

Research Article

Assessment of Selected Physicochemical Properties of Soils under Different Land Uses and Topographic Positions at Gola Wachu Subwatershed, Eastern Ethiopia

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Understanding the influence of land use types and topographic positions on soil physical and chemical properties is vital for sustainable soil management. Therefore, this study was initiated to assess the selected physicochemical properties of soils under different land uses and topographic positions in the subwatershed. The subwatershed area was divided into three land use types (cultivated, grazing, and fallow) and topographic positions (lower, middle, and upper). A total of 27 composite soil samples were collected from (0-20 cm) depth for analysis. All analyzed selected soil physicochemical properties were significantly different by using the least significance difference (LSD) test (P < 0.05) for each type of land use, except for soil texture, C/N, and percent base saturation (PBS). The soil textural classes of all land-use types at each topographic position were clay loam. Overall, the results indicate that most of the selected soil physicochemical properties were lower in soils of cultivated land at each topographic position, signifying that management of soil fertility is required to make agriculture sustainable in subwatershed.

1. Introduction

Rapid population increase and an elongated history of sedentary farming have altered land use types in most countries of the world, especially tropical African countries, and a major cause of environmental deterioration [1, 2]. Agricultural activities alter the physical, chemical, and biological aspects of soil and are key contributors to soil degradation, due to nutrient mining without commensurate fertilizer inputs [3]. In Ethiopia, agriculture is the backbone of the economy, contributing 50% of the gross domestic product (GDP) and 90% of foreign exchange earnings. However, agriculture is under threat because of the unwise use of land resources [4]. Due to continuous agriculture and overgrazing, half of Ethiopia's farmland is moderately to strictly degraded and nutritionally depleted [5]. Land degradation in Ethiopia is caused by the cultivation of fragile soils along steep slopes amidst the prevailing erratic and erosive rainfall patterns, and this situation is aggravated by deforestation and inadequate investments in soil conservation practices such as maintenance of vegetation cover, application of organic matter to the soil, leaving the farmland to undergo fallowing, application of external plant nutrients, and controlled grazing [6, 7]. Consequently, reducing resource depletion, enhancing agricultural output, and attaining food security are the main challenges of the country. Therefore, concerted efforts should be made to conserve the biophysical and socioeconomic environment toward enhancing agricultural productivity while enthroning sustainable agroecosystem.

Various land use and management systems may contribute to differences in management-responsive soil properties. For instance, soil physicochemical parameters in continuous cultivation may differ from those in land that has been left fallow for a long period of time [8, 9]. Soil erosion, leaching, nutrient cycling, carbon sequestration, and other biogeochemical processes are influenced by land-use systems [10, 11]. Wubie and Assen [12] noted that continuous cultivation and application of acid-forming fertilizers affect the transformation and availability of macro- and micronutrients, which in turn affect crop yields and aggravate leaching losses of nutrients in weathered tropical soils. Soil organic carbon can be influenced by land use types, and both biotic and abiotic factors have been recognized as important in this regard [13].

Sufficient knowledge of soil properties at the level of subwatershed is vital for tackling local issues in agricultural production with different management systems. Such knowledge is necessary for developing suitable methods, which can help Ethiopians overcome many of the issues they face in the agricultural sector and in their efforts to conserve and manage natural resources for long-term development.

Among Ethiopian highlands, East Hararghe is the most variable in terms of landscape and is strictly degraded and hence records low farming productivity compared with other regions [14]. In Hararghe region, soil resources are exceptionally diversified in nature owing to the complicated interaction of soil forming factors and processes [15].

High population density in the Gola Wachu subwatershed in the Kersa District of Eastern Ethiopia causes farms to be fragmented and pushes farmers to cultivate on steep slopes. The conversions of forest land and pasture lands into agricultural farms, as well as ongoing overgrazing and cultivation, have severely deteriorated the steep slopes. The cause and extent of the problem in this subwatershed have not been recognized or qualified, neither is information available on how soil physicochemical attributes in various land uses and topographic positions change in reply to land use changes in the subwatershed. As a result, farmers remain without any information about the nutrient status of their soils to sustain their livelihood, and this problem is ongoing. Currently, agricultural productivity in Gola Wachu subwatershed has started to decline, and fertilizer requirements of the soil have become very high. This might be related with periodic changes in land use in this subwatershed. To curb this problem and ensure sustainability of land use in subwatershed, it is imperative to comprehend the status of the various soil properties.

Information on the physicochemical properties of soils across types of land uses and topographic positions at Gola Wachu subwatershed is important for transferring knowledge regarding land use and topographic positions. However, there has been no study in this regard. Therefore, the objective of this research was to assess the selected physicochemical properties of soils from different land uses and topographic positions of this subwatershed. The results of this study are predictable to aid knowledge transmission to stakeholders including farmers, soil scientists, agronomists, and decision-makers.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location. This study was carried out at Gola Wachu subwatershed which is situated in the Kersa district, East Hararghe zone, Oromia Region, Ethiopia. It is located 482 km east of Addis Ababa and 44 km west of Harar city. Geographically, the subwatershed lies between $9^{\circ} 20'0''$ to $9^{\circ} 27'30''$ N and $41^{\circ} 50'0''$ to $41^{\circ} 57'30''$ E at an altitude of 1968 to 2127 m above sea level (Figure 1). The subwatershed covers a total area of 634 ha [16].

