International Journal of Energy and Environmental Science
2022; 7(5): 88-103
http://www.sciencepublishinggroup.com/j/ijees
doi: 10.11648/j.ijees.20220705.13
ISSN: 2578-9538 (Print); ISSN: 2578-9546 (Online)

Characterization of Selected Physicochemical Properties of Soil Under Mechanized Cultivation of Sugarcane at Finchaa Sugar Estate, Western Highland of Ethiopia

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To cite this article:

Tefera Tolesa, Tesfaye Wakgari, Achalu Chimdi. Characterization of Selected Physicochemical Properties of Soil Under Mechanized Cultivation of Sugarcane at Finchaa Sugar Estate, Western Highland of Ethiopia. *International Journal of Energy and Environmental Science*. Vol. 7, No. 5, 2022, pp. 88-103. doi: 10.11648/j.ijees.20220705.13

Received: September 14, 2022; **Accepted**: October 27, 2022; **Published**: October 29, 2022

Abstract: Long year cultivations under sugarcane production causes soil degradation and subsequently results in to change of soil properties. However, information on the effect of long year cultivation of sugarcane on soil physicochemical properties is scanty. A study was conducted in 2020 at Finchaa Sugar Estate to investigate the status of selected physicochemical properties of soil under mechanized sugarcane cultivation for different years. In this line soil samples were collected from 0-30 and 30-60 cm layers of long year cultivated, short term cultivated and virgin land uses for laboratory analysis. The result of this study showed that the highest bulk density value of soils for long year sugarcane cultivated fields under low organic matter content induced soil compaction and the bulk density and total porosity parameters of all crop land fields were out of optimum range for sugarcane production. The available water holding capacity of the surface soils of the study area was in the range of high class for all long term cultivated fields and optimum for sugarcane production. In terms of organic carbon, total nitrogen and available phosphorus contents the fertility status of soils was low. From these findings one can conclude that the low soil porosity and high soil bulk density values of long year sugarcane cultivated land indicates presence of soil compaction and sustainability problem for sugarcane production in the estate. Low organic matter, total nitrogen and available phosphorus noted under the cultivated land may cause sustainability problem to sugarcane production in the estate. To maintain sustainability of sugarcane production in the estate soil management practices that can increase soil organic matter, total nitrogen and available phosphorus is helpful. Therefore, to develop a more general recommendation further research studies are needed.

Keywords: Cultivated Fields, Management Unit, Soil Properties, Sugarcane, Virgin Land

1. Introduction

Long-term intensive mechanized tillage operation under sugarcane production causes soil degradation, which results in subsequent changes in soil physicochemical properties [1]. The problem is more serious in Ethiopia in long-term cultivated fields of sugar estates such as Finchaa Sugar Estate [2]. Study has indicated that tillage operations for long time deplete soil organic matter [3]. The issue of soil compaction more exaggerated by low organic matter and overuse of heavy machines [4]. Beside this, Usaborisut and Niyamapa [5] indicated that long-term sugarcane cultivation under low soil organic matter condition alters soil properties. These changes in soil properties result in increased bulk densities and lower water infiltration that may consequently reduce nutrition uptake and sugarcane yield.

Sugarcane is a perennial and a long duration industrial crop growing in soil types ranging from sandy to very heavy clayey soils [6]. It is one of the main economic commercial crops grown in Ethiopia. Moreover, Ethiopia is one of the countries with the highest sugar cane yield in the world [7, 8]. Sugarcane production in Ethiopia involves mechanized cultivation in order to satisfy the local high demand for white sugar [9].

In mechanized sugarcane cultivation, the use of heavy machinery, such as tractors for operations like cultivation, planting, fertilizer application, weed control and cane extraction, is a common practice [10]. This type of agriculture is associated with the use of larger tractors, more soil cultivation and reduced plant residue returns to soil, as well as greater utilization of pesticides and fertilizers. Nevertheless, machinery overuse and long term intensive cultivation have been found to be the main cause for major soil degradation processes such as acidification, soil crusting, compaction, breakdown of soil structure and loss of organic matter [11].

Loss of soil organic matter is the cause for soil degradation under sugarcane production [12]. For instance, Tesfaye *et al*. [13] reported that the most serious factor associated with soil compaction under sugarcane production is the loss of soil organic matter due to intensive tillage. Moreover, a loss of soil organic matter now considered the most important aspect of soil degradation under cane production and has detrimental effects on soil physical and chemical properties [14].

Although, Ethiopia is one of the countries with the highest sugar cane yield in the world sugar cane yield decline is currently becoming the major area of attention in the Ethiopian sugarcane plantations. For instance, Tesfaye *et al.* [15] clearly indicated the existence of a general decline in cane yield in the Finchaa Sugar Estate. Accordingly, the cane yield declined by 26.6% at Finchaa Estate between 1997-2008 production years. Studies in Ethiopian Sugar Estates also showed that the declining productivity of the fields is mainly due to deplete organic matter along with effects of soil compaction on soil properties [16].

Agricultural sustainability requires periodic evaluation of soil fertility status. This is important to understand the factors, which impose serious constraints on increased crop production under different land use types, and for adoption of suitable land, management practices [17]. Moreover, information about the characterization of soils under long-term cultivation is essential in order to draw up appropriate recommendations for optimal and sustainable utilizations of land resource. The achievement of soil management to maintain enhanced soil fertility status depends on the understanding of how soils respond to land use and practices over time [18]. Furthermore, the importance of soil properties characterization lies in achieving sustainable land use and management systems, to balance productivity and environmental protection.

Soil organic matter is one measure of soil fertility, which decreases because of intensive cultivation. Beside this, soil compaction also aggravates the degradation of soil properties and subsequently deteriorates soil fertility. Particularly, upon cultivation the deterioration of soil fertility is inevitable which may lead to yield decline. Likewise, in sugar cane plantations, soil fertility decreases due to soil degradation found to be one of the major contributors for yield decline.

Identifying and understanding the cause of the yield decline has paramount importance to design and recommend appropriate management strategies. Likewise, in Finchaa Sugar Estate long-term sugarcane production and inappropriate management practices are cause for soil fertility problem and yield decline. So in order to alleviate this problem of the Finchaa sugarcane plantation soil physical and chemical properties assessment is valuable.

Moreover, soil characterization provides information for our understanding of the Physico chemical properties of the soils we depend on to grow sugarcane [19]. Some studies were done in Finchaa Sugar Estate on effect of long-term sugarcane cultivation on soil properties [20]. Nevertheless, a few was known regarding the characterization of soil physicochemical properties under long-term sugarcane production in the study area. Such information is particular important inputs for sugarcane producing community and for land-use-planners in planning land management practices for sustaining the production and productivity of sugarcane in the estate. Keeping this in view, a comprehensive work was undertaken in Finchaa Estate with the objective of determining the effect of long year cultivation of selected physicochemical properties of soil under sugarcane cultivation for different years at Finchaa Sugar Estate.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Geographical Location and Area Coverage

The study was conducted in Finchaa Sugar Estate, which is located at 340 km from Addis Ababa within the Oromia National Regional State (ONRS). It is found in Horo Guduru Wollega Zone at latitude of 9°30’ to 10°00’ North and longitude of 37°15’ to 37°30’East [21]. Finchaa Sugar Estate is bounded by the Amhara National Regional state in the North, Hababo Guduru district in the east, Guduru district in the south, Abey Chomen and Horro districts in the west and Jarte and Amuru districts in the north-west. The total area of land under cultivation at Finchaa Sugar Estate during the study period was about 9000 ha [22].

2.1.2. Climate and Topography

Finchaa Sugar Estate has unimodal rainfall pattern in which majority of the annual rainfalls between May to September. The mean annual rainfall of the estate was 1399.72 mm and the average minimum and maximum temperatures are 14.40 and 30.54°C, respectively (Figure 2). The estate is characterized by a gently undulating surface with a general slope of 1 to 8 percent northwards [23]. It was found at an elevation of 1500 meters above sea level.

