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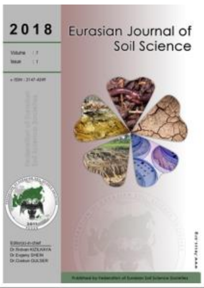

Soil physico-chemical properties and fertility status of long-term land use and cover changes: A case study in Forest vegetative zone of Nigeria

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Abstract

Proper utilization of land is essential to soil quality maintenance and sustainable agricultural development. This study was conducted to evaluate effects of land use management on physico-chemical characteristics of soils in Ekiti State, Southwestern Nigeria. In this study, a total of 105 sampling points in 35 locations comprising of the 3 land uses were sampled. Random sampling pattern of 3 sampling points per location were carried out and undisturbed soil samples were collected at depths up to 30 cm. Soil physical properties (bulk density (BD), water holding capacity (WHC), and particle size distribution) and chemical properties (organic matter content (SOM), cation exchange capacity (CEC), phosphorus (P) and organic nitrogen (SON)), were determined and evaluated. Results showed that natural forest on the overall accumulated more nutrients than plantations and cropland. The highest SOM value of 4.07 % was recorded in the natural forests, while the lowest value of 1.52 % was found in the croplands. Organic matter accumulation showed a decreasing trend in the order: forest > plantation > cropland. Natural forest soils had significantly higher volumetric moisture content (VMC) than plantations and croplands. Correlation analysis of the 11 physico-chemical properties for the study area, showed a significant correlation among 70 of the 190 soil attribute pairs. Land use system reveals a significant decline of soil quality under cropland. Management systems by which soil could be improved towards the development of suitable agricultural management systems must be incorporated during land cultivation. In order to have sustainable land use systems, land use development must not be only economically sustainable but also socially acceptable and environmentally sound. Therefore, strategies to improve agricultural productivity have to seek a sustainable solution that better addresses soil fertility management.

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Introduction

The rapidly increasing human populations and their needs/uses of the land for various agricultural activities have brought about extensive land use changes and soil management practices throughout the world (Cunningham et al., 2005). In the forest vegetative zone of Nigeria, the conversion of natural forests into low input agricultural systems and subsequent deforestation have tremendous impacts on physical and chemical properties of the soils which are of key importance to land management and sustainability. Over the years, soil biodiversity and its physical properties that control water movement and retention in the soils are

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largely affected due to human, animal activities as well as use of machine for soil tillage purposes (Tilahun, 2007). The ability of a soil to generate some products or perform some functions may decline with certain land uses. These manifests as changes in soil properties such as nutrient content (nitrogen, phosphorus, potassium, calcium, magnesium, sodium), pH, organic matter, cation exchange capacity, structure etc (Akinrinde and Obigbesan, 2000; Akamigbo and Asadu, 2001). It has been observed that as the fertility of soil declines, soil structure weakens and the soil becomes susceptible to erosion (Adetunji, 2004). The decline in soil fertility, therefore, has been caused by the increased withdrawal of plant nutrients from the soil without replenishment consequent to increased plant growth.

Soil fertility decline and hence reduced soil productivity is a subject of major concern in Africa as it contributes to hunger (famine), food insecurity and farm or household incomes (Nandwa, 2003). Agricultural sustainability requires periodic evaluation of soil fertility status. This is important in understanding factors which impose serious constraints to increased crop production under different land use types and for adoption of suitable land management practices (Chimdi et al., 2012). However, information about the effects of land use changes on soil physico-chemical properties is essential in order to present appropriate recommendations for optimal and sustainable utilizations of land resources.

Global land use and soil management play a central role in determining our food, material and energy supply because land is a finite resource. The effects of land uses on the environment ranges from minor land cover changes and soil modification to severe desertification, deforestation, erosion, and river encroachment problems. Therefore, there is increasing concern about the land use land cover changes and its negative impacts on soil quality and the environment in many part of the world due to the current global population growth and economic development. In order to have sustainable land use systems, land use development must not be only economically sustainable but also socially acceptable and environmentally sound. Therefore, strategies to improve agricultural productivity have to seek a sustainable solution that better addresses soil fertility management.

