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Original Paper

Assessment of Selected Physical and Chemical Soil Properties and Organic Carbon Stock, Under Different Land-Uses in *Melka Gura* Subwatershed of North Shewa Zone, Oromia, Ethiopia

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Abstract

Changes in land-use, particularly the transformation of natural ecosystems into agro-ecosystems under poor management practices, are widespread in Melka Gura Subwatershed of North Shewa Zone. The current study assessed selected physical and chemical soil properties under three types of land-uses the study area during 2022 to 2023 seasons. Based on the field survey, three types of land-uses were identified for the study. soil samples were collected from 0–20 and 20–40 cm depths following zigzag approach and analyzed using standard laboratory procedures. The results showed that the soil textural classes of all land-uses were loam except for the surface layer (0–20 cm) of plantation forest, which was sandy loam. The mean soil BD in the study area ranged from 1.06 to 1.39 g/cm^3 and were classified as low to moderate. Relatively, the highest mean AWC (194.8 mm/m) was recorded from grazing land at 0–20 cm depth, followed by plantation forest soil. The highest mean values of sand (50.67%), silt (39%), TP (60.13%), pH (5.68), AP (51.38 mg kg^{-1}), exchangeable basic cations (27.96 cmol/kg), CEC (44.57 cmol ($_+$) kg^{-1}), PBS (63.36%), SOC (3.66%), TN (0.5%), SOC stock (68.62-ton ha^{-1}) were registered in the soil of plantation forest land. The highest mean value of BD (1.39 g/cm^{-3}), clay content (19%), Ex. A (4.9 cmol ($_+$) kg^{-1}) and Ex. Al (3.86 cmol ($_+$) kg^{-1}) were recorded in the soil of cultivated land. The highest mean value of SOCS (68.62-ton ha^{-1}) was discovered in plantation forest land and the lowest (48.15-ton ha^{-1}) in cultivated land. Correlation analysis showed highly significant positive relationship between clay and CEC, PWP, and FC but a negative relationship between clay and TP, SOCS, BD and AP. The differences in soil management practices could be the major reasons *for variations in soil properties across land-use types. Therefore proper soil and water conservation practices are important in the study area to reduce further soil fertility degradation.*

Keywords

carbon sequestration, correlation analysis,soil fertility, land degradation, soil texture

1. Introduction

Land-use by humans is primarily influenced by two broad factors: human needs (socioeconomic) and environmental conditions (Gessesse, Chanie, Feyisa, & Jemal, 2017); Land use is the arrangement of land, such as industrial areas, residential areas, and agricultural land, and the inputs associated with land use, while land cover describes the biophysical conditions of the soil surface, such as crops, forests, and grasslands (Ufot, Iren, & Chikere, 2016); In Ethiopia, land use and land cover changes that convert natural ecosystems such as forests, wetlands, and shrubs to croplands, rangelands, and settlements are widespread; Conversion of natural vegetation cover to other land-use types such as croplands, grazing land, human settlements, and urban centers is a cause of biodiversity loss, deforestation, and land degradation (Maitima, Mugatha, Reid, Gachimbi, Majule, Lyaruu, Pomery, Mathai, & Mugisha, 2009); Due to the multiple effects on the nation's economic growth and food security, both of which strongly rely on natural assets, land degradation is of great concern in Ethiopia (Birhanu, 2014); Land degradation refers to the loss of land productivity and ecological qualities as a result of later land-use patterns and associated management (Bai, Dent, Olsson, & Schaepman, 2008); The major causes of land degradation are cultivation on steep land, use of soil with inadequate management, erratic and severe rainfall patterns, deforestation, and overgrazing (Aytenew & Kibret, 2016).

The processes of soil chemical, physical, and biological degradation are connected to the loss of soil quality driven by human activities (Birhanu, Muktar, & Kibebew, 2016); According to various studies, deforestation and forestland farming reduce soil organic matter, plant nutrients including N, Ca, Mg, and K, and increase soil bulk density (Abera, Wolde-Meskel, & Bakken, 2012; Yitbarek, Gebrekidan, Kibret, & Beyene, 2013); which lead to a decrease in soil fertility. Soils are potential reservoir of soil organic carbon, the concentration of which influences the quality and productivity of soils (Xu, Liu, & Kiely, 2011); Changes in the concentration of organic carbon in soils have an impact not only on soils but on the entire environment (Stockmann, Padarian, McBratney, Minasny, de Brogniez, Montanarella, Hong, Rawlins, & Field, 2015). By generating greenhouse gases (GHGs) or by sequestering carbon, soil plays a major role in the biogeochemical cycles of carbon (C) and nitrogen (N) (Selassie & Ayanna, 2013); The key factors affecting soil organic carbon sequestration are soil depth, management approaches, soil dynamics, and other soil characteristics, including bulk density (Selassie & Ayanna, 2013); The carbon balance is altered by changes to land use, particularly when a natural system is transformed into a managed one (Berry, 2011).

Agriculture is a type of land use that both emits and sequesters carbon; Agriculture increases losses of soil organic matter as a result of severe soil erosion brought on by agricultural operations, strong soil organic carbon decomposition after harvest and removal of above-ground biomass (Lal, 2006); However, agriculture can serve as an important C drop if appropriate land use and management practices are implemented (Muche, Kokeb, & Molla, 2015).

In the *Melka Gura* Sub watershed, there is also ongoing deforestation, free grazing, and continual cultivation of steep land areas, which might have led to a decline in the physical, chemical, and biological properties of soils; These might have aggravated crop yield reductions and shortages of food and forage, which are already widely observed throughout the watershed and its surroundings; Due to a lack of site-specific data on the level of land degradation under various land use systems, appropriate soil management practices and agro-ecology based land use decisions by policymakers could not be effectively implemented in Ethiopia in general and in Degem district in particularly.

Although many studies have been carried out (Chemeda, Kibret, & Fite, 2017; Girma, Wogi, & Feyissa, 2020; Fungo, Grunwald, Tenywa, Vanlauwe, & Nkedi-Kizza, 2011; Kassa, Kebede, & Haile Woldeyohannes, 2020) to investigate land use change and its consequences on soil physical and chemical properties in different parts of Ethiopia, such kind of studies are almost non-existent in Degem district in general and in *Melka Gura* sub watershed in particular; Even though it is generally recognized by the local community that the soils are being degraded, scientific information has not been documented for the variation of physical and chemical soil properties and soil organic carbon to know the extent and magnitude of soil degradation across different land-uses in order to recommend appropriate soil management practices. Such information that enables farmers and other land-users to protect the soils from further degradation through the implementation of appropriate soil management practices for optimal and sustainable utilization of the land resources is generally lacking in *Melka Gura* Sub watershed; Thus necessitated a study on the extent of soil degradation in terms of soil fertility related properties under various land use types.

Moreover, conducting systematic investigation in this line is very essential to come up with appropriate information that help farmers to use their resources sustainably through keeping their lands from deterioration; To tackle the above mentioned problems, therefore, this study was conducted with the general objective to examine the variation of selected soil properties under different land uses of *Melka Gura* sub watershed in Degem District, North Shewa, Ethiopia**;** Furthermore, the specific objectives of this study were:

- To assess the status of selected physical and chemical properties of soil under three land use types;
- To assess the status of soil organic carbon stock under three land-use types (plantation forest, grazing and cultivated lands) in *Melka Gura* sub watershed.

2. Materials and Methods

2.1 Description of the Study Area

2.1.1 Location

The study was conducted at *Melka Gura* Sub watershed in Degem District of North Shewa Zone, Oromia Regional State, Ethiopia; Degem, which is the capital town of the district, is located at 138 km from Addis Ababa, and 25 km from Fitche, the administration town of North Shewa Zone, from both in northern direction; The geographical location of Degem district extends from 09° 34’ 30’’ to 10°1’30” N and 038°26’30’’ to 38°44’00˝ E latitude and longitude, respectively; The altitude of Degem district ranges from 1200–3541 meters above sea level; The Sub watershed is located at latitude and longitude between 09° 47’00’’ to 09° 48’15’’N and 038°32’30’’ to 038° 33’30’’E, respectively; having an elevation range from 2978 to 3324 meters above sea level (Figure 1).