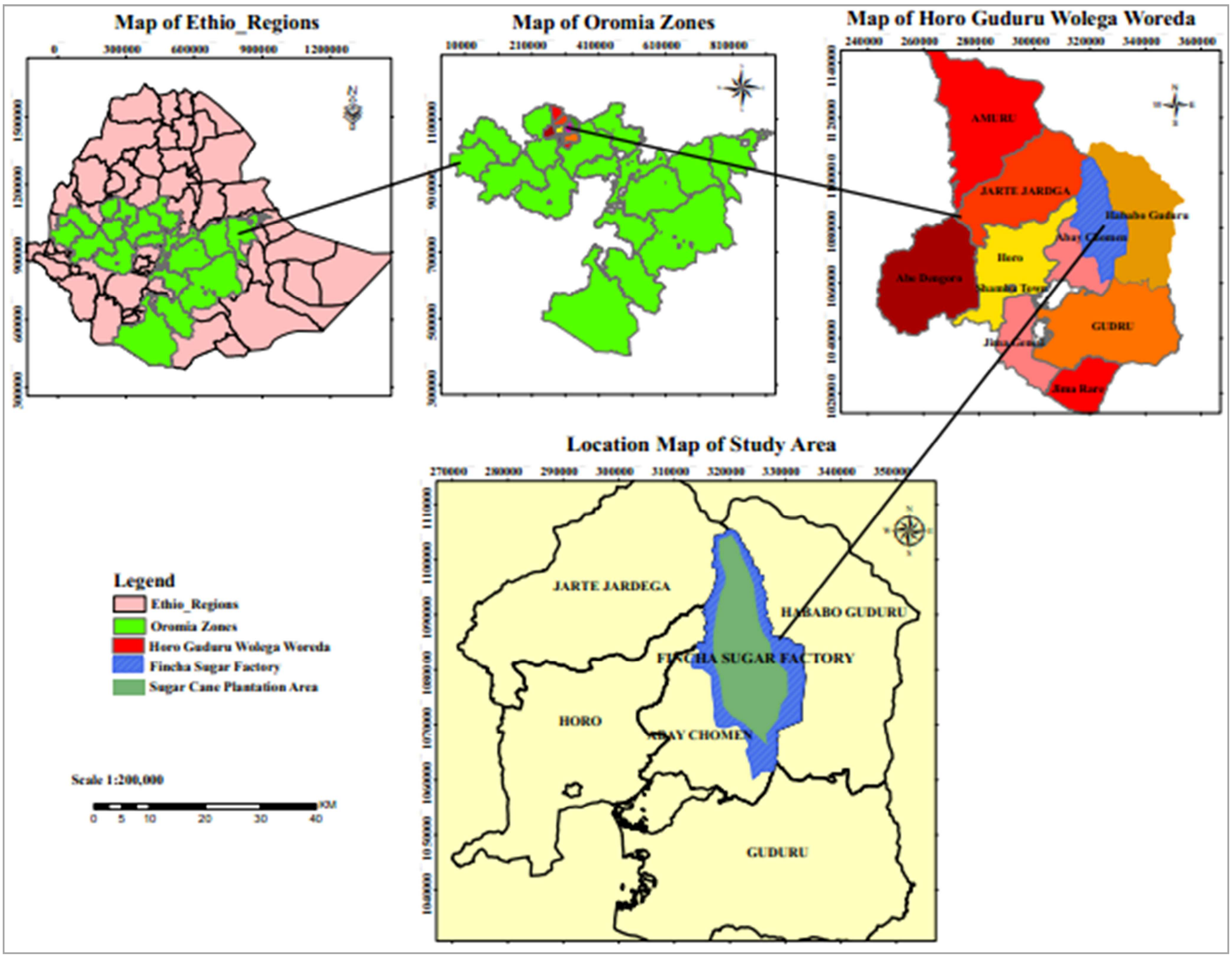

Figure 1. *Location of Finchaa Sugar Estate in Ethiopia.*

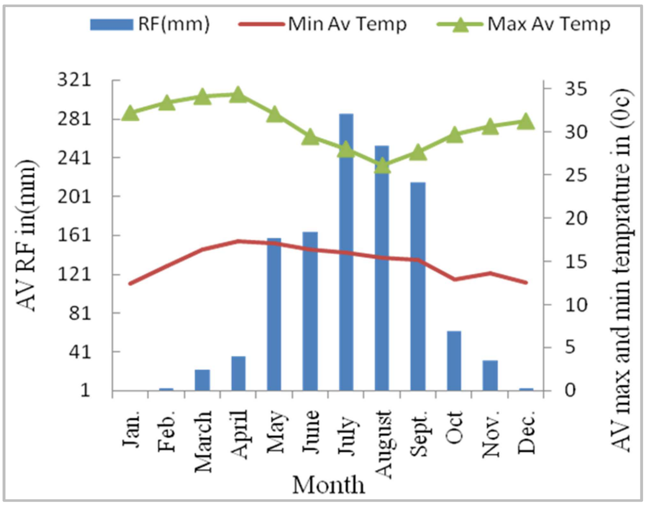

Figure 2. *Rainfall, maximum and minimum temperatures of study area.*

2.1.3. Soil Types, Parent Materials and Soil Management Units

The dominant soil types of Finchaa Sugar Estate are vertisols and Luvisols. The soils are developed from volcanic rocks such as basalt, limestone, granite, and sandstone. In general, Finchaa Sugar Estate has two soil management units in which more than 95 percent of the cultivated soils in Finchaa are grouped in to Luvisols and Vertisols and in use for different agricultural field operations [24].

2.1.4. Population, Farming System and Irrigation Management

The total population of the Finchaa Valley was 13,003 of which 3,098 were permanent (male 2,760 and female 338) and 9,671 were seasonal laborers (male 5870 and 3,801) and 234 contract laborers (male 207 and 27). Generally, the main crops grown in the Finchaa Sugar Estate were sugarcane but sesame and horticultural crops were cultivated in small areas of the estate. The mean land productivity of Finchaa Estate was about 160 t ha^{-1} of cane [25].

Mechanization based land preparation or tillage operations such as uprooting sub soiling; plowing, harrowing, labeling, and furrowing are conducted before planting cane sets. In sugarcane agriculture, the main objectives of tilling the soil were to destroy the old crop and to prepare a weed-free seedbed before planting a new crop. Planting of sugarcane seed is done manually but cultivation and chemical spraying are mechanized. Urea (150-400 $kg.ha^{-1}$) and ammonium phosphate (250 kg ha^{-1}) were the two types of fertilizers in use in the estate [26].

The irrigation water source for Finchaa plantation is the Finchaa River and movable sprinklers were used for water application in the sugarcane fields. In the sprinkler irrigation method, the irrigation water was applied to the land in the form of spray, somewhat as an ordinary rain. This overhead irrigation manually moves from place to place in the field based on the demand for irrigation [27]. In the estate independent of the soil type's irrigation application rate and interval for both soil types is the same and is applied every 15 days for length of 24 hrs. The feel method is used to recognize the need for irrigation. A test is conducted at two depths (0-30 and 30-60 cm) a few days before the expected date of irrigation, and irrigation is scheduled when the test results indicate dry soil [28].

2.2. Method of Study

2.2.1. Site Selection, Soil Sampling and Sample Preparation for Laboratory Analysis

(i). Soil Sampling Site Selection

At beginning of sampling site selection; preliminary survey, professional judgment and consultation with estate experts was undertaken to identify the sampling locations. Land use representatives such as areas covered by sugar cane plantation, areas covered with minimum disturbances (example: forests, bush, bare land, residence area), topography of sites and sugar cane plantation settings were considered.

The study was conducted on both soil management units of the estate (luvisols and vertisols soil management units). Three stages stratified random soil sampling method was used. In the first stage, the estate stratified in to two soil management units. In second stage each soil management unit categorized into three land use types (zero years of cultivation, short year cultivation (<10 years) and long year cultivation (>20 years). In the third stage each land use represented by three sampling sites so that soil samples from each stratum was provide good representation of study area soils. Accordingly, nine sampling sites for each soil management unit randomly assigned. Global Positioning System (GPS) data was taken from each of the sampling sites.

(ii). Soil Sampling

Undisturbed and disturbed composite soil samples were collected from selected sampling sites from two layers (0-30 cm and 30-60 cm) using vertical insertion of core samplers and auger, respectively. One composite soil sample was formed from the twenty sub samples for each soil depth of sampling site using the X-pattern sampling technique. Based on this, a total of 36 composite and core soil samples were collected from both layers.

(iii). Soil Sample Preparation for Laboratory Analysis

For composite soil, samples of 500 g of soil samples were weighed, labeled and kept in plastic bag, and submitted to Finchaa station soil laboratory. All laboratory analyses were done following the procedures described in laboratory manual prepared by Sahlemedhin and Taye [29]. In the laboratory, the undisturbed soil samples that were collected using a core sampler was weighed at field level and after drying it in the oven at 105°C until constant weight was gained as described by Day [30] for analysis of some physical properties. The composite soil samples was air-dried, ground and sieved to remove gravels, roots, and large organic residues before conducting analyses of selected soil physical and chemical properties.

2.2.2. Soil Laboratory Analysis

(i). Soil Physical Analysis

Soil particle size distribution was determined by the hydrometer method [31]. Then, the soil was assigned to a textural class using the USDA soil textural triangle [32]. Soil bulk density obtained from the undisturbed core sample using core method [33]. Average particle density value of 2.65 g cm^{-3} was used to compute total porosity of soil. Total porosity was computed from the values of bulk density and particle density as described by Brady and Weil [34]. To determine the available water holding capacity (AWHC) of the soil, water content at field capacity (FC) and permanent wilting point (PWP) were measured at -1/3 and -15 bars soil water potential, respectively, using the pressure plate apparatus [35].

(ii). Soil Chemical Analysis

The pH of the soil was measured in water (1:2.5 soil: water ratio) by glass electrode pH meter [36]. Soil organic carbon was determined using the Walkley and Black wet oxidation procedure [37]. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Jackson [38]. Available soil P was extracted according to the standard procedure of Olsen extraction method [39]. The P extracted with this method was measured by spectrophotometer following the procedures described by Murphy and Riley [40].

Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) was determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7. Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer [41, 42]. Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean [43]. Available micronutrients (Fe, Cu, Zn and Mn) were extracted by DTPA and measured by atomic absorption spectrophotometer as described by Lindsay and Norvell [44].

2.3. Data Analysis and Interpretation

The soil physical and chemical parameters were subjected to analysis of variance using the general linear model procedure of the statistical analysis system using SAS 9.2

software [45]. The least significance difference (LSD) test was used to separate significantly differing treatment means after main effects were found significant at P ≤ 0.05. Moreover, simple correlation analysis was executed to reveal the magnitudes and directions of relationships between selected soil parameters.

3. Results and Discussion

3.1. Effect of Land Use and Soil Depth on Soil Physical Properties

Selected soil physical properties measured for soils under different land use types and soil depths presented in Tables 1, 2 and 3 below.

(i). Particle Size Distribution

Particle size distribution of soil affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices [46]. Despite the fact that, soil texture is an inherent soil property, management practices or intensive cultivation may be contributed indirectly to the changes in particle size distribution particularly in the surface layers as result of removal of soil by sheet and rill erosions, and mixing up of the surface and the subsurface layers during continuous deep tillage activities.

In the present study, all the particle size distribution fractions were significantly (P ≤ 0.05) affected by both land use and soil depth of soil management unit, while the interaction effect was not significantly (P > 0.05) affected none of them (Tables 1, 2*)*. The highest mean values of the three separates were 57.3% (for long-term cultivated vertisols), 50.17% (for virgin Luvisols), and 11.92% (for luvisols short term cultivated), respectively, for clay, sand and silts contents. Whereas, the lowest mean values were clay (42.5%), sand (32%) and silt (7.33%), respectively, for virgin Luvisols, long term cultivated Vertisols and for virgin Luvisols (Table 1).