Soil physical and chemical properties play a central role in transport and reaction of water, solutes and gases in soils, their knowledge is very important in understanding soil behaviour to applied stresses, transport phenomena in soils, hence for soil conservation and planning of appropriate agricultural practices. The anthropogenic changes in land use have altered the characteristics of the Earth's surface, leading to changes in soil physico-chemical properties such as soil fertility, soil erosion sensitivity and content of soil moisture (Abad et al., 2014). These changes may be caused by soil compaction that reduces soil volume and consequently lowers soil productivity and environmental quality (Abad et al., 2014). Soil physical and chemical properties have been proposed as suitable indicators for assessing the effect of land-use changes and management (Janzen et al., 1992; Alvarez and Alvarez, 2000). This approach has been used extensively by several authors to monitor land-cover and land-use change patterns (Schroth et al., 2002; Walker and Desanker, 2004; Yao et al., 2010). Therefore, this study was carried out to in order to evaluate the influence of different land use types on soil physicochemical properties in soils of Southwestern Nigeria.

Material and Methods

Experimental Site and Procedure

Experimental Site

The study was conducted in Ekiti State in the forest vegetative zone of Nigeria. Ekiti State is located between Latitudes 7° 15' to 8° 5' N and Longitude 4° 45' to 5° 45' E (EKSG, 2009). The State is mainly an upland zone with elevation ranging from 250 to 540 m above sea level (a.s.l.) (Simon-Oke and Jegede, 2012). The State lies on an area underlain by metamorphic rock and is potentially rich in mineral deposits which include kaolin, columbite, channockete, iron ore, barite, aquamine, gemstone, phosphate, limestone, gold among others largely deposited in different towns and villages within the State (Olorunfemi and Fasinmirin, 2017). The climate of the State is a tropical climate with two distinct seasons (rainy season (April – October) and dry season (November – March)). The air temperature ranges between 21° and 28° with high humidity. Ekiti State has a total annual rainfall of about 1400 mm with a low co-efficient of variation about 30% during the peak of rainfall, and an average of about 112 rainy days per annum (Adebayo, 1993). The vegetation of Ekiti State is of the guinea forest with its attendant climate, flora and fauna (EKSG, 2009).

Experimental Procedure

Soil samplings were conducted across 35 different locations under three different land uses in Ekiti State (Figure 1) to determine their physiochemical properties. The different land uses (treatments) in the study area include intensive row crops under minor grazing, agricultural tree crop plantations *(Tectona grandis*, *Gmelina arborea*, *Elaeis guineensis, Musa acuminata)*, and forests (dominantly trees/woodlands/shrubs, disturbed and undisturbed forests). The croplands have been put under manual tillage (using Cutlass and Hoe) for cassava and yam cultivation sometimes intercropped with maize for more than 15 consecutive years according to the farmers. *Tectona grandis* plantations were established since the past 25 to 29 years while *Musa acuminata* has been under cultivation for over 10 years. *Elaeis guineensis* plantations are about 23 years old. The forest soils are uncultivated and comprise of shrubs, woodlands and deciduous trees under the protection of the state forest reserve agency. The land uses studied were categorized under three (3) main treatments, which include croplands (CP), plantation agriculture (PA) and natural forests (NF).

The three land uses represent the treatment with different numbers of replicates (locations) as stated. In all the 35 locations, 17 croplands, 11 plantation agricultural sites and 7 natural forests were examined. Three sampling points were randomly selected per location for each land use treatment for detailed infiltration measurements and soil sampling. For the determination of soil moisture content, bulk density, total porosity, macro and micro porosity, three (3) sampling points were randomly selected per location and three (3) undisturbed samples were collected at each sampling point. Soil samples collected were packed in plastic bags, and transferred to the laboratory for physiochemical analysis.

