Dynamics of Soil Physical and Chemical Properties under Different Current Land Use Types and Elevation Gradients in the Sala Watershed of Ari Zone, South Ethiopia

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Received 14 March 2023; Revised 18 February 2024; Accepted 18 April 2024; Published 27 April 2024

Academic Editor: Arisekar Ulaganathan

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The dynamics of soil physical and chemical properties have been increasing due to inappropriate land use and unsustainable land management practices in Ethiopia. This study aims to assess the dynamics of selected soil physical and chemical properties under different current land use types and altitudinal gradients in the Sala watershed of Ari Zone in South Ethiopia. In the study area, analyzing and understanding the dynamics of soil physicochemical properties under different land use types play a vital role in sustainable soil productivity. Before collecting a soil sample, land use types and altitudinal variations were surveyed in the study watershed. Three random strata were selected from the watershed, and the major adjacent land use types in each stratum were identified across elevation gradients. A total of 30 composite soil samples were collected from different land uses and elevations using a zigzag sampling technique at 0–20 cm soil depth from upland (12), midland (9), and lowland (9). Laboratory results showed that most soil physical and chemical properties had poor ratings in the watershed area. All soil properties were significantly affected by land use types and elevation factors ($P < 0.05$), except for soil texture, TN, and CEC. Soil texture is highest in the upper and lower elevations of grazing land (61.3%) and shrubland (55.4%), while lowest in cultivated land (11.3%) and barren land (11.6%) at higher altitudes. The highest mean of soil texture was dominated by clay soil (55%) in shrubland followed by sand soil (50.30%) in the barren land and silt soil (20.06%) in cultivated land. Chemical soil properties (pH, SOM, TN, Av. P, Av. K, and CEC) were significantly varied under each land use type across altitudes. The results of this study showed that inappropriate land use and unsustainable agricultural practices had more significantly influenced the soil fertility status. Therefore, appropriate soil and water conservation measures should be implemented in the studied watershed to improve soil fertility and crop productivity.

1. Introduction

Soil is the primary resource for practically all land uses and the most significant component of sustainable agriculture [1]. It is the basic resource for economic development and for maintaining sustainable productive landscapes and people’s livelihoods, especially for countries with agrarian economies. However, this critical natural capital base becomes vulnerable to decay and degradation over time [2–4], manifesting as land and soil degradation. Land use land cover provides significant advantages for reasoned and optimal use of land resources through policy implications, whereas land use land cover changes and climate change highly influence agricultural production [5]. Soil degradation is a major agricultural and environmental issue affecting agricultural productivity and food security in Ethiopia [6–8]. The deterioration of soil physical, chemical, and biological properties has had a major contribution to soil degradation due to serious soil erosion, overcultivation, suboptimal use of fertilizer, inappropriate land uses, or other management practices on soils. Land use change and associated ecosystem changes can also have significant impacts on soil’s physical, chemical, and biological properties [9, 10]. Soil fertility on small farms remains a major concern, especially in developing countries such as Ethiopia, where more than 90% of the population depends on agriculture for food and
soil's physical and chemical properties [33, 34]. This jeopardizes the country's annual crop production and productivity and affects the food security of local farmers [35].

Soil fertility needs to be maintained through sustainable use of land resources, as soils can quickly lose their quality and quantity due to several reasons.

In the country of Ethiopia, several studies have investigated the impact of land use land cover types on soil physical and chemical properties [28, 33, 36–50]. The effects of land use on soil properties could vary depending on several factors, such as slope, landscape positions, soil types, soil depth, land use, and their management [29, 51–53]. Improper agricultural practices and land cover changes can affect soil physical and chemical properties and biological activity, leading to rapid degradation of soil quality [12]. According to studies conducted in many parts of Ethiopia, there were different statuses of soil physical and chemical properties for different types of land use and altitudinal gradients. However, no studies on the effects of land use type and altitudinal gradients on soil physical and chemical properties have been carried out in the Sala watershed of Ari Zone in South Ethiopia.