In both soil management units, soil under sugarcane cultivation land has higher clay and lower sand contents as compared to the virgin land use. Whereas, for both soil management unit virgin lands had higher sand and lower clay contents as compared to cultivated land uses. The difference in the distribution of sand and clay fraction between the cultivated and virgin soils likely attributed to the mixing of soils during normal tillage activities and sub soiling operations of sugarcane cultivation field. Similarly, occurrence of higher sand fraction in virgin land ascribed to the removal of clay particles through erosion leaving the sand particles behind. In agreement with this, Negasa and Tesfaye [47] also reported the variation in particle size distribution due to the removal of soil particles through erosion and mixing of the surface and subsurface soils during deep tillage activities. Generally, the particle size distribution of the study area of soils in all locations ranged from sandy clay to clay. This might be due to long-term effect of pedogenesis processes such as erosion, deposition, eluviations, weathering and cultivation.

Table 1. *Effect of land use on particle size distribution, bulk density and total porosity.*

SMUG	Particle size distribution						
	Land use	%Sand	%Clay	%Silt	TC	Bd (gcm^{-3})	%TP
L Uvisols	Long year cultivated	42.50[b]	47.67[a]	9.83[b]	SC	1.42[a]	43[b]
	Short year cultivated	45[ab]	43[b]	11.92[a]	SC	1.38[a]	44[b]
	Virgin land	50.17[a]	42.5[b]	7.33[b]	SC	1.3[b]	47[a]
	LSD (0.05)	5.15	0.4	2.35		0.02	3.41
	CV (%)	14.25	18.53	26.50		5.70	6.20
Vertisols	Long year cultivated	32.00[c]	57.33[a]	10.50	C	1.4[a]	46[b]
	Short year cultivated	37.50[b]	52[b]	10.33	C	1.29[b]	51[ab]
	Virgin land	46.70[a]	44[c]	9.20	C	1.2[b]	53[a]
	LSD (0.05)	3.49	5.12	Ns		0.09	2
	CV (%)	17.8	14.86	22.75		7.00	5.50

SMUG=Soil Management Unit Groups, LSD=List significant differences, CV%=Coefficient Variation, S=Sand, C=Clay, SC=Sand Clay, TC=Textural Clay, Bd= Bulk density, TP=Total Porosity.

Considering the effect of soil depth, there was a significantly (P ≤ 0.05) difference in the soil particle size distribution between the soil depths (Table 2). In both soil management units' sand content decreased with soil depth. In opposite to sand content, clay content increased with soil depth. The highest mean clay content (55%) recorded at subsurface layer of Vertisols and in contrary to this the mean highest sand content (48.9%) was determined for top layer of Luvisols. The higher clay content in subsurface and higher sand content at surface soil layer may be due to selective removal of clay particles by downward water movement leaving behind the sand fractions at top surface of the soil. In line with this, increase in clay content and decrease in sand content with increasing depth was reported by Worku and Tesfaye [48]. Additionally, Chemada *et al.* [49] also stated that for long period cultivated fields the clay content increased from the surface to subsurface soil layer.

Table 2. *Effect of soil depth on particle size distribution, bulk density and total porosity.*

SMUG	Particle size distribution						
	Soil depth	**%Sand**	**%Clay**	**%Silt**	**TC**	**Bd (gm^{-3})**	**%TP**
Luvisols	0-30cm	48.9^{a}	41^{b}	9.66^{a}	SC	1.41^{b}	45.6^{a}
	30-60cm	42.9^{b}	50^{a}	7.1^{b}	SC	1.45^{a}	44^{b}
	LSD (0.05)	5.8	6.15	1.9		0.03	0.08
	CV%	18	20	27		5.9	7
Vertisols	0-30cm	41.5^{a}	47^{b}	11^{a}	C	1.28^{b}	52^{a}
	30-60cm	36^{b}	55^{a}	8.88^{b}	C	1.36^{a}	49^{b}
	LSD (0.05)	2.85	4.18	2.12		0.07	2.84
	CV%	15	11.9	21		5.4	6

SMUG=Soil Management Unit Groups, LSD=List significant differences, CV%=Coefficient Variation S=Sand, C=Clay, SC=Sand Clay, TC=Textural Clay, Bd= Bulk density, TP=Total Porosity.

(ii). Soil Bulk Density

Soil bulk density was an indicator of soil compaction. The soil bulk density of study area was significantly ($p \leq 0.05$) varied among the land uses and soil depth, whereas, interaction effect was not significant ($P>0.05$) for both soil management units (Tables 1, 2). It ranges from 1.2 to 1.42g cm^{-3}, the lowest (1.2 g cm^{-3}) bulk density value obtained from Vertisols virgin, and the highest (1.42g cm^{-3}) value recorded from Luvisols long term cultivated. In both soil management units of the estate the highest bulk density was recorded under long year cultivated land use, while, the lowest bulk density was obtained from virgin land use (Table 1 and Table 2).

The highest bulk density value of soils under long year sugarcane cultivation could be due to induced soil compaction resulted from long year mechanized cultivation of sugarcane. Moreover, the relatively highest bulk density recorded for long year sugarcane cultivated field might be due to low organic matter effect of the field which can be evidenced by negative correlation (r = -0.70) between bulk density and organic matter (Table 10). In agreement with this, Gemechu and Tesfaye [50] reported inverse relationship between bulk density and organic matter as well as high bulk density of cultivated fields than uncultivated virgin fields.

The optimum bulk density for sugarcane production was 1.1 to 1.2 g/cm^{-3} for clay soils and 1.30 to 1.40 g/cm^{-3} for sandy soils [51]. With respect to these critical values, the bulk density of all luvisols soil management unit land uses and Vertisols long year cultivated land use were out of this optimum range. So the higher bulk density value of land uses than these critical values indicate presence of soil compaction and sustainability problem for sugarcane production in the estate (Tables 1 and 2). In addition, the highest bulk density noted under the cultivated land could limit root growth, gas exchange and availability of less mobile plant nutrients.

Similarly, bulk density value was significantly ($P \leq 0.05$) affected by soil depth (Table 2). However, the highest (1.45 $g.cm^{-3}$) and the lowest (1.28 $g.cm^{-3}$) mean values of bulk density were recorded from the subsurface layer of Luvisols and top layer of Vertisols, respectively (Table 2). In both soil management units of the estate bulk density increased from 0-30 to 30-60 cm. This might be due to decrease in organic matter in reverse to bulk density variation along the depth (Table 2). The bulk density of study area was increased with soil depth. Similar to this, Celik [52] reported increase of bulk density with depth.

(iii). Total Porosity

The total porosity was depending on the proportion of soil particles and could be easily affected by soil management practices. Total porosity of soil was significantly ($P \leq 0.05$) varied with land uses in both soil management units whereas, interaction effect was not significant ($P>0.05$) for both soil management units (Table 2). It ranges from 43 to 53% and lowest (43%[)]) total soil porosity value was obtained from Luvisols long year cultivated land and the highest (53%) value was recorded from vertisols virgin lands. In both soil management units of the estate the highest total soil porosity was recorded from virgin land use, while, the lowest total soil porosity was obtained from long year cultivated land use (Tables 1 and 2).

The higher total soil porosity value under virgin land could be due to the lower bulk density values resulting from the positive effects of the higher organic matter content in the virgin soils which can be evidenced by positive correlation (r = 0.70) between total porosity and soil organic matter. Likewise, the lowest total porosity recorded under long year cultivated land use field might be due to low organic matter and high soil bulk density of the field which can be confirmed by negative correlation (r = -1) between total porosity and soil bulk density (Table 10). In agreement with this, Tesfaye [53] reported inverse relationship between soil total porosity and soil bulk density. The total porosity of soils usually lies between 30 and 70%, whereas, in clay soils total porosity less than 50% can restrict root growth [54]. As per this optimum value, total porosity values for the long year cultivated fields were out of optimum value.

The estate total porosity was significantly ($P \leq 0.05$) affected by soil depth for both soil management units (Table 2). The relatively maximum (52%) and the minimum (44%) values of total soil porosity recorded from the 0-30 cm layer Vertisols and subsurface layer of Luvisols, respectively (Table 2). Soil total porosity percentage of estate was decreased from top to subsurface layer (Table 2). This might be due to decrease in organic matter in reverse to bulk density variation along the depth (Table 2). Similarly, Rao *et al*. [55] also reported highest total porosity at the surface layers due to high organic matter content and low bulk density of top layer relative to subsurface layer.

(iv). Soil Water Content

The soil volumetric water content at field capacity and permanent wilting point were ranged from 36.8 to 50.3% and 20 to 30%, respectively. The computed values of available water holding capacity of estate fields were averaged between 168 and 203 mm/m. The comparatively maximum values of soil water content at FC (50.3%) and PWP (30%) were scored under long-term cultivated land and the lowest value of soil water content at FC (36.8%) and PWP (20%) were recorded under virgin lands (Table 3). Moreover, the highest (203 mm/m) and lowest (168 mm/m) available water holding capacities were recorded under long year cultivated vertisols and virgin Luvisol, respectively (Table 3). In both soil management units of the estate the highest soil water content at FC and PWP as well as AWHC were recorded for long-term cultivated land uses. While, the lowest soil water content at FC and PWP as well as AWHC were recorded at virgin land uses (Tables 3). The variation in water content at FC and PWP and AWHC might be due to differences in their particle size distributions and bulk density.

The highest mean values of volumetric water content at field capacity and permanent wilting point and available water holding capacity of soils under long-term cultivation might be resulted from the relatively higher clay and bulk density for long year cultivated fields (Table 3). Similarly, Ayoubi *et al*. [56] reported that higher AWHC of long term cultivated lands compared to virgin fields due to high clay percentage. The lowest water content at field capacity and permanent wilting point and available water holding capacity for virgin land use could be due to lowest clay content and bulk density soils under virgin field. In agreement with this, Tesfaye [57] reported the smallest soil water content at field capacity, permanent wilting point and available water holding capacity of virgin field due to its low clay content and bulk density. In terms of AWHC rating developed by Bremner [58], the AWHC of the surface soils of the study area was in the range of high (for all long term-cultivated fields) and medium for all other fields (Table 2). As per this optimum values, all the fields under sugarcane are above this threshold value for sugarcane production.

