on grassland may be attributed to the low value of bulk density, whereas ploughing or tillage activities cause high values of bulk density in the cultivated land of the study area. Soil bulk density values under grazing land were higher than all other studied land-use types except cultivated land of the study area. In short, the lower soil bulk density of grassland may be due to higher clay content and less disturbance of the soil beneath the grassland. The higher bulk density of soil in cultivated land could be due to the practice of ploughing in cultivated soil, which tends to reduce the amount of organic matter in that soil through animal trafficking and exposes the soil surface to direct raindrop strikes. Several researchers [26, 28] found the same result and evidence for the current finding. Furthermore, the higher bulk density under the eucalyptus plantation and cultivated land compared to the natural forest could be attributed to poor soil aggregation [21].

Soil depth had significant (p<0.05) effects on bulk density values. The highest (1.47gcm^{-3}) value of bulk density was recorded in subsurface soil whereas a low (1.30g cm^{-3}) value of bulk density was recorded in the surface layer of the studied soil. Lowering organic matter with depth may contribute to the high value of bulk density in subsurface soil. Overweighting surface horizons on subsurface layers may also cause high values of bulk density in subsurface layers. In line with current findings [25-27] reported low values of bulk density in surface soil and high value of bulk density in subsurface soil due to the high value of OM in surface soils than subsurface soil.

The land-use types and soil depth of the studied area had a significant (p<0.05) effect on total porosity, field capacity and permanent wilting point. The higher (55.30%) and lower (41.00%) values of total porosity were recorded in grassland and cultivated land of the study site respectively. The highest

(40.09%) and lowest (36.96%) values of water content at field capacity were recorded in the forest and grazing land of the study area, respectively, whereas the highest (24.71%) and lowest (22.34%) values of PWP were recorded in the forest and cultivated land of the study, respectively. Even if the differences were not statistically significant, there were numerical variations in the AWHC of the studied soil. As a result, the highest (15.54%) and lowest (14.39%) AWHC values were found in the grass and grazing land of the study site, respectively (Table 4).

The higher values of total porosity in grassland may be due to high organic matter in grassland and higher bulk density is attributable to lower total porosity in cultivated land of the study site. The higher mean value of soil total porosity in soils of forest land use type can be attributed to lower animal trampling, whereas the lowest porosity can be attributed to higher animal tracking in soils of grazing land use. A decrease in total porosity in grazing and cultivated land soils was attributed to a reduction in pore size distribution, and it is also closely related to the magnitude of soil organic matter loss, which depends on the intensity of soil management practices [26, 29]. Moreover, high values of organic matter and clay content may be the cause for high values of water content at field capacity and permanent wilting points in the soil of forest land.

The soil depth of the study area had a significant (p<0.05) effect on the total porosity, field capacity and permanent wilting point. The high values of all respective parameters in surface soil may be due to high OM on surface soil caused by

various residues. Furthermore [30] reported similar findings to the current study in which the water content at PWP was higher under forest land and lowest under grazing and cultivated land. The observed results generally demonstrated that soils under different land uses differed in their water content at FC and PWP due to differences in the sand, silt, and clay content. Contrary to current findings [23, 31] reported that soil water content at FC, PWP and AWHC increased with depth for soils under different management practices).

According to the author [32], the favourable total porosity of sand particles was around 40%, whereas that of clay-content soil was around 50% and above to sustain and regulate the activities of soil biota. Taking this as a baseline, the findings of this study confirm no problems with soil properties via water infiltration and soil aeration under adjacent different land-use types in the study area. The observed bulk density values in this study are within the expected ranges in most mineral soils. Because the soil bulk density of the current study area was within the expected values, aeration and water movement within the soil structure are in a favourable situation, allowing plant growth and determining the number and diversity of soil microbes, which provide a versatile function in agrarian activities. According to [32], the critical bulk density of clay soil is approximately 1.4 cm^{-3}. As a result, the bulk density of soil surface in current study area was within a reasonable range for agricultural purposes.

Table 4. Effects of land use types, soil depth and their interaction on soil physical properties.