2.1.2. Climate. Gola Wachu subwatershed receives a mean annual rainfall of 665 mm according to the data gathered from National Meteorology Agency (NMA) over a twenty-one-year period (1995–2015). The pattern of rainfall in the subwatershed was bimodal. The primary raining season is from July to September, and the short raining season is from March to June. August had the highest average yearly rainfall. The mean minimum and maximum annual air temperatures in the study area were 12 and 24°C, respectively, based on 18 years (1997–2014) of climate data acquisition from the National Metrology Agency, with a mean annual air temperature of 18°C (Figure 2).

2.1.3. Geology and Soils. The Kersa district geology is characterized by the Adigrat Formation, which is made up of sandstones and shells, based on the Ethiopian geological map, which was first available in 1973 at a scale of 1: 2000000. The lower half of the landscape is enclosed by the Hamanlei series development, which contains Oxfordian limestone, whereas the top section is covered with less complicated undifferentiated Precambrian rock. Furthermore, according to Mulat et al. [15], the Hararghe highlands are characterized by crystalline bedrocks made primarily of granitic rock and gneiss. Leptosols, Regosols, Cambisols, Luvisols, and Vertisols are the principal soil types found in subwatersheds [15].

2.1.4. Land Use Types, Vegetation, and Farming Systems. In Gola Wachu subwatershed, various types of land uses are found; the main ones were cultivated, fallow, and grazing land use types (Figure 3). The proportion of several types of land use found in Gola Wachu subwatershed was also identified from the area of land use types using ArcGIS 10.4. The agricultural pattern of the subwatershed is primarily survival agriculture, with crop mixed and livestock production. Livestock is an important aspect of the agricultural system because it provides food, draught power, and revenue to households. Sorghum and maize are the most popular rain-fed field crops and are commonly intercropped with common beans and khat. In addition, Eucalyptus camaldulensis and Eucalyptus globule trees dominated the vegetation around homesteads (Table 1).



FIGURE 1: Location map of the study area [16].



FIGURE 2: Mean monthly rainfall and mean monthly minimum and maximum temperatures of the study area [15].

2.2. Site Selection and Soil Sampling. Field observations and reconnaissance field surveys were conducted prior to soil sample collection, and informally group deliberations with agricultural specialists were conducted to identify representative types of land use. Hence, the entire subwatershed area was divided into three (upper, middle, and lower)

topographic positions through the south aspect, and the key land use types were recognized as three adjacent types of land uses (cultivated, grazing, and fallow).

A purposive sampling technique was used, in order to reduce differences of land uses in climate, geology, soil type, and topography. The slope map of the subwatershed was



FIGURE 3: Land use map of the study area using the satellite image of Landsat 8 OLI.

TABLE 1: Description of the dominant types of land uses in Gola Wachu subwatershed in the Kersa district, Eastern Ethiopia.

No.	Land uses	Brief description
1	Cultivated land	This includes the area utilized for crop production under rain-fed conditions. Mixed cropping, in which khat is intercropped with sorghum, is the most common cropping system. Only a few quantities of OM are reimbursed to the soil, and residue of crop is practically never changed to the soil since it is used for other reasons such as fuel wood, feed of animal, and construction material (e.g., sorghum). The farmers use mostly chemical fertilizers (DAP, urea) for crop production rather than organic fertilizers
2	Grazing land	Land utilized for community cattle grazing and achieved through a controlled system in which livestock is restricted in stalls and fed with a carry and cut system
3	Fallow land	This comprises land that was formerly heavily cultivated but is now uncultivated and in need of rehabilitation

classified using the DEM of ArcGIS 10.4 versions by considering the altitude of the subwatershed. The subwatershed was divided into three slope positions based on the altitude levels (Figure 4).

Soil samples were collected in three replications from nine sampling plots comprising the selected three types of land use in each of the three topographic positions. The sampling plots were square plots of $10 \text{ m} \times 10 \text{ m}$ area recognized at the midpoint of each plot of the studied types of land use. At each sampling plot, eight subsamples were collected from a depth of 0 to 20 cm using a soil auger. The sampling was carried out by the two-way diagonal method from the angles and middles of the square plots after which the soil samples were mixed to form a composite sample. Undisturbed soil samples were also collected using steel core samplers of a 100 cm^3 volume. In this way, 27 each of



FIGURE 4: Topographic positions' and soil sampling points' map.

disturbed composite soil samples and undisturbed soil samples were collected for the analyses of relevant soil properties.

2.3. Soil Sample Preparation and Laboratory Analyses. The disturbed composite soil samples were minimized to 1 kg and packaged in closed plastic bags and tagged, which included proper labeling of land use type, topographic position, collection date, and the sample field code. Prior to analysis, these disturbed soil samples were air-dried at room temperature, pulverized with a pestle and mortar, and passed through a 2 mm sieve in the laboratory for all soil properties except for total nitrogen and organic carbon. For the analysis of total nitrogen and organic carbon, the soil samples were further passed through 0.5 mm sieve to remove coarser materials. The undisturbed samples were carried out following the standard analytical procedures, described as follows.

2.3.1. Analysis of Soil Physical Properties. The selected soil physical properties, including soil texture and BD, were determined. Soil texture analysis was performed using the Bouyoucos hydrometer method [17]. The organic matter (OM) was destroyed with hydrogen peroxide H_2O_2 , and the dispersing agent was sodium hexa-metaphosphate (NaPO₃)₆. Finally, the soil textural classes were determined using the USDA system textural triangle. The BD of the soil was determined on undisturbed (core) soil samples using Blake's [18] techniques which involved dividing the masses of the oven-dried soils (g) by their corresponding volumes (cm³).

