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Effect of land use types on selected physical and chemical properties of Ultsiols in Umudike, Southeastern Nigeria.

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ABSTRACT

Field and laboratory studies were done to evaluate the effect of land use types on selected physical and chemical properties of soils in Umudike, southeastern Nigeria. Five land use types were studied: rubber plantation, oil palm plantation, forest land, cassava farm land and pasture land. Under each land use system, 3 sampling points were located. Around each of the 3 sampling points, soil samples were collected at two depths (0 – 20 and 20 – 40 cm) using soil auger and core samplers. Samples collected with the auger were air-dried and sieved through 2mm sieve for determination of some physical and chemical properties. Results from the study showed that the textural class of the soils was sandy loam except in rubber plantation which was clay loam. Forest land recorded the lowest bulk density values (1.32 Mg/m^3 and 1.49 Mg/m^3) at 0-20 and 20-40 cm depths respectively. Forest land had the highest total porosity at the two depths and highest hydraulic conductivity, the bulk density of the soils increased with depth, whereas total porosity and the saturated hydraulic conductivity decreased with depth. Forest land was also observed to have higher exchangeable bases, organic matter, total nitrogen and available phosphorus. Cassava farm land was low in organic matter, total nitrogen, effective cation exchange capacity and exchangeable bases. Conclusively, it was observed that the use to which the land was put significantly affected the physical and chemical properties of the soil at different depths; land use had significant impact on soil physical and chemical properties.

1.0. Introduction

Land use type is a complex process shaped by human activity affected by ecological, economic, and social drivers, and capable of influencing a wide range of environmental and economic conditions (Wu, 2003; MacDonald *et al.,* 2000). When the selection of land use type involves economic considerations, especially for agricultural purposes, the applied management practice is commonly driven by agricultural needs such as crop farming for food supply and cultivation techniques for monetary gains. On the other hand, economic reasons can also drive land abandonment (Kosmas *et al.,* 2000)

One of the main challenges related to the selection of applied land use is implementing sustainable and efficient use of natural resources such as soils and surface and subsurface waters. Due to intensified agricultural production, natural resources encounter increasing anthropogenic pressure. Consequently, the effects of land use and land cover change on soil properties have drawn much attention over the past several decades.

Land use and soil management practices influence the soil organic matter and related soil processes, such as moisture transmission (Liu *et al.,* 2016). As a result, it can modify the processes of soil water transport and re-distribution of nutrients. Some land use systems include continuous cropping, forestland and bush fallowing (Agoume and Birang, 2009). Forest land use system has caused positive modifications in the soil physical properties (Shepherd *et al.,* 2000), resulted to the development of tree biomass and increased availability of plant nutrient (Mao *et al.,* 2010). The conversion of forest and pasture land into crop land is known to deteriorate soil properties, reduce the soil water transmission, change the distribution and stability of soil aggregates (Singh and Singh, 1996) and soils may become more susceptible to erosion since macro aggregates are disrupted (Six *et al.,* 2000). Continuous cropping decreases moisture conducting characteristics of soils while increasing the depletion the organic matter (Celik, 2005). Bush fallowing can alter soil organic matter content through the amounts of organic residues that are returned (Neris *et al.,* 2012). Usually, the larger the amount of residues returned over a period of several years, the higher the level of organic matter (Malgwi and Abu, 2011). Changes in soil properties attributed to changes in land use types are difficult to estimate due to the time scale of the changes (Garcia-Estringana *et al*., 2012). It is also difficult to distinguish land use induced changes from changes caused by other effects such as changes in climate (Hu *et al.,* 2009). However, the effect of climate manifests on a much longer time scale compared to that of land use change (Novak *et al.,* 2009). This is especially true for land use change with anthropogenic origin, which typically occurs instantaneously and has an immediately dramatic effect on soil structure (Mahe *et al.,* 2005).

Various studies have been conducted to assess the effect of land use changes on soil physical and chemical properties in Nigeria. Onwudike (2017) showed that Soil properties vary from one land use system to another and determining the current nutrient concentration in these land use types is vital for soil nutrient management. Akinmutimi *et al*. (2020) also observed that various land use types have varied effects on soil physical and chemical properties. Also, Sedano *et al.* (2020) stated that the use of land for various purposes could affect soil fertility.

In Umudike, Abia State, Nigeria, the indiscriminate land use practices have given rise to serious ecological problems and the degradation of the land resources. Efforts to address these problems

are highly apt in order to actualize the agricultural transformation agenda of the Federal Government and meet the millennium development goals. Umudike lies in the humid rain forest agro ecological zone with lots of potentials for agricultural production. Adequate study of soils of the various land use types will help generate information necessary for proper land use planning.