Treatment	Sand	Silt	Clay	BD	TP	FC	PWP	AWHC
LUT								
FL	27.55[cd]	15.55[d]	56.88[a]	1.28[c]	51.70[b]	40.09[a]	24.71[a]	15.38[ab]
GR	26.77[d]	19.88[c]	53.33[b]	1.18[d]	55.30[a]	39.12[ab]	23.58[ab]	15.54[ab]
EL	36.66[b]	26.77[a]	36.55[d]	1.47[b]	44.23[c]	37.96[c]	23.12[bc]	14.84[ab]
CL	28.33[c]	26.66[a]	45.00[c]	1.56[a]	41.00[d]	38.03[c]	22.34[c]	15.69[a]
GZ	39.44[a]	23.22[b]	37.33[d]	1.45[b]	45.11[c]	36.96[c]	22.57[bc]	14.39[b]
LSD (0.05)	2.43	2.054	1.8657	0.048	1.823	1.38	1.21	1.2175
Depth								
0-15	35.93[a]	22.40[a]	41.66[c]	1.30[c]	50.81[a]	41.26[a]	26.42[a]	14.84[a]
15-30	32.40[b]	22.26[a]	45.33[b]	1.39[b]	47.26[b]	38.35[b]	22.66[b]	15.69[a]
30-45	26.93[c]	22.60[a]	50.46[a]	1.47[a]	44.32[c]	35.68[c]	20.71[c]	14.97[a]
LSD (0.05)	1.11	1.59	1.44	0.03	1.41	1.07	0.93	0.94
LUT	***	***	***	***	***	***	**	ns
Depth	***	ns	***	***	***	***	***	ns
LUT*Depth	**	ns	**	ns	ns	ns	ns	ns
CV (%)	4.69	9.52	4.23	3.60	3.99	3.75	5.41	8.34

Main effect means within columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001.

3.2. Effects of Land-Use Types, Soil Depth and Their Interaction on Soil pH, OM, TN and C:N Ratio

Soil pH of the study area was significantly (p<0.05) affected by land-use types. The lowest (5.25) and highest (5.42) values of soil pH were recorded grazing and grassland

of the study site respectively (Table 5). In the soils of the studied site, the soil pH of grassland > eucalyptus plantation land > forest land > cultivated land > grazing land. Lower soil pH values in cultivated and grazing lands may be due to cation removal with high-yield harvesting and animal feeding. Cations leaching as the soil is disturbed by tillage may also reduce soil pH in cultivated land. In line with current

findings, [2, 3, 23, 26] reported low soil pH in cultivated and grazing land compared to adjacent land use types due to basic cations depletion through crop harvesting. Furthermore, the soil depth had a significant ($p < 0.05$) effect on the soil pH of the study site. Accordingly, the lowest (5.11) and highest (5.52) values of soil pH recoerded in surface and subsurface, respectively. This could be due to cations leaching from the surface to the subsurface of various land-use types. The decomposition of high OM on surface soil also contributes to soil pH reduction. In agreement with this finding, several researchers reported a negative correlation between soil pH and OM due to nitrification, root activity and organic matter decomposition [23, 25, 26].

The interaction effects of land use types with soil depth influenced the soil pH of the studied site significantly ($p < 0.05$). As a result, the lowest (4.92) and highest (5.60) soil pH values were found in surface soil of grazing land and subsurface soil of cultivated land, respectively. Similar with this finding, [23, 27] reported the interaction effects of land use types with soil depth on soil reaction (pH).

According to the soil pH rating established by [32], the soil pH of the study area ranged from very strong acid (4.5-5.0) to moderately acidic (5.6-6.0). Particularly, surface soil pH values in the study area were in the range of very strong acidic which limits crop production and microbial activities unless amended with lime, farm yard manures, compost, vermicompost, biochar etc.

There were significant differences ($p < 0.05$) in soil organic matter among land-use types of the study site. Accordingly, the highest (3.83%) and lowest (1.58%) values of OM were recorded under forest and eucalyptus land-use types respectively (Table 5). Numerically high values of OM were recorded under forest and grassland whereas low values of OM were recorded under eucalyptus plantations and cultivated lands. The higher quantity of OM in forest and grassland soil is mainly due to the addition of more plant residues on its surfaces and their reduced rate of disturbance as compared to the other land-use types. Inconsistent with current findings [3, 23, 26] reported high values of organic matter under forest land than adjacent land use types such as cultivated and grazing lands due to intensive cultivation of land and total removal of crop residues for animal feed and source of energy for cultivated land. Also [31] reported low values of soil organic matter under eucalyptus land than adjacent cultivated and grassland-use types due to the slow decomposing rate of Eucalyptus leaves and debris collection for fuelwood that could reduce the accumulation of organic matter under the tree canopy.