2.3.2. Analysis of Soil Chemical Properties. Selected soil chemical properties such as pH, electrical conductivity (EC), cation exchange capacity (CEC), exchangeable bases (Ca, Mg, Na, and K), total nitrogen content, organic matter (OM), available P, and micronutrients (Fe, Cu, Zn, and Mn) were analyzed.

In a supernatant suspension of 1:2.5 soil-to-water ratio, the pH (pH-H₂O) of the soil was potentiometrically determined with a glass electrode and pH meter [19]. The EC (dS/m) was obtained from a suspension prepared for pH analysis [19]. The wet oxidation method was used to analyze soil organic carbon content [20]. Soil OM was approximated from soil organic carbon with multiplying the latter by 1.724.

Total nitrogen (TN) was measured titrimetrically according to Jackson's description of the Kjeldahl method (1973). The ratio of soil organic carbon-to-total nitrogen (C : N ratio) was obtained. After leaching soil samples with 0.5 M sodium bicarbonate (NaHCO₃) at pH 8.5 by using the Olsen extraction method, available phosphorus was determined calorimetrically using a spectrophotometer [21]. The CEC was evaluated using the ammonium acetate ($C_2H_7NO_2$) saturated sample and then replenished with sodium from a penetrated NaCl solution after extra ammonium was removed by repetitive alcohol washing [22].

Using 1N ammonium acetate, exchangeable basic cations (Ca, Mg, K, and Na) were extracted at pH 7 [22]. Using an atomic absorption spectrophotometer (AAS), exchangeable Ca and Mg were determined from the ammonium acetate extract, whereas exchangeable K and Na were determined using a flame photometer from the same extract [22]. The ratio of the sum of exchangeable bases to CEC multiplied by 100 was used to calculate the percent base saturation. According to Serstu and Taye Bekele [23], the accessible micronutrients in the soil (Fe, Mn, Zn, and Cu) were extracted using the diethylene triamine penta acitic acid (DTPA) and subsequently measured using an AAS.

2.4. Statistical Analysis. To determine statistical differences in soil properties in types of land use and topographic positions, the laboratory analysis data were subjected to twoway analysis of variance (ANOVA) using the general linear model (GLM) procedure of the statistical analysis system (SAS) software version 9.1.3 [24]. Fisher's test of least significant difference (LSD) was used to compare and separate significant means at P < 0.05.

3. Results and Discussion

3.1. Selected Physical Properties of Soils under Different Land Uses and Slope Positions

3.1.1. Soil Texture. Soil texture characteristics including sand, clay, and silt contents did not show significant differences (P < 0.05) between different types of land use and topographic positions in Gola Wachu subwatershed (Table 2). Thus, the textural classes of all soils of the three types of land use in each of the three topographic positions were clay loam. Soil texture is an inherent soil characteristic that is predominantly regulated by soil forming processes or soilforming factors, specifically the parent material [15], and it can be considered a soil parameter that is not significantly altered in the short run by types of land use and management of soil [25].

TABLE 2: Soil texture and bulk density under different land uses in each topographic position.

Soil	Land use types	Topographic positions			
properties		Lower	Middle	Upper	LSD(0.05)
$C_{res} = \frac{1}{2} \left(0/2 \right)$	Cultivated land	40 ^a	41 ^a	40 ^a	
Sand (%)	Grazing land	41 ^a	42^{a}	41 ^a	NS
	Fallow land	40^{a}	41 ^a	40^{a}	
$C:I_{+}(0/)$	Cultivated land	22 ^a	23 ^a	23 ^a	NC
Siit (%)	Grazing land	23 ^a	23 ^a	23 ^a	INS
	Fallow land	23 ^a	24 ^a	25 ^a	
$C_{low}(0/)$	Cultivated land	38 ^a	36 ^a	37 ^a	NS
Clay (%)	Grazing land	36 ^a	35 ^a	36 ^a	
	Fallow land	37 ^a	35 ^a	35 ^a	
$PD(1)^{3}$	Cultivated land	1.27 ^a	1.29 ^b	1.33 ^c	0.06
BD (g/cm [*])	Grazing land	1.19 ^a	1.27 ^b	1.29 ^c	
	Fallow land	1.25 ^a	1.28 ^b	1.29 ^c	

BD = bulk density; LSD = least significant difference; NS = nonsignificant; means within rows and columns followed by different letters in superscripts are significantly different at $P \le 0.05$ according to Fisher's LSD.

Although there were no significant differences in soil texture, a nominally high clay content (38%) was verified in cultivated land of the lower topography, which might be as a consequence of severe cultivation, clearing, and leveling of farming fields. The comparatively lower percentage of clay particles in grazing and fallow land uses on the upper topography may be due to less erosion and less transportation of materials (especially finer soil particles) from one place to another. In general, there were no significant variations among the three topography and land uses. This indicates that the influence of land use at different topographic positions on soil texture is minimal. The results agree with those reported by Tewabe [3], showing relatively only slight variations in soil texture along different topographic positions and in various land use types. According to the critical levels suggested by Hazelton and Murphy [26], the clay fraction of the soil of the Gola Wachu subwatershed was moderate, the sand fraction was high, and the silt fraction ranged from low to moderate.