Sala watershed was hugely beneficial for agricultural production and productivity. The area is also characterized by diverse topographical features and different land use systems, as well as different natural resources. However, the study Sala watershed is facing the problems of overgrazing, poor land and soil management practices, deforestation, severe soil erosion, and loss of soil productivity. Regarding this, the area of the watershed has led to the decline of soil productivity, a decrease in land and crop product and productivity, and a decrease in agricultural income and food security. For this reason, researching and understanding the soil physicochemical properties in different land use types is necessary to reduce ongoing soil degradation and improve the sustainable use of soil resources. The findings of this study will assist farmers, environmental and natural resource practitioners, and different stakeholders, as well as policymakers in developing appropriate land use plans aimed at improving soil fertility and restoring declining agricultural productivity. Therefore, the main objective of this study was to assess the dynamics of selected soil physical and chemical properties under different current land use types and altitudinal gradients in the Sala watershed, South Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The study was carried out in the Sala watershed of North Ari woreda in Ari Zone, South Ethiopia, which is located between 6°7′30″ and 6°12′30″ N latitude and 36°40′0″ and 36°45′ 00″ E longitude and has an elevation range of 1391–3210 meters above the sea level (Figure 1). It is located 585 km south of Addis Ababa. North Ari woreda boundary lies on the east Uba Debre Tsehay woreda, on the west Basketo Zone, on the south Woba Ari woreda, and on the north Geze Gofa and Oyda woredas. The topography of the study watershed is characterized by a flat to steep slope landscape. The major soil type in the study area is Orthic Acrisols (very deep, well-drained, and dark brown loamy soil). The mean minimum

livelihood [11]. Soil quality can deteriorate rapidly due to inappropriate agricultural practices and land cover changes [12, 13]. The unusual agricultural practices can result in a loss of potential soil nutrients and soil quality, thereby affecting agricultural production, food security, and livelihoods [14]. Therefore, changes in land use (LU) have a significant impact on the dynamics of soil properties [15].

Soils of sub-Saharan African countries including Ethiopia are characterized by huge and widespread negative nutrient balance (this means that input minus removal) and low productivity [16]. A significant decrease in soil nutrients in East Africa is due to the deterioration of physical, chemical, and biological properties [17]. The low fertilizer application rates, low crop residue turnover, inadequate use of manure and fertilizer, and poor land management practices lead to soil nutrient deficiencies [18]. In addition, soil compaction, loss of soil structure, degradation of soil organic matter, soil acidity, and salinity are examples of problems of soil degradation due to inadvertent land use change [19]. Land use land cover changes are one of the worldwide variations that have the most significant effects on the natural environment and ecosystem due to human activities [20]. Land use change and the continued use of land for crops and grazing have resulted in devastating losses of soil nutrients, particularly in the highlands where erosion is more severe [21]. The rate of soil quality degradation depends on several factors, such as land use system, soil type, altitudes, topography, and climatic conditions [22]. The main causes of land degradation are high population pressure, excessive livestock pressure on grasslands, land use change, inappropriate agricultural practices, large-scale deforestation of natural forests (agricultural expansion, fuel, and construction), agricultural expansion (cultivation of steep slopes and marginal areas), and the rugged nature of the landscape [23–27].

Most agricultural soils in the highlands of Ethiopia suffer from persistent loss of soil fertility due to severe soil erosion and land use change, chemical degradation (nutrient loss through harvesting, erosion, leaching, and others), physical degradation (surface sealing and crust formation), and biological degradation (decrease of soil humus content), and the resulting soil degradation leads to a decline in agricultural productivity [28, 29]. The fertility status of Ethiopian soils has deteriorated, threatening crop production; this is due to continuous management, reduced manure application, removal of crop residues and animal manure as fuel wood and erosion, and low essential soil fertility [30]. Changes in land use and soil management have significant impacts on the physical and chemical environment, thereby affecting soil fertility and agricultural productivity [31, 32]. Soil properties vary greatly by the soil type and location, reflecting differences in parent material, climate, and land use [23]. Among watersheds, especially in areas with multiple land uses and complex topography, topography and land use type can be major factors in determining the state of soil's physical and chemical properties [33, 34]. This jeopardizes the country's annual crop production and productivity and affects the food security of local farmers [35].
and maximum temperatures are 11°C in the winter and 22.3°C in the summer, respectively, with a mean temperature of 16.65°C. Between 1200 and 2218 mm of annual rainfall, with an average of 1709 mm, is received in the watershed area. There is a bimodal rainfall pattern in the study area, with two seasons. The spring (Belg), from February to May, is when there is the least amount of rain, and the summer (Kremt), from June to September, is when there is the most. The main land use land cover (LULC) classes include cultivated lands, grazing lands, shrublands, wetlands, settlements, and barren lands.

