Fertility Status of Acid Soils under Different Land Use Types in Wolaita Zone, Southern Ethiopia

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1. Introduction

Agricultural sustainability requires periodic evaluation of soil fertility status, which is important in understanding factors that impose serious constraints to crop production under different land use types and for adoption of suitable land management practices [1]. The land-use systems play a tremendous role in influencing nutrient availability and cycling and may also influence secondary succession and biomass production [2, 3]. Soil acidity and associated low nutrient availability are key constraints to crop production in acidic soils, mainly Nitisols of Ethiopian highlands [4]. Haile et al. [5] estimated that ~43% of the Ethiopian crop land is affected by soil acidity. The soil acidity in Ethiopia is dominated by strong acid soils (pH 4.1–5.5) [6]. The decline in soil fertility is caused by land use type changes [7]. The loss of soil fertility in Ethiopia is related mainly to cultural practices such as low fertilizer use, removal of vegetative cover, and burning plant residues or the annual burning of vegetation on grazing land. In addition to soils developed from parent materials low in carbonate minerals, soil acidification takes place in areas where mean rainfall exceeds evapotranspiration [5]. The existence of high exchangeable acidity in a soil usually demonstrates the occurrence of exchangeable hydrogen, exchangeable aluminum as either Al\(^{3+}\) or partially neutralized Al-OH compounds such as Al\((\text{OH})_3^+\), and weak organic acid ions held at the colloidal surfaces of the soil [8]. The specific adsorption of organic anions on hydrous iron and Al surfaces and the corresponding release of hydroxyl ions could also increase the pH...
and available P in the soil solution. Similar to the western, southern, and central highlands of Ethiopia, severe soil acidity problem has been reported recently in the highland areas of Wolaita Zone, southern Ethiopia. However, the degree, extent, and causes of the problem had not been yet examined. The major agricultural constraints in Wolaita area are shortage of land for crop cultivation and livestock grazing, decline of soil fertility, rainfall variability, and pests and diseases. Nowadays, due to increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, which accelerate soil erosion. Indeed, there are limited efforts in the study area to tackle soil acidity through the use of lime although the scale of operation is not commensurate with the problem. Knowledge on the distribution, degree, extent, and causes of severe soil acidity in the Wolaita can assist policy makers, researchers, extension workers, and farmers to improve the fertility and productivity of the acid. Thus, this study was conducted to determine the physicochemical properties of different land use types and extents of soil acidity of the Wolaita Zone, southern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Sites. The study was conducted in Sodo Zuria, Damot Gale, Damot Sore, and Boloso Sore districts of Wolaita Zone, southern Ethiopia (Figure 1) during 2015. This zone is located at 385 km to south west from Addis Ababa, capital city of the country. These districts were purposely selected because they have high population, land shortage, over grazing, and high agriculture potential from the 12 districts in Wolaita Zone. The sites are located between 03°35′30″–03°58′36″ E and 06°57′20″–07°04′31″ N with altitudinal range of 500 to 2950 m above sea level. As per the recent nine years (2007–2015) climatic data, the mean annual rainfall is about 1355 mm (Figure 2). The mean average monthly temperature for the last nine years is 20°C [9].

2.2. Soil Sampling Design and Procedure. A randomized complete block research design used for collecting soil samples in the three representative land use types and four districts (Sodo Zuria, Damot Gale, Damot Sore, and Boloso Sore) with three replications of each at three peasant association, which are similar in their agro ecology, altitude, and slope, were selected. After the selection of the three peasant association, the land use types were systematically selected on the basis of contour line, similarity in soil color by visual observation, slope and altitude to reduce their natural difference, and soil type diversity impacts on the soil acidity. A total of 108 soil samples were collected in triplicates from the three land use types of both sites. Each composite soil sample was prepared from 15 subsamples taken by inserting an auger to a depth of 20 cm from randomly marked sampling points of each land use types at both sites.

2.3. Soil Sampling and Preparation. Soil samples were air-dried, ground, and passed through 2 mm sieve at the Soil Laboratory of the Hawassa Research Center. The physicochemical analyses of the soil samples were conducted at Regional Soil Laboratory following standard laboratory procedures. The bulk density determinations were done at Soil Laboratory in Wolaita Sodo University, College of Agriculture. Triplicate soil samples from each sites and land use types were collected.