3.1.2. Bulk Density. Bulk density (BD) was significantly different among types of land use at each topographic position. The information presented in (Table 2) shows that BD was higher (1.33 g/cm^3) significantly in cultivated land of upper topography and lower (1.19 g/cm^3) in grazing land of lower topography. The highest BD in cultivated land on the upper topography could be associated with exhaustive tillage activities, which might provisionally lose the plowed layer of soil and in the long term lead to increases in bulk density and decreases in the amount of OM content, which result in poor soil structure. Poor soil structure influences the waterholding capacity, which results in the degradation of soil quality. However, lower BD in grazing land on the lower topography might be owing to the outcome of high OM,

which results in high porosity owing to better structure or aggregation. In addition, bulk density was significantly higher in upper topography of cultivated land as compared to lower topography which might have been a difference due to high soil erosion, low organic matter content, and low porosity in the upper slope than the middle and lower topographies. Similar findings have been reported by Ayoubi et al. [27] and Mulat et al. [15].

According to the critical level specified by Hazelton and Murphy [26], the bulk density of Gola Wachu subwatershed was ranged between low to moderate (1.19 to 1.33 g/cm³). Thus, the bulk density values noted for the soils in the subwatershed were in the normal range. This may not limit root penetration and/or plant growth, air circulation, and the accessibility of highly movable vital nutrients such as P and K.

3.2. Selected Chemical Properties of Soils under Different Land Uses and Slope Positions

3.2.1. Soil pH and Electrical Conductivity (EC). Soil pH (H₂O) and electrical conductivity mean values showed significant variation among the types of land use in each topographic position. The soil pH showed as significantly different at ($P \le 0.05$). The higher soil pH value (6.92) was found in the lower topography of grazing land, while the lower soil pH value (5.89) was recorded on the upper topography of cultivated land (Table 3). This might be related to less soil erosion in grazing land than in cultivated and fallow land and higher deposition of basic cations in the lower topography. In addition, the higher soil pH value in grazing land may be related to inadequate removal of basic cations through leaching and erosion. In other words, the case for lower soil pH value under cultivated as well as fallow land on upper topography might be due to the reduction of basic cations through continuous usage of acid forming inorganic fertilizers and intensive cultivation. These findings are similar to those of Gebreselassie et al. [28], who found low pH values in the soils of cultivated land, which was attributed to extensive farming and the usage of acid forming inorganic fertilizers. In addition, Gonfa et al. [29] revealed that lower pH values in cultivated land were owed to lessening of basic cations in harvesting crop and high microorganism oxidation that produces organic acids, which deliver H ions to the solution of the soil and thus drop the pH of the soil.

Based on the rating of soil pH suggested by Tadesse [30], the values of soil pH noted in the three land uses at three topographic positions of the subwatershed were ranged from moderately acidic to neutral.

Electrical conductivity (EC) was also different in land use types and topographic positions (Table 3). Considering the impact of land use types at each topographic position on EC, the lowest EC (0.02 dS/m) was recorded on cultivated land of upper topography and the highest EC (0.068 dS/m) was recorded on grazing land of lower topography. The electrical conductivity shows an increasing trend down the topography. The case for the highest EC recorded in grazing land

Soil		Topographic positions			
properties	Land use types	Lower	Middle	Upper	LSD(0.05)
	Cultivated land	6.14 ^a	6.10 ^b	5.89 ^c	0.026
рн	Grazing land	6.92 ^a	6.82 ^b	6.79 ^b	0.036
	Fallow land	6.64 ^a	6.49 ^b	6.09 ^c	
EC(dS/m)	Cultivated land	0.049 ^a	0.03 ^b	0.02 ^c	0.015
EC (dS/m)	Grazing land	0.068^{a}	0.05 ^b	0.041 ^c	0.015
	Fallow land	0.064 ^a	0.042 ^b	0.035 ^c	
OM(0)	Cultivated land	1.29 ^a	1.19 ^b	1.15 ^c	0.055
OM (%)	Grazing land	1.98 ^a	1.93 ^b	1.85 ^c	0.055
	Fallow land	1.74 ^a	1.58 ^b	1.55 ^b	
T. (0/)	Cultivated land	0.15 ^a	0.14 ^a	0.12 ^b	0.114
IN (%)	Grazing land	0.18 ^a	0.17^{a}	0.14^{b}	0.114
	Fallow land	0.16 ^a	0.14^{a}	0.13 ^b	
C. N. matia	Cultivated land	5.64 ^a	5.45 ^a	5.30 ^a	NC
C:N ratio	Grazing land	7.58 ^a	6.68 ^a	6.54 ^a	INS
	Fallow land	6.63 ^a	6.25 ^a	6.12 ^a	
Av. P	Cultivated land	3.37 ^a	2.77 ^b	2.04 ^b	0.000
(mg/kg)	Grazing land	7.08 ^b	6.09 ^a	4.66 ^c	0.088
	Fallow land	4.25 ^b	3.87 ^a	3.93 ^a	

LSD = least significant difference; NS = nonsignificant; means within a row and column followed by different letters in superscripts are significantly different at $P \le 0.05$ according to Fisher's LSD.

on the lower topography may be *t* as it contained the highest quantity of basic cations. In contrary, the cultivated upper topography contained the lowest quantity of basic cations, which may have been depleted by concentrated cultivation and washed away of basic cations by leaching and erosion. According to the rating recognized by the US Salinity Laboratory Staff [31], the soils of Gola Wachu subwatershed fall under nonsaline (low EC, <2 dS/m) conditions.