The objectives of this study were;

To determine the effects of land use types on soil physical properties.

To determine the effects of land use types on soil chemical properties.

2.0. Materials and Methods

2.1. Study Area

This study was carried out in Umudike, Ikwuano Local government area of Abia State which lies between latitude 5° 28´ and 19.79´´ N and longitude 7°.32´ and 33.59´´ 0f the equator. It lies at an altitude of 122m above sea level (Nwosu *et al.,* 2016). it is a semi urban settlement about 11km south east of Umuahia the state capital. Umudike is the home to National Root Crop Research Institute and Michael Okpara University of Agriculture, Umudike. Majority of the people are farmers. The climate of the study area is typically of humid tropics with fairly even and uniform temperature throughout the two seasons (dry and rainy) of the year (Nigeria Meteorological Agency, 2015).

2.2. Description of the land use types used for the study

The different land types in the study area serve different purposes like; cultivation of arable crops, pasture, plantation crops like cassava, rubber, plantain, cocoa, the lands were also left on fallow for certain number of years to allow the soil restore its organic matter content and maintain soil fertility.

2.3. Soil Sampling

Under each land use system, 3 sampling points were located randomly. Around each of the 3 sampling points within a land use, soil samples were collected at 2 depths (0 – 20 and 20 – 40 cm) using soil auger. This constituted a total of 6 samples for each land use and a grand total of 12 bulk samples for the 3 land uses. Two core samples were collected, one at 0 – 20 cm and the other at 20 – 40 cm from each of the 3 sampling points making a total of 6 core samples in each land use. Also a total of 12 core sample was collected for analysis.

2.4. Sample Preparation

The soil samples collected with the soil anger was air-dried and sieved through 2mm sieve size. The base of the core samples was covered with a cheese cloth and saturated in water for determination of some physical properties.

2.5. Laboratory Analysis

The following properties were determined in the laboratory:

2.5.1. Soil Particle size analysis.

Particle size analysis was carried out using the Bouyoucos hydrometer method as described by Kettler *et al.* (2001).

Soil Bulk density: Bulk density was determined by the method described by Blake (2003). Soil samples were oven-dried at 105˚C to a constant weight, and bulk density calculated using the equation:

$$\ell b = \frac{M_s}{V_t}$$

Where;

ℓb = bulk density (g/cm^3)

M_s = mass of oven dry soil (Mg)

V_t = total volume of soil (cm^3)

The total volume of the soil was calculated from the internal dimensions of the cylinder.

2.6. Soil Porosity:

Total porosity: total porosity was determined from bulk density value assuming particle density to be 2.65 kgm^{-3} for mineral soils.

$$P_t = \frac{\left(1 - \frac{Bd}{Pd}\right)}{2} \times 100$$

Where Bd is bulk density and Pd is particle density.

2.5.2. Mean weight diameter

The mean weight diameter (MWD) as an index of macro aggregate stability was determined by the wet sieving method of Kemper and Rosenau (1986).

2.6. Soil pH determination

Soil pH was determined in 1:2.5 soil to water suspension and in 1N KCl using a 1: 2.5 soil to salt suspension, and the pH value read with a glass electrode pH meter.

2.6.1. Organic carbon

Organic carbon was measured by the dichromate wet oxidation method of Walkley and Black (1934).

2.6.2. Total nitrogen

The total nitrogen was determined using the micro-Kjeldhal distillation method of Bremner (1996). The ammonia from the digestion was distilled with 45% NaOH into 2.5% boric acid and determined by titrating with 0.05 N KCl.

2.7. Available phosphorus

Available phosphorus was determined by using the Bray-2 extraction method.

2.8. Soil Exchangeable bases

Calcium (Ca) and magnesium (Mg) were determined by titration method (Bower *et al*., 2002). Sodium (Na) and potassium (K) were extracted with 1N ammonium acetate solution (NH_4OAc), and determined using flame photometer.

2.9. Total exchangeable acidity

The titrimetric method using 1 N KCl extract of McLean (1982) was used in the determination of total exchangeable acidity (Al^{3+} and H^+).

2.110. Effective cation exchange capacity (ECEC)

This was evaluated by the summation method as follows:

ECEC = TEB + TEA ------------------------------------ (viii)

Where; ECEC = Effective cation exchange capacity (cmolkg^{-1}), TEB = Total exchangeable bases (cmolkg^{-1}), TEA = Total exchangeable acidity (cmolkg^{-1})

2.11. Statistical Analysis

Analysis of variance (ANOVA) for randomized complete block design (RCBD) was used to compare the influence of the land use system and depth on the measured soil properties. Significantly different means were separated using least significant difference at 5% level of probability ($p \leq 0.05$).