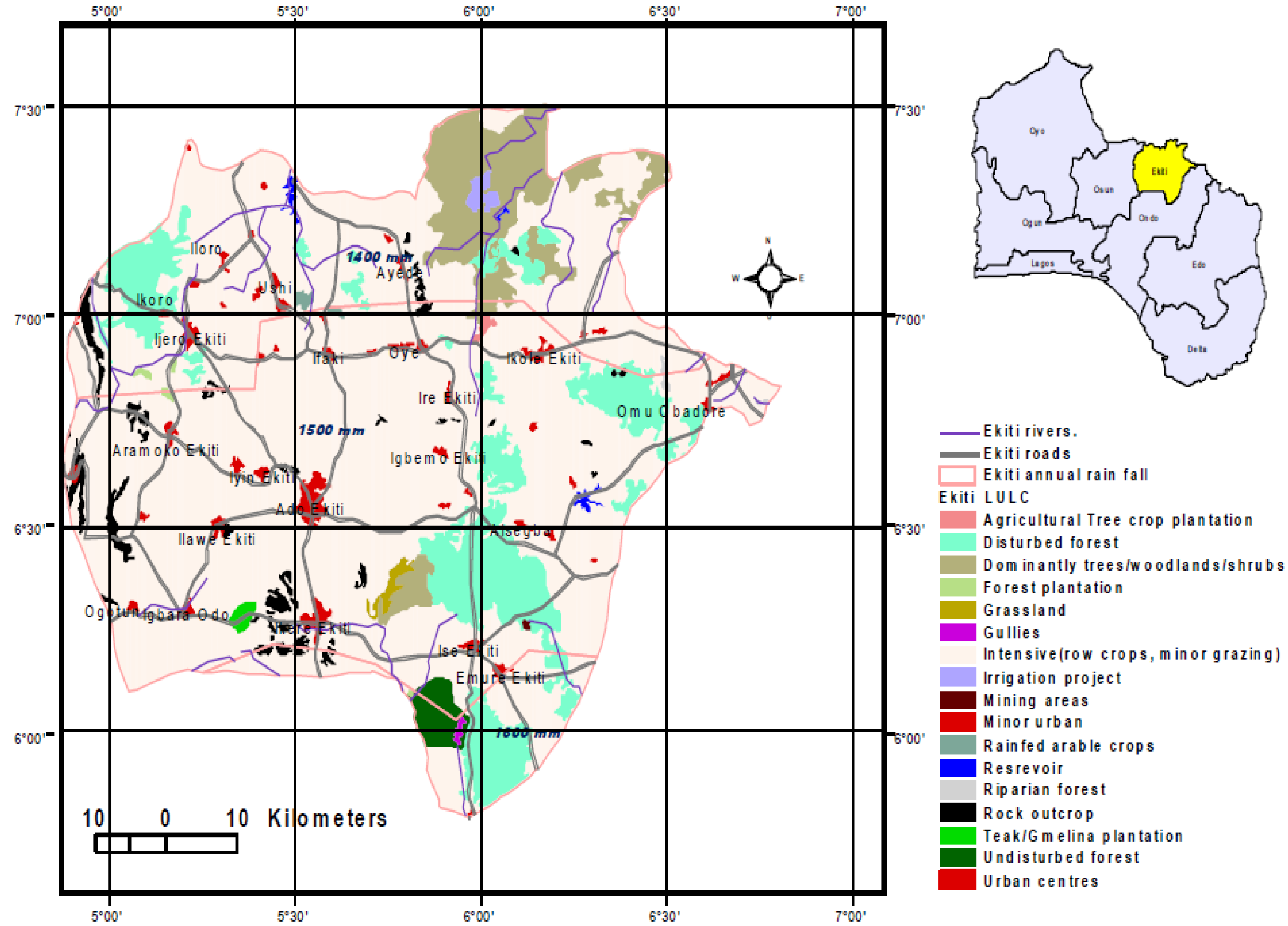

Figure 1. Land use and land cover map of Ekiti State (Source: EKSG, 2009).

Measurements

Physico-chemical characterization of soils

Chemical characterization of the sampled soils included the analysis of organic matter (SOM), organic carbon (SOC), cation exchange capacity (CEC) at pH 7.0, base saturation, Al^{3+} saturation and soil pH; whereas the physical characterization consists of particle size analysis, water holding capacity (WHC), bulk density (BD) and total porosity (PT) determination. The samples were allowed to dry in the open air until reaching friability. The organic carbon was determined using the Walkley - Black wet oxidation procedure and the soil organic matter content was determined from the organic carbon (Nelson and Sommers, 1996). Soil pH was determined in distilled water using the pH meter with water ratio of 1:2. Available phosphorus (P) and exchangeable cations were determined. Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al., 1998). The exchangeable potassium (K^+) and sodium (Na^+) was extracted with HCl solution and their levels determined by flame photometry (Vogelmann et al., 2010; Olorunfemi et al., 2016) and exchangeable magnesium (Mg^{2+}) and calcium (Ca^{2+}) determined by atomic absorption spectrophotometer after extraction with KCl 1.0 mol l^{-1} (Senjobi and Ogunkunle, 2010). The cation exchange capacity (CEC) at pH 7.0 was determined following the procedure described by Reeuwijk (2002). Soil particle sizes were determined using the hydrometer method described in Agbede and Ojeniyi (2009) and classification was carried out using the USDA classification system (Soil Survey Staff, 1999). Soil water holding capacity (WHC) was determined following the method described by Ibitoye (2006). The bulk density (BD) was obtained by the gravimetric soil core method described by (Blake and Hartage, 1986) and the particle density (PD) was assumed to be 2.65 g cm^{-3} (Osunbitan et al., 2005; Li and Shao, 2006; Zhang et al., 2006; Price et al., 2010). The total porosity (PT) was obtained from BD and PD using the equation and relationship developed by Danielson and Sutherland (1986).