Generally, the EC values in soils of various types of land use in varied topographic positions are not in range that could cause salinity problems and damage the growth of plants. Besides, the commonly low EC values could be accredited to the powerful process of leaching, which eradicates base forming cations from the soil.

3.2.2. Soil Organic Matter. Soil organic matter (SOM) showed significant variation in land use types at each topographic position ($P \le 0.05$). Higher organic matter content was found in the lower topography of grazing land (1.98%) and lower OM content in upper topography of farming land (1.15%) (Table 3). This might be associated with lessened soil degradation and highest OM in grazing land than in fallow and cultivated lands. Similarly, a study in the Bollen watershed, Northwestern Ethiopia, by Kefale [3] indicated that the comparatively low organic matter content noted in cultivated lands soils may be associated with

generally poor practice of applying OM to soil, complete removal of the biomass from cropped fields, steep relief that aggravates removal of the organic material by erosion, and intensive cultivation practices. Uzoh et al. [32] also suggest that organic matter is deposited down through the soil profile.

The OM content showed an increasing trend down topographies for each type of land use in the study area. The case for the lower OM content in the upper slope could be correlated to the steep topography that aggravated the removal of organic material by erosion, and the higher organic matter contented in the lower slope position could be due to less erosion of soil and high organic matter deposition.

According to the critical level specified by Tadesse [30], the soil OM content of various land use types in each topographic position of the subwatershed was categorized as low. This result indicates that the status of soil fertility of the subwatershed is depleted and requires some management intervention to ensure sustainable use of the soil resources in the subwatershed.

3.2.3. Total Nitrogen and C/N Ratio. The total nitrogen (TN) content of the soils was significantly ($P \le 0.05$) influenced by the type of land use at each topographic position. The total nitrogen mean values were higher (0.18%) in grazing land on the lower topography and lower (0.12%) in cultivated land on the upper topography (Table 3). The highest total nitrogen in grazing land of the lower slope might be associated with the involvement of OM added through litter from the dispersed trees, including acacia species that contribute to fixation of nitrogen, urine, and feces of animals during grazing. In contrast, the lower TN in cultivated and fallow land of upper topography might be due to the low OM content caused by the absence of litter fall and crop residue removal. This outcome agrees with the findings of Kefale [3]. Crop residues have been shown to have the advantage of immobilizing nitrogen, which lowers nitrogen mineralization [33].

Following the rating recommended by Tadesse [30], the total *N* content of the different types of land use with slope positions was in range of low to moderate. The total nitrogen content of the grazing land and fallow land of soils of each topography was moderate, whereas it was low in the cultivated land of upper topography soils.

The carbon-to-nitrogen (C/N) ratio in soil is a better indicator of newly added residues. It had a direct impact on decomposition of residue and the cycling of nitrogen in our soils. The soil C/N ratios of the Gola Wachu subwatershed were not significantly influenced by land use type across the topographic positions (p > 0.05). However, a slight numerical variation was observed. Higher carbon-to-nitrogen ratios were found on grazing land on the lower topography, and a lower carbon-to-nitrogen ratio was detected on cultivated land on upper topography (Table 4). The highest C/N ratio in grazing land could be related to the higher OM content through the adding of manure and fall of litter from woody species. The lowest C/N ratio in the upper topography of the cultivated land could be related with the

TABLE 4: Soil exchangeable bases, cation exchange capacity, and percent base saturation under different land uses in each topographic position in the subwatershed.

Soil properties	Land use	Topographic positions			
son properties	types	Lower	Middle	Upper	LSD(0.05)
Ca (cmol	Cultivated land	19.54 ^a	19.25 ^{ab}	18.23 ^b	2 (0
(+)/kg)	Grazing land	21.98 ^a	21.18 ^{ab}	20.0 ^b	2.68
	Fallow land	20.59 ^a	20.36 ^{ab}	19.86 ^b	
Mg (cmol	Cultivated land	9.08 ^a	8.23 ^b	7.85 ^a	1.07
(+)/kg)	Grazing land	10.14 ^a	9.93 ^b	9.85 ^c	1.07
	Fallow land	9.72 ^a	9.04 ^b	8.92 ^c	
K (cmol	Cultivated land	0.92 ^a	0.68 ^b	0.56 ^c	0.072
(+)/kg)	Grazing land	1.17^{a}	1.07^{b}	0.98 ^c	0.073
	Fallow land	1.02^{a}	0.84^{b}	0.68 ^c	
Na (cmol	Cultivated land	0.84 ^{ba}	0.71 ^b	0.65 ^c	0.006
(+)/kg)	Grazing land	0.92 ^a	0.81 ^b	0.75 ^c	0.096
	Fallow land	0.87^{a}	0.76 ^b	0.72 ^b	
CEC (cmol	Cultivated land	48.66 ^a	47.07 ^b	46.04 ^c	1 27
(+)/kg)	Grazing land	52.06 ^a	51.15 ^b	50.11 ^c	1.37
	Fallow land	51.33 ^a	49.84 ^b	49.22 ^b	
	Cultivated land	61.41 ^a	60.88 ^a	57.69 ^a	NG
PB2 (%)	Grazing land	70.72 ^a	66.04 ^a	60.88 ^a	NS
	Fallow land	65.11 ^a	63.60 ^a	60.71 ^a	

CEC = cation exchange capacity; PBS = percent base saturation; LSD = least significant different; NS = nonsignificant; means within a row and column followed by a different letter in superscripts are significantly different at $P \le 0.05$ according to Fisher's LSD.

depletion of OM content. Higher and lower carbon-tonitrogen ratios were verified in the lower and upper topographies of each land use, respectively. This could imply higher OM and total nitrogen in the lower topography than in the middle and upper topographies. Generally, plants can take up nitrogen because of this carbon-to-nitrogen ratio.