2.1.2 Climate

Climatic conditions of Ethiopia are generally the result of a difference in altitude; Climatic conditions in Degem District, North Shewa Zone are divided into three agro-climatic zones: *Dega* (30 %) which extends from 2300-3541; *Woy*nadega (38 %)extends from 1500-2300 and Kola (32 %) ranged from 1200-1500 meters above sea level; The area is characterized by bimodal rainfall distribution pattern; The main rainy season, summer (Ganna) extends from June to September, while short rainy season, spring (Badhesa) extends from March to May; Based on data from the previous five years, the area's mean monthly rainfall is 1475.3 mm, and its monthly minimum and maximum temperatures are 5.6 ^{0}C and 23 ^{0}C, respectively (Figure 1)

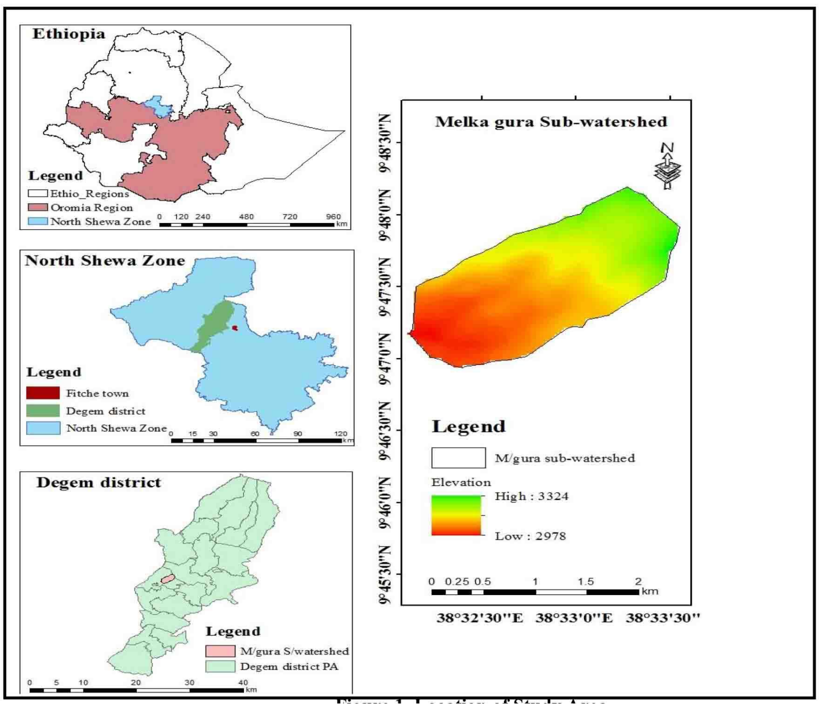
1


Figure 1. Location of Study Area

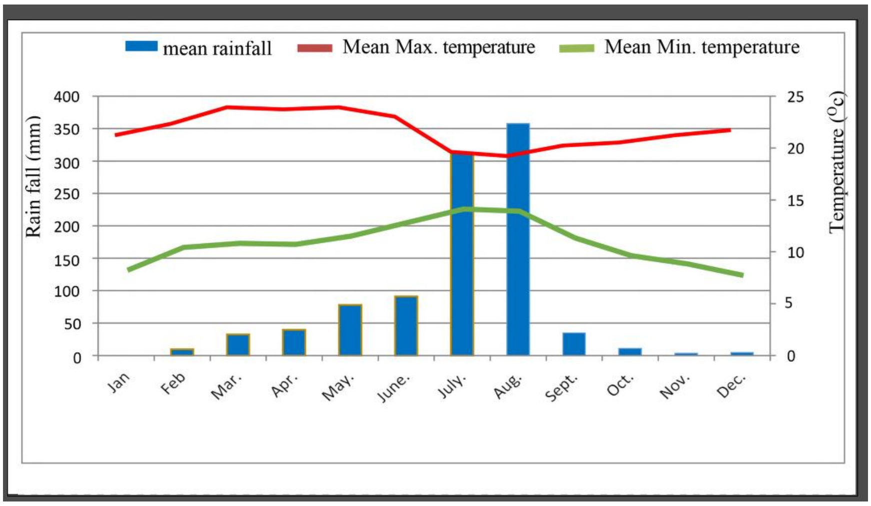


Figure 2. Five Years' Climate Data of the Study Area (Gundo Meskel Meteorology Station, 2020)

2.1.3 Topography and Soils

Topographically, North Shewa Zone in general and Degem District in particular are characterized by relief types that include plains and mountains; whereby in Degem District, plains account for about 38%, mountainous areas for about 24% and other 38% is Plateaus; The major soil type in the study area includes Nitisol, Vertisols, and Cambisols (Lemma, 2021; Day, 1965).

2.1.4 Demographic Characteristics

According to the ECSA, in 2013, Degem *Woreda* had a total population of 119,243, of which 58,967 were male and 60,276 were female; The urban population is approximately 8,502, with 3,961 men and 4,541 women. The remaining 110,741 populations of the *Wereda* are residents of rural areas (55,006 males and 55,735 females); The two largest ethnic groups are Oromo (88.89%) and Amhara (10.92%), with the remaining ethnic groups accounting for about 0.19% of the population.

2.1.5 Farming System and Land Uses

Mixed farming system (crop and livestock production) is the common farming practice in the study area. Rain-fed agriculture, supplemented with traditional irrigation, is the dominant crop production system in the study area; The major annual crops grown under rainfed in the study area are barley (*Hordeum vulgare*), wheat (*Triticum aestivum)*, faba bean (*Vicia faba)*, field pea (*Pisum sativum*); A few horticultural crops, such the potato (*Solanum tubersoum*), tomato (*Lycopersicum esculentum*), garlic (*Allium sativum*), hot pepper (*Capsicum frutescence*), and onion (*Allium cepa L.*), are also grown using irrigation and rainwater; Land is either cultivated or plowed with draft animals, and agriculture is entirely dependent on rainfall; The main livestock in the study area are cattle, goat, sheep, poultry, and horses; They provide transportation, milk, meat, and milk products, and their manure is utilized to maintain the fertility of the soil; The main sources of income for farmers are milk and milk-related goods. However, due to the shortage of grazing lands, livestock production is decreasing from year to year in the study area; The total area of the district is 67,070 ha, of which 34.39 % is cultivated land, 13.6 % is forest, 27.38 % is bush land, 2.47% is degraded land and the remaining 22.16 % is grazing land (Day, 1965).

2.2 Field Survey

Melka Gura Sub watershed, which is located in Degem district (Figure 1), was selected based on the presence of different land-use systems. Prior to taking soil samples, the land-use history of the watershed was assessed by conducting field observations and interviews with local community leaders and agricultural experts; In order to obtain general information on the variations in the study area and its surroundings, land-use types and elevation ranges were recorded through visual field observation using a Global Positioning System (GPS); Based on the information obtained, three land-uses (plantation forest, grazing land and cultivated land) were identified for soil sampling (Table 1); For the determination of soil physical and chemical characteristics and organic carbon stock, composite soil samples were collected from a 25 m x 25 m plot area from each land-use type (cultivated, grazing, and plantation forest lands) at two soil depth-ranges (0–20 and 20–40 cm) in three replications;

Representative soil sampling points were identified at random and composite soil samples were prepared from randomly collected sub-samples within each plot using an auger in a zigzag (Z) pattern for disturbed soil samples, and undisturbed soil samples were collected from a single point presumed to be representative of the area using core samplers; The samples were composited replication-wise for each land-use to make a total of 18 composite samples for all three land-use types considered (3LU x 3 rep x 2depth-ranges); Five sub-samples were taken to prepare one composite (1kg) soil sample from each land-use for each replication; Additionally, for each land-use type, three replicates of undisturbed soil samples (18 for BD, FC and PWP) of known volume were taken for determination of soil bulk density and water retention characteristics; During the soil sample collection, areas near trees, marshy areas, dead plant debris, old manure locations and crop field borders were all omitted to avoid border effects; For the purpose of determining selected soil physical and chemical properties and organic carbon stock, the samples were carefully labeled, bagged and transported to the soil laboratory; Finally, all soil samples were analyzed in order to increase precision and their mean of soil samples were compared to show their variation across land uses;

Table 1. Description of Selected Land Use Types and Land Cover Classes

Land use class	Description
Plantation forest	Forests established artificially by afforestation on land which previously did not carry forest for about 50 years; The afforested land was planted in 2008 (14 years ago), being characterized by fast-growing environmentally friendly tree species for animal feed, fuel, timber, *etc*; The tree species found in this plantation land-use include: *Vachellia abyyssinica, Acacia abyssinica, Croton macrostachyus, Cordia africana, Olea europaea, Vernonia amygdalina, Erythrina abyssinica* and many others; This land-use covers about 100 ha of the total area of the sub watershed

Grazing land	Areas of temporary or permanent grass cover, with continuous grazing systems prone to overgrazing; Short grass species dominate these grazing land units. This land-use covers about 150 ha of the total area of the sub watershed
Cultivated land	The land has been used for annual rain fed field crops (barley, wheat, faba bean, teff, potato, tomato, garlic, onion, etc.) at least for 16 years; The land management practices for the cultivation of such crops in the sub-watershed include repeated contour plowing, application of chemical fertilizers and herbicides, compost application in some cases, hand weeding, *etc.;* In this land-use, the crop residue is collected, piled and used for animal feed, fuel, and in some cases for house construction and as a source of cash; This unit covers about 450 ha of the total area of the sub watershed

Source: Field Survey of 2022.