$$PT = 1 - \frac{BD}{PD} \quad (1)$$

where: BD = Bulk density and PD = Particle density (= 2.65 Mg/m^3). The default value of 2.65 Mg/m^3 is used as a 'rule of thumb' based on the average bulk density of rock with no pore space (Fasinmirin and Olorunfemi, 2013). Micro porosity (*Mic*) and macro porosity (*Mac*) were obtained following the method described by Olorunfemi and Fasinmirin (2017).

Ca^{2+}, Mg^{2+}, Na^+ ions were isolated from the soil complex with flame photometer to estimate SAR and ESP using following equations.

$$SAR = \frac{Na}{\sqrt{\frac{1}{2} \times (Ca + Mg)}} \quad (2)$$

$$ESP = \frac{exchangeable\ Na^+}{CEC} \times 100 \quad (3)$$

where SAR is sodium absorption ratio and ESP is exchangeable sodium percentage.

Statistical Analysis

Each soil property was compared using Pearson correlation coefficient at 1 and 5% significant levels and the existence of inter-relationships between data set was tested by linear correlation. Soil properties were subjected to statistical analysis to determine the mean, standard deviation, coefficient of variation, and linear and nonlinear regressions using Statistical Analysis System (SAS) (SAS Institute Inc., Cary, NC) and MINITAB 17. Soil properties were subjected to the Tukey test at 5% level of significance. One way Anova was used to test for significance among the treatments and post hoc comparison was used to compare the soil physical and chemical properties from the different land uses.

Results and Discussion

Soil physical properties

Soil particle size analysis

The particle size distribution of the different land uses is shown in Table 1. The sand, silt, and clay percentages of the soil samples from the croplands sites at an average of 0 – 30 cm soil depth ranged from 240 g kg^{-1} to 540 g kg^{-1}, 120 g kg^{-1} to 320 g kg^{-1}, and 220 g kg^{-1} to 500 g kg^{-1} respectively, while soil samples from the plantation agriculture sites ranged from 300 g kg^{-1} to 640 g kg^{-1}, 400 g kg^{-1} to 280 g kg^{-1} and 220 g kg^{-1} to 560 g kg^{-1} for sand, silt, and clay, respectively. Similarly, the soil samples collected from the natural forests ranged from 240 g kg^{-1} to 540 g kg^{-1}, 100 g kg^{-1} to 300 g kg^{-1} and 200 g kg^{-1} to 500 g kg^{-1} for sand, silt, and clay respectively. Sampled soils did not show significant differences in the sand, silt, and clay percentages among CP, PA, and NF soils at 0.05 level. However, there were little variations in the particle size composition of the sampled soil of the different land uses. Numerically, croplands have the highest average sand contents (438.82 g kg^{-1}) and the least average clay content (328.24 g kg^{-1}) respectively. Despite the fact that texture is an inherent soil property, management practices may have 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 tillage activities (Tilahun, 2007). It can also be stated that the effect of soil tillage on soil particle size by Gülser et al. (2016) reported that heterogeneity and variation of soil physical parameters in a field due to soil plowing should be taken into consideration for a successful agricultural management. Therefore, differences in particle size distribution, which can be attributed to the impact of deforestation and farming practices such as continuous tillage or cultivation and intensive grazing, can be observed, though not significant ($p \le 0.05$) (Tilahun, 2007).