Table 3. *Effect of land use on available water holding capacity.*

MUG	Land use	Water retained (%v/v) at		AWHC (mm/m)
		FC	PWP	
Luvisols	Long year	45^a	25.5^a	195
	Short year	40.5^b	22.5^b	180
	Virgin land	36.8^b	20^b	168
	LSD (0.05)	3.7	2.7	Ns
	CV (%)	9.50	14	9.50
Vertisols	Long year	50.3^a	30^a	203
	Short year	42^b	23^{ab}	190
	Virgin land	38^b	21^b	170
	LSD (0.05)	7.56	5.93	Ns
	CV (%)	9.50	14	9.50

SMUG= soil management unit group, LSD=list significant differences, CV%=coefficient Variation, FC= field capacity, PWP=permanent wilting point, AWHC= available water holding capacity.

3.2. The Effect of Land Uses and Soil Depth on Selected Soil Chemical Properties

(i). Soil pH

Soil pH is a measure of the availability of plant nutrients, activity of microorganisms and the solubility of soil minerals. The pH of the study area was significantly ($P \leq 0.05$) varied among the land uses in both soil management units and soil depth but not with interaction effects (Table 4). It was averaged between 5.6 and 6 pH and the highest soil pH (6) was obtained from Vertisols virgin land use and the lowest (5.6) value was recorded from Luvisols long-term sugar cane cultivated land. In both soil management units of the estate the lowest soil pH value was recorded under long term sugar cane cultivated land, while, the highest soil pH value was obtained from virgin land use (Table 4).

The lower soil pH value of soils under long term sugar cane cultivated land might be due to leaching of basic cation by percolating water during rainfall, irrigation of cultivated fields and continuous soil disturbance during cultivated; which can be evidenced by positive correlation (r = 0.21, 0.11, 0.09 and 0.04) between Ca, Mg, K and organic matter, respectively (Table 10). The relatively higher mean value of soil pH under the virgin land might be due to higher organic matter content of virgin field than other land uses. In agreement to this, BAI [59] indicated that low pH of soils under long-term cultivated fields because of removal of basic cations during irrigation of the cultivated fields.

As per rating of soil pH by Tekalign [60] soil pH of the study area of both soils, management units were within the ranges of slightly acidic to moderate acid. As described by Arian [61] the optimum value of pH for sugarcane crop production is pH 6 to 7.5. With respect to this optimum values, pH of all Luvisol land uses were out of this range.

Soil pH of study area was significantly ($P \leq 0.05$) affected by soil depths in both soil management units (Table 6). The highest pH (at subsurface layer of Vertisols) and lowest pH (at surface layer of luvisols) were 6.25 and 5.65, respectively (Table 6). The pH values were higher at subsurface than surface soil layers for both soil management units might be due to increase in basic cation accumulation at subsurface relative to surface soil layer (Table 6). Loss of base forming cations down the soil profiles through leaching, depletion of basic cations due to crop residue harvest and continuous use of ammonium based fertilizers such as diammonium in the cereal based cultivated fields could contribute to increased acidity level. In line with this, Kumar *et al* [62] reported an increase in soil pH with soil depth due to accumulation of bases at subsurface soil layer.

(ii). Soil Organic Carbon

The soil organic carbon is a nutrient sink and source in addition to improving soil physical properties. The soil organic carbon was significantly (p≤0.05) varied among the land uses and soil depth but not significantly (P > 0.05) affected by interaction effect in both soil management unit (Tables 4, 5). The soil organic carbon for this study varied between 1.17 and 2.27%. The lowest (1.17%) soil organic carbon value was obtained from Luvisols long-term cultivated land and the highest (2.27%) value was recorded from Vertisols virgin land. In both soil management units of the estate the highest soil organic carbon value was recorded under virgin land use types, while, the lowest soil organic carbon value was obtained from long year cultivated land use (Table 4).

The lower soil organic carbon value of soils under long year cultivated land might be attributed to the continuous intensive tillage operation that aggravates organic matter deterioration and insufficient inputs of organic substance from the farming system due to residue removal. In agreement with this, Nega and Heluf [63] reported that intensive cultivation removes crop residues through intensifying oxidation of organic matter in the cultivated lands. Moreover, the highest soil organic carbon value recorded under virgin land field might be due to high accumulation of organic residues the field without tillage. In agreement with this, Woldeamlak and Stroosnijder [64] reported higher organic matter content of uncultivated fields due to better availability of organic residue in uncultivated field.

As per rating of soil organic carbon by Berhanu [65] soil organic carbon of the study area both long and short years sugarcane, cultivated fields were categorized as low to medium range. Whereas, organic carbon contents of virgin fields of vertisols were in medium range. The low OC noted under the cultivated land could be one indicator for low availability of plant nutrients and unsustainable farming practices, which require management practices that improve these conditions. As suggested by Greenland *et al.* [66], the critical value of soil organic carbon for crop production was 2% below which soil structural stability will undergo a significant decline. With respect to these critical values, soil organic carbon contents of both soil management units of cultivated land uses were below this critical value.

In both soil management unit the mean soil organic carbon was significant (P≤0.05) for soil depth (Table 5). The highest mean value of soil organic carbon (2.2%) and the lowest (1.42%) were recorded from top layer of Vertisols and subsurface layer of Luvisols, respectively (Table 5). In both soil management units of the estate soil organic carbon decreased down the depth. This might be due to accumulation of plant residues at the upper surface soil layer (Table 5). In line with this, Iqbal *et al* [67] and Abdisa [68] reported that soil OM decreases with increasing soil depth due to more accumulation of organic substance on the upper surface soil layer.

(iii). Total Soil Nitrogen

Nitrogen (N) is the fourth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen and hydrogen. In both soil management unit, the total nitrogen content was significantly (P≤0.05) affected by the land uses and soil depth but interaction effect was not (Tables 4, 5). Total nitrogen content of this study varies from 0.1 and 0.17%. Lowest (0.1%) total nitrogen content was obtained from Luvisols long-term cultivated land and the highest (0.17%) was recorded from Vertisols virgin field (Tables 4 and 5). Across the land uses, distribution of total N followed similar patterns with soil OC distribution.

The lowest soil total nitrogen value of soils under long year sugarcane cultivation could be attributed to low organic matter content of this fields as the result of rapid mineralization following intensive and continuous tillage operation applied to the fields. In contrary to this, the relatively highest total nitrogen content recorded under the virgin land field might be due to relatively high accumulation of residues on the virgin land. This can be evidenced by positive correlation (r = 0.25) between soil total nitrogen and soil organic carbon (Table 10). Similar to this, Khresat *et al.* [69] also suggested decline in TN of cultivated fields due to rapid mineralization of organic matter. According to the rating of total N by Murphy [70] total N in the study area of all land uses type of luvisol and long year sugarcane cultivated vertisols fields was rated as low, while, virgin land of vertisols was rated as medium.

So the low total soil nitrogen value of cultivated land uses indicate presence of high rates of microbial decomposition and nitrogen transformation which can cause sustainability problem to sugarcane production in the estate (Tables 4 and 5). This could be in turn slow down an accumulation of soil total N in cultivated fields. In such a progressive decline in the soil total N along with continuous cultivation of sugar cane; industrial residues management in the farming system can potentially improve this condition of the estate.

Similarly, total nitrogen content in both soil management units was significantly (P≤0.05) affected by soil depth (Table 5). The highest (0.17%) and the lowest (0.12%) mean values of total soil nitrogen were recorded from the top layer of Vertisols and subsurface layer of Luvisol, respectively (Table 5). In both soil management units of the estate soil total nitrogen decreased from top to subsurface layer. This could be attributed to the relatively higher amount of organic residues and biomass on surface of lands (Table 5). This finding is in agreement with the finding by Takele *et al.* [71] in which they reported that the soil total nitrogen decreases with increasing soil depth due to more accumulation of residues on the upper surface soil layer.

(iv). Carbon to Nitrogen Ratio (C:N)

Carbon to nitrogen ratio (C:N) is an indicator of net N mineralization and accumulation in soils. The carbon to nitrogen (C:N) ratio of the study area was significantly ($P \leq 0.05$) varied among the land uses and soil depth. Nevertheless, carbon to nitrogen ratio was not significantly ($P>0.05$) affected by interaction effect for both soil management units (Tables 4, 5). Carbon to nitrogen ratio of this study ranges from 11.3 to 14.3. The lowest (11.3) carbon to nitrogen ratio was obtained from Luvisol short term cultivated and the highest (14.3) was recorded from Luvisol virgin field. In both soil management units of the estate the highest carbon to nitrogen ratio was recorded from virgin land use, while, the lowest carbon to nitrogen ratio was obtained from cultivated land uses (Tables 4 and 5).

Moreover, the relatively lower total carbon to nitrogen for sugarcane-cultivated field could be due to low organic residues as result of rapid decomposition in cultivated fields. In addition, improvement in aeration during tillage operation enhances mineralization rates in cultivated fields. Similarly, the higher C:N ratio in virgin land may indicate the better availability of carbon bearing materials in the virgin land. Moreover, 11.3 to 14.3 C:N ratio is narrow as well as normal for arable soils, decomposition rate is very rapid and N can be released. The narrow C:N ratio for cultivated fields than uncultivated field might be due to higher microbial activity and more CO_2 evolution. In line with this, Abbasi *et al* [72] also reported the narrow C:N ratio in soil of cultivated land due to higher activities of microorganism and more CO_2 release to the atmosphere.

As suggested by Cottenie [73] the C:N ratio (11.3 to 14.3%) values of both soil management units of study areas of all land use type were classified under low class. This might be due to low carbon input from the mono cropping fields, which could not compensate for the rapid mineralization of organic matter of the study area. The C:N ratio of the study areas less than 14.4% may indicate that organic residues in the soils is minimum. Basically, the narrower the C:N ratio of the study area indicates that the more need for applying organic residues to the fields.

Carbon to nitrogen ratio of the study area was significantly ($P \leq 0.05$) affected by soil depth (Table 2). The highest (12.9) and the lowest (11.8) ratio of carbon to nitrogen were recorded from the top layer of Vertisols and subsurface layer of Luvisol, respectively (Table 5). In both soil management units of the estate carbon to nitrogen ratio decreased down the depth. The lower C:N ratio at sub surface layer was due to low content of nitrogen and carbon in subsurface relative to top layers.