2.4. Soil Laboratory Analysis. The collected composite soil samples were air-dried, ground, and sieved to pass through a 2 mm sieve except for soil organic carbon (OC) and total N (TN) analysis which were passed through 0.5 mm sieve. Soil particle size distribution was determined by hydrometer using Bouycous method [10]. Soil pH in water was determined with a digital pH meter at soil: water ratio of 1:2.5 [11]. The reserve acidity was measured in 0.1 M CaCl₂ using the same pH meter at the soil: 0.1 M CaCl₂ ratio of 1:2.5 [12]. The ΔpH was calculated by subtracting soil pH (KCl) from soil pH (H₂O). Bulk density was determined using the core sampling method [13]. Total porosity of the soil was calculated from the soil bulk and the particle densities; where 2.65 g cm⁻³ was used as a standard value for soil particle density; soil moisture content was measured by gravimetric method [11]. Organic carbon content of the soils was determined following the wet combustion method of Walkley and Black as outlined by Sahlemedhin and Taye [14]. Soil total nitrogen was analyzed by wet-oxidation procedure of the Kjeldahl method [15]. Available phosphorus was measured by following Bray II extraction using spectrophotometer [16]. Exchangeable Ca and Mg were measured from the extract with atomic absorption spectrophotometer (AAS), while exchangeable K and Na were determined by flame photometer. Exchangeable acidity was analyzed by [17]. Aluminum saturation percentage was calculated as the ratio of the exchangeable Al to CEC of the respective soil samples random powder method, and calcium carbonate content was determined by rapid titration method as described by Black [18]. Available Fe, Mn, Zn, and Cu were extracted by diethylene triamine pentaacetic acid (DTPA) method by using AAS [19].

2.5. Statistical Analysis. Mean comparisons using the least significant difference (LSD) test at probability of 5% level were done for the different land uses systems and correlation analysis has been done for the different soil properties and land uses systems using the SAS software [20], to see the relationship between parameters.

3. Results and Discussion

3.1. Effect of Land Use Types and Locations on Physical Fertility of Acid Soils. The textural analysis results revealed that 75% of all the land use types considered in this study were found to be clay loam (Table 1). However, sand, silt, and clay content in these soils were varied significantly (P < 0.05) among the land use types. According to Hazelton and Murphy [21], who rated all sand, silt, and clay contents of soils into high (>40%), moderate (25–40%), and low (10–25%), the sand contents high in soils of enset-coffee land
Use of all locations and crop and grazing land uses were moderate (Table 1). The silt to clay ratio was 0.7, which is significantly lower than enset-coffee and crop land uses of Damot Gale district. Averaged over locations, values for Damot Sore crop land (0.8), grazing land (0.8), Sodo Zuria grazing land (0.9), Damot Gale grazing land (0.7), and Boloso Sore (0.8) grazing land uses showed similar trends due to the fact that the soils were might be of similar origin. It has been reported that silt/clay ratios less than unity indicate low values, signifying that the soils are pedogenically ferraltic in nature [22].

3.2. Soil Bulk Density and Total Porosity of Acid Soils. Bulk density value was not significantly ($P > 0.05$) affected by land uses and locations (Table 2). However, numerically the highest mean (1.39 g·cm$^{-3}$) value of bulk density was recorded on the Boloso Sore crop land and the lowest mean (0.98 g·cm$^{-3}$) value under Damot Gale enset-coffee land (Table 2), which might be resulted from compaction of soil due to intensive cultivation in all locations of the crop land. Soil bulk density was positively and significantly correlated with the silt and negatively ($r = -0.95$) with total porosity of the soil, respectively. This might be due to the reciprocal relationship between soil bulk density and total porosity, which shows the degree of soil compaction. Similar results were reported by Takele et al. [1]; Abad et al. [23] suggested that the bulk density of cultivated land was higher than that of adjacent grazing land.