The soil depth of the study area significantly ($p < 0.05$) affected organic matter contents. Accordingly lowest (1.23%) and highest (4.50%) values were recorded in the subsurface and surface of the studied soil respectively. Several researchers reported high soil organic matter on surface soil than in subsurface soil layers. This is attributed partly to the continuous accumulation of un-decayed and partially decomposed plant and animal residues in the surface soils [25, 26, 33]. Furthermore, the interaction of land use types and soil depth also significantly ($p < 0.05$) affected the soil organic matter. The lowest (0.64%) and highest (5.91%) values of soil organic matter were recorded in the subsurface soil of eucalyptus plantation land and the surface soil of grassland respectively. In brief, according to [32] rates of the soil OM of the study area ranged from extremely low (<0.70%) to very high (>5.15%).

Land-use types, soil depth and their interaction had a significant ($p < 0.05$) effect on the total nitrogen of the study site (Table 5). Among land-use types of the study site, the lowest (0.07%) and highest (0.19%) values of total nitrogen were recoerded under eucalyptus plantation and grassland respectively. In the case of soil depth the lowest (0.068%) and highest (0.244%) values of TN were recorded under subsurface and surface soil layers respectively. Considering the interaction effects of land use types and soil depth the lowest (0.04%) and highest (0.31%) values of total nitrogen were recorded in subsurface layers of cultivated and surface soil layers of grassland respectively. Total nitrogen shows a nearly consistent trend with soil organic matter in all land management practices under the study site. This indicates the strong relationships between total nitrogen and organic matter of studied soils. Several authors found the same result with the current finding [25, 27, 33]. The highest mean value of TN content was obtained in forest land vegetation cover which improved the soil organic matter contents, forest land may have nitrogen-fixing trees, plant dead bodies and foliage fall in forest ecosystems can increase organic matter content which enhances soil nitrogen content. Generally, according to [32] rates of the soil TN in the study area ranged from very low (<0.05%) to high (0.25–0.50%).

In agreement with organic carbon and total nitrogen, C: N ratio also varied markedly due to changes in land uses and soil depth of the study site. It was significantly ($p < 0.05$) affected by land use and soil depth but not significantly affected by the interaction of land use types with depth (Table 5). Considering land-use types narrow (9.46:1) and wider (11.99:1) values were recorded under grazing land and forest land respectively. Soil depth also significantly ($p < 0.05$) affected C: N ratio of the current finding soils. Accordingly, the narrow (10.54:1) and wider (11:1) values were registered under subsurface and surface soil layers respectively. In agreement with this finding [3] reported a wider C: N ratio under forest land than in grazing and cultivated lands due to the high organic carbon in forest land. In contrast with the current finding [22, 29] reported a wider C: N ratio in subsurface soil layers than in surface soil layers due to aeration during tillage and high microbial communities that enhance decomposition in surface soil layers resulted for narrow C: N ratio. The wide C: N ratios observed in the soils under study indicated a low level of mineralization of OM and a low level of release of N to the soil systems. In general, a C: N ratio of around 10:1 indicates a relatively faster decomposition rate and improved N availability to plants.

Table 5. *Effects of land-use types, soil depth and their interaction on soil pH, OC, OM, TN, C: N ratio and Available Phosphorous.*

Treatment	pH	OC	OM	TN	C: N	Av. P
LUT						
FL	5.34[ab]	2.22[a]	3.83a	0.18ab	11.99[a]	5.02[b]
GR	5.42[a]	2.01[a]	3.47a	0.19a	10.17[b]	5.55[a]
EL	5.35[ab]	0.92[c]	1.58c	0.07d	11.71[a]	3.73[c]
CL	5.28[b]	1.33[b]	2.29b	0.13c	10.81[ab]	5.22[b]
GZ	5.25[b]	1.53[b]	2.65b	0.16b	9.46[b]	3.52[c]
LSD (0.05)	0.11	0.22	0.38	0.02	1.39	0.31
Depth						
0-15	5.11[c]	2.61[a]	4.50[a]	0.24[a]	11.00[a]	6.31[a]
15-30	5.34[b]	1.49[b]	2.57[b]	0.13[b]	10.95[a]	4.54[b]
30-45	5.52[a]	0.71[c]	1.23[c]	0.06[c]	10.54[a]	2.97[c]
LSD (0.05)	0.087	0.1715	0.296	0.0196	1.0843	0.2469
LUT	*	***	***	***	**	***
Depth	***	***	***	***	*	***
LUT*Depth	*	**	**	**	ns	ns
CV (%)	2.19	14.31	14.33	17.48	13.42	7.18

Main effect means within columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001.