2.3 Soil Sample Preparation

The composite samples from each land-use type were air-dried, ground and passed through a 0.5 mm sieve for total N and OC; and a 2 mm sieve was used for other soil physical and chemical properties; The soil samples were then analyzed at three laboratories based on the availability of laboratory equipments necessary; Soil moisture characteristics (FC and PWP) were analyzed at Oromia Engineering Corporation; some soil physical and chemical properties like BD, SOC, pH and exchangeable acidity were analyzed at Fitche Agricultural Research Center; and the remaining soil physical and chemical properties were analyzed at Batu Soil Research Center following the standard laboratory procedures.

2.4 Laboratory Analysis of Selected Soil Physical and Chemical Properties

2.4.1 Analysis of Soil Physical Properties

Soil texture was determined by using the Bouyoucos hydrometer method after destroying organic matter and dispersing the soil by using sodium hexametaphosphate as described by (Sahlemedhin & Taye, 2000); The USDA classification system was used to identify soil textural classes; Bulk density of the core samples was estimated after drying in an oven at 105 °C for 24 hours. The values were calculated by dividing the mass of the oven-dried soil (g) by the corresponding volume (cm^3) of the core sampler (Brady & Weil, 2017) (Eq. 1);

$$\text{Bulk density } (g/cm^3) = \frac{M(g)}{V(cm^3)}, \text{ where, } V=\pi r^2 h \quad (1)$$

where, M= Mass of oven-dry soil (g); V= Volume of core sampler (cm^3), and r and h are radius and height of the core sampler respectively; The values of bulk density (BD) and particle density (PD), with the latter assumed to be the frequently accepted average value of 2.65 g cm^{-3} [25] were used to estimate the total porosity (%) of the soil (Eq. 2)

$$\text{Total porosity } (\%) = (1 - \frac{BD}{PD})*100 \quad (2)$$

The pressure plate extraction method was used to determine the water content at field capacity (FC) and permanent wilting point (PWP) (Motsara, 2015); The available water content (AWC) was calculated by subtracting the permanent wilting point water content from the field capacity water content (Eq. 3).

2.4.2 Analysis of Soil Chemical Properties

The pH (pH-H_2O) of the soil was determined potentiometrically for supernatant suspension of a 1:2.5 soil to water ratio using a glass electrode and pH meter (DL, 1994); The soil sample was saturated with potassium chloride solution and titrated with sodium hydroxide to estimate the exchangeable acidity (Walker, Pearson, Casarim, Harris, Petrova, Grais, Swails, Netzer, Goslee, & Brown, 2012); Wet oxidation method outlined by (Bremner, & Mulvany, 1982) was used to determine soil organic carbon, and the percentage of organic matter of the soils was estimated by multiplying the percent organic carbon by 1.724 based on the assumption that organic matter (OM) is made of 58 % carbon; Total nitrogen was measured titrimetrically following the Kjeldhal method as described by (Bray & Kurtz, 1945).

Bray-II method was selected to determine available phosphorus (Chapman, 1965); Exchangeable basic cations (Ca, Mg, K, and Na were extracted using 1 N ammonium acetate solution of pH 7 (Were, Bui, Dick, & Singh, 2015); Exchangeable K and Na were determined from the same extract using a flame photometer (FP), whereas exchangeable Ca and Mg were determined from this extract using an atomic absorption spectrophotometer (AAS) (Were, Bui, Dick, & Singh, 2015); Cation exchange capacity (CEC) of the soil was determined from ammonium acetate saturated samples of the basic cation extraction, which was subsequently replaced by sodium being percolated by sodium chloride solution after removal of excess ammonium by repeated washing with alcohol (Were, Bui, Dick, & Singh, 2015). CEC of clay was computed as follow;

$$\text{CEC of clay} = \frac{\text{CEC soil} - 200(\%\text{OM})}{\%\text{ of clay}} \quad (4)$$

The percent base saturation (PBS) of the soil samples was calculated by dividing the sum of the basic exchangeable cations (Ca^{2+}, K^+, $Mg^{2+,}$ and Na^+) by the CEC of the soil and multiplying by 100

2.5 Estimation of Soil Organic Carbon Stock

The soil organic carbon stock was computed according to (Kebebew, Bedadi, Erkossa, Yimer, & Wogi, 2022) as indicated in the following equation:

Where SOCst = soil organic carbon stock, SOC = Soil organic carbon (%) of a given soil depths; BD (Bulk density) = soil mass per sample volume (kg m^{-3}); D = depth of soil in m.

Then SOC stock per hectare (ton C ha^{-1}) was estimated using (Bremner, & Mulvany, 1982) equation:

$$SOCst\ di = \frac{SOC(\%)/100 * BD(\frac{g}{cm^3}) * D(m) * 10{,}000\ m^2ha^{-1}}{100} \quad (6)$$

where: SOCs di is the amount of OC stock per unit hectare of land (ton ha^{-1}) to specified soil depth (di); C (%) = Soil organic carbon (%) data obtained from the laboratory from soil analysis result for each soil layers; In this equation C must be expressed as a decimal fraction; BD was the bulk density of soil samples

2.7 Statistical Analysis

Descriptive statistics descriptive statistics (mean, median, standard deviation, maximum, and minimum) were employed to observe the status and difference of selected soil physicochemical properties and organic carbon stocks under the three land use types; Pearson's correlation coefficient was also computed to examine the relationship between different soil properties

3. Results and Discussions

3.1 Physical Properties of Soil Under Different Land Use Types

3.1.1 Soil Texture

Different soil texture fractions across different land use types and soil depths were identified through laboratory analysis (Table 2); Sand fraction of soil under plantation forest land was the highest mean (50.67) and (48.17%) at surface and subsurface, respectively, followed by grazing land soil (48%) at 0–20 cm depth. Relatively, the lowest sand fraction was recorded for soil from cultivated land; the sand fraction of the soil showed a decreasing trend from surface to subsurface. In contrast to this data, (Assefa, Elias, Soromessa, & Ayele, 2020; Mulat, Kibret, Bedadi, & Mohammed, 2018) reported the largest sand fraction from cultivated lands, and they suggested that high sand contents from cultivated areas may be caused by soil erosion and poor soil water holding capacity; The lowest mean silt fraction was recorded for soil of cultivated land at a depth of 20-40 cm, while the highest mean of silt content (39 %) was recorded for soil of plantation forest land at 0-20 cm depth (Table 2); Comparatively, the soil of grazing land had even higher silt content than cultivated land soil; This was in line with the finding of (Girma, 2020), who reported the highest silt content on grazing lands and the lowest on cultivated lands

On average, the clay content was found to be the highest in cultivated land soil (Table 2); This result is supported by (Fungo, Grunwald, Tenywa, Vanlauwe, & Nkedi-Kizza, 2011) who reported the highest clay content in surface and subsurface soil of cultivated land. This might be due to continued and intensive cultivation; Generally, the subsurface soil layers had more clay than the surface layers, while sand and silt content appeared to decrease with soil depth; which may be due to clay translocation; The finding of (Hazelton & Murphy, 2016) also showed higher clay content in the subsurface than in surface soil; The higher levels of clay found in areas of cultivated land may be the result of enhanced physical and chemical weathering brought in by the cultivation practices; (Rashid, Abera, Agegnehu, & Zelleke, 2010) classified soil sand, silt, and clay contents into three categories: high (>40 %); moderate (25-40 %); and low (10-25 %); According to their classification, the soils of all examined land uses have high sand, moderate silt and low clay contents; According to the USDA classification system, soil textural classes of plantation forest land was classified as sandy loam at 0-20 cm and loam at 20-40 cm depth; whereas soil textural classes in grazing and cultivated lands were classified as loam soil.