(v). Available Phosphorus

In both soil management units available phosphorus was significantly ($P \leq 0.05$) affected by the land use and soil depths but not significantly ($p \geq 0.05$) affected by interaction effect (Table 4). The mean available phosphorus of this study varies from 3.25 to 6 ppm. The lowest (3.25 ppm) available phosphorus content was obtained from Luvisols long term cultivated fields and the highest (6 ppm) value was recorded from Vertisols virgin land use. In both soil management units of the estate the highest available phosphorus content was recorded under virgin land use, while, the lowest available phosphorus content was obtained from long year cultivated land use (Tables 4 and 5).

The highest available phosphorus content value of soils recorded for virgin land use could be due to the high content of soil organic matter for this land use. In agreement with this finding, Abad *et al* [74] reported high available P for uncultivated land than cultivated land due to its better soil organic matter content. As per the ratings of available P by Landon [75] the available P of the soil under cultivated fields was rated as very low in both soil management units, whereas, soil available P for Vertisols virgin land was rated as low. The values of available P determined from this study were even below the critical range of P (8 mg kg^{-1}) for Ethiopian soils suggested by Haque [76]. So the low available phosphorus values of all cultivated land uses may indicate the effects of numerous crop harvest, erosion, fixation and low accumulation of soil organic matter content in the estate field (Tables 4 and 5) which can be evidenced by positive correlation ($r = 0.62$) between available phosphorus and organic matter (Table 10). In line with this, Eyayu *et al.* [77] reported the decline in available P among soils of cultivated land uses mostly due to reduction in soil organic matter during the cultivation of the fields.

Table 4. *Effect of land use on soil pH, OC, TN, C:N and AvP.*

SMUGS	Land use	pH (1:2.5)	%OC	%TN	C:N	AvP (ppm)
LUVISOL	Long	5.6^{b}	1.17^{b}	0.10^{b}	11.70^{b}	3.25^{b}
	Short	5.74^{ab}	1.65^{a}	0.14^{a}	11.40^{b}	3.50^{b}
	Virgin	5.9^{a}	1.86^{a}	0.13^{a}	14.30^{a}	4.5^{a}
	LSD (0.05)	0.14	0.21	0.01	1.84	0.305
	CV%	4.9	23.6	27	29	6
VERTISOL	Long	5.66^{b}	1.70^{c}	0.14^{b}	12.56^{b}	4^{b}
	Short	5.87^{ab}	1.97^{b}	0.16^{b}	11.90^{b}	4.1^{b}
	Virgin	6^{a}	2.27^{a}	0.17^{a}	13.3^{a}	6^{a}
	LSD (0.05)	0.21	0.18	0.01	0.06	1.17
	CV%	5.97	13.9	29	30	19.5

SMUG= soil management unit group, OC = Organic carbon, TN =Total nitrogen, C:N= Carbon to nitrogen ratio, AvP= Available phosphorus, CV%= coefficient of variation, LSD= list significant difference.

In both soil management units, mean available phosphorus values were significantly ($P \leq 0.05$) affected by soil depths (Table 5). The highest (5.18-ppm) and the lowest (3.5-ppm) mean values of available phosphorus were recorded from the top layer of Vertisols and subsurface layer of Luvisols, respectively (Table 5). In both soil management units of the estate available phosphorus content decreased from top to subsurface layers. This might be due to decrease in organic matter down the depth (Table 5). In line with this, Dawit *et al* [78] reported that available P in the soil mostly better available where the soil organic matter content is high.

Table 5. *Effect of soil depth on OC, TN, C:N, AvP and pH.*

SMUG	Soil Depth	pH (1:2.5)	%OC	%TN	C:N	AvP (ppm)
Luvisols	0-30	5.65^{b}	1.68^{a}	0.14^{a}	12	4.30^{a}
	30-60	6^{a}	1.42^{b}	0.12^{b}	11.80	3.50^{b}
	LSD (0.05)	0.26	0.165	0.02	Ns	0.249
	CV%	5	25	27	29	6.8
Vertisols	0-30	5.9^{b}	2.20^{a}	0.17^{a}	12.90	5.18^{a}
	30-60	6.25^{a}	1.77^{b}	0.14^{b}	12.60	4.33^{b}
	LSD (0.05)	0.35	0.15	0.01	Ns	0.345
	CV%	4.9	7.4	29	30	19

SMUG= soil management unit group, OC = Organic carbon, TN =Total nitrogen, C:N= Carbon to nitrogen ratio, AvP= Available phosphorus, CV= coefficient of variation, LSD= list significant difference.

(vi). Exchangeable Bases (Ca, Mg, K, Na)

Soil exchangeable bases (Ca, Mg and Na) of this study was significantly ($P \leq 0.05$) affected by land use change and soil depths but interaction effect was not significant ($P > 0.05$) (Tables 1, 2). In both soil management unit all the highest mean values of the Ca, Mg, K, and Na (10, 2.9, 1, and 0.3 cmol/kg) were recorded under the virgin land use types respectively. Whereas, all the lowest mean values of Ca, Mg, K and Na (6.63, 1.5, 0.25, and 0.2 cmol/kg) were scored from the long-term cultivated sugarcane fields (Table 6). The highest exchangeable bases recorded under virgin land use might be due to its relatively high organic matter content, which could be confirmed by positive correlation (r=0.19, 0.41, 0.44, 0.45) between organic matter content and Ca, Mg, K and Na, respectively (Table 10). In agreement with this finding, Nega and Heluf [79] indicated that virgin lands contain high base cations due to their relatively high organic matter content. Moreover, Wakane and Heluf [80] reported that intensive cultivation and continuous use of inorganic fertilizers in the cultivated fields that will enhance loss of base cations through leaching, erosion and crop harvest.

According to nutrient rating by FAO [81] the exchangeable Ca, Mg and K contents of study area of both soil management units of all land use types were categorized as moderate class and the exchangeable Na of the study area of both soil management units was in the range of low rate under all land use types. This indicates that the study area was characterized by moderate contents of exchangeable bases except exchangeable Na, which is low. This might be indirectly showing that the value of exchangeable base of the study area is almost sufficient for sugar cane cultivation. Compared to virgin land the lower concentrations of exchangeable Ca, Mg, and Na contents recorded in soils of cultivated could be attributed to continuous losses in the harvested parts of plants and leaching of basic cations from top soils of cultivated land. Similarly, Dudal and Decaers [82] and He *et al.* [83] revealed that, domination of soil by extractable acidic Al^{3+} and Fe^{2+} ions as well as adsorption of the cations by higher content of clay in their top soils of cultivated land resulting relatively lower contents of Ca, Mg, K and Na ions in the soil.

Considering the effect of soil depth of both soil management units; there was a significant ($P \leq 0.05$) difference in the soil exchangeable base between the soil depths (Table 7). In both soil management units soil exchangeable base content increased with soil depth. The highest mean values 9.5, 3, 0.95, and 0.3 cmol/kg of exchangeable bases (Ca, Mg, K and Na), respectively, were recorded under the subsurface layer of Vertisols except the highest Na was recorded from subsurface layer of Luvisol. However, the lowest mean values 6.5, 2.2, 0.5, and 0.23 cmol/kg of exchangeable bases (Ca, Mg, K and Na), were recorded from the surface layers of Luvisols respectively. The higher soil exchangeable base contents at subsurface soil layer might be due to increasing trend of exchangeable bases with depth, which might be due to downward leaching of exchangeable cations by runoff. Similarly, Bore and Bedadi [84] reported that the exchangeable bases were increasing with increasing of soil depth due to its susceptibility to leach downward by runoff and water percolation.

(vii). Soil CEC

The ability of a soil to retain cations in a form that is available to plants known as cation exchange capacity (CEC). In both soil management units CEC of the soil was significantly ($P \leq 0.05$) varied among land uses and soil depth but interaction effect was not significantly ($P>0.05$) affected soil CEC for both soil management units (Tables 6, 7). Cation exchange capacity of this study was averaged between 26.79 and 15 cmol/kg. The highest 26.79 cmol/kg CEC value was obtained from Vertisols virgin land and the lowest 15 cmol/kg was recorded from Luvisol long term cultivated field. In both soil management units of the estate the lowest soil CEC was recorded for long years cultivated land use, while, the highest soil CEC was obtained from virgin land use (Tables 6 and 7).

The relatively highest soil CEC value recorded under virgin land field could be due to its high organic matter content which can be confirmed by positive correlation (r=0.49) between soil CEC and organic matter (Table 10). As per the ratings of CEC suggested by Hazelton and Murphy [85] the CEC value of study area of both soil management units of all land use types were categorized as moderate class (Tables 6 and 7).

***Table 6.** Effect of land use on exchangeable bases and CEC.*

SMUG	Land use	Exchangeable Bases (cmol/kg)				CEC (cmol/kg)
		Ca	Mg	K	Na	
Luvisols	Long	6.63^{b}	1.5^{b}	0.25^{b}	0.2	15^{b}
	Short	8^{b}	2^{b}	0.4^{b}	0.23	16^{b}
	Virgin	9.5^{a}	2.7^{a}	0.7^{a}	0.28	19.67^{a}
	LSD (0.05)	1.16	0.2	0.3	Ns	3.67
	CV (%)	26.5	19.6	26.8	29	12.9
Vertisols	Long	7^{b}	1.7^{b}	0.3^{b}	0.23^{b}	15.63^{b}
	Short	9.15^{b}	2.5^{b}	0.5^{b}	0.26^{b}	19^{a}
	Virgin	10^{a}	2.9^{a}	1^{a}	0.3^{a}	26.79^{a}
	LSD (0.05)	0.7	0.18	0.45	0.04	4
	CV (%)	18.75	12.6	29	28	12.4

SMUG =Soil management Unit Group, LSD=List significant differences, CV%=Coefficient Variation, Ca =Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, CEC=Cation Exchange Capacity.

In both soil management units the CEC of the soil was significantly (P ≤0.05) affected by soil depth (Table 7). The highest (28.59 cmol/kg) and the lowest (21 cmol/kg) mean values of soil CEC recorded from the subsurface layer of Vertisols land and top layer of Luvisol, respectively (Table 2). In both soil management units of the estate soil CEC increased from top to subsurface layer. The highest CEC in the bottom layers of all soil management units might be due to high percentage of clay translocated to sub surface layer (Table 2). In line with this, Nigussie and Kissi [86] reported that the CEC of soil was higher in the subsurface of soil layer under different land uses due to translocated clay to subsurface. Moreover, the lowest CEC at the surface layers of all land uses could be due to leaching and downward movement of clay particles. Similarly, Fassil and Yamooh [87] and Deekor, [88] also reported low CEC at surface layer due to escaping of clay through leaching from surface layers of the fields.