3.0. Results and Discussion

3.1. Particle size distribution

The particle size distribution of the soils studied is shown in Table 1. The table showed that at the two depths of 0 – 20 and 20 – 40 cm, the texture of soils was observed to be sandy loam in the land use systems studied except in rubber plantation which was observed to have a sandy clay loam texture at 0 – 20 cm and clay loam at the sub-depth. The particle size distribution of soils varied significantly with the land use systems and with depth.

In comparison with the other land uses, forest land had the highest sand content (724.00 g kg^{-1}) at 0 – 20 cm, while rubber plantation recorded the lowest (590.00 g kg^{-1}) at 20 – 40 cm depth. With regard to the silt contents, rubber plantation was observed to have the highest silt content (140.00 g kg^{-1}) at the sub-depth (20 – 40 cm) whereas, cassava land recorded the lowest (72.00 g kg^{-1}) at the top soil (0 – 20 cm). Rubber plantation had the highest clay content (270.00 g kg^{-1}) compared to other land uses at the two depths, while oil palm plantation recorded the lowest (172.00 g kg^{-1}) at 0 – 20 cm depth.

Generally, the sand contents decreased with depth while the silt and clay contents increased. However, the silt content under oil palm plantation decreased with depth. With regards to the land use systems, the sand, silt and clay particles of the different land use systems were significantly ($p \leq 0.05$) different from each other at all depths.

The high sand contents of the soils could be attributed to their being derived from unconsolidated sand deposits formed over coastal plain sands (Asawalam *et al*., 2009; Chukwu, 2013). The sandy loam texture observed in oil palm plantation and forest land, corroborated the report of Ufot *et al*. (2016), who reported sandy loam texture for a tree crop plantation and forest land in Alokwa, Imo State. The higher clay contents observed in cassava land could be attributed to increased cultivation (Oguike and Onwuka, 2017). This may be as a result of either increase of clay translocation from the surface to subsurface horizons or removal of clay from the surface by runoff (Jaiyeoba, 2003). On the contrary, Shepherd *et al.* (2000) observed that changes due to a land use do not show easily for particle size. Soil texture unlike biochemical attributes is an inherent property of the soil that is not easily influenced by land use types (Nanganoa *et al.,* 2019). However certain land uses may encourage accelerated clay illuviation due to exposure to rainfall, erosion and leaching as a result of continuous cultivation.

The clay contents in rubber plantation were slightly higher probably because the land is either not under cultivation, thus clay illuviation brought about by gradual profile development (Lal, 1996). The increase in clay with soil depth maybe due to dissolution and leaching of clay materials as a result of intense torrential rainfall (Oguike and Onwuka, 2017), argillation of clay, lessivage and sorting of soil materials (Ojanuga, 2003). Rao *et al.* (1996) observed that for better growth, establishment of rubber are obtained on clayey than sandy soils. This is expected since the inherent physical and chemical characteristics of clay give it the capacity to retain nutrients and water. White *et al.* (1997) postulated that soil texture with sufficient clay, preferably a minimum amount of 35% to retain adequate moisture and nutrients and about 50% sand to allow for expression of good physical soil properties like aeration and drainage can be considered as desirable for successful optimum rubber cultivation.

3.2. Soil Bulk density, total porosity and hydraulic conductivity

The bulk density, porosity and saturated hydraulic conductivity of the soils studied are shown in Table 2. At the two depths of 0 – 20 and 20 – 40 cm, rubber plantation had the highest bulk densities with values ranging from 1.61 at 0 – 20 cm to 1.78 Mg m^{-3} at 20 – 40 cm. The lowest bulk densities were observed in forest land at the two depths with values ranging from 1.32 Mg m^{-3} at 0 – 20 cm to 1.49 Mg m^{-3} at 20 – 40 cm. With regard to porosity, forest land had