3.1.2 Bulk Density and Total Porosity

The bulk density values of soil of the studied land use types showed great variability with respect to the contents of organic matter, and animal trampling; In all studied land uses, the value of soil bulk density increases with depth; The highest mean bulk density was recorded for soil cultivated land at 20-40 cm and the lowest was for that of plantation forest land at 0-20 cm; The lowest bulk density results recorded for soil of plantation forest land might be due to higher organic matter content as a result of addition of plant litter; Higher soil bulk density is related to land management practices including plowing, continuous cultivation, and overgrazing; The maximum bulk density was recorded from cultivated lands (1.47 g/cm^3) and the minimum value (1.01 g/cm^3) was registered from soil of plantation forest lands; As soil depth increases, bulk density often increases due to overlying weight and decline in soil organic matter (SOM)

Deforestation and tillage practices may have caused soil compaction, reduced infiltration, and consequently an increase in bulk density at the surface; Similarly, (Gessesse, Chanie, Feyisa, & Jemal, 2017; Kidanemariam, Gebrekidan, Mamo, & Kibret, 2012) reported higher bulk density for soil of cultivated lands; (Mulat, Kibret, Bedadi, & Mohammed, 2018) similarly reported the higher BD in cultivated lands and proposed that the higher bulk density may be caused by the absence of soil conservation measures that remove soil organic matter; Soil bulk density is classified as very high (>1.9 %), high (1.6–1.9%), moderate (1.3–1.6%), low (1–1.3%), and very low (< 1%) as rated by (Rashid, Abera, Agegnehu, & Zelleke, 2010). As a result, the soil bulk densities in the studied area ranged from low to moderate (Table 2); The low values demonstrate that in these soils, BD is not anticipated to restrict root and water movement. Variations in total porosity are seen in relation to bulk density; The soil of cultivated land had the lowest mean total porosity (47.55 %), while soil of plantation forest land had the highest mean total porosity (60.13 %) at 0-20 cm depth; Due to the high concentration of organic matter, soil porosity was higher for plantation forest land compared to that of other land use types (Jemal & Tesfaye, 2020); It has been reported that the increased porosity, which is related to the improved soil aggregation, is directly related to the decrease in bulk density with organic matter additions

Additionally, the root movements result in an increase in pore spaces, which in turn causes an increase in the spacing between soil particles (Engda, Kassahun, Collick, Adissu, Ashagrie, Tessema, Derebe, Solomon, & Steenhus, 2008); In comparison to the surface layer, the subsurface layers have less organic content, less aggregation, and fewer root penetrations, which causes them to be more compacted and have fewer pore spaces; In general, there was a negative and highly significant correlation between soil bulk density and total porosity, and a highly significant and negative correlation was observed between BD and SOM (-1**) (Table 8)

Table 2. Selected Physical Properties of Soil under Different Land Use Types (Mean ± std.)

LU types	Depths (cm)	Particle size distribution (%)			STC (USDA)	BD (g/cm^3)	TP (%)
		Sand	Silt	Clay			
PF	0-20	50.67±7.51	39±6.56	10.33±1.53	Sandy loam	1.06±0.04	60.13±1.39
	20-40	48.17±6.93	38.66±7.09	13.17±2.75	Loam	1.16±0.06	56.40±2.42
GL	0-20	48±3.61	38±4.36	14±1.73	Loam	1.25±0.14	52.82±5.47
	20-40	46±5.29	36.33±6.56	17.67±3.06	Loam	1.31±0.1	50.64±3.86
CL	0-20	48.00±4	35±6	17.00±2	Loam	1.38±0.02	47.81±0.8
	20-40	47.00±1	34±1	19.00±2	Loam	1.39±0.09	47.55±3.44

LU=Land use; PF=Plantation forest; GL=Grazing land; CL=Cultivated land; STC=Soil textural class; Std=Standard deviation.

3.1.3 Soil Water Characteristics

The observed outcomes typically demonstrated that the soils under various land uses differed in their water content at FC, PWP, and AWC (Table 3) because their sand, silt, and clay contents varied (Table 2); The highest mean of water content at FC (437.8mm/m) was retained at 0-20 cm soil depth of grazing land followed by plantation forest (422 mm/m) land. The lowest mean water content at FC was recorded for soil of cultivated land; The highest mean of soil water retention was found in grazing land soil at FC (437.8mm/m) at 0-20cm, PWP (253.3 mm/m) at 20-40 cm and AWC (194.8 mm/m) at 0-20 cm depths; This result is consistent with (Tilhun, 2015), who reported that grazing land had soils with increased soil moisture contents; The relatively high moisture content in the soils on grazing lands may be explained by the residual effects of underground grass biomass that facilitate infiltration and undisturbed soil due to tillage, which facilitates evaporation loss, even though intensive free grazing on these lands removes the majority of the above-ground biomass

Compared to the soil of grazing land and that of cultivated land, the maximum mean value of AWC was measured for the soil of grazing land (194.8 mm/m) at 0–20 cm and the lowest for that of cultivated land (118 mm/m) at 20–40 cm depths; This might be due to grazing lands has high amounts of organic carbon, overall porosity, and low bulk density, which support the soil macrospores and soil structure and increase the soil's ability to hold water; This is supported by (Fentie, Jembere, Fekadu, & Wasie, 2020; Chemeda, Kibret, & Fite, 2017; Kakaire, Makokha, Mwanjalolo, Mensah, & Emmanuel, 2015) who obtained similar results. However, the low AWC recorded from cultivated land was due to high soil bulk density and low OC content; This was in agreement with the result of (Tellen & Yerima, 2018) who stated that higher soil bulk density results less amount of water at field capacity.

Generally, moisture contents under plantation forest and grazing land were high when compared to cultivated lands; This could be due to soil surface cover, which reduces soil water evaporation and increases infiltration rates; however, the absence of surface cover and cultivation, which increase soil water evaporation, leads to low moisture contents in cultivated land; This finding was in line with (Negassa & Gebrekidan, 2003) who stated that sparse or absence of a light canopy or surface cover can lead to a higher rate of soil water evaporation. Soil moisture content at FC and PWP had positive and significant correlations with clay contents (0.53* and 0.51*) respectively; However, sand and silt contents showed a negative and insignificant correlation with soil moisture contents at FC and PWP (Table 8)

Table 3. Soil Water Characteristics under Different Land Uses of Study Area (mean ± std.)

Land uses	Soil depths (cm)	Soil Water content (mm/m)		
		FC	PWP	AWC
PF	0-20	422±1.01	246±0.60	176±0.78
	20-40	420±0.50	248±0.17	172±0.53
GL	0-20	437.8±5.50	243±2.35	194.8±7.68
	20-40	395±0.87	253.3±1.38	141.7±1.05
CL	0-20	360±0.20	207.7±0.42	152.3±0.50
	20-40	328±2.21	210±0.70	118±2.01

FC=Field capacity; PWP=Permanent wilting point; AWC=Available water content.

3.2 Chemical Properties of Soil under Different Land Use Types

3.2.1 Soil pH, Exchangeable Acidity, Exchangeable Aluminum and Available Phosphorus

The chemical soil analysis results revealed that the highest average soil pH-H2O value (5.68) was recorded at 20-40 cm soil depth in grazing land, followed by that of plantation forest (5.6); whereas the lowest average value (5.41) was recorded in cultivated land at 0-20 cm soil depth (Table 4); The lowest soil pH values of cultivated land soil might be due to removal of basic cations through harvested crops and due to the acidifying effect of NH_4^+ containing chemical fertilizers used for crop production; Similar research findings were reported by, who detected the loss of basic cations and the acidifying effects of NH_4^+ sourced chemical fertilizers as the causes of soil pH reduction; On the other hand, soils of all land-use types had pH-values classified as moderately acidic according to [54]; This could be the result of high rainfall amounts that might have caused leaching of basic cations leaving behind H^+ and Al^{3+} ions on the exchange complex (Tilhun, 2015).