***Table 7.** Effect of soil depth change on exchangeable bases and CEC.*

SMUG	Soil Depth	Exchangeable Bases (cmol/kg)				CEC (cmol/kg)
		Ca	Mg	K	Na	
Luvisols	0-30	6.5^{b}	2.2^{b}	0.5^{b}	0.23	21^{b}
	30-60	8.5^{a}	2.8^{a}	0.82^{a}	0.28	23^{a}
	LSD (0.05)	2	0.42	0.28	Ns	2
	CV%	20.5	12	27	30	16.5
Vertisols	0-30	8^{b}	2.5^{b}	0.62^{b}	0.25	25.80^{b}
	30-60	9.5^{a}	3^{a}	0.95^{a}	0.3	28.59^{a}
	LSD (0.05)	3.2	0.45	0.3	Ns	2.5
	CV%	17	16	26	29	9.6

SMUG =Soil Management Unit Group, LSD=List significant differences, CV%=Coefficient Variation, Ca=Calcium, Mg = Magnesium, K = Potassium, Na = Sodium, CEC=Cation Exchange Capacity.

(viii). Exchangeable Acidity

Soil acidity occurs when acidic H^+ ion occurs in the soil solution to a greater extent and when an acid soluble Al^{3+} reacts with water (hydrolysis) and results in the release of H^+ and hydroxyl Al ions into the soil solution. In this study the soil exchangeable acidity was not significan (P >0.05) for all factors considered (Tables 4, 5). It was averaged from 0.49 to 0.02 meq/100g. The highest (0.49 meq/100g) exchangeable acidity content value was obtained from Vertisols long year cultivated land and the lowest 0.02 meq/100g) value was recorded from Vertisols virgin land. In both soil management units of the estate the highest exchangeable acidity content was recorded under long year cultivated land use, while, the lowest exchangeable acidity content was obtained from virgin land (Tables 4 and 5).

The higher exchangeable acidity value of soils under long year cultivated land use might be due to removal of Ca, Mg, and K by Leaching and crop uptake of basic cations, and long term application of inorganic fertilizers which can lead to higher exchangeable acidity under sugarcane cultivated lands. At low pH values, solubility of exchangeable acidity was high while at high pH solubility of exchangeable acidity is declining [89].

The exchangeable acidity was not significantly (P > 0.05) affected by soil depth (Table 5). However, the highest (0.04 meq/100g) and the lowest (0.024 meq/100g) mean values of exchangeable acidity were recorded from the top layer of Vertisols and subsurface layer of Luvisols, respectively (Table 5). In both soil management units of the estate exchangeable acidity content decreased from 0-30 to 30-60 cm might be due to increase in basic cations along the soil depths. In agreement with this, Getachew and Tilahun [90] reported that increase of basic cations down the depth was the root cause of soil acidity decline down the depth.

(ix). Micro Nutrients (Fe, Cu, Mn and Zn)

The term micronutrients refer to elements that are required by plants in very small quantities. In the present study, except Cu, all the soil micronutrients were not significantly ($P \geq 0.05$) affected by land use, soil depth and none of them are significantly ($P > 0.05$) affected by interaction effect (Tables 8, 9). The highest mean values of the soil micronutrients Fe, Cu, Mn and Zn were 149.6, 4.7, 108.6, and 1.89 mg/kg were recorded under long year cultivated lands respectively. Whereas, the lowest mean values Fe, Cu, Mn and Zn were 120.9, 2.46, 82.75 and 0.9 mg/kg were recorded under virgin lands uses respectively (Table 8).

Table 8. *Effect of land use on micronutrients (Fe, Cu, Mn, and Zn) and exchangeable acidity.*

SMUG	Land use	Micro nutrients (mg/kg)				Acidity (meq/100g)
		Fe	Cu	Mn	Zn	
Luvisols	Long	123.40	3.59[a]	104.80	1.89	0.033[a]
	Short	122.60	3.3[b]	101	1.29	0.022[a]
	Virgin	120.9	2.46[b]	93.89	0.9	0.021[a]
	LSD (0.05)	Ns	0.84	Ns	Ns	Ns
	CV (%)	7.4	22.9	12.6	29	25
Vertisols	Long	149.60	4.70[a]	108.60	1.60[a]	0.49[a]
	Short	141.50	4.48b[a]	82.75	1.22[b]	0.03[ab]
	Virgin	129.58	2.95[b]	90.78	0.97[b]	0.02[b]
	LSD (0.05)	Ns	1.46	Ns	0.25	0.01
	CV (%)	21	28.80	25.50	22	25.5

SMUG =soil management unit groups, Fe= Iron, CU =cupper, Mn =manganese, Zn= zinc, LSD=list significant difference, CV= coefficient of variation.

Among soil management units, soils under long year sugarcane cultivated land had highest soil micronutrient contents as compared to the virgin land uses types might be due to enhanced microbial activity and mineralization of micronutrients from remaining residues after harvest during cultivation of sugarcane fields. The relatively higher concentrations of Fe and Mn ions in soils of cultivated land may be attributed to intensive rainfall which exposes soils to excessive leaching of exchangeable basic cations, and causes the predomination of acidic cations such as Al^{3+}, Fe^{3+} and Mn^{2+} ions in to the soil. In line with this, Han *et al.* [91] reported higher solubility, availability and plant uptake of micronutrients such as Fe^{3+} and Mn^{2+} in acidic soil conditions.

As per the critical rating recommended by Jones [92], the contents of all micronutrients were high in all land use types. The solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn and Zn) are more under acidic conditions. As suggested by Jone [92] at low pH values solubility of micronutrients is high while at high pH solubility and availability of micronutrients to plant is declining.

Table 9. *Effect of soil depth on micronutrients (Fe, Cu, Mn, and Zn) and exchangeable acidity.*

SMUG	Soil Depth	Micro nutrients (mg/kg)				Acidity (meq/100g)
		Fe	Cu	Mn	Zn	
Luvisols	0-30	130.26[a]	3.39	104.68	1.53	0.03
	30-60	114.38[b]	2.84	95.42	1.20	0.024
	LSD (0.05)	9	Ns	Ns	Ns	Ns
	CV%	6.6	25.8	12	29.5	24
Vertisols	0-30	151	4.27	100.67	1.30	0.04
	30-60	129	3.80	87.40	1.20	0.03
	LSD (0.05)	Ns	Ns	Ns	Ns	Ns
	CV%	21	28.8	25.5	22	29.5

SMUG =soil management unit groups, Fe= Iron, CU =cupper, Mn =manganese, Zn= zinc, LSD=list significant difference, CV= coefficient of variation.

Considering the effect of soil depth; in both soil management unit groups the soil micro nutrients such as Fe, Cu, Mn and Zn was significantly ($p \leq 0.05$) affected by soil depths (Table 9). The results of the study also indicated that the contents of all these micronutrients (Fe, Cu, Mn, and Zn) were higher at the surface layer than in the subsoil layer in both soil management units. The higher content of micronutrients of this study at surface layer than sub surface layers might be due to better accumulation of organic residual material and low soil pH at top layer. In line with this, Tesfaye *et al.* [93] suggested that the presence of organic matter in top layer could be promoting the availability of micronutrients better than subsoil layer.

Table 10. *Correlation analyze among selected soil physicochemical properties.*

	Sand	Clay	Silt	Bd	Tp	PH	Ca	Mg	CEC	Na	K	OC	Avp	TN
Sand	1													
Clay	-0.96^{**}	1												
Silt	-0.15^{ns}	0^{ns}	1											
Bd	0.06^{ns}	-0.07^{ns}	0.25^{ns}	1										
Tp	-0.05^{ns}	0.06^{ns}	0.25^{ns}	-1	1									
PH	-0.10^{ns}	0.06^{ns}	0.51^{*}	-0.16^{ns}	0.16^{ns}	1								
Ca	0.08^{ns}	0.13^{ns}	0.44^{*}	-0.22^{ns}	0.23^{ns}	0.21^{ns}	1							
Mg	0.37^{ns}	-0.31^{ns}	0.29^{ns}	-0.45^{*}	0.46^{*}	0.11^{ns}	0.44^{*}	1						
CEC	0.29^{ns}	0.19^{ns}	-0.3^{ns}	-0.3^{ns}	0.31^{ns}	0.29^{ns}	0.04^{ns}	0.26^{ns}	1					
Na	0.02^{ns}	0.05^{ns}	-0.19^{ns}	-0.51^{*}	0.5^{*}	-0.08^{ns}	0.08^{ns}	0.31^{ns}	0.36^{ns}	1				
K	0.46^{*}	-0.35^{ns}	-0.33^{ns}	-0.2^{ns}	0.2^{ns}	-0.09^{ns}	0.16^{ns}	0.31^{ns}	0.33ns	0.34^{ns}	1			
OC	0.13^{ns}	0.07^{ns}	0.02^{ns}	-0.7^{**}	0.71^{**}	0.04^{ns}	0.19^{ns}	0.41^{*}	0.49^{*}	0.44^{*}	0.45^{*}	1		
AvP	0.13^{ns}	0.31^{ns}	0.33^{ns}	-0.67^{*}	0.68^{*}	0.09^{ns}	0.37^{ns}	0.52^{*}	0.4^{*}	0.37^{ns}	0.4^{*}	0.62^{*}	1	
TN	-0.13^{ns}	0.10^{ns}	-0.01^{ns}	-0.32^{ns}	0.32^{ns}	-0.35^{ns}	0.1^{ns}	0.29^{ns}	0.43^{*}	0.18^{ns}	0.02^{ns}	0.25^{ns}	0.4^{*}	1

Bd= bulk density, TP=Total porosity, Ca=Calcium, Mg =magnesium, CEC=cation exchange capacity, K=potassium, OC=organic carbon. AVP=Available phosphorus, TN=Total nitrogen, ** more significant at $p<0.01$,*significant at $p<0.05$ and ns=non significant.