Table 1. Summary statistics for surface soil parameters under different land uses

Land uses	Croplands	Plantations	Forests
Statistics	Mean ± STD (CV)	Mean ± STD (CV)	Mean ± STD (CV)
Sand (g kg^{-1})	438.82 ± 82.61(0.19)a	471.67 ± 101.79 (0.22)a	417.14 ± 124.05 (0.30)a
Silt (g kg^{-1})	232.94 ± 47.93 (0.21)a	185.00 ± 67. 76 (0.37)a	217.14 ± 68.73 (0.32)a
Clay (g kg^{-1})	328.24 ± 81.26 (0.25)a	343.33 ± 102.99 (0.19)a	365.71 ± 115.31 (0.32)a
Silt/Clay	0.76 ± 0.26 (0.34)a	0.61 ± 0.31(0.52)a	0.68 ± 0.39 (0.58)a
WHC (%)	43.14 ± 7.52 (0.17)b	42.93 ± 5.08(0.12)b	53.66 ± 10.56 (0.20)a

Means in a row that do not share 'a' letter are significantly different. Where STD = standard deviation and CV = coefficient of variation

Water holding capacity (WHC)

The WHC of all soil sites ranged widely from 29.27 to 71.83 % with an average value of 44.50 %. The average WHC value was found to be significantly affected by land uses [$F(2, 32) = 5.83$, $p \le 0.01$] (Table 2). Post hoc comparisons of means showed that average WHC value of NF sites is significantly higher than that of PA and CP which are homogenous. The statistics of WHC of the different land uses show that NF has maximum WHC value of 71.83 % and minimum value of 43.38 % with an average of 53.66 % (± 10.56). The WHC of the PA ranged from 51.94 % to 34.86 % with an average value of 42.52 % (± 4.70) while that of CP has ranged from 64.49 % to 29.27 % with an average value of 43.07 % (± 7.76).

Table 2. Analysis of variance of the surface soil properties between land uses

Properties	Mean Square		F - Value	Significance
	Trt (Land use type)	Error		
Sand (g kg^{-1})	7833	9825	0.8	ns
Silt (g kg^{-1})	8779	3571	2.46	ns
Clay (g kg^{-1})	3558	9440	0.38	ns
Silt/Clay	0.08854	0.09627	0.92	ns
WHC (%)	330.35	56.64	5.83	**

*** = $P \le 0.001$; ** = $P \le 0.01$; * = $P \le 0.05$ ns = not significant, Trt – treatment

The highest WHC value (71.83 %) was recorded in NF soil which also has the highest organic matter content (4.07 %), while the lowest (29.27 %) occurred in CP with organic matter content of 1.55 %, which was among the least recorded. Correlation between WHC and OMC (r = 0.58, N = 35, $p \le 0.01$) showed a significant positive relationship. This was probably due to the ability of SOM to act as a sponge in the soil, thereby retaining soil moisture. Organic matter intimately mixed with mineral soil materials has a considerable influence in increasing moisture holding capacity (FAO, 2005). Soil organic matter is able to store a quantity of water which corresponds to a multiple of the organic matter's weight (Hudson, 1994; Emerson, 1995).

It is also noteworthy that soil texture also influences the water retention capabilities of soils of the different locations as soils with high clay percentage or both (high clay percentage and organic matter content) tends to have high water holding capacity. The results of the correlation analysis between WHC (%) and Clay percentage in all the 35 sites revealed a significant and positive relationship (r = 0.54, N = 35, $p \le 0$ .01). Water holding capacity of any soil is determined by its texture, structure, and the amount of organic matter it contains. Olorunfemi and Fasinmirin (2017) from their findings reported that soils having high proportion of sands are associated with low WHC. Water holding capacity depends upon the capillary pore spaces in the soil. Soil with very high proportion of sand have very low water holding capacity due to large pore spaces between the particles which enables the water to percolate freely into deeper layers leaving upper layers practically dry. In clay soil, due to very small size of the pore spaces (fine capillaries) the water is retained in the capillary spaces as capillary water and therefore the water does not percolate freely. The result shows that if clay and organic matter contents increase, water holding capacity of the soil also increases (FAO, 2005). This observation is similar to the findings of Senjobi and Ogunkunle (2011) who state that the water holding capacity of the soils increases with increase in clay content of the soils in their study to assess the extent to which different land use types influences land degradation and productivity in Ogun State, Nigeria. Knowing the soil water storage capacity allows the irrigator to determine how much water to apply at one time and how long to wait between each irrigation schedule. The soil texture and the crop rooting depth affect the total amount of water that is stored in the soil within the plant's root zone.