Table 1: Particle size distribution of soils studied

Land use	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Texture
		0 – 20 cm		
Rubber plantation	670.00	80.00	250.00	Sandy clay loam
Oil palm plantation	716.00	112.00	172.00	Sandy loam
Forest land	724.00	87.00	189.00	Sandy loam
Cassava land	710.00	72.00	218.00	Sandy loam
Pasture land	705.00	87.75	207.25	Sandy loam
Mean	705.00	87.75	207.25	
		20 – 40 cm		
Rubber plantation	590.00	140.00	270.00	Clay loam
Oil plantation	710.00	109.00	181.00	Sandy loam
Forest land	719.00	90.00	191.00	Sandy loam
Cassava land	699.00	81.00	220.00	Sandy loam
Pasture land	679.50	105.00	215.50	Sandy loam
Mean	679.50	105.00	215.50	
$LSD_{0.05}$				
Land use	3.14	1.20	1.37	
Depth	5.21	3.68	2.11	
Land use × depth	1.05	1.23	2.41	

the highest at the two depths. The highest total porosity ranged from 44.20 % at 20 – 40 cm to 51.00 % at 0 – 20 cm. Rubber plantation recorded the lowest total porosity which ranged from 33.00 % at 20 – 40 cm to 39.70 % at 0 – 20 cm. In comparison with other land uses, forest land had the fastest saturated hydraulic conductivity ranging from 0.28 to 0.40 cm sec^{-1} at the two depths while cassava land was the slowest, ranging from 0.19 to 0.22 cm sec^{-1}. Generally, the bulk density of the soils increased with depth, whereas total porosity as well as the saturated hydraulic conductivity decreased with depth (Table 2).

These observations reflected the influence of organic matter on the parameters (Table 5). With reduced organic matter content, bulk density increased while total porosity decreased, resulting to a reduction in saturated hydraulic conductivity (Baunhardt and Lascano, 1996). The variation in bulk density and total porosity may be attributed to the level of organic matter in the soil (Okolo *et al*., 2013). The low bulk density and high porosity with a fast saturated hydraulic conductivity observed under forest land may be as a result of the high organic matter content of the forest land. This concurred with the findings of Onwuka (2018) who reported that the high level of organic matter in the forest land of Umudike led to low bulk density, high total volume and favored transmission of water under saturated conditions. The slow saturated hydraulic conductivity observed under cassava land may be attributed to the low mean weight diameter, high bulk density and the mechanical disruption of the pore arrangements by tillage (Celik, 2005). The low bulk densities, high total porosities and fast saturated hydraulic conductivities of oil plantations and forest land may be attributed to their high organic matter contents (Oguike *et al.,* 2006; Oguike and Mbagwu, 2009). Root systems and litter falls of trees from oil plantation and forest land may have increased their saturated hydraulic conductivity (Banuhardt and Lascano, 1996). As organic matter decreased from forest land to cassava land, the total porosity reduced. This was consistent with the observations of Oguike *et al*. (2006).

A significantly (P<0.05) lower bulk density vale was observed in Forest plantation compared to other land uses. The possible reason for this is because the long fallow observed in forest plantation coupled with the absence of tillage activities has left the soil undisturbed thereby reducing the bulk density. The bulk density in other land use types was observed to be high because of various tillage and human activities which compact the soil thereby increasing the soil bulk densities of the various land use types.

Table 2: Bulk density, total porosity and hydraulic conductivity of soils studied

Land use	Bulk density (Mg m^{-3})	Total porosity (%)	Ksat (cm sec^{-1})
	0 – 20 cm		
Rubber plantation	1.61	39.70	0.25
Oil palm plantation	1.50	44.18	0.29
Forest land	1.32	51.00	0.40
Cassava land	1.55	42.00	0.22
Pasture land	1.50	44.00	0.30
Mean	1.50	44.18	0.29
	20 – 40 cm		
Rubber plantation	1.78	33.00	0.22
Oil plantation	1.62	39.25	0.24
Forest land	1.49	44.20	0.28
Cassava land	1.58	40.80	0.19
Pasture land	1.64	39.00	0.25
Mean	1.62	39.25	0.24
$LSD_{0.05}$			
Land use	0.04	1.11	0.02
Depth	0.06	1.94	0.01
Land use × depth	0.10	1.80	0.01

3.3. Aggregate stability

The aggregate stability measured at mean weight diameter (MWD) and dispersion ratio (DR) varied significantly with the land use types and depths (Table 3). At the depths of 0 – 20 and 20 – 40, forest land was observed to be most stable having the highest mean weight diameter (MWD) with values 2.20 and 2.00 mm, respectively at the macro aggregate level. Cassava land was the least aggregated and also showed the greatest tendency to disperse at the two depths with the lowest mean weight diameter (MWD) and highest dispersion ratio (DR). The values ranged from 1.19 to 1.24 mm for MWD and 49.97 to 50.07 % for DR. Forest land showed the lowest tendency to disperse with the lowest dispersion ratio at the two depths which varied from 30.70 to 30.80 %.