![Figure 1: Location of the study sites, Wolaita districts, southern Ethiopia.](image1)

![Figure 2: Nine years (2007–2015) mean monthly rainfall and mean maximum and minimum temperatures of the study areas [9].](image2)

3.3. Soil Moisture Content and Water Holding Capacity. Moisture content and WHC of the soils were significantly ($P \leq 0.05$) affected by land uses (Table 2). Considering the effects of land use, the highest (20.71%) in Damot Gale enset-coffee land and lowest (18.05%) crop land. Similarly, the highest moisture content was record (26.37%) and lowest was record from (21.43%) water holding capacity were recorded in the enset coffee and crop land, respectively. Similar results were reported by Mengistu et al. [24] that the water content at PWP was highest (19.71%) under the forest land and lowest in the grazing land (16.17%) and the cultivated land 16.56%.
3.4. Effect of Land Use Types and Locations on Chemical Fertility of Acid Soils

3.4.1. Active and Exchangeable Acidity. The pH (H₂O, KCl and CaCl₂) values of the soils varied between 5.12 to 7.0, 4.21 to 6.31, and 4.3 to 6.50 in different locations with land use types, respectively. Based on the rating suggested by Hazelton and Murphy [21], the soils can be categorized as strongly acidic to neutral, very strongly acidic to slightly acidic, and extremely acidic to slightly acidic pH (H₂O, KCl and CaCl₂), respectively. It was lowest in soils of the Sodo Zuria grazing land use, and the highest soil pH value was also recorded in the Damot Gale enset-coffe land use compared to the crop and grazing land soils. Similarly, the lesser average soil pH in the crop and grazing lands is apparently due to the excessive removal of organic cations and associated cations by crop produce and over grazing, respectively, that they would not have a chance to return back and neutralizes the acid soil. In line with this, Mengistu et al. [24] pointed out that although acidity is naturally occurring, removal of plant residues carrying organic anions and excess cations from the farm or paddock is likely to accelerate soil acidification. The change in pH between [pH (H₂O) and pH (KCl, CaCl₂)] was greater than or equal to one across the soils sampling sites (Table 3). Soil pH (KCl) indicated the potential acidity and presence of weatherable minerals when the difference between pH (H₂O) and pH (KCl) is greater than unity [25]. Reserve acidity indication of the soils samples pH was found to range from 4.3 to 6.50 in different locations with land use types. Reserve acidity of soil was always higher than the active acidity. The difference between reserve and active acidity, ΔpH, of the studied soils was positive and found to range from 0.23 to 1.80 in different locations. This indicated that the studied of Damot Sore and Boloso Sore soil samples had considerable more reserve acidity in the soils. Tsehaye et al. [26] reported ΔpH values, which are to be in the range of 0.8 to 1.3 with a mean of 1.0. The reserve acidity values of the soils revealed that the reserve acidity

| Land use types | Sodo zuria | Damot gale |
|---------------|------------|------------|
| Particle size distribution | Silt/clay ratio | Texture class |
| Sand % | Clay % | Silt % | | Sand % | Clay % | Silt % |
| Enest-coffee | 35a | 33a | 29a | 1.0 | Clay loam | 22a | 37a | 25a | 0.8 | Sandy clay loam |
| Crop land | 39b | 29b | 33b | 1.1 | Clay loam | 40b | 26b | 50b | 2.0 | Clay loam |
| Grazing land | 26c | 38c | 38c | 0.9 | Clay loam | 38c | 37a | 25a | 0.7 | Clay loam |
| Mean | 40 | 30 | 33 | 0.9 | 40 | 30 | 30 | 1.0 |
| CV (%) | 12 | 12 | 11 | 10 | 13 | 10 |
| LSD (0.05) | 7 | 8 | 8 | 10 |

| Land use types | Damot sore | Boloso sore |
|---------------|------------|------------|
| Particle size distribution | Silt/clay ratio | Texture class |
| Sand % | Clay % | Silt % | | Sand % | Clay % | Silt % |
| Enest-coffee | 28a | 24a | 35 | 2.4 | Silt loam | 28a | 39a | 25a | 1.3 | Clay loam |
| Crop land | 41b | 39b | 33 | 0.8 | Clay loam | 36b | 26b | 46b | 1.8 | Loam |
| Grazing land | 31c | 37c | 32 | 0.8 | Clay loam | 36b | 35c | 29c | 0.8 | Clay loam |
| Mean | 29 | 35 | 43 | 1.1 | 32 | 29 | 35 | 1.1 |
| CV (%) | 10 | 13 | 10 | 11 | 8.6 | 7.8 | 9.4 |
| LSD (0.05) | 5 | 3 | 7 | 7 |