The surface layer of cultivated land soil had the highest exchangeable acidity (4.9 cmol $_{(+)}$ kg^{-1}), while the subsurface layer of grassland soil had the lowest (2.83 cmol $_{(+)}$ kg^{-1}) exchangeable acidity (Table 4); The highest exchangeable acidity recorded for the surface soil of cultivated land might be related to the low amount of basic cations found in this layer due to plant uptake and the acidifying effect of NH_4^+ containing inorganic fertilizers; This is consistent with the finding of (Chama & Murphy, 2007), who reported the highest soil exchangeable acidity for the soil of cultivated and grazing lands. Similar results are attributed to intensive agricultural practices and continued chemical fertilizer use that might increase exchangeable acidity (Chemeda, Kibret, & Fite, 2017); The highest mean value of exchangeable Al^{+} was recorded also for the soil of cultivated land, whereas the lowest record was that of plantation forest land; A non-significant negative association (r^2 = -0.24) was found between the pH and the total exchangeable Al^{+} (Table 8); This result is consistent with that of (Chama & Murphy, 2007), who found that the concentration of Al^{+} increases as pH decreases

The highest mean value of AP (51.38 mg kg^{-1}) was recorded for soil of plantation forest land followed by that of grazing land; and the lowest AP-value (12.14 mg kg^{-1}) was recorded in the soil of cultivated land; The presence of low pH and high exchangeable aluminum appears to be primarily responsible for the low available P status in the soil of cultivated and grazing land, due to the fact that exchangeable Al^{+} have the potential to fix available P from the soil solution (Gupta, 2004)

Table 4. Soil pH, Exchangeable Acidity, Exchangeable Al and AP of Soil of the Study Area (mean ± std.)

LU	Depths (cm)	pH	Ex. A (cmol $_{(+)}$ kg^{-1})	Ex. Al (cmol $_{(+)}$ kg^{-1})	AP (mg kg^{-1})
PF	0-20	5.58±0.22	3.23±2.64	2.43±2.21	51.38±9.71
	20-40	5.60±0.14	2.90±1.50	1.70±0.90	49.29±5.23
GL	0-20	5.46±0.40	4.89±0.24	2.64±0.68	24.11±1.35
	20-40	5.68±0.36	2.83±0.78	1.68±0.55	22.32±1.82
CL	0-20	5.41±0.11	4.9±1.33	3.86±0.94	16.20±5.90
	20-40	5.57±0.03	4.48±0.91	2.78±0.58	12.14±1.75

AP=Available phosphorus; Ex.A=Exchangeable acidity; Ex.Al=Exchangeable aluminum; PF=Plantation forest; GL=Grazing land; CL=Cultivated land; Std=Standard deviation.

On the other hand, AP decreased with increasing soil depth; which could be attributed to decreasing OM content with depth; This result is in agreement with (Eshetu, 2019), who reported decreased AP values with increased soil depth in the soils around Chilalo Mountain, Southeastern Ethiopia; The higher AP content in the soil of plantation forest followed by grazing land could be attributed to the relatively higher organic matter content in the soil as AP is strongly associated with SOM content; This indicates that variations in AP contents among soils of different land-uses are mostly a function of total SOM dynamics (Dilnesa, 2021); In contrast to these findings (Kenye, Sahoo, Singh, & Gogoi, 2019) reported the higher available phosphorus from cultivated lands compared with grazing lands and attributed the phenomenon to the application of diammonium phosphate (DAP) and NPS fertilizers for crop production

On the other hand, available P was positively and non-significantly correlated with sand, silt, and soil pH; while it was positively and significantly associated with SOC and negatively but non-significantly associated with clay content (Table 8); In general, the soils of all land-uses studied were in the range of very low to medium (12.14- 51.38 mg kg^{-1}) in terms of AP status, according to Ankerman and Large, as referenced by (Yifru & Taye, 2011).

3.2.6 Soil Organic Carbon

Land use has an impact on organic matter and soil organic carbon; The plantation forests had the highest mean SOC (4.09 %), while the cultivated land had the lowest mean SOC (1.36 %) at a depth of 20 - 40 cm (Table 5);The lowest mean SOC (1.36 %) in cultivated land may be the result of organic matter being depleted as a consequence of continuous cultivation, crop residues removal, and a lack of or insufficient supply of organic inputs; The higher SOC is likely caused by greater vegetation, which produces more litter fall and returns it to the soils as organic matter (Xiong, Grunwald, Corstanje, Yu, & Bliznyuk, 2016). This shows various land use types result in variations in the SOC content; The result was also in agreement with that of (Tilhun, 2015) who reported the lowest organic carbon content for soil of cultivated land and the highest for soil of natural forest land. According to [64] continual soil cultivation causes a decrease in the amount of soil organic matter; The higher SOC in the soil of plantation forest lands indicates the functionality of the ecosystem; It contributes to numerous flows and transformations of organic materials, energy, and biodiversity (Aytenew & Kibret, 2016). Generally, this study showed that, plantation forest land had high to medium level of soil organic carbon, whereas grassland and cultivated land had medium to low levels of SOC; which indicates the primary role of vegetation cover and degree of ecosystem disturbance by human (Table 5).

Table 5. Organic Carbon, Organic Matter and Total Nitrogen Contents of Soil under Different

LU	Soil depths (cm)	SOC (%)	Ratings (Tekalign,1991)	TN (%)	Ratings (Tekalign,1991)
PF	0-20 cm	3.66±0.21	High	0.50±0.01	High
	20-40 cm	2.61±0.48	Medium	0.41±0.10	High
GL	0-20 cm	2.17±0.37	Medium	0.35±0.06	High
	20-40 cm	2.08±0.66	Medium	0.31±0.01	High
CL	0-20 cm	1.84±0.56	Medium	0.20±0.03	Medium
	20-40 cm	1.36±0.76	Low	0.15±0.05	Medium

Land Use Types (mean ± std.).

3.2.7 Total Nitrogen

Maximum TN (%) value was recorded for the soil of plantation forests and the lowest for that of cultivated land at 0-20 cm depth; whereby the values decreased towards the subsoil similar to the trend in SOM (Table 5 and Table 10); The values in total nitrogen were positively but not significantly correlated with organic matter content (Table 8), indicating that higher total nitrogen in soil of plantation forest and grazing land was due to relatively higher organic matter contents of these land-use types; Rapid decomposition of OM due to repeated tillage operations, which increase aeration and microbial accessibility of organic matter, might be responsible for the comparatively low TN content recorded for soil of the cultivated land; This outcome is consistent with the findings of (Chemeda, Kibret, & Fite, 2017; Fungo, Grunwald, Tenywa, Vanlauwe, & Nkedi-Kizza, 2011; Aytenew, & Kibret, 2016); According to (Eyayu, Heluf, Tekalign, & Mohammed, 2009) ratings, the TN (%) values of the study area soils were medium under soil of cultivated land, and high under both grazing land and plantation forest land (Table 5); According to (Eyayu, Heluf, Tekalign, & Mohammed, 2009) ratings the TN (%) of the study area were medium under soil of cultivated land, and high under both grazing land and plantation forest land soil (Table 5)

3.2.3 Exchangeable Basic Cations

As indicated in Table 6, concentration of exchangeable basic cations was found in the order of Ca > Mg > K > Na in soil of all different land use systems; The highest mean value of Ca (16.65 (cmol $_{(+)}$ kg^{-1}) was recorded for soil of plantation forest land and the lowest (4.8 (cmol $_{(+)}$ kg^{-1}) was for that of cultivated land; These results were in agreement with the findings of (Fungo, Grunwald, Tenywa, Vanlauwe, & Nkedi-Kizza, 2011); (Chemeda, Kibret, & Fite, 2017) also reported similar results; This variation in the concentration of exchangeable bases could be due to variations in management practice, systems of land utility, and the various in soil texture and OM;

The variation in the exchangeable bases (Ca^{2+}, Mg^{2+}, and K^{+}) might be due to leaching losses, the amount of clay minerals, and the conversion of forest land into other land uses; This study confirms the findings of (Gelaw, Singh, & Lal, 2015), who found that activities that cause acidity result in reduced exchangeable Ca and Mg. Relatively, the mean value (9.45 cmol $_{(+)}$ kg^{-1}) of exchangeable Mg was the highest for soil under plantation forest and the lowest (4.5 (cmol $_{(+)}$ kg^{-1}) was for that of cultivated land (Table 6); The lowest mean values (4.5 cmol $_{(+)}$ kg^{-1}) of exchangeable Mg in soil of cultivated land might be attributed to the impact of intensive farming and abundant crop production with little to no input;