The total population of the studied watershed was approximately 39,646, of whom 18,622 (46.97%) were males and 21,024 (53.03%) were females. The economic activity of the study area is characterized by a subsistence system of mixed crop and livestock farming. Predominant seasonal and annual crops in the watershed include teff (Eragrostis tef), sorghum (Sorghum bicolor), banana (Musa mesta), potato (Solanum tuberosum), taro (Colocasia esculenta), cassava (Manihot esculenta), barley (Hordeum vulgare), wheat (Triticum vulgare), and bean (Phaseolus vulgaris). The most common animals in the study watershed are cattle, donkeys, goats, sheep, and mules. In the study, the watershed also grows cash crops like korerima (Aframomum corrorima or Ethiopian cardamom), as well as coffee (Coffea Arabica). The staple food in the study area is enset (Ensete ventricosum).

2.2. Soil Sampling Procedures and Laboratory Analysis. The Sala watershed has been selected for purposive sampling due to different current land use types affecting the soil properties in the study area. To achieve the aim of the study, both primary and secondary data sources were used. The primary data were obtained from field observations and soil samples, while the secondary data were obtained from relevant materials such as research reports and journals from various sources. Land use types and altitudinal gradients were surveyed before soil samples were collected. Four land use types were identified, namely, cultivated land, grazing land, shrubland, and barren land. Elevation gradients were classified as upper, middle, and lower.

Three random strata were selected from the watershed elevation, and the major adjacent land use types in each stratum were identified across elevation gradients, of which four were at the top (CL, GL, SL, and BL), three in the middle (CL, GL, and BL), and three at lower altitudes (CL, GL, and SL), with one depth and three replicates per sample field (4 * 3 * 3 * 3 elevations * 1 depth * 3 replicates) (Table 1). Soil samples were collected at three elevations, upper (2500–3210), middle (1900–2500), and lower (1391–1900), followed by identified land use types across elevation gradients. A total of 30 composite soil samples were collected from different current land use types and altitudinal gradients using a zigzag sampling technique at 0–20 cm soil depth from upland (12), midland (9), and lowland (9).
2.3. Laboratory Analysis. Soil samples for laboratory analysis were used quantitatively to assess the dynamics of selected soil physical and chemical properties under different land use types and elevation gradients at the Sala watershed. For soil sampling, 1 kg of representative mixed soil from each sample category was collected in plastic bags, secured, labeled, and shipped for laboratory analysis at Arba Minch University’s Chemistry Soil Laboratory Center. They were air-dried in the shade, mixed well, ground with pestle and mortar, and sieved to pass through a 2 mm sieve for laboratory analysis, except for soil organic matter and total nitrogen analysis, which were ground to pass through a 0.5 mm sieve.

Soil texture was analyzed according to the procedures described by the FAO [54] using the hydrometer method. Soil pH was determined in a 1:2.5 soil-water suspension using the method described [55]. The soil organic matter (SOM) content was calculated by multiplying soil organic carbon content by a factor of 1.724 [56]. Total N was measured using the Kjeldahl method, the available P was quantified using the Olsens method [57], the available potassium (AK) content was measured by Flame photometry after extraction with ammonium acetate [58], and cation exchange capacity (CEC) was determined after extraction with ammonium acetate [59].

2.4. Statistical Analysis. Tables 1 and 2 show the soil's physical and chemical properties that were obtained using laboratory data. One-way MANOVA following the GLM procedure was used to assess the statistical variances of land use types and altitudinal gradients on soil properties. To determine the effects of land use types and elevations (independent variables) on soil physical and chemical properties (dependent variables), the selected physicochemical soil laboratory tests were analyzed using a one-way multivariate analysis of variance at \( P < 0.05 \) (Table 3).

3. Results

3.1. Dynamics of Soil Physical Properties under Different Land Use Types across Elevation Gradients. The laboratory results of the soil samples are statistically summarized of the Sala watershed in Table 1. The result showed that soil physical properties vary according to land use types and elevation gradients (Table 1).