CV = coefficient of variation, LSD = least significant difference.

| Land use types | Sodo zuria | Damot gale |
|---------------|------------|------------|
| Particle size distribution | WHC (%) | BD (g·cm⁻³) | TP (%) | MC (%) | BD (g·cm⁻³) | TP (%) | MC (%) |
| Sand % | Clay % | Silt % | | | | |
| Enest-coffee | 1.12a | 59.02a | 19.90a | 24.95a | 0.98a | 64.36a | 18.53a | 22.78a |
| Crop land | 1.33b | 51.51b | 18.14b | 21.43b | 1.16b | 57.57b | 18.05b | 22.06a |
| Grazing land | 1.28c | 53.12c | 19.95c | 24.95c | 1.20c | 56.24c | 20.59c | 26.34b |
| Mean | 1.24 | 54.55 | 19.33 | 23.78 | 1.11 | 59.39 | 19.09 | 23.72 |
| CV (%) | 12.05 | 10.03 | 7.83 | 10.47 | 8.58 | 5.86 | 8.63 | 10.07 |
| LSD (0.05) | 0.15 | 5.47 | 1.51 | 2.49 | 0.09 | 3.46 | 1.64 | 2.38 |

| Land use types | Damot sore | Boloso sore |
|---------------|------------|------------|
| Particle size distribution | WHC (%) | BD (g·cm⁻³) | TP (%) | MC (%) |
| Sand % | Clay % | Silt % | | | | |
| Enest-coffee | 1.08a | 59.38a | 20.05a | 26.15a | 1.24a | 54.73a | 20.85a | 26.37a |
| Crop land | 1.18b | 54.05b | 19.70b | 25.08b | 1.35c | 51.38c | 18.44b | 22.76b |
| Grazing land | 1.14c | 58.54c | 20.71a | 25.08b | 1.35c | 51.38c | 18.44b | 22.76b |
| Mean | 1.13 | 57.32 | 20.71 | 25.26 | 1.33 | 51.84 | 19.27 | 23.97 |
| CV (%) | 4.89 | 2.47 | 2.31 | 2.86 | 8.85 | 7.75 | 6.64 | 7.86 |
| LSD (0.05) | 0.05 | 1.41 | 0.46 | 0.72 | 0.11 | 4.01 | 1.27 | 1.88 |

BD = bulk density, TP = total porosity, MC = moisture content, and WHC = water holding capacity.
value changes with different sites as well as with the land use types as observed for the case of active acidity.

3.5. Exchangeable Base. Average exchangeable Ca, Mg, K, and Na ions are presented in Table 4 which showed significant (P ≤ 0.01) variation among difference locations within land use types. The exchangeable bases were low in both the soils of the crop and grazing land use types as compared to that of the enset-coffee land use. Hence, the low CEC and exchangeable cations in the crop land and grazing lands are clearly attributed to the presence of relatively low pH. The low-pH soil colloids are sites that adsorb hydroxyaluminum and cease to function for cation exchange thereby could reduce the CEC of a soil. Exchangeable Ca was dominant in the exchange sites of the soil colloidal materials of the soil studied; this was followed by Mg, K, and Na ions in that order. However, Bore and Bedadi [27] reported that the highest and lowest exchangeable Ca were in the forest (25.4 Cmolc kg⁻¹) and grazing 15.2 Cmolc kg⁻¹) lands, respectively.

As per the ratings of FAO [28], the exchangeable Na in the soils of the sampling sites was low; the exchangeable Ca and Mg were medium to high in all sites which had high values while the exchangeable K was low except the enset-coffee land use in Sodo Zuria and Damot Gale sites which had high values, while the exchangeable K was low except the enset-coffee land use in Sodo Zuria and Damot Gale sites which had high values in contradiction with the generally held view that Ethiopia soils are rich in potassium [29]. The present studies are in line with Teshome et al. [30] who observed highest and lowest exchangeable Ca in forest and cultivated lands, respectively, in western Ethiopia of Ababo area.