At the macro aggregation level, forest land was better than the other land use systems closely followed by oil palm and rubber plantations. Cultivated land had fewer stable aggregates. This observation supported the findings of Celik (2005), who reported that mean weight diameter of soil aggregates was significantly greater in forest land and crop plantations than in cultivated land.

The lower content of organic matter due to the removal of top soil and vegetation may be responsible for the lower aggregate stability under cassava land (Musah, 2013). The lower mean weight diameter observed in cassava land may also be attributed to tillage with traditional implements and clean weeding, together with reduced organic matter (Oguike and Mbagwu, 2009). Cultivation breaks up soil aggregates and exposes previously inaccessible organic matter to microbial attack and accelerates decomposition and mineralization of organic matter (Shepherd *et al*., 2001; Musah, 2013). The higher value of mean weight diameter observed under forest land may be attributed to the high organic matter contents of the soils (Table 5). This can be associated with increase in the percentage of binding materials (polysaccharides, humic and humin) available in the organic materials enabling soil particles to aggregate with each other (Eneje and Lemoha, 2012; Turgut and Kose, 2015).

Table 3: Aggregate stability of soils studied

Land use	MWD (mm)	DR (%)
	0 – 20 cm	
Rubber plantation	2.02	40.27
Oil palm plantation	1.87	40.48
Forest land	2.20	30.70
Cassava land	1.24	49.97
Pasture land	2.03	40.97
Mean	1.87	40.48
	20 – 40 cm	
Rubber plantation	1.80	40.37
Oil palm plantation	1.78	39.90
Forest land	2.20	30.80
Cassava land	1.19	50.07
Pasture land	1.92	41.07
Mean	1.78	39.90
$LSD_{0.05}$		
Land use	0.09	0.12
Depth	0.06	0.16
Land use × depth	0.05	0.11

pH and available phosphorus of the soil

The pH and available phosphorus of the soils varied significantly with the land use systems (Table 4). The pH of the soils ranged from 5.00 (strongly acidic) to 6.30 (moderately acidic) across the different land use systems and depths. At the depths of 0 – 20 and 20 – 40 cm, forest land was observed to have the highest soil pH with values 6.30 and 6.00, respectively. The rubber plantation was observed to have the lowest pH at 0 – 20 and 20 – 40 cm depth with values 5.40 and 5.00. Under available phosphorus, forest land recorded the highest at the two depths (Table 4) with values 5.40 and 2.62 mg kg^{-1}, respectively, while cassava land was observed to have the lowest available phosphorus at the two depths (1.61 and 1.52 mg kg^{-1}).

Interestingly, forest land had a moderate acidic reaction whereas other land uses had a strongly acidic soil reaction (Brady and Weil, 2002). As shown in Table and referring to depth, the means indicated significant ($p \leq 0.05$) decrease in pH and available phosphorus.

Acidic condition of the soils could be attributed to the high annual rainfall condition and resultant of the soil profiles in the study area, (Eshett *et al*., 1990; Ahukaemere *et al*., 2014). Ahukaemere *et al*., (2014) also reported increased acidification of soils due to greater oxidation of anions like sulphides and nitrites.

The decrease in pH with increase in soil depth may be as a result of larger organic matter content observed at the top soils which helped to bind tightly with aluminium ions and reduce their activity in the soil solution, which thereby raised soil pH and reduced acidity (Nega and Heluf, 2013). The decrease of soil pH with depth might also be attributed to the increase in clay contents with depth which have the tendency to furnish hydrogen ions from clay colloidal surface to the solution thereby reducing soil pH. The moderately acidic nature of the soil under forest land could be attributed to the high exchangeable bases as a result of the presence of wastes, litter fall and roots (Alemayehu and Sheleme, 2013).

The lower Available phosphorus (Av. P) content in the cassava land might be related to phosphorus fixation (Yimer *et al.,* 2006). The overall available phosphorus was higher in the top than in the lower soil layer. According to

(Landon, 1991) rating, Av. P across all land uses were low. The Av.P deficiency in soils of the study area maybe due to the inherent low-P status of the parent material and erosion loss

Table 4: pH and available phosphorus of soils studied

Land use		pH	Av. P (mg kg^{-1})
	0 – 20 cm		
Rubber plantation		5.40	4.51
Oil palm plantation		5.90	4.07
Forest land		6.30	5.40
Cassava land		5.70	1.61
Pasture land		5.90	4.76
Mean		5.83	4.07
	20 – 40 cm		
Rubber plantation		5.00	2.50
Oil palm plantation		5.53	2.34
Forest land		6.00	2.62
Cassava land		5.50	1.52
Pasture land		5.60	2.71
Mean		5.53	2.34
$LSD_{0.05}$			
Land use		0.03	0.07
Depth		0.07	0.15
Land use × depth		0.10	0.18