3.1.1. Soil Texture. Results showed that soil texture in the studied watershed was insignificantly affected by land use types and elevation gradients \( (P < 0.05) \) (Table 3). The soil was dominated by clay fraction in most soils across different land use types and elevations (Table 1). The highest (61.3%) and lowest (20.25%) clay soils were found under the upper and lower grazing and cultivated lands, respectively (Table 1). The highest mean of clay content was recorded in shrubland soils (55%) followed by grazing land (53.16%), cultivated land (34.96%), and barren land (31.35%) (Table 3). The mean clay content ranged from 31.35% (barren land) to 55% (shrubland) and 38.06% (lowland) to 48.95% (upland) across land use types and altitudinal gradients, respectively (Table 3).

The highest proportion (53.3%) in the grain size distribution of sandy soil was found on cultivated land and the lowest (24%) on grazing land (Table 1). In the study watershed area, the highest mean of sand content was recorded in barren land soils (50.30%) followed by cultivated land (44.96%), grazing land (28.20%), and shrubland (25.70%) (Table 3). The mean sand content ranged from 25.70% to 50.30% and 35.52% to 40.04% across land use land cover types and elevations, respectively (Table 3). Silt fraction was lowest (11.3%) on the upper cultivated land and highest (26.5%) on the lower cultivated land (Table 1). The highest mean of silt content was recorded in cultivated land soils (20.06%) followed by shrubland (19.30%), grazing land (18.63%), and barren land (18.35%). The mean silt content ranged from 14.45% to 22.91% across elevations (Table 3).

3.2. Dynamics of Soil Chemical Properties under Different Land Use Types across Elevation Gradients

3.2.1. Soil Reaction (pH). The results of soil pH were significantly affected by land use types and elevation \( (P < 0.05) \) (Table 3). According to Table 2, the cultivated and shrub areas had the lowest soil pH values (4.23) and the highest soil pH values (7.34), respectively. The highest mean values of pH content were recorded in shrubland soils (7.10) followed by grazing land (5.66), cultivated land (5.26), and barren land (4.62) (Table 3). The mean pH content ranged from 4.62 (barren land) to 7.10 (shrubland) and 5.09 (upland) to 6.47 (lowland) across land use types and elevations, respectively (Table 3).

The overall soil reaction (pH) of the studied watershed ranged from strongly acidic (pH 5.5) to moderately alkaline (7.3–8.4) according to the pH rating category proposed [60]. The pH value of strongly acidic soil is more pronounced in the highlands and midlands than in the lowlands (Table 2). With this in mind, the majority of the land use types in the upland and midland elevations (cultivated, grazing, and barren lands) of the pH value of the watershed could be

| Table 1: Soil textures at different land use types across elevation gradients. |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Physical property | Upper land | Middle land | Lower land |
| Soil texture | CL | GL | SL | BL | CL | GL | BL | CL | GL | SL |
| Sand (%) | 47.2% | 24% | 25.2% | 50% | 34.4% | 34.2% | 50.6% | 53.3% | 26.4% | 26.2% |
| Clay (%) | 41.5% | 61.3% | 54.6% | 38.4% | 43.2% | 45.7% | 24.3% | 20.2% | 52.5% | 55.4% |
| Silt (%) | 11.3% | 14.7% | 20.2% | 11.6% | 22.4% | 20.1% | 25.1% | 26.5% | 21.1% | 18.4% |
| Textural class | Sandy clay | Clay | Clay | Sandy clay | Clay | Clay | Sandy clay loam | Sandy clay loam | Clay | Clay |

Land use types: CL, cultivated land; GL, grazing land; BL, barren land; SL, shrub land.
classified as highly acidic, while the remaining land use types could be classified as highly acidic in various elevations and could be categorized as moderately acidic to moderately alkaline (Table 2). Therefore, the pH was marked variation among land use types across elevations (Table 2).

### 3.2.2. Soil Organic Matter (SOM)

Land use type and elevation had a highly significant ($P < 0.05$) effect on organic matter content (Table 3). The analysis showed that soil organic matter in the studied watershed was highest (5%) under the grazing land and lowest (1.14%) on the barren land (Table 2). The highest mean OM content was recorded in grazing land (4.43%) followed by shrubland (3.99%), cultivated land (3.56%), and barren land (1.39%) (Table 3). The mean of OM content ranged from 1.39% to 4.43% across land use types (Table 3). Karltun, Mamo, Bekele, Gameda, and Kidanu [60] classified the soil organic matter content in the studied watershed as moderate (3.09–5), low (2.92–3.0), and very low (1.14–1.65) depending on the recorded land use types and elevations (Tables 2 and 3). Based on the data [60], most of the sampled soils in the studied watershed were classified as medium in average total nitrogen content, but the remains are very low (Tables 2 and 3).