4. Conclusion and Recommendation

4.1. Conclusion

The result of this study showed that in both soil management units' soils under sugarcane cultivation lands have higher clay and lower sand contents as compared to the virgin land. In all land uses, sand content decreased with soil depth in contrary to clay content. Moreover, the highest bulk density value of soils for long year sugarcane cultivated fields under low organic matter content induced soil compaction and the bulk density and total porosity values of all cultivated fields were out of optimum range for sugarcane production. The available water holding capacity of the surface soils of the study area was in the range of high for all long-term cultivated fields and optimum for sugarcane production.

The analysis result further indicated that the soil was in the ranges of slightly acidic to moderate acid. In both soil management units of the estate the relatively lowest soil CEC was recorded for long years cultivated land use. Beside this, in terms of organic carbon, total nitrogen and available phosphorus content the fertility status of study area soils was low.

From these findings one can conclude that the low soil porosity and high soil bulk density values of long year sugar cane cultivated land indicates presence of soil compaction and sustainability problem for sugarcane production in the estate. Low OC noted under the cultivated land may be resulted in to low availability of plant nutrients and unsustainable farming practices, which require management practices that improve these conditions. It is also possible to conclude that the low soil total N in the study area of all lands under long year sugarcane cultivated fields indicates presence of high rates of microbial decomposition and nitrogen transformation which can cause sustainability problem to sugarcane production in the estate.

4.2. Recommendation

There is a strong need to use appropriate assessment techniques to determine soil compaction effects and its amelioration processes. The most robust assessment tools should be determined to critically evaluate the status of soil compaction for designing management strategy. To maintain sustainability of sugarcane production in the estate soil management practices that can increase soil organic matter, total nitrogen and available phosphorus is helpful. Therefore, to develop more general recommendation further research studies are needed.

Acknowledgements

The authors would like to thank Finchaa Sugar Estate Research Station Staff for providing us labour, technical support, laboratory facilities and laboratory analysis during the implementation of this study. Our special gratitude should also be extended to Ambo University for facilitating the study.

References

[1] Kodešová, R., Kočárek, M., Kodeš, V., Drábek, O., Kozák, J., and Hejtmánková, K. (2011). Pesticide Adsorption in Relation to Soil Properties and Soil Type Distribution in Regional Scale. J. Hazard. Mater, 186: 540–550.

[2] Tesfaye, W., Kibebew, K., Bobe, B., Melesse, T. and Teklu, E. (2020a). Effects of Compaction at Different Moisture Contents on Selected Soil Properties and Sugarcane Growth and Sugar Yield at Metahara Sugar Estate. *American Journal of Agricultural Research*, 5: 78.

[3] Alvarez, C. R., Taboada, M. A., Gutierrez, F. H., Fernandez, P. L. and Prystupa, P. (2009). Topsoil properties as affected by tillage systems in the Rolling Pampa region of Argentina. *Soil Science Society of American Journal*, 73: 242-1250.

[4] Abdullah, L. P, Schjønning, S, S. E. and Munkholm. L (2014). The of organic matter application and intensive tillage and traffic on soil structure formation and stability. *Soil Tillage Research*, 136: 28-37.

[5] Usaborisut, P and Niyamapa, T. (2010). Effects of machine-induced soil compaction on growth and yield of sugarcane. *American Journal Agricultural Biological Science,* 3: 269-273.

[6] Ridge, R. (2013). Sugarcane fertilizing for high yield. *International Potash Institute*, Coral Cove, Australia.

[7] Verma, R. S. (2004). Sugar cane production technology in India. Lucknow, International book distributing co.

[8] Alemayehu, D, Lantinga. E. (2016). Impact of long-term conventional cropping practices on some soil quality indicators at Ethiopian Wonji Sugarcane Plantation. *Crop Science Technology*, 4: 224.

[9] Tesfaye, W., Kibebew, K., Bobe, B., Melesse, T. and Teklu, E. (2019). Effects of Sub soiling and Organic Amendments on Selected Soil Physicochemical Properties and Sugar Yield in Metahara Sugar Estate. *American- Eurasian Journal of Agricultural Research*, 19: 312-325.

[10] Ambachew, D. and Ademe, A. (2009). Determination of optimum nitrogen and phosphorus rate for sugarcane at Finchaa Sugarcane plantation. Proc. *Ethiopian Sugar Ind. Biennial conf,* 1: 117-125.

[11] Barzegar, A. R, Manhood, S. H., Hamedi and Abdolvahabi, F. (2005). Long-term sugarcane cultivation effects on physical properties of fine textured soils. *Journal of Agricultural Science and Technology*, 7: 59-68.

[12] Hamza, M. A. and Anderson, W. K. (2005). Soil compaction in cropping systems. A review of the nature, causes and possible solutions. *Soil Tillage Research*, 82: 121-124.

[13] Tesfaye, W., Kibebew, K., Bobe, B., Melesse, T and Teklu, E. (2018). Long Term Effects of Cultivation on Physicochemical Properties of Soils at Metahara Sugar Estate. *American-Eurasian Journal of Agricultural Research*, 18: 246-257.

[14] Ambachew, D. and Abiy, F. (2009). Assessment of some soil physicochemical properties of soils of Wonji Shoa, Metahara and Finchaa Sugarcane Plantations. Ethiopian Sugar Corporation Research and Training Service Division, 118-130.

[15] Tesfaye, W., Kibebew, K., Bobe, B., Melesse, T. and Teklu, E. (2020b). Effects of long-term sugarcane production on soils physicochemical properties at Finchaa sugar Estate. *Journal of Soil Science and Environmental Management, 11: 30-40.*

[16] Garside AL, Bell MJ, Robot ham BG, Magarey RC, Stirling GR., (2005). Managing yield decline in sugarcane cropping systems. *International Sugar Journal* 107: 16-26.

[17] Chimdi, A., Heluf, G., Kibebew, K. and Abi, T. (2012). Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences,* 2: 57 – 71.

[18] Wakene, N., Heluf, G. (2004). Forms of phosphorus and status of available micronutrients under different land use systems of Alfisols in Bako areas of Ethiopia. Ethiopian *Journal of Natural Resources,* 5: 17-37.

[19] Ogunkunle, AO. (2005). Effect of land use on soil degradation and soil productivity decline on Alfisols and Ultisols in outstate in Southern Western Nigeria. *Agricultural Conspectus Scientificus*, 75: 9-19.

[20] Tesfaye. W. (2021c). Effectiveness of Sugar Industry Organic Wastes in Reducing Soil Compatibility in Soils of Three Ethiopian Sugar Estates. *International Journal of Energy and Environmental Science, 6: 86-95.*

[21] Getahun, K. (2013). Land use changes induced by irrigation development in the Fincha'a Valley Sugar Estate, Nile Basin, Ethiopia. *Journal of Biodiversity and Environmental Sciences,* 3: 31-47.

[22] FVSE, (2019). Finchaa Valley Sugar Estate Annual Report. Finchaa.

[23] Michael, M, Seleshi, B. (2007). Irrigation practices in Ethiopia: Characteristics of selected irrigation schemes. Integrated Water Management Institute, Colombo, Srilanka.

[24] Getahun, K. (2016). Soil Quality Attributes Induced by Land Use Changes in the Fincha'a Watershed, Nile Basin of Western Ethiopia.

[25] Awulachew, S. (2007). Water resources and irrigation development in Ethiopia. IWMI WorkingPaper123. Colombo, Sri Lanka: International Water Management Institute.

[26] Ambachew (2012). Effect of long-term sugarcane cultivation on sugarcane yield of Finchaa Sugar Estate.

[27] Tesfaye. W. (2021a). Extent of Soil Compaction under Mechanized Sugarcane Cultivation at Wonji-Shoa Sugarcane Estate. *World Journal of Agricultural Sciences, 17: 338-350.*

[28] (RDC) Research and Development Center (2016). Standard Operating Procedure for Sugarcane Production at Finchaa Sugar Estate. Revised by Research and Development Center.

[29] Sahlemedin. S, Taye. B. (2000). Procedure for soil and plant analysis. National Soil Research Center, EARO, Addis Ababa, Ethiopia.

[30] Day, P. R. (1965). Hydrometer method of particle size analysis. pp. 562-563.

[31] Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal,* 54: 464-465.

[32] Soil Survey Staff (1998). Key to Soil Taxonomy. Seventh edition. Blacking Pocahontas Press Inc., USDA.

[33] Blake and Hartage (1986). Soil bulk density obtained from the undisturbed core sample using core method.

[34] Brady, N. C., & Weil, R. R. (2008). The nature and properties of soils (14th Ed.). The Iowa State, India: PVT. Ltd.

[35] Klute, A. (1965). Determing the available water holding capacity (AWHC) of the soil, water content at field capacity (FC) and permanent wilting point (PWP) were measured at -1/3 and -15 bars soil water potential, respectively, using the pressure plate apparatus.

[36] Peach, M. (1965). Hydrogen ion activity in "methods of soil analysis." Pp. 374-390.

[37] Walkley A, Black (1934). An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science*, 63: 251-263.

[38] Jackson, M. (1958). Soil Chemical Analysis. Prentice Hall, Inc., Englewood Cliffs. New Jersey.

[39] Olsen, S. R., Cole, C. V., Watanable, F. S. and Dean, L. A. (1954). Estimation of available phosphorous in soil by extraction with sodium bicarbonate. United States Agricultural cultivated, USA.

[40] Murphy J, Riley J. (1962). A modified single solution method for the determination of phosphorus in natural waters. *Analytical Chimica Acta,* 27: 31-36.

[41] Chapman, H. D. (1965). Cation exchange capacity. In: C. A. Black, L. E. Ensminger and F. E. Clark (Eds). Methods of soil analysis. Agronomy, 9: 891-901.

[42] Rowell, D. L. (1994). Soil science methods and applications. Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, UK. 350.

[43] McLean, E. O. (1965). Methods of Soil Analysis. Aluminum. pp. 978-998.

[44] Lindsay, W., and Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal*, 42: 421-428.