3.4. Total nitrogen and organic matter

Table 5 shows the total nitrogen and organic matter content of soils under the different land use types and depths. The Table showed that at the depths of 0 – 20 and 20 – 40 cm, forest land recorded the highest total nitrogen (0.18 and 0.16 g kg^{-1}, respectively) while cassava land recorded the lowest total nitrogen (0.08 and 0.06 g kg^{-1}, respectively). Similarly, the highest (20.00 and 14.90 g kg^{-1}) organic matter was observed in forest land at the depths of 0 – 20 and 20 – 40 cm, respectively. Cassava land recorded the lowest (13.50 and 12.10 g kg^{-1}) at the depths, respectively. As shown in Table 4.5 and referring to depth, the means indicated significant ($p \leq 0.05$) decrease in total nitrogen and organic matter.

The relatively higher total nitrogen in the forest land than in other land uses could be associated with the relatively higher organic matter which in turn resulted from plant and root biomass as well as residues being returned to the soil system. According to (Landon, 1991) ratings, the total nitrogen content in soil of the study area was found to be generally low. The principal cause for lower contents of total nitrogen comes from biomass removal during crop harvest and insufficient replenishment through manure or fertilizers

Organic matter content of the study area was in the range of 12.10 to 20.00 g kg^{-1} which was rated low to high according to (Enwezor *et al*., 1989). Organic matter was also found to decrease with depth, this could be attributed to the fact that organic residues are incorporated or deposited on the soil surface which makes organic matter to be generally reduced at lower depth Ahukaemere *et al*., (2014). The lower organic matter observed in cassava land may be attributed to the effects of continuous cultivation that aggravated organic matter oxidation (Alemayehu and Sheleme, 2013; Wakene, 2011; Malo *et al*., 2003). The higher organic cxxmatter under oil palm plantation and forest land may be attributed to the continuous input and decomposition of litter falls and roots (Kleber *et al*., 2011; Wu *et al*., 2011). This was in agreement with findings of Urisotle *et al*. (2006) who found out that the roots of grasses and trees and the fungi hyphae under oil palm plantation and forest land, probably were responsible for the high organic matter.

Table 5: Total nitrogen and organic matter content of soils studied

Land use	Total nitrogen (g kg^{-1})	Organic matter (g kg^{-1})
	0 – 20 cm	
Rubber plantation	0.14	15.30
Oil palm plantation	0.14	15.70
Forest land	0.18	20.00
Cassava land	0.08	13.50
Pasture land	0.17	16.00
Mean	0.14	15.70
	20 – 40 cm	
Rubber plantation	0.09	13.90
Oil palm plantation	0.11	13.93
Forest land	0.16	14.90
Cassava land	0.06	12.10
Pasture land	0.14	14.80
Mean	0.11	13.93
$LSD_{0.05}$		
Land use	0.01	0.13
Depth	0.03	0.11
Land use × depth	0.06	0.18

3.5. Exchange capacity of the soil

3.5.1. Exchangeable calcium

The exchangeable calcium content of soils varied significantly with the land use types and with depth (Table 6). Exchangeable Ca was rated low to high as its values across the depth and land use systems ranged from 1.88 to 5.15 cmol kg^{-1}. Data presented in Table 4.6 revealed that the calcium content was significantly affected by different land use types. The highest calcium content (5.15 and 3.21 cmol kg^{-1}) at 0 – 20 and 20 – 40 cm, respectively were observed under forest land use. However, the lowest was found under cassava land (2.00 and 1.88 cmol kg^{-1}) in surface and sub-surface soils. Higher exchangeable calcium content in the forest soils may be due to addition of leaf litter and plant residue in the forest land. Patil and Prasad (2004), also observed higher exchangeable Ca^{2+} in the forest soils of lower Shiwalik hills in Himachal Pradesh. The highest exchangeable Ca (5.15 cmol kg^{-1}) was observed on the surface layer of forest land where as lowest (2.00 cmol kg^{-1}) on the surface layer of cassava land. This may be attributed to high organic matter and relatively high pH on the surface layer of forest land and its leaching from the surface layer of cassava land soil. Gebeyaw (2007) reported that cultivation led to reduction and leaching of exchangeable cations, especially in acidic tropical soils. The higher exchangeable calcium observed in forest land, oil and rubber plantation might be due to its source from organic matter and it is one of the most abundant basic cations surrounding the colloidal soil surface (Gebreyohannes, 2001). According to the ratings recommended by FAO (Xueli *et al.,* 2012), the soil is ranged low in cultivated land to high in forest land, oil and rubber plantation in their exchangeable Ca content (Table 6).