### 3.2.3. Total Nitrogen (TN)

According to the analysis of variance, the results showed that the available phosphorus content of the studied watershed was significantly ($P < 0.05$) influenced by the land use type and elevation (Table 3). The highest mean Av. P content was recorded in shrubland (120.10 mg/kg) followed by grazing land (64.67 mg/kg), cultivated land (52.33 mg/kg), and barren land (20.18 mg/kg) (Table 3). The Av. P mean ranged from 20.18 mg/kg to 120.10 mg/kg and 40.69 mg/kg to 95.74 mg/kg across land use types and elevations, respectively (Table 3), but most soils contain medium (0.15–0.3) based on ratings proposed by scholars [60]. According to the analysis of variance, the results showed that the available phosphorus content of the studied watershed was significantly ($P < 0.05$) influenced by the land use type and elevation (Table 3). The highest mean Av. P content was recorded in shrubland (120.10 mg/kg) followed by grazing land (64.67 mg/kg), cultivated land (52.33 mg/kg), and barren land (20.18 mg/kg) (Table 3). The Av. P mean ranged from 20.18 mg/kg to 120.10 mg/kg and 40.69 mg/kg to 95.74 mg/kg across land use types and elevations, respectively (Table 3). According to the analysis of variance, the results showed that the available phosphorus content of the studied watershed was significantly ($P < 0.05$) influenced by the land use type and elevation (Table 3). The highest mean Av. P content was recorded in shrubland (120.10 mg/kg) followed by grazing land (64.67 mg/kg), cultivated land (52.33 mg/kg), and barren land (20.18 mg/kg) (Table 3). The Av. P mean ranged from 20.18 mg/kg to 120.10 mg/kg and 40.69 mg/kg to 95.74 mg/kg across land use types and elevations, respectively (Table 3). According to the analysis of variance, the results showed that the available phosphorus content of the studied watershed was significantly ($P < 0.05$) influenced by the land use type and elevation (Table 3). The highest mean Av. P content was recorded in shrubland (120.10 mg/kg) followed by grazing land (64.67 mg/kg), cultivated land (52.33 mg/kg), and barren land (20.18 mg/kg) (Table 3). The Av. P mean ranged from 20.18 mg/kg to 120.10 mg/kg and 40.69 mg/kg to 95.74 mg/kg across land use types and elevations, respectively (Table 3).
the upper and middle lands and high (80–150 mg/kg soil) in the lowland soils of the watershed, while the mean of different land use types was low to high ranges (15–150 mg/kg soil) (Table 3).

3.2.5. Available Potassium (Av. K). Available potassium was significantly (P < 0.05) influenced by land use types and elevations (Table 3). With a mean of 156.13 mg/kg, available potassium was highest in shrubland (235.4 mg/kg) and lowest in barren land (76.86 mg/kg) (Table 2). The highest mean Av. K content was recorded in shrubland (217.08 mg/kg) followed by cultivated land (187.99 mg/kg), grazing land (137.90 mg/kg), and barren land (86.38 mg/kg) (Table 3). The Av. K mean ranged from 86.38 mg/kg to 217.08 mg/kg and 139.63 mg/kg to 181.35 mg/kg across land use types and elevations, respectively (Table 3). The available potassium content of the shrubland was significantly increased (Tables 2 and 3). According to Karlton, Mamo, Bekele, Gameda, and Kidanu [60], the mean available potassium in the upper, middle, and lower soils of the watershed was low (90–190 mg/kg soil), while the land use types were low (<90 mg/kg soil) and medium (190–600 mg/kg soil) (Table 3).