Soil of plantation forest land had the highest average exchangeable K content (1.82 (cmol $_{(+)}$ kg^{-1}), while soil of grazing land had the lowest (0.36 (cmol $_{(+)}$ kg^{-1}) (Table 6); The maximum concentration was found in the soil of plantation forest land, which was associated with its high pH value (Table 10). This agreed with research findings published by (Ufot, Iren, & Chikere, 2016) that high K concentrations were found in high pH tropical soils; Generally, the reason why cultivated land uses have lower exchangeable K content than other land uses could be because K is continuously lost with the harvested parts of cultivated plants;

Relatively the highest mean soil exchangeable Na^{+} concentrations were found in soil used for plantation forest and grazing at 20-40 cm depth, whereas the lowest concentrations were found in soil of cultivated land ((0.03 (cmol $_{(+)}$ kg^{-1} soil); According to (Baker, Ochsner, Venterea, & Griffis, 2007; Roy, Finck, Blair, & Tandon, 2006) land use types have an influence on exchangeable Na as well, much like they do on exchangeable Ca, Mg, and K. With increasing soil depth, concentration of exchangeable basic cations increases as well; The current study indicates that there are more clay particles in the subsurface soil than in the surface soil, which may be related to the increasing trend of exchangeable basic cations with soil depth; Positively charged ions (cations) can be adsorbed and held by electrostatic force on the surfaces of the clay mineral components of soil (Mamo, 2011) As a result, clay content controls the exchangeable base contents in the subsurface layers;

In sodic soils, sodium(Na) is frequently abundant; However, it was discovered that the soils of the study area were all acidic, which contributed to the low salt levels in the soils from all of the land uses that were investigated; Generally, the Na contents of the study area were categorized as very low class according to the ratings of (Gao & Chang, 1996). In general, the findings showed that the exchangeable base contents were well retained in the soil of plantation forest lands due to nutrient recycling, in contrast to grazing and cultivated lands, where basic nutrients are lost during grazing and crop harvesting; According to (Diacono & Montemurro, 2011), Ca dominated the exchange complex, followed by Mg, K, and Na, indicating productive agricultural soils

3.2.4 Cation Exchange Capacity

A soil's CEC is an important indicator of soil fertility and nutrient availability; They markedly vary depending on the dominant clay mineralogy, weathering intensity, and soil texture; The analysis of the soil sample results showed that Cation Exchange Capacity (CEC) varied from land use type to land use type; The highest mean of CEC (44.57 cmol $_{(+)}$ kg^{-1} soil) was recorded in soil from plantation forests, and the lowest (29.52 cmol $_{(+)}$ kg^{-1} soil) was recorded in soil from cultivated lands (Table 6); This result is in agreement with the findings of (Engda, Kassahun, Collick, Adissu, Ashagrie, Tessema, Derebe, Solomon, & Steenhus, 2008; Kenye, Sahoo, Singh, & Gogoi, 2019); The CEC values in the soil of cultivated land decreased mainly due to the reduction in OM content. Minimum CEC was observed when cultivated land soil was contrasted with soil from plantation forest and grazing lands (Table 10); This may suggest that there are fewer exchangeable cations in the soil. This finding is consistent with (Negassa & Gebrekidan, 2003) conclusion that low CEC may indicate the soil will have fewer exchangeable cations required as crop nutrients and that nutrients are weekly retained and hence may be leached out

When compared soil of plantation forest with grazing lands the highest and the lowest mean of CEC in plantation forest soil and the lowest in grazing land might be due to the presence and absence of soil organic matter or high soil organic matter in the soil of plantation forest land while it was less in the soil of grazing land; The maximum cation exchange capacity (CEC) levels observed in the soil of plantation forests (Table 10) are likely a result of the high levels of organic matter accumulation and high soil pH present in these areas, both of which promote higher CEC, This results were in agreement with (Kenye, Sahoo, Singh, & Gogoi, 2019); This indicates that the quantity and degree of organic matter decomposition have the greatest impact on soil CEC. The CEC is often higher when higher soil organic matter (SOM) results. Because the SOM decomposition rate, which accounts for the majority of CEC, is completely pH-dependent

The CEC of the soil on the cultivated land in the study area may have decreased due to OM depletion caused by continual cultivation; Accordingly, (Fetene & Amera, 2018) reported that soil erosion, limited recycling of crop and dung residues, declining fallow periods, leaching, and other factors have all led to the depletion of basic cations and lowering of CEC on cultivated land when compared to adjacent land uses; Clay and organic matter both provide negatively charged surfaces that are essential in the exchange process; Therefore, the CEC of a soil essentially depends on the relative numbers and types of these colloidal components. Because it supplies more negatively charged surfaces than clay particles do, organic matter in particular plays a significant role in the exchange process (Kebede & Yamoah, 2009); The CEC of the soils in the studied area diminishes as it moves from surface to subsurface. The highest CEC was observed for the surface soil, which also had the highest levels of organic matter, suggesting that the declines in CEC value with increasing depth may be related to the positive association between organic matter and CEC (Table 6); This result was consistent with the finding of (Addise, Bedadi, Regassa, Wogi, & Feyissa, 2022) who stated that the CEC values declined with increasing soil depths

The most important factors influencing soil CEC are soil type, pH, clay particle type, and OM concentration; (Seyoum, 2016) suggest that the amount and kind of clay minerals are the main sources of high CEC since both clay and organic colloidal molecules are negatively charged and hence have the capacity to act as anions; Regarding the CEC of the clay fraction, the soil of PF had the highest mean (309.29 cmol $_{(+)}$ kg^{-1} clay) followed by that of GL soil, while the soil of CL had the lowest mean (130.63 cmol $_{(+)}$ kg^{-1} clay) CEC-clay values (Table 6); According to the CEC of the soil and clay fraction, the dominant type of clay minerale in plantation forest land soil seems to be mainly vermiculite though the presence of smectitic clay minerals is also not exclusive especially in soil of cultivated land

According to (Taddesse, 2008) higher CEC values may indicate that the soils have a high potential to sustain induced change. In line with this, PF and GL soils had relatively large buffering capacities, but CL soil had low buffering capacities. According to a study by (Amanuel, Yimer, & Karltun, 2018) the reflection of the basic cations existing in a given soil, and the natural and/or anthropogenic activities that are acting on these cations have an impact on the soil's CEC. According to (Rashid, Abera, Agegnehu, & Zelleke, 2010) rating of soil CEC, the soil of plantation forests was rated as very high as compared to the soil of other land use types, while the CEC of grazing and cultivated land soils was categorized as high (Table 10). The CEC of the soil of studied land uses had a significant and positive correlation with its total porosity (0.75**), clay (0.75**), soil OM (0.71**), AP (0.94**), and PBS (0.61**) (Table 8).

3.2.5 Percent Base Saturation

The percent base saturation (PBS) of the studied area was influenced by the forms of land use and the depth of the soil (Table 6). The highest mean (63.36 %) and the lowest mean (31.69 %) PBS was registered from the soil of plantation forestland and cultivated land uses respectively (Table 6).

Typically, changes in basic cation concentration also affect the soil's percentage of base saturation. According to (Chemeda, Kibret, & Fite, 2017) the soil of cultivated land uses had the lowest PBS (%) mean values while grassland had the highest mean values. According to (Rashid, Abera, Agegnehu, & Zelleke, 2010), PBS rates in the study area were low in cultivated and moderate to high rates in grazing and plantation forest land soils respectively.

Due to the relatively high OM (soil colloidal sites and storehouse of exchangeable bases) in the subsurface layer of forest land compared to the surface layers of cultivated and grazing lands, the highest mean PBS (63.36 %) was observed in the subsurface layer of plantation forest land in this study, whereas the lowest mean (31.69 %) was on the surface layer of cultivated land. PBS (%) increased with increasing depth (surface to subsurface layer) for all land use types due to the washing down of basic cations and increased pH. This result is in agreement with the finding of [43,73] who reported that the plantation forest >grazing land >cultivated lands. The highest PBS from the soil of PF and GL may be due to high pH, organic matter and the addition of cow dugs whereas the lowest PBS from cultivated land may be the result of low soil pH which lead to a decrease in soil base saturation, continuous losses in the harvested parts of the plants from the cultivated and intensity of cultivation *etc*. The surface mean PBS (54.09 %) of the plantation forest of the *Melka Gura* Subwatershed was moderate, according to the ratings suggested by [39, 77]. Similarly, the mean surface and subsurface PBS for plantation forest soil (54.09 %) and (63.36 %) were weakly leached. However, PBS of grazing land soil (41.74%) and 57.13 % were classified as moderately leached to weakly leached, whereas the mean PBS for cultivated land soil (31.69 % and 39.69 %) was classified as moderately leached.