3.2.4. Available Phosphorus. Available phosphorus (P) was affected significantly ($P \le 0.05$) by types of land uses across topographic position. The higher (7.08 mg/kg) and lower (2.04 mg/kg) available phosphorus contents were found at lower topography of grazing and upper topography of cultivated lands, respectively (Table 3). This may be due to high OM concentration in lower topography soils of grazing land that releases P at the time of mineralization. In soils, organic compounds raise the availability of P by forming inorganic phosphates that can further simply assimilated by plants. The cause of low available phosphorus content for fallow and cultivated lands as well as upper topography zone of the subwatershed might be in line with the outcomes stated by Mbibueh et al. [5] that accessibility of P in greatest soils of Ethiopia was depleted by the influences of fixation and erosion. This study is also reliable with the studies by Mulat et al. [15] as well as Gonfa et al. [29], who found that alteration in plant cover, nutrient cycling, and biomass production in the ecosystem can impact soil P dynamics. Nonetheless, the findings of this study differed from those of Kiflu and Beyene [34], who stated that accessible P was the highest in cultivated land soils than in grassland soils. Longstanding manure and house refuse treatments, as well as the resulting rise in microbial activity, were blamed by the authors for the greater concentration of accessible P discovered in cultivated land. Besides, considering the topographic position of the highest and lowest available phosphorus was verified on lower and upper topographies of each land use, respectively (Table 3). This might be owing to the fact that normally available phosphorus is powerfully attached to particles of soil and is thus simply transported during erosion down the topography. The result is also in harmony with Gadana et al. [35] who stated that the most widespread phosphorus loss in Ethiopia is owing to erosion of soil particularly in the highland areas.

Based on Landon [36], the soil available phosphorus level of <4 mg/kg is valued as low, 5–7 mg/kg as intermediate, and >8 mg/kg is valued as high. Therefore, the available phosphorus level of the soils in the subwatershed was in the range of low to medium.

3.2.5. Exchangeable Bases. Exchangeable Ca and Mg were significantly different ($P \le 0.05$) between types of land uses in each topographic position. The highest exchangeable Ca (21.98 cmol (+)/kg) was noted under grazing land use type at lower topography, and lower exchangeable Ca (18.23 cmol (+)/kg) was detected under cultivated land of upper topography (Table 4). Higher exchangeable Ca on grazing land of lower topography might be due to high CEC and OM. The lower exchangeable Ca soils of cultivated land in upper topography may be related to low pH and SOM (Table 3). Also, lower exchangeable Ca might be related to extensive removal by harvesting crop with no/little OM input into the soil. These results are consistent with Gonfa et al. [29], who found that agriculture increases Ca²⁺ leaching, particularly in acidic tropical soils. Donis and Assefa [37] found decreased Ca in the cultivated fields of surface horizon, which they attributed to Ca removal during crop harvest, excessive leaching from continuous cultivation, and OM decomposition. Generally, higher accumulation of exchangeable Ca was observed at the lower topographic positions and may be owed to particle movement from the upper position to the lower position and the prevalence of closely flat to gently undulating topography at the lowest soil sampling site. The ratings given by FAO [38] on the exchangeable Ca soils of the subwatershed fall in the range of medium.

Exchangeable Mg varied in response to variation types of land use among topographic positions. The mean values of exchangeable Mg value in the grazing land use type were 9.85, 9.93, and 10.14 cmol (+)/kg on upper, middle, and lower positions, respectively, and those under the cultivated land use type were 7.85, 8.22, and 9.08 cmol (+)/kg on upper, middle, and lower positions, respectively, and those under the fallow land use type were 8.92, 9.04, and 9.72 cmol (+)/kg on upper, middle, and lower positions (Table 5). The highest (9.97 cmol (+)/kg) mean values of exchangeable Mg were

TABLE 5: Extractable micronutrients of soils in different land uses in each topographic position of the study area.

Soil	Land use types	Topographic positions			
properties		Lower	Middle	Upper	LSD(0.05)
	Cultivated land	13.84 ^a	13.68 ^{ab}	13.23 ^c	0.200
Fe (mg/kg)	Grazing land	15.48 ^a	15.31 ^a	14.90 ^b	0.398
	Fallow land	14.63 ^a	14.29 ^a	13.82 ^b	
	Cultivated land	19.93 ^a	19.08 ^b	19.07 ^b	0.106
Mn (mg/kg)	Grazing land	22.17 ^a	21.99 ^b	21.98 ^b	0.106
	Fallow land	21.98 ^a	21.25 ^b	20.63 ^b	
7 (1)	Cultivated land	0.55 ^a	0.52 ^a	0.47 ^b	0.113
Zn (mg/kg)	Grazing land	0.89 ^a	0.76 ^b	0.72 ^{bc}	
	Fallow land	0.64 ^a	0.61 ^a	0.55 ^{ab}	
	Cultivated land	1.28 ^a	1.26 ^{ab}	1.18 ^c	0.00
Cu (mg/kg)	Grazing land	1.37 ^a	1.34 ^{ab}	1.31 ^{ab}	0.09
	Fallow land	1.32 ^a	1.29 ^b	1.27 ^b	