Potassium to magnesium ratio of the studied soils varied from 0.05:1 to 0.26:1, which indicated Mg-induced K deficiency using the rating of Laekemariam [31]. This can be corrected by K application to bring the K to Mg ratio closer to one. If there is a high preferential K adsorption on the exchange sites of clay minerals, the amount of K desorbing may then decline, resulting in a reduced K uptake at low soil exchangeable K to Mg ratio. Therefore, attempts should be made to supply the plants with potassium in physiologically correct ratio and in a sustainable manner. Loide [32] suggested indicative K: Mg ratios of 0.7:1 and 1:1 for clay and loamy textured soils, respectively. In silt loam textured soils of Damot Gale, the K: Mg ratio varied from 0.2 to 1.6, while the ratio ranged between 0.1–1.5 in clay textured soils of Damot Sore and Sodo Zuria districts. Accordingly, to these, silt loam soils and clay soils had shown Mg induced K deficiency. Similar trends were obtained on K: Ca ratio in different land uses and sites.

The calcium to magnesium ratio across studied districts using the rating of Laekemariam [31] has shown the low level of Ca (1–4) on 35% and balanced (4–6) on 60% and low Mg (6–10) on 5% of the samples. These rates are lowest in Sodo Zuria crop land (1.99) and highest in Damot Sore crop land (3.55). This shows that soils under the land uses are of low fertility probably due to intense land use practice and excessive loss of Ca through leaching by the high tropical rainfall [33]. Addition of lime and organic manure can be used to supply Ca and improve soil fertility under the land use types [34]. The observed order of cation in the exchange complex (Ca > Mg > K > Na) could also support the existence of Mg induced K deficiency (Table 5). Hence, K-containing fertilizer should be considered for soils of the study areas. It has been suggested that the proportions of the basic cations of the effective CEC are more relevant to plant performance than the actual levels [21]. According to Havlin et al. [35]; the range of critical values for optimum crop production for K, Ca, and Mg are from 0.28–0.51, 1.25–2.5, and 0.25–0.5 C mol·kg⁻¹ soil, respectively. Accordingly, the exchangeable K, Ca, and Mg contents of the soils are above the critical values. However, this does not prove a balanced proportion of the exchangeable bases. Potassium uptake would be reduced as Ca and Mg are increased; conversely, uptake of these two cations would be reduced as the available supply of K is increased [35]. In addition, the ratio of exchangeable Ca: Mg should not exceed 10:1 to 15:1 to prevent Mg deficiency and also the recommended K: Mg is < 5/1 for field crops, < 3/1 for vegetables and sugar beets, and <2/1 for fruit and green house crops [35].

There was great variation in effective cation exchange capacity (ECEC) of the soils under the different land use
The highest and lowest ECEC were recorded at Damot Gale enset coffee land and Sodo Zuria grass land, whilst the values (14.10 C mol·kg⁻¹ and 15.02 C mol·kg⁻¹) were recorded in the cropland at Sodo Zuria and Boloso Sore respectively. In line with ECEC, the highest value of CEC (21.20 C mol·kg⁻¹) was observed in Damot Sore enset-coffee land soil and the lowest (17.60) was recorded in Boloso Sore crop land, the CEC value was not consistent showing that there was no significance difference among different land use systems (Table 6). According to Mesfin et al. [36] in Wolaita soils showed that kaolinite is 29.8% for Damot Sore and 7.8% for Damot Pulasa Districts.

3.6. Organic Carbon, Total Nitrogen, Available Phosphorus, and Carbon to Nitrogen (C: N) Ratio. The data in Table 7 showed the OC, TN, and available P contents of the soils studied. According to the rating suggested by Karlton et al. [37]; the soil OC content was low in range (1.30 to 1.71%). Moreover, the TN contents of all the soils studied were in the low ranges (0.13 to 0.19%). Hazelden and Murphy [21] classified soil organic carbon percentages of <1.0, 1.0–1.71, 1.72–3.0, 3.1–4.29, and >4.3 as very low, low, medium, high, and very high, respectively. The lowest amount of organic matter in the soil might be due to low addition of crop residue, and continuous cultivation and rapid oxidation of soil OM. In conformity to the present observation, complete removal of aboveground biomass [30, 38], intensive cultivation [39], insufficient application of organic inputs [38] and Wolaita agricultural land [31].