3.5.2. Exchangeable Magnesium

The concentration of exchangeable Mg^{2+} significantly varied with land use systems and soil depth (Table 6). Magnesium was rated low as means were in the range of 1.01 to 2.45 cmol kg^{-1} across the depths and land use systems. Exchangeable magnesium was higher at the two depths in forest land (2.45 and 2.18 cmol kg^{-1}) than in other land uses. The lower exchangeable Mg^{2+} in cassava land was probably due to the removal of vegetation cover as a result of human interference. In the top surface soil layer (Table 4.6), the concentration of exchangeable Mg^{2+} was higher in forest land (2.45 cmol kg^{-1}) than in cassava land (1.19 cmol kg^{-1}). The significantly higher concentration of exchangeable Mg^{2+} in the top than in the lower soil layer was probably due to wastes and litters in the soil, because they are good sources of Ca^{2+},K^{+}, P, and Mg^{2+} (Voundi Nkana *et al.,* 1998) and pumping of bases from the subsoil by the vegetation and returning them into the topsoil (Yimer *et al.,* 2006). A critical concentration of 0.2 cmolkg^{-1} soil is required for tropical soils (Landon, 1991) and this would indicate that exchangeable Mg^{2+} is not a limiting nutrient in the soil of the study area. Concentration of exchangeable Mg^{2+} showed a significant variation with land use systems and soil depth. Generally, the concentration of exchangeable Mg^{2+} was higher (sufficient) than the critical level of 0.5 cmolkg^{-1} soil as suggested by (Landon, 1991); a concentration less than this value would require an application of magnesium limestone accordingly.

3.5.3. Exchangeable Sodium

The exchangeable sodium content of the soils varied significantly with the land use systems and with depth (Table 6). Exchangeable sodium was rated low as its values across the depth and land use systems ranged from 0.18 to 0.75 cmol kg^{-1}. The data in Tables 4.6 depicted that the sodium was significantly affected by different land use systems at the two depths. The highest sodium contents (0.75 and 0.40 cmol kg^{-1}) were observed under forest land use at the depths 0 – 20 and 20 – 40 cm, respectively. The lowest exchangeable sodium was found in cassava land which ranged from 0.18 cmol kg^{-1} at 20 – 40 cm to 0.21 cmol kg^{-1} at 0 – 20 cm depth. In all soils, cation exchange sites are invariably occupied by calcium ions followed by magnesium, potassium and sodium in decreasing order. This is in agreement with jenny's potassium - sodium theory (1933) that the leaching causes preferential loss of monovalent ions and at the same time greater loss of sodium than potassium. Similar results have been reported by Kumar (2005). The concentration of exchangeable Na^{+} was the smallest component in the exchange complexes. This result was in line with (Yimer *et al.,* 2006) that the concentration of Na^{+} was lower in cropland than in the native forest. Since the concentration of exchangeable Na^{+} did not exceed 1 cmol kg^{-1} soil (Landon, 1991), the soil in the study area would not be regarded as sodic soil.

3.5.4. Exchangeable Potassium

The concentration of exchangeable potassium significantly varied with land use systems and soil depth (Table 6). Exchangeable potassium was rated low to medium as the mean values were 0.21 to 0.90, the medium potassium content could be attributed to the acidity of the soil. Table 4.6 depicted that the potassium content was significantly affected by different land use systems at various depths. The highest potassium contents (0.90 and 0.55 cmol kg^{-1}) at 0 – 20 and 20 – 40 cm depths, respectively were found in the forest land use. However, the lowest were found in cassava land (0.34 and 0.21 cmol kg^{-1}) at 0 – 20 and 20 – 40 cm depths, respectively. There was a significant variation in the overall concentration of exchangeable K^{+} with land use types and soil depth. Lemenih *et al.* (2005) also reported that the concentrations of exchangeable K^{+} was lower in soil under the farmlands compared to the adjacent forest. The higher concentration of exchangeable K^{+} in the top surface layer than in the lower soil layer (Table 6) suggests that vegetation pumps bases such as K^{+}, Ca^{2+} and Mg^{2+} from the subsoil to the topsoil (Yimer *et al.,* 2006). According to (Landon, 1991) ratings, the studied soil under different land use systems has low to meduim concentration of exchangeable K^{+} ($\geq$0.6 cmol kg^{-1} soil), and thus, response to K fertilizer is likely.