LSD = list significant difference, means within a row and column followed by different letters in superscripts are significantly different at $P \le 0.05$ according to Fisher's LSD.

found in grazing land soils followed by fallow land, whereas the lowest one (8.38 cmol (+)/kg) was found in cultivated land (Table 4). This might be related to higher leaching of exchangeable Mg based on the upper topographic position, and intensive cultivation and land clearing in cultivated land may lower the amount of this exchangeable Mg. The exchangeable Mg reduced in the grazing-to-cultivated land that may be related to higher soil OM observed in the grazing land. Besides, comparatively less exchangeable Mg detected in the cultivated land soils might be for the lower SOM and intensive farming which is the reason for leaching and deletion in crop harvest. This agrees with the study of Gonfa et al. [29], who found which intensive agriculture increases Ca2+ and Mg2+ depletion, particularly in acidic tropical soils. Based on FAO [38], exchangeable Mg of the soils in the research area is in the high to very high range.

Exchangeable K diverse in response to different types of land was used at each topographic position. The higher exchangeable K (1.17 cmol (+)/kg) was noted in the grazing type of land use of lower topography and the lower K⁺ (0.56 cmol (+)/kg) was detected under the cultivated land of upper topography (Table 4). The higher exchangeable K might be due to existence of various tree species types in the grazing land that drives the cation over their deep roots, whereas the lower exchangeable K in the agricultural/cultivated land was possibly due to great K⁺ removal by soil erosion and intensive cultivation. According to Gonfa et al. [29], high levels of weathering and intense farming, as well as the usage of acid forming inorganic fertilizers (urea and diammonium phosphate), influence the distribution of potassium in soils and contribute to its reduction. This could be probable case for the comparatively lower exchangeable K in the soils of CL, especially at upper topography. In contrary, exchangeable K shows an increasing trend from upper slope to lower topographic position. This variation might be related to higher soil erosion and leaching on upper topography in contrast with lower and middle topography. According to the FAO [38] critical value, the exchangeable potassium of soils of the subwatershed was in the range of medium to high. The detected exchangeable K mean values of soil in the subwatershed fall in the range of medium in the cultivated land and fallow land while high in the grazing land use type.

Exchangeable Na also shows variation amongst types of land use in each topographic location. It was higher (0.92 cmol (+)/kg) in the grazing land of lower topography and lower (0.65 cmol (+)/kg) in the cultivated land of upper topography (Table 4). The lower exchangeable sodium in upper topography of the cultivated land may be related to soil erosion, leaching, and deposition of soil particles on the upper topographic position to lower topographic position. As ratings by FAO [38], exchangeable Na mean values soils were from medium to high in the subwatershed. The recorded exchangeable Na mean values of soils of the subwatershed dropped in the range of medium in the cultivated land use type of upper topography, while they were high in fallow and grazing land use types of all topographic positions.

Generally, investigation by Gebrekidan and Negassa [39] indicated that differences in spreading of exchangeable bases depend on particle size distribution, mineral existence, the weathering of degree, climatic conditions, management practices of soil, intensity of cultivation, and development degree of soil and parent material as when the soil is formed. Moreover, restricted recycling of crop residue and dung in the soil, deforestation, leaching, much less usage of chemical fertilizers, decreasing fallow periods or extensive cropping, and erosion of soil have contributed to the reduction of basic cations and CEC in the cultivated land as compared to the grazing land.

3.2.6. Cation Exchange Capacity and Percent Base Saturation. Cation exchange capacity (CEC) mean values of soils in subwatershed were significantly ($P \le 0.05$) influenced by types of land use and topographic positions. The highest (52.06 cmol (+)/kg) and lowest (46.04 cmol (+)/kg) CEC mean values were observed in grazing of lower topography and cultivated land use of upper topography, respectively (Table 5). The CEC mean values in the cultivated land of upper topography reduced chiefly due to a decrease in the OM content. The higher cation exchange capacity in the grazing land of lower topography might be due to joint impact and involvement of organic matter and amount and types of clay content in the soil. The findings are in agreement with those of Lemma et al. [40, 41], who found that cation exchange capacity of soil varies as land uses change. Moreover, Gebreselassie et al. [28] and Kiflu and Beyene [34] concluded that higher CEC in the grazing land was caused by high organic matter and clay content. The CEC values reveal an increasing trend from the upper to lower topographic position (Table 4). This may be linked to the increment of clay and OM content of the upper topographic and lower topographic positions. As per ratings of the cation exchange capacity of soil by Hazelton and Murphy [26], the CEC soil in the subwatershed was classified as very high in all types of land use in each topographic position.

Percentage base saturation (PBS) does not significantly (P > 0.05) vary by types of land use in each topographic position. However, relatively higher mean values (70.72%) and the lower mean values (57.69%) of PBS were recorded under the grazing land of lower topography and cultivated land of upper topography, respectively (Table 4). The case for high PBS content in the grazing land may be associated with high SOM of the soil, and that of the low PBS content observed in the cultivated land of upper topography might be associated with the lower pH and lower SOM content. Seemingly, Abate [42] recommended that difference in PBS might be due to difference in pH, soil organic carbon content, particle size distribution, intensive of cultivation, parent materials, soil management practices, slope, and leaching. Processes that modify the amount of basic cations have an effect on percent base saturation in general. According to the saturation rating given by Hazelton and Murphy [26], percent base saturation soils in the subwatershed was were the range of moderate to high indicating the presence of weakly to moderately leaching conditions.