[45] SAS (Statistical Analysis System) (2004). SAS/STAT user's guide. Proprietary software version 9.00. SAS Inst., Inc., Cary, NC.

[46] Gupta, P. K. (2004). Soil, plant, water and fertilizer analysis. Shyam Printing Press, Agrobios, India. 438p.

[47] Negessa, G., Tesfaye, W. (2021). Influence of Organic and Chemical Source Fertilizers on Soil Physicochemical Properties and Nutrient Concentration of Nitisol in Welmera District, Central Ethiopia. *World Journal of Agricultural Sciences*, 17: 295-307.

[48] Worku, A., Tesfaye, W. (2021). Effect of Integrated Application of Compost and NPS Fertilizer on Selected Soil Physicochemical Properties and Yield of Barley (Hordeum vulgare L.) at Welmera, Ethiopia. *International Journal of Applied Agricultural Sciences*, 7: 298-310.

[49] Chemada, M., Kibret, K., Fite, T. (2017). Influence of different land use types and soil depths on selected soil properties related to soil fertility in Warandhab Area, Horo Guduru Wallaga Zone, Oromiya, *Ethiopia.*

[50] Gemechu, C., Tesfaye, W. (2021). Effect of Integrated Use of Coffee Husk Compost and NPS Fertilizer on Soil Physicochemical Properties and Yield of Coffee (Coffea arabica L.) at Haru, Ethiopia. *Agriculture, Forestry and Fisheries*; 10: 233-244.

[51] Tolera, E. and Tesfaye, W. 2021. The Effect of Application of Vermicompost and NPS Fertilizer on Selected Soil Properties and Yield of Maize (Zea May L.) at Toke Kutaye, Ethiopia. *International Journal of Applied Agricultural Sciences*, 7: 247-257.

[52] Çelik, I. (2005). Land use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil and Tillage Research, 83, 270-277.

[53] Tesfaye, W. (2021 d). Status of Selected Physicochemical Properties of Soils Under Long Term Sugarcane Cultivation Fields at Wonji-Shoa Sugar Estate. American Journal of Agriculture and Forestry 2021; 9 (6): 397-408.

[54] Hillel, D. (2004). Introduction to Environmental Soil Physics. Elsevier Academic Press, p. 44.

[55] Rao, P. L., Jayasree, G., Pratibha, G., and Prakash, T. (2017). Effect of Soil Amendments on Physical Properties of Soil in Maize (Zea mays L.). *International Journal of Current Microbiology and Applied Sciences*, 6: 2082-2091.

[56] Ayoubi, S., Khormali, F., Sahrawat, K. L., & Rodrigues de Lima, A. C. (2011). Assessing impacts of land use change on soil quality indicators in a loessial soil in Golestan Province, *Iran. Journal of Agricultural Science and Technology*, 13: 727-742.

[57] Tesfaye. W. (2021b). Long Term Sugarcane Cultivation Effect on Selected Physical and Hydraulic Properties of Soils at Three Ethiopian Sugarcane Estates. *American Journal of Plant Biology, 6: 60-72.*

[58] Bremner, J. M., Mulvaney, C. S. (990). Simple and practical methods to evaluate analytical data soil profiles, *Mozambique*, 3: 123-125.

[59] Booker Agricultural International (BAI) in association with Generation Integrated Rural Development Consultant (2009). Re-evaluation of the Plantation Soils at Metahara Sugar Factory, Final Report, BAI, London, England.

[60] Tekalign, T. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis.. *International* Livestock Research Center for Africa, Addis Ababa. Working Document No. 13.

[61] Arian, A, Ahmed M, Khan, A. (2000). Some physicochemical characteristics of soils in sugarcane cultivate areas of Nawabshah, Sindh, Pakistan. *Pakistan Jornounal of Botony,* 32: 93-100.

[62] Kumar, R., Rawat, K. S and Yadav, B. (2012). The effects of land use types and soil depth on soil properties of Agedit watershed, Northwest Ethiopia.

[63] Nega, E., Heluf, G. (2006). Land use changes and their effects on physical and chemical properties in Senbat sub-watershed, western Ethiopia. M.Sc. Thesis Submitted to School of Graduate Studies, Alemaya University, Ethiopia. 72p.

[64] Woldeamlak, B. and Stroosnijder, L. (2003). Effects of agro-ecological land use succession on soil properties in the Chemoga watershed, Blue Nile Basin, Ethiopia. Geoderma 111: 85-98.

[65] Berhanu Debele, (1980). The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

[66] Greenland, D. J., Rimmer, D. & Payne, D. (1975). Determination of the structural stability class of English & Welsh soils, using a water coherence test. *Journal of Soil Science*, 26: 294-303.

[67] Iqbal, M., Khan, A. G., Hassan, A. U., Amjad, M (2012). Soil physical health indices, soil organic carbon, nitrate contents and wheat growth as influenced by irrigation and nitrogen rates. *International Journal of Agriculture and Biology,* 14: 20-28.

[68] Abdisa, B., Kibebew, K., Bobe, B., Tesfaye, B., and Markku, Y. (2018). Effects of lime, vermicompost and chemical P fertilizer on yield of maize in Ebantu District, Western highlands of Ethiopia. *African Journal of Agricultural Research*, 13: 477-489.

[69] Khresat, S., Al-Bakri, J and Al-Tahhan, R. (2008). Impacts of land use/cover change on soil properties in the Mediterranean region of northwestern Jordan. Land Degradation and Development 19: 397-407.

[70] Murphy, H. F. (1968). A report on fertility status and other data on some soils of Ethiopia. Collage of Agriculture HSIU. Experimental Station Bulletin No. 44, Collage of Agriculture: 551p.

[71] Takele, L., Chimdi, A., Abebaw, A. (2014). Dynamics of Soil fertility as influenced by different land use systems and soil depth in West Showa Zone, Gindeberet District, Ethiopia. Agriculture, Forestry and Fisheries 3 (6): 489-494.

[72] Abbasi, M. K, Zafar, M., Khan, S. R. (2007). Influence of different land-cover types on the changes of selected soil properties in the mountain region of Rawalakot Azad Jammu and Kashmir. *Nutrient Cycling in Agro ecosystems*, 78: 97-110.

[73] Cottenie, A., (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome.

[74] Abad, J. R. S., Hassan, K., Alamdarlou, E. H. (2014). Assessment the effects of land use changes on soil physicochemical properties in Jafarabad of Golestan province, Iran. Bulletin of Environment, *Pharmacology and Life Sciences*, 3: 296-300.

[75] Landon, J. (1991). Booker tropical soil manual: A handbook for soil Survey and agricultural land evaluation in the tropics and subtropics. Booker Tate limited, London, England.

[76] Haque, (1991). Soil, plant, water, fertilizer, animal manure and compost analysis.. *International* Livestock Research Center for Africa, Addis Ababa. Working Document No. 13.

[77] Eyayu, M. (2009). The effects of land use types and soil depth on soil properties of Agedit watershed, Northwest Ethiopia. *Ethiopian Journal of Science and Technology.*

[78] Dawit, S. (2002). Soil organic matter dynamics in the sub humid agro ecosystems of the Ethiopian highlands: Evidence from natural C-13 abundance and particle-size fractionation.

[79] Nega, E. and Heluf, G. (2013). Effect of land use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in senbat watershed, western Ethiopia. *Journal Agriculture and Biology Science*, 8: 206–212.

[80] Wakene, N., Heluf, G. (2001). Assessment of important physicochemical properties of nit sols under different management systems in Bako area, Western Ethiopia. M.Sc. Thesis, Alemaya University, Alemaya, Africa, p. 109.

[81] FAO (Food and Cultivated Organization),(2006). Plant Nutrition for Food Security: A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin Food and Agriculture Organization, Rome, Italy. Available at: access date. No. 16.

[82] Dudal, R. and J. Decaers (1993). Soil organic matter in relation to soil productivity. pp. 377-380.

[83] He ZL, Alva AK, Calvert DV, Li YC, Banks DJ. 1999. Effects of nitrogen fertilization of grapefruit trees on soil acidification and nutrient availability in Riviera fine sand. Plant and Soil 206, 11-19.

[84] Bore G., Bedadi, B. (2015). Impacts of land use types on selected soil physic-chemical properties of Loma Woreda, Dawuro Zone. *Southern Ethiopia. Science Technology and Arts Research Journal,* 4: 40-48.

[85] Hazelton, P, Murphy B. (2007). Interpreting soil test results: What do all the numbers mean 2nd Edition. CSIRO Publishing. p. 152.

[86] Nigussie, A., Kissi, E. (2012). Physicochemical characterization of nitisol in Southwestern Ethiopia and its fertilizer recommendation using NuMaSS. *Global Advanced Research Journal of Agricultural Science,* 1: 66-73.

[87] Fassil, K., & Yamoah. (2009). Soil fertility status and numass fertilizer recommendation of TypicHapluusterts in the Northern highlands of Ethiopia. *World Applied Sciences Journal,* 6: 1473-1480.

[88] Deekor, T. N. (2012). Changes in soil properties under different land use covers in parts of Odukpani, Cross River State, *Nigeria. Journal of Environment and Ecology*, 3, 86-99.

[89] Girma, C. and Gebreyes, G. (2018). Organic and Inorganic fertilizer application and its effect on yield of wheat and soil chemical properties of Nitisols. *Ethiopian Institute of Agricultural Research (EIAR)*, 217-225.

[90] Getachew, A. and Tilahun, A. (2017). Integrated soil fertility and plant nutrient management in tropical agro-ecosystems: a review. *Pedosphere*, 27: 662-680.

[91] Han, F. X., Kingery, W. L., Hargreaves, J. E., Walker, T. W. (2007). Effects of land use on solid-phase distribution of micronutrients in selected Vertisols of the Mississippi Delta. Ww *Geoderma,* 142: 96-103.

[92] Jones, J. B. (2003). Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, FL, USA. 48 (1): p. 70-71.

[93] Tesfaye, W., Kibebew, K., Bobe, B., Melesse, T., and Teklu, E. (2019). Effects of subsoiling and organic amendments on selected soil physicochemical properties and sugar yield in Metahara sugar estate. *American-Eurasian Journal of Agricultural Research*, *19*, 312-325.