3.2.6. Cation Exchange Capacity (CEC). Cation exchange capacity (CEC) values differed significantly between land use types (P < 0.05), but there were insignificant differences in elevation (Table 3). The highest (39.56 cmol(+)/kg⁻¹) and lowest (22.85 cmol(+)/kg⁻¹) CEC values were observed under shrub and barren lands, respectively (Table 2). The highest mean CEC was recorded in shrubland (37.25 mg/kg) followed by grazing land (34.28 mg/kg), cultivated land (29.21 mg/kg), and barren land (23.76 mg/kg) (Table 3). The CEC mean ranged from 23.76 mg/kg to 37.25 mg/kg and 29.24 mg/kg to 32.61 mg/kg across land use types and elevations, respectively (Table 3). In the studied watershed, the mean of CEC of the different land use types and elevations ranged from high (25–40) to moderate (12–25) (Table 3) as determined by the soil classification [61].

4. Discussion

4.1. Dynamics of Soil Physical Properties under Current Land Use Types across Elevation Gradients

4.1.1. Soil Texture. The study results showed that the soil texture was varied across different land use types and elevations in the Sala watershed (Tables 1 and 3). The highest mean soil texture was clay soil followed by sand and silt soil fractions across land use types and elevations (Table 3). Results showed that the soil texture in the study watershed area was dominated by the clay content across land use types (Table 1). Eyayu, Heluf, Tekalign, and Mohammed [62] reported that soils with high clay content have sufficient particle-to-particle contact points to form strong bonds when the soil dries. The high mean sand content in the soils of cultivated and barren lands might be due to the removal of fine particles by water erosion and leaving coarse fractions in cultivated and barren lands (Table 3). This result is consistent with Gebrelibanos and Assen [63] who explained that croplands and grazing lands are very susceptible to erosion because they have less vegetative cover.

This result is also consistent with Guteta and Abegaz [64] who reported that a higher percentage of sand in agricultural lands might be due to less protection of the soil from erosion, which resulted in selective removal of the silt and clay fractions (Table 1). According to Lemenhi [65] and Belayneh [66], intensive grazing, agricultural practices, and deforestation alter soil texture by leading to more soil erosion. In the study watershed area, differences in topography, parent material, land use, and land management techniques impact the sand, silt, and clay content in different land uses and land covers. Generally, the variation of soil texture implies the effects of land use land cover types on soil properties, which are triggered by different utilization and management systems of land use types [29]. Therefore, the variations in soil texture could be attributed to different soil management practices across land use types and altitudinal gradients in the study watershed area.

4.2. Dynamics of Soil Chemical Properties under Different Current Land Use Types across Elevation Gradients

4.2.1. Soil Reaction (pH). The pH mean content was highest (7.10%) under shrubland and lowest (4.62%) on barren land across land use types as shown in Table 3. The observed comparatively higher pH in shrubland soils could be related to a higher SOM content (Tables 2 and 3). Consistent with this, Kidanemariam et al. [67] reported that the high pH of soils from forests or shrubland could be due to the high accumulation of organic matter on the surface. It is believed that pH increases as the elevation of the watershed decreases (Table 3). According to Mohammed [68], the soil in high altitudes and higher slopes had low pH values, probably suggesting the washing away of solutes and basic cations from the highland parts. As a result, the soil pH ranged from strongly acidic (pH 5.5) to moderately alkaline (7.3–8.4) according to the pH rating category proposed [60]. In this regard, most soils of the uplands have lower pH and strongly acidic behavior across land use types (Table 2). Therefore, the mean soil pH in the area showed that soils in most land use types and altitudinal gradients have been not in a good range for agricultural productivity (Table 3). This indicates that it might be due to applied inorganic fertilizers, precipitation variability, farming practices, accelerated erosion, microbial oxidation, cation depletion, and steepness of the land. According to Kennedy and Smith [69], soil pH is highly sensitive to changing natural environments, repeated cultivation of the same plots, and the presence of heavy rainfall, which results in the leaching of basic cations.

In the upper and middle watershed elevations, the lower pH in soils from cultivated and barren lands could be due to basic cations being removed by surface runoff and deep infiltration into cultivated land since less vegetation is present on barren and cultivated lands compared to other land uses (Table 2). Supporting the finding is that pH in
cultivated and/or barren land may have been lowered by basic cation removal in Ethiopia [4, 43]. Correspondingly, various research results showed that basic cations removal through crop harvest [4, 69, 70], leaching due to excessive precipitation, steepness of the topography, application of inorganic fertilizer [4, 71], and mineralization and formation of humic substances [67] were reported as causes for soil acidity formation. Soil acidity affects the process of other nutrient transformations, solubility, or availability of many plant-essential nutrients. The main reasons for the lowest soil pH in cultivated land are poorly managed farms, improper use of ammonium-based fertilizers, and accelerated erosion, resulting in soil degradation [72]. Therefore, the agricultural solution to acidic soils is the application of lime, organic and inorganic fertilizers, and land use management to achieve a pH level suitable for the soil most plant productivity in the studied watershed, which is favorable.