3.3. Effects of Land-Use Types, Soil Depth and Their Interaction on Soil Available Phosphorous

The available phosphorous of the study area was significantly (p ≤ 0.05) affected by land use and soil depth. Considering the land use types the lower (3.52mg/kg) and higher (5.55mg/kg) values of available P were recorded in grazing and grassland respectively (Table 5). The relatively high content of available P in the grass and forest land could be attributed to the high content of soil OM, which results in the release of organic phosphorus, which increases available P in the grass and forest land. This finding is also consistent with that [6], who found that available P was higher in forest land than in grazing and cultivated land. However, cultivated land at the study site had higher levels of available phosphorous than eucalyptus plantation and grazing land. This could be due to the long-term use of mineral P fertilizer, as indicated by several farmers in the area. Following the current result, the author [33] suggest that the ongoing phosphorus fertilizer applications may be the cause of the higher P content of maize farm soils compared to grassland soils. Similar findings were made by the author [3], who found high P availability under enset farms as a result of rapid mineralization, crop residue additions and manure.

In case of soil depth the lower (2.97mg/kg) and higher (6.31mg/kg) values were recorded in the subsurface and surface layers of the study site respectively. This may be due to high organic matter on the surface soil than on the subsurface soil of the study site. In agreement with the current finding [23, 26] reported high values of Av. P on surface soil than subsurface soil due to high organic matter on the surface soil. Generally, according to [32] rates of the soil available P in the study area ranged from very low (<5mg/kg) to low (5-10mg/kg). This may be due to lower pH values of soil that initiate the solubility of heavy metals such as Al and Fe which can fix available P in the soils. Thus, it requires an additional source of P fertilizers particularly for crop production.

3.4. Effects of Land-Use Types, Soil Depth and Their Interaction on Soil Exchangeable Cations

The types of land use and soil depth had a significant (p<0.05) impact on exchangeable cations (Ca, Mg, K, and Na). Except for Na, all of the aforementioned cations were also significantly (p <0.05) affected by the interactions between soil depth and land use types of the study area. Accordingly, considering land use types lower and higher values of exchangeable Cations (Ca, Mg, K, and Na) were registered in cultivated and grassland respectively (Table 6). Considering soil depth exchangeable cation values were found to be lower in surface soil and higher in subsurface soils. The lowest mean values of all exchangeable cations were found in cultivated land, followed by eucalyptus plantation land, while their highest mean values were found in grassland, followed by forest land. This might be the result of the accumulation of organic matter in the soil through grassroots, plant corpses, leaf and litter fall accumulation in the grass and forest land, but not necessarily for others. This finding is in line with the authors [3, 26] who found that grass and forest lands had higher exchangeable cations than other nearby land use types due to the accumulation of organic matter. On the other hand, the subsurface soil of the current study site had higher exchangeable cation values than its surface soil. This may be due to leaching or downward movement of aforementioned cations constituents within soil depth. In agreement with this result, [23] reported high values of exchangeable cations in subsurface soil than in surface soil due to leaching and erosion from surface soils.

Moreover exchangeable Ca, Mg and K of the studied site were significantly (p<0.05) affected by interaction effects of land use types and soil depth. Accordingly, the lowest (6.77cmol (+) kg^{-1}) and highest (14.72cmol (+) kg^{-1}) values of exchangeable Ca were recorded in the surface soil of

cultivated land and subsurface soil of grassland respectively (Table 6). The lowest (0.92cmol (+) kg^{-1}) and highest (8.60cmol (+) kg^{-1}) values of exchangeable Mg were recorded in the surface soil of cultivated land and subsurface soil of grassland respectively. Similarly, the lowest (0.23cmol (+) kg^{-1}) and highest (2.10cmol (+) kg^{-1}) values of exchangeable K were recorded in the surface soil of cultivated land and subsurface soil of grassland respectively. According to the rating set by [34], the concentration of exchangeable Ca observed in studied soils was categorized as

medium (5-10cmol (+) kg^{-1}) to high (10-20cmol (+) kg^{-1}) levels whereas the concentration of exchangeable Mg observed in studied soils was categorized as low (0.3 - 1.0cmol (+) kg^{-1}) to very high (>8cmol (+) kg^{-1}) levels. According to the same author, the concentration of exchangeable K observed in studied soils was categorized as low (0.2 - 0.3cmol (+) kg^{-1}) to very high (>1.2cmol (+) kg^{-1}) levels whereas the concentration of exchangeable Na observed in studied soils was categorized as very low (< 0.10cmol (+) kg^{-1}) to medium (0.3-0.7cmol (+) kg^{-1}) levels.