The carbon to nitrogen (C: N) ratio of the soils also varied between 7.36 and 14.16. The carbon to nitrogen (C: N) ratios of the soils at Wolaita zone was significantly affected by soil land use types (P ≤ 0.05) (Table 7). On the other hand, although slight numerical variation was observed among the location, C/N ratio was not significantly affected by locations. This indicates that the rate at which total N decreased with land use types was much higher than reduction in carbon. Therefore OM and TN content have direct relation to soil acidity. The present finding was in line with Yihenew and Getachew [40] who reported highest values of C: N contents under grazing land use in northwestern Ethiopian soils. Mesfin et al. [36] revealed that available P with both Olsen and Bray II extraction methods for Wolaita acidic soils.

Table 4: Mean values (n = 108) of exchangeable base and percentage of base saturation in different location and land use types of study areas.

| Land use types | Sodo zuria | Damot gale |
|----------------|------------|------------|
|                | Ex.Ca (C mol·kg⁻¹) | Ex.Mg (C mol·kg⁻¹) | Ex.K (%) | Ex.Na (%) | PBS | Ex.Ca (C mol·kg⁻¹) | Ex.Mg (C mol·kg⁻¹) | Ex.K (%) | Ex.Na (%) | PBS |
| Enest-coffee   | 9.10a      | 4.50b      | 1.20a      | 0.34a     | 74.47a | 11.44a | 3.53a      | 0.75a     | 0.18a     | 85.02a |
| Crop land      | 8.76b      | 4.39a      | 0.24b      | 0.23b     | 70.80b | 11.26b | 3.22b      | 0.31b     | 0.14b     | 78.45b |
| Grazing        | 8.46c      | 4.10c      | 0.57c      | 0.34a     | 70.48a | 11.08c | 3.46c      | 0.68c     | 0.17a     | 80.25b |
| Mean           | 8.77       | 4.33       | 0.67       | 0.30      | 71.91  | 11.26c | 3.40       | 0.56c     | 0.16      | 81.24  |
| CV (%)         | 4.30       | 5.66       | 9.60       | 5.72      | 10.52  | 8.82   | 10.20      | 8.60      | 8.50      | 11.98  |
| LSD (0.05)     | 0.47       | 0.35       | 0.20       | 0.15      | 0.56   | 0.16   | 0.75       | 0.18      | 0.05      | 0.86   |

Table 5: Mean values (n = 108) of basic cation saturation ratio, K saturation percentage, and calcium carbonate in different locations and land use types.

| Land use types | Sodo zuria | Damot gale |
|----------------|------------|------------|
|                | K: Mg (%)  | K: Ca (%)  | Ca: Mg (%) | K-index % | CaCo₃ (%) | K: Mg (%)  | K: Ca (%)  | Ca: Mg (%) | K-index % | CaCo₃ (%) |
| Enest-coffee   | 0.26a      | 0.13a      | 2.02a      | 0.17a     | 24.15a | 0.21a | 0.06a     | 3.24a      | 0.04a     | 23.70a |
| Crop land      | 0.05c      | 0.03b      | 1.99b      | 0.16b     | 71.01a | 0.19c | 0.03b     | 3.44b      | 0.02b     | 81.36b |
| Grazing        | 9.93c      | 3.30c      | 0.29c      | 0.17a     | 70.20b | 0.11b | 0.06a     | 3.25a      | 0.03b     | 79.89c |
| Mean           | 7.95       | 3.27       | 0.29       | 0.16      | 71.21  | 0.10b | 0.06a     | 3.31       | 0.03      | 81.72  |
| CV (%)         | 4.94       | 5.36       | 8.80       | 7.40      | 10.67  | 4.33   | 8.05       | 6.36       | 7.60      | 12.34  |
| LSD (0.05)     | 0.47       | 0.21       | 0.23       | 0.21      | 0.67   | 0.46   | 0.44       | 0.02       | 0.12      | 0.41   |
### Table 6: Mean values ($n=108$) of cation exchangeable capacity in different locations and land use types.