4.2.2. Soil Organic Matter (SOM). The mean SOM content ranged from 1.39% (barren land) to 4.43% (grazing land) and 2.71% (upland) to 4.10% (lowland) across land use types and elevations, respectively (Table 3). The low SOM in barren and cultivated lands (upper and middle lands) might be because of continuous cultivation, limited use of organic residue, and accelerated erosion (Table 2). This result was revealed by Fentie, Jember, Fekadu, and Wasie [43] that the SOM varies with land use and land cover changes. Analysis of this result suggested that differences in elevation, cropping intensity, cropping system, and soil management practices could account for differences in OM content between different land use types. As we have observed, laboratory results showed that the soil organic matter can be affected by different land use types and elevation gradients (Tables 2 and 3).

Soil organic matter content decreased with increasing altitudinal gradients in the studied watershed, possibly reflecting a temperature drop with increasing altitude; therefore, the accumulation of organic matter decreased (Tables 2 and 3). The result of the present study is consistent with a study by Buraka, Elias, and Lelago [44], and the addition of vegetation residues under bushland or shrubland and washing of topsoil from the upper and middle slopes to the lower slope could be attributed to the increased SOM in bushland and lower slope, while the low SOM and OC in cultivated and barren land and upper slope could be due to continuous cultivation, limited use of organic residue, and accelerated erosion (Table 2). As a result, soil organic matter affects total nitrogen, available phosphorus, CEC, and other physical and chemical properties [73, 74]. Hence, soil organic matter (SOM) can be increased by improving soil management.

4.2.3. Total Nitrogen (TN). The mean total nitrogen content was highest (0.26%) under shrubland and lowest (0.08%) on cultivated land across land use types as shown in Table 3. The highest mean (0.26%) of total nitrogen found in shrublands could be the high organic matter content, which is the main source of soil total nitrogen due to the release of nitrogen during mineralization and ideal forest or shrubland microclimate conditions that tempered soil temperature and hence reduced TN loss through volatilization [47, 75]. The lowest mean (0.08%) of TN measured in cultivated land could be due to continuous management leading to the depletion of organic matter residues, surface runoff, and downward leaching of negatively charged nitrates [9, 72, 76]. The lower TN soils in cultivated land could be related to the rapid mineralization of the organic substrates after intensive management, reduced use of organic inputs, removal of crop residues, and deforestation (Tables 2 and 3).

The results of the current study agree with those [77–79] who reported that low inputs of nitrogen (such as crop residues and animal fertilizers) and problems with nitrogen leaching (nitrate ions) caused by higher summer precipitation also contribute to lower total nitrogen levels in soils of the study area. This considerable increase of TN in forests and low slope could be attributed to the addition of plant residues and the removal of nutrient-rich topsoil from upper and middle slopes to lower slope by soil erosion, which agreed with the study conducted [80]. This result suggests that the change in TN is directly related to the change in SOM content levels across different land use types and the elevation of the study area (Tables 2 and 3). The results followed the findings [67, 81, 82] reported lower soil TN due to intensive cultivation, lower input, and a higher rate of mineralization in Ethiopian soils.

4.2.4. Available Phosphorus (Av. P). The mean available phosphorus was highest (120.10 mg/kg) under shrubland and lowest (20.18 mg/kg) on barren land across land use types (Table 3). The high Av. P in shrubland could be due to the high SOM content leading to the release of organic phosphorus and hence an increase in Av. P under shrubland (Tables 2 and 3). This result agrees with the findings of Abad, Khosravi, and Alamdarlo [83] who reported that Av. P was high in forest and shrublands compared to the adjacent grazing and cultivated lands. The highest concentration of AP resulted from high OM accumulation that releases AP during the mineralization of Selassie and Ayanna [79], while the lowest AP might be related to a low pH value that causes fixation and immobilizations [84]. The comparative lower content of available P in the soils of cultivated and barren land use types might be attributed to the higher clay content of the soil and inherent P deficiency of the soil (Tables 2 and 3). This may also be due to the low soil pH, which causes p-fixation. The low soil AP values observed in the studied watershed agree with those [85] who reported that the availability of P in most Ethiopian soils has decreased due to fixation, crop removal, and water erosion. Variations in available phosphorus content in soils could be related to the intensity of soil weathering or soil disturbance with different land use types and erosion losses.