Table 6. Soil Exchangeable bases, CEC and PBS under Different Land Uses of Study Area (mean ± std.)

LU	SD (cm)	Exchangeable basic cations(cmol$_{(+)}$ kg^{-1})				CEC of soil (cmol$_{(+)}$ kg^{-1})	CEC of clay (cmol$_{(+)}$ kg^{-1})	PBS (%)
		Ca	Mg	K	Na			
PF	0-20	14.40±0	8.55±0.45	1.08±0.35	0.08±0	44.57	309.29	54.09
	20-40	16.6±1.35	9.45±0.45	1.82±0.84	0.09±0	44.18	267.12	63.36
GL	0-20	8.35±2.05	6.75±2.25	0.36±0.03	0.08±0	37.34	213.29	41.74
	20-40	10.35±0.45	7.20±2.25	0.56±0.03	0.09±0	31.83	139.50	57.13
CL	0-20	4.8±0.52	4.50±0.9	0.39±0.08	0.03±0.02	30.77	143.71	31.69
	20-40	5.85±0.45	5.05±0.55	0.59±0.08	0.05±0.01	29.52	130.63	39.12

SD=Soil depth; Std = Standard deviation; CEC=Cation exchange capacity; PBS=Percent base saturation.

3.4 Variation of Organic Carbon Stocks in Soil under Different Land Use Types

The analytical results of soil collected from different land use types in the study area indicate that land uses had an impact on the amount of soil organic carbon stored and its carbon dioxide equivalence. Soil of plantation forests produced the greatest mean SOC stocks (68.62-ton ha^{-1}) among all the land uses examined. Cultivated land soil produced the lowest amount, whereas grazing land soil was intermediate. In all three land uses, soil organic carbon stocks were consistently decreased with depth. The maximum SOC stocks were registered from soil of plantation forest and minimum was from cultivated lands (Table 10).

The higher biomass inputs and slow rate of litter decay might be the main causes of the higher SOC stocks recorded for soil of plantation forest land. The lowest average SOC stocks recorded for the soil of cultivated land might be due to the low input of organic matter to the soil and high rates of oxidation of soil organic matter due to tillage. This agrees with who reported lower SOC stocks in agricultural areas, especially in cultivated lands. The quantity of organic carbon stored in the soil is governed by SOC (%) and BD. Bulk density was negatively and significantly correlated (-0.57*) with the soil organic carbon stocks (Table 8). reported SOC stock had a negative correlation with BD as the lower soil layer contained lower SOC content but had a higher bulk density.

SOC stocks in the studied land uses were proceeds in the following order: SOC stock of plantation forest greater than that of grazing land, and cultivated land soil. Additionally, SOC stock showed decreasing under soils of all land uses with the soil depth. This result is in parallel with the findings of [37,77] who reported a decreasing SOC stock towards the subsurface in relation to soil organic carbon that decreased also with soil depth.

Comparing soil of grazing land with cultivated lands more SOC and SOC stocks were found in grazing lands. This variation could be related to the high roots of grass and high grass root biomass turnover rate, which is important as protection from erosion and lack of tillage. This finding was supported by [36] who reported relatively higher SOC stock for grazing land followed by cultivated land.

Table 7. Soil Organic Carbon Stock (ton/ha) under the Different Land Uses (mean ± std.)

	SOC stock (ton ha^{-1})		
LU Types	0-20 cm	20-40 cm	Total carbon stock (ton ha^{-1})
CL	50.95±15.01	45.34±16.78	48.15
PF	77.28±1.09	59.95±8.81	68.62
GL	54.16±9.10	53.99±13.34	54.08

Table 8. Correlation Coefficients among Different Soil Physical and Chemical Properties and SOC Stocks

variables	BD	CEC	Ca	Ex.A	FC	K	Mg	Na	OM	P	PBS	PH	PWP	SOCS	TN	AP	Clay	Sand	Silt

BD	1													
	-0.													
CE	75													
C	**	1												
	-0.	0.8												
	77	5*												
Ca	**	*	1											
Ex.	-0.	-0.	-0.											
A	21	34	49	1										
	-0.	0.6												
	68	8*	0.5	-0.										
FC	**	*	8*	11	1									
		0.7	0.7											
	-0.	1*	9*	-0.	0.2									
K	43	*	*	43	5	1								
	-0.	0.7	0.7	-0.										
	54	9*	8*	52	0.5	0.5								
Mg	*	*	*	*	7*	9*	1							
	-0.	0.6	0.7		0.6		0.6							
	57	2*	7*	-0.	6*	0.4	7*							
Na	*	*	*	49	*	3	*	1						
	-0.	0.7	0.6											
	77	1*	7*	-0.	0.4	0.3	0.5	0.5						
OM	**	*	*	44	3	2	9*	6*	1					
	-1.	0.7	0.7		0.6				0.7					
	00	5*	7*	-0.	8*	0.4	0.5	0.5	7*					
P	**	*	*	21	*	3	4*	7*	*	1				
	-0.	0.6	0.9	-0.		0.6	0.8	0.8						
PB	57	1*	0*	60	0.4	6*	2*	0*	0.5	0.5				
S	*	*	*	**	6	*	*	*	3*	7*	1			
	0.2	0.1	0.1	-0.	-0.	0.1	0.5	0.2	0.1	-0.	0.3			
PH	3	5	6	46	07	1	0*	9	2	23	5	1		
					0.6			0.7				0.		
PW	-0.	0.4	0.5	-0.	4*	0.1	0.5	7*	0.4	0.4	0.5	2		
P	42	8	4*	19	*	6	3*	*	0	2	7*	0	1	
SO	-0.	0.6	0.5	-0.	0.2	0.2	0.5	0.5	0.9	0.5	0.4	0.	0.3	1

CS	57	0*	6*	49	9	5	5*	2*	6*	7*	7	2	9						
	*	*					*		*			5							
					0.7			0.7				0.	0.8						
	-0.	0.4	0.4	-0.	9*	0.1	0.4	5*	0.3	0.4	0.4	0	7*	0.2					
TN	43	9	6	15	*	4	8	*	0	3	5	4	*	5	1				
	-0.	0.9	0.9		0.6	0.7	0.8		0.7	0.7	0.7			0.6	0.				
	79	4*	1*	-0.	0*	7*	1*	0.5	3*	9*	3*	0.	0.4	0*	4				
AP	**	*	*	45	*	*	*	8*	*	*	*	11	3	*	1	1			
	0.7	0.7	0.6				0.6		-0.	-0.		-0		-0.	-0	-0.			
Cla	0*	5*	6*	0.1	0.5	0.4	2*	-0.	75	70	0.5	.0	0.5	69	.3	76			
y	*	*	*	2	3*	1	*	42	**	**	0*	4	1*	**	9	**	1		
												0.			-0				
San	0.1	0.2	0.0	0.1	-0.	-0.	0.1	0.0	0.3	0.1	-0.	3	-0.	0.3	.0	0.0	-0.		
d	3	1	8	9	13	24	2	9	1	3	03	3	10	2	8	8	19	1	
												-0			0.		-0.	-0.	
	-0.	0.4	0.4	-0.	-0.	0.5	0.3	0.2	0.3	0.4	0.3	.2	-0.	0.2	3	0.5	56	67	
Silt	42	1	3	16	24	3	6	0	1	2	8	8	23	4	2	2*	*	**	1

		Cultivated lands				Plantation forest				Grazing land			
Variabl	SD			Mea	SD			mea	SD			mea	SD
es	(cm)	min	max	n	V.	min	max	n	V.	min	max	n	V.
		44.0	52.0	48.0		43.0	58.0	50.6		44.0	51.0	48.0	
	0-20	0	0	0	4.00	0	0	7	7.51	0	0	0	3.61
	20-4	46.0	48.0	47.0		40.5	54.0	48.1		40.0	50.0	46.0	
sand	0	0	0	0	1.00	0	0	7	6.93	0	0	0	5.29
		29.0	41.0	35.0		32.0	45.0	39.0		35.0	43.0	38.0	
	0-20	0	0	0	6.00	0	0	0	6.56	0	0	0	4.36
	20-4	33.0	35.0	34.0		31.0	45.0	38.6		30.0	43.0	36.0	
Silt	0	0	0	0	1.00	0	0	6	7.09	0	0	0	6.56
		15.0	19.0	17.0			12.0	10.3		13.0	16.0	14.0	
	0-20	0	0	0	2.00	9.00	0	3	1.53	0	0	0	1.73
	20-4	17.0	21.0	19.0		10.0	15.0	13.1		15.0	21.0	17.6	
clay	0	0	0	0	2.00	0	0	7	2.75	0	0	7	3.06
	0-20	1.37	1.41	1.38	0.02	1.02	1.10	1.06	0.04	1.08	1.34	1.25	0.14
BD	20-4	1.29	1.47	1.39	0.09	1.10	1.23	1.16	0.06	1.19	1.39	1.31	0.10