Table 6. Effects of land use types, soil depth and their interaction on soil exchangeable cations, CEC and PBS.

Treatment	Ca	Mg	K	Na	SEB	CEC	PBS
LUT							
FL	9.98[b]	3.93[b]	0.96[b]	0.26[a]	15.13[b]	39.52[b]	38.34[b]
GR	12.88[a]	6.70[a]	1.63[a]	0.29[a]	21.51[a]	45.91[a]	48.37[a]
EL	8.46[c]	2.41[d]	0.59[d]	0.13[c]	11.59[d]	36.00[d]	32.41[c]
CL	8.12[c]	2.14[d]	0.52[d]	0.11[c]	10.91[d]	35.30[d]	31.48[c]
GZ	9.42[b]	3.37[c]	0.82[c]	0.21[b]	13.82[c]	38.21[c]	36.50[b]
LSD (0.05)	0.5963	0.54	0.1315	0.0457	1.2997	1.2965	3.6158
Depth							
0-15	8.42[c]	2.41[c]	0.59[c]	0.13[c]	11.56[c]	41.27[a]	27.87[c]
15-30	10.14[b]	4.02[b]	0.98[b]	0.20[b]	15.35[b]	39.74[b]	37.89[b]
30-45	10.76[a]	4.70[a]	1.14[a]	0.26[a]	16.87[a]	35.96[c]	46.50[a]
LSD (0.05)	0.4619	0.4182	0.1019	0.0354	1.0067	1.0042	2.8008
LUT	***	***	***	***	***	***	***
Depth	***	***	***	***	***	***	***
LUT*Depth	***	***	***	ns	***	***	***
CV (%)	6.34	15.10	15.07	23.22	9.25	3.45	10.03

Main effect means within a column followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001

3.5. Effects of Land-Use Types, Soil Depth and Their Interaction on Soils CEC and PBS

Land use types, soil depth and the interaction of land use types and soil depth all significantly (P ≤ 0.05) affected the cation exchangeable capacity (CEC) values of the soils in the study area. Regarding different land use types, soil from grasslands had the highest CEC value (45.91cmol (+) kg^{-1}) and soil from cultivated land had the lowest CEC value (35.30cmol (+) kg^{-1}) (Table 6). This might be because grassland has higher soil organic matter than cultivated land in the studied soil. In terms of soil depths, surface soils at the study site had the highest value of CEC (41.27cmol (+) kg^{-1}) and subsurface soils had the lowest (35.96cmol (+) kg^{-1}) value of CEC.

Under different land-use types, CEC values decreased from the surface to the subsurface layer. Soil organic matter showed a similar pattern, pointing to a strong positive correlation between SOM and cation exchange capacity. The lowest (32.34cmol (+) kg^{-1}) value of CEC was recorded in subsurface soils of cultivated land while the highest (50.17cmol (+) kg^{-1}) value of CEC was recorded in surface soil of grassland when interaction effects of land use types and soil depth were taken into account. In consistent with the current findings several authors [23, 28 and 35] reported a positive correlation between SOM and CEC. The soil CEC of the study area was generally rated as high (25 – 40cmol (+)

kg^{-1}) to very high (>40cmol (+) kg^{-1}), based on [34] rating.

Land-use types, soil depth and the interaction of land use types and soil depth were significantly (P ≤ 0.05) affected the percentage of base saturation (PBS) of the soils in the study area (Table 6). In terms of the land use types, grassland had the highest PBS values (48.37%) and cultivated land had the lowest (31.48%). Regarding soil depth, the highest (46.508%) and lowest (27.87%) values of PBS were recorded in the surface and subsurface soil layers, respectively. In the case of the interaction effect of land-use types with soil depth the highest (66.20%) and lowest (21.01%) values of PBS were registered in the subsurface soil of grassland and surface soil of cultivated land, respectively. In most cases, the PBS tracks the exchangeable cation trends in the current study area. According to the research [34], soil PBS rates in the study area ranged from low (20-40%) to high (60-80%). Furthermore, the percentage of base saturation levels indicates the intensity of leaching or coverage of leaching in terms of exchangeable base depilation. As a result, the percentage of base saturation in the study area's soil could be classified as strongly leached (15-30%) to weakly leached (50-70%).