3.5.6. Effective cation exchange capacity (ECEC)

The effective cation exchange capacity (ECEC) of the soils varied significantly with the land use systems and with depth (Table 6). The ECEC of the soil varied widely as the means were 3.45 to 9.37 cmol kg^{-1} across the depths, however ECEC of the soils ranged from low to medium according to the rating of Esu (1991) CEC <6 low, 6-12 medium and > 12 high.

The effective cation exchange capacity (ECEC) was significantly affected by different land use systems at different depths (Tables 6). The highest effective cation exchange capacity (9.37 and 6.52 cmol kg^{-1}) was observed under forest land use at the depths 0 – 20 and 20 – 40 cm, respectively. The lowest effective cation exchange capacity was found in cassava land which ranged from 3.45 cmol kg^{-1} at 20 – 40 cm to 3.86 cmol kg^{-1} at 0 – 20 cm depth. This may be due to comparatively higher organic matter contents coupled with higher clay in forest land. The results are in agreement with the findings of Billet *et al.* (1990) and Pandey *et al.* (2019). Decrease in ECEC reflects the textural and organic matter changes in deforestation (Khormali *et al.,* 2009). The decrease in soil erosion and nutrient loss through runoff may have helped to increase in organic matter and clay content in forest land and rubber plantation. Effective cation exchange capacity showed significant variation across all land use systems and soil depth. According to (Landon, 1991) ratings, the concentration of ECEC was found to be low in cassava land, indicating the low fertility status of the soil under the cassava land use system (Foth, 1990). The soil fertility levels under rubber plantation, oil palm plantation and forest land was medium due to the relatively higher content of organic matter.

Table 6: Exchange capacity of soils studied

Land use	Ex. Ca	Ex. Mg	Ex. Na	Ex. K	ECEC
	←	(Cmol kg^{-1})	←		
		0 – 20 cm			
Rubber plantation	4.06	1.19	0.46	0.72	6.60
Oil plantation	4.02	1.70	0.51	0.69	7.05
Forest land	5.15	2.45	0.75	0.90	9.37
Cassava land	2.00	1.19	0.21	0.34	3.86
Pasture land	4.88	1.96	0.62	0.79	8.36
Mean	4.02	1.70	0.51	0.69	7.05
		20 – 40 cm			
Rubber plantation	2.00	1.03	0.33	0.41	4.12
Oil plantation	2.50	1.38	0.33	0.42	4.87
Forest land	3.21	2.18	0.40	0.55	6.52
Cassava land	1.88	1.01	0.18	0.21	3.45
Pasture land	2.90	1.30	0.39	0.50	5.38
Mean	2.50	1.38	0.33	0.42	4.87
$LSD_{0.05}$					
Land use	0.11	0.02	0.01	0.08	0.81
Depth	0.15	0.06	0.09	0.02	1.21
Land use × depth	0.02	0.10	0.12	0.11	1.03

4.0. Summary and Conclusion

Land use system had significant impacts on soil physical and chemical properties in the study area. The textural class of the soil under study was sandy loam except in rubber plantation which was clay loam. The textural classes of the soils under the land use types studied were sandy loam except in rubber plantation which was clay loam. Forest land recorded the lowest bulk density values (1.32 Mg/m^3 and 1.49 Mg/m^3) at 0-20 and 20-40 cm depths respectively. With regards to porosity, forest land also had the highest total porosity at the two depths and highest hydraulic conductivity. Generally, the bulk density of the soils increased with depth, whereas total porosity and the saturated hydraulic conductivity decreased with depth. Forest land was observed to have higher exchangeable bases, organic matter, total nitrogen and available phosphorus. Cassava land was found to be low in organic matter, total N, ECEC and exchangeable bases especially on the surface layer. In comparison with other land use types studied, the cassava land was poorer in soil nutrients with lower pH which has become limiting for crop production. The pH of the soils ranged from strongly acidic to moderately acidic. Soil organic matter and total nitrogen contents of the rubber plantation showed slightly lower than oil pam plantation. Generally, the available P contents of the soils of the study area rated as very low. Among exchangeable bases (Ca, Mg, K and Na), the exchange complex of the soils was predominantly occupied by divalent basic cations (exchangeable Ca followed by exchangeable Mg). The exchangeable Ca and Mg were highest at forest land. The magnitudes of exchangeable Ca and Mg in land use systems were rated as low to medium for both Ca and Mg. The exchangeable K was found to range from low to medium in soils of the land use systems. Therefore, exchangeable K content is inadequate for the production of most crops and K deficiency would be expected in the soil of study area at the moment. On the other hand, the exchangeable Na was also found to be low in the land use systems which is beneficial for the growth of most crops in the study area.

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