3.2.7. Extractable Micronutrients (Fe, Mn, Cu, and Zn). The same to other soil properties analyzed in this study and the four extracted micronutrients (Cu, Mn, Fe, and Zn) were statistically different in soils of various types of land use in each of the three topographic positions. The highest contents of available Fe (15.48 mg/kg soil), Mn (22.17 mg/kg soil), Cu (1.37 mg/kg soil), and Zn (0.89 mg/kg soil) were observed in the grazing land of lower topographies, while the lowest (13.23, 19.07, 1.18, and 0.47 mg/kg soil) contents of Fe, Mn, Cu, and Zn were recorded in the cultivated land of upper topographies, respectively (Table 5). The lower extracted Fe, Mn, Cu, and Zn contents of the cultivated land of upper especially upper topography may be owing to the minor SOC content and leaching of extracted micronutrients by erosion. This outcome is in harmony with the finding of Abate [42] who stated that the difference in the intensity of leaching, possibly high erosion and rainfall in that specific microclimate, might also be accountable for the lower level of micronutrients. Furthermore, these differences of extracted micronutrients of the subwatershed agreed with the study of Gebrekidan and Negassa [39] who stated that micronutrients are affected by different land uses variously.

Micronutrient availability is specifically sensitive to alter in the soil environment, according to Wajahat et al. [43]. OM, soil pH, sand, and clay content are aspects that influence the level of micronutrients. In addition to these, intensity of farming, properties of soil drainage, type of soil, erosion, and leaching could also be accountable for the difference in soil micronutrient content. The recent study was also likewise examined that variances in the content of extracted micronutrients in each land use type may be related to the effect of several aspects, such as anthropogenic and environmental factors, soil pH, parent material, soil texture, SOC, CEC, and available P in soils, which influence the obtainability of micronutrients in various types of land use in the subwatershed.

According to the critical level suggested by Jones [44], the mean values of Fe and Mn in types of land use at each topographic position were in high range for grazing land and fallow land at each topography and medium for the cultivated land of all topographies. The Zn content was found in the medium range in soils of the three land uses on the three positions except being low for the cultivated land of upper topography. The content of Cu was found in the low range in the types of land use across the positions. The results indicate that soils of the cultivated land, particularly those on the upper topography, are deficient in copper (Cu) and therefore require intervention. Furthermore, the high levels of Mn and iron could result in toxicity effects.

4. Summary and Conclusions

Gola Wachu subwatershed is featured by great population pressure, continuous cultivation, and over grazing that leads to land use degradation. According to the results obtained from this study, most of the soil properties significantly varied among three land use types and topographic positions. The results show that the textural classes of all soils in three major types of land use on the three topographic positions are clay loam and did not show a significance difference in various types of land uses in each topographic position. Furthermore, the bulk density mean values observed in soils in the three major land use types in each topographic position were below the critical value at which it may not cause compaction and hence may not affect plant root penetration.

Soil chemical properties such as pH, EC, OM, Av. P, TN, CEC, exchangeable bases (Ca, Mg, K, and Na), and extracted micronutrients (Fe, Mn, CU, and Zn) showed variability amongst land use types in each topographic position, while C/N and PBS did not show variance amongst land use types in each topographic position. A consistently higher pH value was detected in soils of the grazing land of lower topography followed by the fallow and cultivated lands. The EC mean values verified in soils of various types of land use on varied topographic positions are not in the range that might cause the problem of salinity and damage the plant growth. SOM mean values ranged in low, and TN mean values ranged in low to moderate. Available P, exchangeable bases, CEC, and micronutrients were found higher in the grazing land of lower topography in comparison to fallow and cultivated lands at each topography.

From the outcomes obtained in this study, it can be summarized that most soil properties significantly varied under three land use types at each topographic position. In this subwatershed, the results clearly showed that there is an indication of soil fertility decline particularly on the upper topographic positions of the farm/cultivated land as compared to fallow and grazing lands. Thus, based on the findings of this study, it could be suggested that integrated soil fertility management practices such as soil and water conservation practice, addition of soil organic matter, appropriate use of inorganic fertilizers, and reduction in deforestation, and overgrazing need to be undertaken to protect degradation of land and to improve and restore the lost soil fertility status on the cultivated land and eventually improve agricultural productivity on a sustainable basis.

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

All authors contributed to this work. The corresponding author contributed mainly, and the other two authors gave advice and contributed to other related works.

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Supplementary Materials

Table S1: ratings of bulk density and particle size distribution for a given soil. Table S2: ratings of soil pH based on pH (H₂O) and organic matter (OM). Table S3: ratings of available phosphorus and total nitrogen. Table S4: ratings of exchangeable basis, CEC, and PBS in the soil. Table S5: explanatory values for DTPA-extracted Cu, Mn, Fe, and Zn (mg/kg). Table S6: mean squares ANOVA for the impact of types of land use and slope positions of selected soil properties. Table S7: mean squares ANOVA for the interaction impact of types of land use and slope positions of selected soil properties. (*Supplementary Materials*)

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