3.6. Effects of Land-Use Types, Soil Depth and Their Interaction on Soil Micronutrients

Soil extractable micronutrients (Fe, Mn, Zn and Cu) of the studied area were significantly (p<0.05) affected by land-use

types and soil depth. Except Cu other micronutrients did not show any significant variation in the interaction of land use types with soil depth. Concerning land use types, the highest (26.02mg/kg) and lowest (21.00mg/kg) values of Fe were obtained in cultivated and grassland respectively (Table 7). The highest (47.73mg/kg) and lowest (41.30mg/kg) values of Mn were recorded in eucalyptus plantations and grassland respectively. The highest (4.75mg/kg) value of Zn was recorded in cultivated land whereas the lowest (3.53mg/kg) value was obtained in forest land. The highest (2.80mg/kg) value of Cu was recorded in eucalyptus plantation land whereas the lowest (1.78mg/kg) value was obtained in grassland. Regarding the soil depth, high values of all extractable micronutrients were obtained on topsoil layers. This may be due to high organic matter on the surface soil than on subsurface soil because it forms complexes that protect them from leaching. The result of the current finding is in agreement with those [28] who found a positive correlation between micronutrients and organic matter. Following the interaction effect of land use types and soil depth the highest (28.38mg/kg) and lowest (19.80mg/kg) values of Fe were recorded in surface layers of cultivated land and subsurface soil layer of forest land respectively. The highest (49.90mg/kg) and lowest (40.07mg/kg) values of Mn were recorded in surface layers of cultivated land and subsurface soil layer of forest land respectively; whereas the highest (5.53mg/kg) and lowest (3.24mg/kg) values of Zn was recorded in surface layers eucalyptus plantation land and subsurface soil layer of forest land respectively. High extractable micronutrients on cultivated land than adjacent land use types were also reported [23]. According to the rating [32], the extractable Fe, Mn and Zn were high whereas Cu ranged from low (0.3–2.5mg/kg) to medium (2.6–5.0mg/kg) in the studied soil of the site.

Table 7. *Effects of land use types, soil depth and their interaction on Soil micronutrients.*

Treatment	Fe	Mn	Zn	Cu
LUT				
FL	22.40[b]	42.53[c]	3.53[c]	1.82[d]
GR	21.00[c]	41.30[c]	3.62[c]	1.78[d]
EL	25.84[a]	47.73[a]	4.72[ab]	2.80[a]
CL	26.02[a]	47.43[a]	4.75[a]	2.44[b]
GZ	23.30[b]	45.54[b]	4.42[b]	2.33[c]
LSD (0.05)	1.3771	1.8256	0.3108	0.0955
Depth				
0-15	26.00[a]	47.25[a]	4.64[a]	2.45[a]
15-30	23.78[b]	44.52[b]	4.19[b]	2.25[b]
30-45	21.36[c]	42.96[c]	3.80[c]	2.00[c]
LSD (0.05)	1.0667	1.4141	0.2408	0.074
LUT	***	***	***	***
Depth	***	***	***	***
LUT*Depth	ns	ns	ns	***
CV (%)	6.03	4.22	7.66	4.43

Main effect means within columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001.

4. Conclusions

This study found that the quality of soil resources significantly changed when natural ecosystems were transformed into managed agroecosystems. The prominent soil features that make up the soil properties governing soil fertility and productivity in these tropical soils were a significant response of these soils to changes in land use. The traditional low-external-input agriculture of the study area is significantly impacted by this human-induced change, which affects not only the surface soils but also the subsurface soils. Since agriculture is the mainstay of the neighbourhood economy, it is crucial to maintain the soil resources required to grow crops and pasture sustainably support production. This means that the nitrogen and phosphorus nutrients lost due to agricultural use should be replenished and restored into the system to prevent a negative nutrient balance. The cost of replenishing these vital plant nutrients, on the other hand, is substantial and has a significant impact on the economic viability and sustainability of this smallholder agriculture. This implies that land-use change is not only the primary cause of soil degradation, but it also harms the agricultural economy. As a result, this study suggests that more detailed and extensive studies of this type are required for better monitoring and understanding of the impact of such land use changes.

Conflict of Interests

The author has not declared any conflict of interest.

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