	0												
		46.9	48.4	47.8		58.6	61.4	60.1		49.2	59.1	52.8	
	0-20	2	9	1	0.80	5	0	3	1.39	5	2	2	5.47
	20-4	44.3	51.1	47.5		53.7	58.5	56.4		47.6	54.9	50.6	
P	0	6	9	5	3.44	6	0	0	2.42	3	9	4	3.86
		35.8	36.2	36.0		41.3	43.3	42.2		37.4	47.3	43.7	
	0-20	0	0	0	0.20	0	0	0	1.01	5	0	8	5.50
	20-4	30.5	34.9	32.8		41.5	42.5	42.0		38.5	40.0	39.5	
FC	0	0	0	0	2.21	0	0	0	0.50	0	0	0	0.87
		20.3	21.1	20.7		24.0	25.2	24.6		24.5	29.2	26.8	
	0-20	0	0	7	0.42	0	0	0	0.60	0	0	3	2.35
	20-4	20.3	21.7	21.0		24.7	25.0	24.8		24.3	26.9	25.3	
PWP	0	0	0	0	0.70	0	0	0	0.17	0	0	3	1.38
		14.7	15.7	15.2		16.7	18.1	17.6			22.8	16.9	
	0-20	0	0	3	0.50	0	0	0	0.78	8.25	0	5	7.68
	20-4		13.2	11.8		16.8	17.8	17.2		13.1	15.2	14.1	
AWC	0	9.50	0	0	2.01	0	0	0	0.53	0	0	7	1.05

Table 9. Descriptive Statistics of Soil Physical Properties of Different Land Uses

Table 10. Descriptive Statistics of Soil Chemical and SOCS Properties of Different Land Uses

		Cultivated lands				Plantation forest				Grazing land		
Variables	SD (cm)	min	max	Mean	SDV.	min	max	mean	SDV.	min	Max	mean
	0-20	5.30	5.51	5.41	0.11	5.40	5.82	5.58	0.22	5.00	5.70	5.46
PH	20-40	5.55	5.61	5.57	0.03	5.46	5.73	5.60	0.14	5.45	6.10	5.68
	0-20	4.09	6.43	4.90	1.33	1.22	6.21	3.23	2.64	4.71	5.16	4.89
Ex. A	20-40	3.56	5.36	4.48	0.91	1.60	4.53	2.90	1.50	2.00	3.55	2.83
	0-20	2.81	4.61	3.86	0.94	0.78	4.94	2.43	2.21	2.04	3.38	2.64
Ex. Al	20-40	2.22	3.38	2.78	0.58	0.89	2.67	1.70	0.90	1.13	2.23	1.68
	0-20	4.50	5.40	4.80	0.52	14.40	14.40	14.40	0.00	6.30	10.40	8.35
Ca	20-40	5.40	6.30	5.85	0.45	15.30	18.00	16.65	1.35	9.90	10.80	10.35
	0-20	3.60	5.40	4.50	0.90	8.10	9.00	8.55	0.45	4.50	9.00	6.75
Mg	20-40	4.50	5.60	5.05	0.55	9.00	9.90	9.45	0.45	5.40	9.00	7.20
	0-20	0.35	0.48	0.39	0.08	0.73	1.43	1.08	0.35	0.33	0.38	0.36
K	20-40	0.51	0.66	0.59	0.08	0.98	2.65	1.82	0.84	0.45	0.66	0.56
	0-20	0.02	0.06	0.03	0.02	0.08	0.08	0.08	0.00	0.08	0.08	0.08
Na	20-40	0.04	0.05	0.05	0.01	0.09	0.09	0.09	0.00	0.09	0.09	0.09

CEC	0-20	29.38	32.15	30.77	1.39	43.84	45.29	44.57	0.73	34.48	40.19	37.34	2
	20-40	28.84	30.19	29.52	0.68	42.02	46.33	44.18	2.16	31.62	32.03	31.83	0
PBS(%)	0-20	29.67	34.96	31.69	2.85	53.17	55.00	54.09	0.92	39.08	44.55	41.74	2
	20-40	35.11	43.20	39.12	4.05	62.51	64.19	63.36	0.84	50.08	64.16	57.13	7
TN	0-20	0.17	0.22	0.20	0.03	0.50	0.51	0.50	0.01	0.30	0.41	0.35	0
	20-40	0.10	0.20	0.15	0.05	0.35	0.52	0.41	0.10	0.30	0.32	0.31	0
AP	0-20	12.03	20.37	16.20	4.17	44.51	58.24	51.38	6.86	23.15	25.06	24.11	0
	20-40	10.90	13.38	12.14	1.24	45.59	52.99	49.29	3.70	21.03	23.61	22.32	1
%OC	0-20	1.31	2.43	1.84	0.56	3.43	3.86	3.66	0.21	1.78	2.51	2.17	0
	20-40	0.49	1.91	1.36	0.76	2.12	3.08	2.61	0.48	1.37	2.67	2.08	0
SOCS	0-20	25.99	55.89	41.73	15.01	76.69	78.70	77.93	1.09	38.68	56.88	47.73	9
	20-40	11.56	41.88	30.87	16.78	46.44	64.02	55.58	8.81	32.82	59.14	47.23	1

Ex. A=Exchangeable acidity; Ex. Al=exchangeable aluminum; SD=soil Depth; SDV=Standard deviation.

4. Conclusions

Based on the result of the study, variations in soil physical and chemical properties and organic carbon stocks were observed under soils of selected land use types in the study area. This variation may be caused by frequent tillage practice, crop residue removal, intensive use of inorganic fertilizer, and conversion of forest land to other land uses. Most of the physical and chemical characteristics of soils in the study area, including particle size distribution, bulk densities, total porosity, soil moisture characteristics, soil pH (H2O), CEC of soil, CEC of clay, exchangeable bases (Ca, Mg, K, and Na), PBS, SOC, SOCS, total N, AP, exchangeable acidity and aluminum, exhibited variations in fertility status in response to variations in land uses. The fertility status of the soils under the cultivated lands showed overall changes toward the direction of loss of their fertility compared to the adjacent plantation forest and grazing land soils. In general, based on the findings, it was possible to say that soil physical and chemical properties, as well as soil organic carbon stock status show variation among land use systems. It is also recommended that controlled grazing, increased fallow period, avoiding deforestation and using multipurpose agro-forestry practices should be more practiced in the study area to reduce further loss of soil fertility. In order to reduce the ongoing loss of soil nutrients caused by the conversion of land use systems at the Melka Gura sub watershed, additional research must be done on the effects of land use change on properties related to soil fertility as well as on integrated soil and water conservation practices.

Author Contributions

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supervision, A.K., and L.W.; funding acquisition, D.G. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrophotometer
AP	Available Phosphorus
AWC	Available Water Content
BD	Bulk Density
CEC	Cation Exchange Capacity
CL	Cultivated Land
ECSA	Ethiopian Central Statistical Agency
Ex. A	Exchangeable Acidity
Ex. Al	Exchangeable Aluminum
FAO	Food and Agricultural Organization of the United Nations
FC	Field Capacity

FPh	Flame Photometer
GHG	Green House Gases
GL	Grazing Land
GPS	Global Positioning System
LU	Land Use
M	Molarity
MoA	Ministry of Agriculture
N	Normality
OM	Organic Matter
P	Porosity
PBS	Percent Base Saturation
PD	Particle Density
PF	Plantation Forest
PPM	Parts Per Million
PWP	Permanent Wilting Point
SD	Soil Depth
SOC	Soil Organic Carbon
SOCS	Soil Organic Carbon Stock
SOM	Soil Organic Matter
TN	Total Nitrogen
USDA	United State Department of Agriculture