4.2.5. Available Potassium (Av. K). The mean Av. K ranged from 86.38 mg/kg (barren land) to 217.08 mg/kg (shrubland) and 139.63 mg/kg (upper land) to 181.35 mg/kg (lower land) across land use types and elevations, respectively (Table 3).
The higher available potassium in forestland or shrubland could be related to the return of potassium to soils by the decomposition of leaves and other parts of plants [86]. In this finding, the most probable reasons for the different amounts of available K in different land use land covers of the watershed may be variations in the type and amount of clay, parent materials, intensity of cultivation, leaching, and soil management practices. Weathering of the parent materials in the studied area could provide sufficient potassium to compensate for the potassium deficiency of the plants as the parent materials are high in potassium [87]. Hence, the increase of potassium in the shrubland may be attributed to natural fertilizer.

4.2.6. Cation Exchange Capacity (CEC). The analysis showed that cation exchange capacity was highest under the shrubland and lowest on the barren land (Table 2). The mean CEC ranged from 23.76 mg/kg (barren land) to 37.25 mg/kg (shrubland) and 29.24 mg/kg (upland) to 32.61 mg/kg (lowland) across land use types and elevations, respectively (Table 3). The highest mean CEC value (37.25 cmol (+) kg\(^{-1}\)) in the studied watershed was observed under shrubland, followed by grazing land (34.28 cmol (+) kg\(^{-1}\)), which is attributed to the high clay content and the accumulation of basic, but the lowest mean CEC (23.76 cmol (+) kg\(^{-1}\)) was under barren land classified as medium [62, 88, 89]. This result agrees with the results [90], who suggested that the CEC of soil in shrubland was higher than that of adjacent grazing and cultivated land at a soil depth of 0–20 cm (Tables 2 and 3).

As mentioned by Molla, Getnet, and Mekonnen [84], the higher CEC could be the result of better OM accumulation from the return of vegetative biomass to the soil. The CEC of soil is strongly affected by the amount and type of clay and the amount of OM present in the soil of the study area (Tables 2 and 3). It is generally accepted that the SOM accounts for 25%–90% of the total CEC of mineral soil Oades [91] and that the higher the CEC in studied watershed soils, the better the soil can store mineral elements [92]. The reason for this is that the soil CEC values in agricultural land uses decreased mainly due to the reduction in organic matter content [90]. Therefore, soil CEC is expected to increase through the improvement of the soil OM content.

5. Conclusion

In the Sala watershed area, soil physical and chemical properties were significantly varied under different land use types across elevation gradients. The study showed that land use practices and elevation gradients have been significantly affecting the important soil physical and chemical properties. The majority of the soils in the area are dominated by clay soil fractions. The soil pH ranges from strongly acidic to moderately alkaline in the study area. The soils in the studied area have been affected by acidic soils and deficiency in soil nutrients. Laboratory results showed that most selected soil chemical properties (pH, OM, TN, Av. P, Av. K, and CEC) had poor ratings in land use types and elevation gradients. In the study area, the findings indicated that the selected soil physicochemical properties under different land use types had been significantly decreasing. In general, the field observation and laboratory findings suggest that soil fertility has depleted as a result of improper land use and lack of land management practices. To restore soil fertility and enhance crop productivity in the watershed area, integrated soil management practices such as soil and water conservation measures, adequate application of organic and inorganic fertilizers, and liming in acidic soils should be implemented. In addition to this, due to the low levels of soil nutrients, further studies should focus on quantifying nutrient inflows and outflows on an agricultural scale and their effect on the sustainability of nutrient management.

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

The authors made a valuable and unreserved contribution as well as read and approved the final article. The authors have agreed to submit the manuscript for publication.

Acknowledgments

The authors thank all the farmers who allowed their land to be sampled during soil sampling. The authors are also grateful for the assistance of the laboratory technicians at the Chemistry Laboratory Center, Arba Minch University, Ethiopia.

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