| Land use types | Sodo zuria | Damot gale |  |  |
|----------------|------------|------------|---|---|
|                | ECEC | CEC soil (C molc·kg$^{-1}$) | CECap | ECEC | CEC soil (C molc·kg$^{-1}$) | CECap |
| Enset-coffee   | 15.56 | 20.33a | 70.10 | 16.36 | 18.70a | 93.50 |
| Crop land      | 14.10 | 19.22b | 66.27 | 15.36 | 18.80a | 72.30 |
| Grazing land   | 13.92 | 19.11b | 50.28 | 16.07 | 19.40b | 52.43 |
| Mean           | 14.52 | 19.55 | 62.21 | 15.93 | 18.96 | 72.74 |
| CV (%)         | 11.10 | 12.01 | 2.09 |
| LSD (0.05)     | 1.56 | 1.79 |

|                | Sodo zuria | Damot gale |  |  |
|----------------|------------|------------|---|---|
|                | ECEC | CEC soil (C molc·kg$^{-1}$) | CECap | ECEC | CEC soil (C molc·kg$^{-1}$) | CECap |
| Enset-coffee   | 15.72 | 21.20a | 93.36 | 15.42 | 17.60a | 67.69 |
| Crop land      | 15.17 | 20.60b | 52.82 | 15.02 | 17.60a | 55.00 |
| Grazing land   | 15.58 | 19.50b | 52.70 | 15.35 | 18.60b | 53.14 |
| Mean           | 15.67 | 20.43 | 66.29 | 15.26 | 17.93 | 58.61 |
| CV (%)         | 11.6 | 10.3 | 1.85 |
| LSD (0.05)     | 1.79 |  |

### Table 7: Mean Values ($n=108$) of organic carbon (OC), total nitrogen (TN), and available Phosphorus (Av.P) in different locations and land uses.

| Land use types | Sodo zuria | Damot gale |  |  |
|----------------|------------|------------|---|---|
|                | TN (%) | Av.P (mg kg$^{-1}$) | OC (%) | C : N | TN (%) | Av.P (mg kg$^{-1}$) | OC (%) | C : N |
| Enset-coffee   | 0.17a | 18.70a | 1.60a | 9.41 | 0.14a | 20.58a | 1.70a | 12.14 |
| Crop land      | 0.16b | 10.57b | 1.50b | 9.37 | 0.12b | 11.74b | 1.60b | 13.33 |
| Grazing land   | 0.16b | 12.00c | 1.60c | 10.00 | 0.12b | 14.56c | 1.70a | 14.16 |
| Mean           | 0.16b | 13.76c | 1.56 | 0.30 | 15.63 | 1.66 | 14.21 |
| CV (%)         | 11.6 | 10.3 |  |
| LSD (0.05)     | 1.79 |  |

|                | Sodo zuria | Damot gale |  |  |
|----------------|------------|------------|---|---|
|                | TN (%) | Av.P (mg kg$^{-1}$) | OC (%) | C : N | TN (%) | Av.P (mg kg$^{-1}$) | OC (%) | C : N |
| Enset-coffee   | 0.17a | 17.72a | 1.71a | 10.05 | 0.14a | 16.87a | 1.41a | 7.42 |
| Crop land      | 0.13b | 10.70b | 1.40b | 10.76 | 0.12b | 7.44b | 1.30b | 8.66 |
| Grazing land   | 0.19c | 13.87c | 1.40b | 7.36 | 0.12b | 8.25b | 1.51c | 9.43 |
| Mean           | 0.16b | 14.10 | 1.50 | 9.39 | 0.16 | 10.85 | 1.40 |
| CV (%)         | 5.70 | 8.55 |  |
| LSD (0.05)     | 0.05 | 2.34 | 0.14 |

### Table 8: Mean values of ($n=108$) available micronutrients in different location with land use types.

| Land use types | Sodo zuria | Damot gale |  |  |
|----------------|------------|------------|---|---|
|                | Fe (mg kg$^{-1}$) | Cu (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) | Fe (mg kg$^{-1}$) | Cu (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) |
| Enset-coffee   | 172.20a | 6.33a | 12.51a | 143.67a | 146.50a | 3.62a | 11.17a | 142.40a |
| Crop land      | 182.20b | 0.31b | 12.77a | 143.22b | 157.70b | 0.23b | 11.84b | 140.20a |
| Grazing land   | 177.00c | 0.15c | 11.97b | 136.39b | 149.40c | 0.80c | 11.31b | 131.80b |
| Mean           | 177.06 | 4.26 | 12.41 | 107.76 | 181.20 | 2.05 | 11.44 | 140.13 |
| CV (%)         | 9.34 | 7.80 | 11.49 | 14.67 | 10.8 | 8.4 | 7.90 | 12.70 |
| LSD (0.05)     | 1.64 | 3.32 | 0.42 | 0.47 | 7.10 | 1.88 | 0.40 | 0.78 |

|                | Sodo zuria | Damot gale |  |  |
|----------------|------------|------------|---|---|
|                | Fe (mg kg$^{-1}$) | Cu (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) | Fe (mg kg$^{-1}$) | Cu (mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) |
| Enset-coffee   | 123.30a | 2.86a | 10.10a | 132.50a | 97.30a | 3.93a | 9.58a | 116.50a |
| Crop land      | 129.40b | 0.80b | 10.70b | 147.30b | 101.70b | 1.25b | 8.98b | 123.80b |
| Grazing land   | 125.90c | 2.50c | 10.30c | 139.00c | 99.50c | 2.20c | 9.40a | 122.60c |
| Mean           | 125.90 | 2.05 | 10.36 | 139.60 | 99.50 | 2.26 | 9.32 | 122.46 |
| CV (%)         | 7.42 | 8.40 | 9.40 | 10.89 | 9.40 | 7.20 | 12.60 | 12.70 |
| LSD (0.05)     | 1.30 | 1.74 | 0.48 | 0.52 | 4.30 | 1.89 | 0.17 | 0.68 |
were low. The lowest available P (7.44) was observed in strongly acidic soil (crop land of Boloso Sore District). This may be due to the P fixation with Fe and Al as indicated by the favorable acidic soil reactions indicated by the results of the present study.

3.7. Available Micronutrients. The contents of available micronutrients (Fe, Mn, Zn and Cu) were significantly (P ≤ 0.05) affected by land use, location and their interaction of land use and location (Table 8). The range value of micronutrients for the entire districts in their order is indicated as follows Fe (97.30 to 182), Mn (116.50 to 147.30), Zn (8.98 to 12.77) and Cu (0.23 to 6.33 mg·kg⁻¹) and considering the ratings proposed by FAO [28] across district had sufficient (Fe, Mn, Zn) and Cu low to optimal contents. The highest contents of Fe, Mn, Zn and Cu were recorded under the enset-coffee and grazing land uses of four sites (Table 8), while the lowest contents of Fe, Mn, Zn and Cu were observed under the crop lands of four sites. Likewise, EthioSIS [6] reported sufficient Mn levels in different soil types of Ethiopia including Vertisols. Znic deficiency is mostly not expected on acidic soil [41]. The results reported that Mehlich 3 extracts comparable amounts of micronutrients (Fe, Zn, and Mn) were the sufficiency for Wolaita soil [31]. Generally, Cu content in all soil samples of study districts were found to be yield limiting nutrients, whereas Fe, Mn and Zn levels were sufficient for crop production. It was accounted to low level of soil OM. In line with this finding, the study in some Nitisols of Ethiopia indicated Cu deficiency [39].

4. Conclusions

The physical and chemical properties of soils in the study area vary from land use types and location. The enset coffee land system and grazing land were medium to higher in values, OC, total N and available P, CEC, exchangeable bases, and micronutrients content especially on the surface layer; this might be due to coarser texture of the soil, and the magnitudes of exchangeable Ca and Mg in land use types were rated as low to medium for Ca and medium to high for Mg. Although it is clayey in texture and relatively better in available P, crop land was lower in soil nutrients with lower pH which has become limiting for crop production in all locations. Therefore, it is suggested that besides physical and biology conservation practices, controlled grazing or cut and carry system and integrated soil fertility management techniques are recommended to improve productivity of acidic soils of the study area.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors’ Contributions

Mesfin Kassa, Fassil Kebede, and Wassie Haile contributed equally to this study.

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