Bulk density

The bulk density (BD) of soils in all project sites ranged from 1.15 Mg m^{-3} to 1.41 Mg m^{-3} with a mean value of 1.29 Mg m^{-3} (± 0.08) in the superficial layer (0 – 10 cm), 1.24 Mg m^{-3} to 1.5 Mg m^{-3} with a mean value of 1.34 Mg m^{-3} (± 0.06) in the 10 – 20 cm depth, and from 1.29 Mg m^{-3} to 1.54 Mg m^{-3} having an average value of 1.43 Mg m^{-3} in the 20 – 30 cm depth (Table 3). One – way ANOVA demonstrated that bulk density differed significantly among the soil depths ($F(2, 102) = 42.06$, $p \leq .05$). The mean bulk density was significantly lower in the 0 – 10 cm depth than in the 10 – 20 cm depth, and the BD of the 10 – 20 cm depth was equally significantly lower than that of the 20 – 30 cm soil depth. In all the sites of the different land uses, bulk density showed an increasing trend down the depths (0–10 cm, 10–20 cm and 20–30 cm) respectively. Bulk density typically increases with depth because of changes in soil texture, gravel content, and structure (Landsberg et al., 2003), but also because of biological activity on surface soils with high organic matter content and vegetation residues which decreases down the soil profile (Doerr et al., 2000). Reduced aggregation, root penetration and less pore space of the subsurface layers compared to surface layers equally lead to increase bulk density down the soil layers (USDA, 2008). This is also expected because of the overburden weight of soil above the subsurface layers (Sands et al., 1979). This is consistent with the findings of Price et al. (2010) who discovered that the mean bulk density of the upper layers was significantly ($p < 0.001$) lower than the lower layers in their study to characterize soil physical properties under three land-use classes (forest, pasture, and managed lawn) in the southern Blue Ridge Mountains of southwestern North Carolina. In all the sites, the bulk density showed a regular increase with depth (i.e. higher bulk density at the lower soil layers) (Table 3), except at four (4) locations whose bulk density decreased slightly in the 10 - 20 cm soil layer, though the general trend of increase in bulk density was observed in others layers. This is in agreement with the work of Siltecho et al. (2010), who obtained similar findings of regular increase in bulk density down the soil profiles under a young rubber tree plantation and a ruzi grass but observed a slight decrease in bulk density under natural forest.

Table 3. Summary of statistics for segmented soil physical parameters under different land uses

Parameters	Land uses	Croplands	Plantations	Forests
/Statistics	Depths (cm)	Mean ± STD (CV)	Mean ± STD (CV)	Mean ± STD (CV)
BD (Mg m^{-3})	0 – 10	1.30 ± 0.07 (0.06)a	1.29 ± 0.09 (0.07)a	1.27 ± 0.06 (0.05)a
	10 – 20	1.34 ± 0.05 (0.04)a	1.36 ± 0.07 (0.05)a	1.29 ± 0.06 (0.05)a
	20 – 30	1.43 ± 0.05 (0.04)a	1.43 ± 0.05 (0.04)a	1.41 ± 0.06 (0.04)a
PT (m^3 m^{-3})	0 – 10	0.51 ± 0.03 (0.05)a	0.51 ± 0.03 (0.07)a	0.52 ± 0.02 (0.04)a
	10 – 20	0.49 ± 0.02 (0.04)ab	0.48 ± 0.02 (0.05)b	0.51 ± 0.02 (0.05)a
	20 – 30	0.45 ± 0.02 (0.03)a	0.46 ± 0.02 (0.04)a	0.47 ± 0.02 (0.05)a
Mic (m^3 m^{-3})	0 – 10	0.10 ± 0.02 (0.14)a	0.10 ± 0.01 (0.10)a	0.13 ± 0.02 (0.16)b
	10 – 20	0.12 ± 0.02 (0.13)a	0.11 ± 0.01 (0.09)a	0.15 ± 0.03 (0.17)b
	20 – 30	0.13 ± 0.02 (0.14)a	0.12 ± 0.01 (0.06)a	0.17 ± 0.03 (0.17)b
Mac (m^3 m^{-3})	0 – 10	0.41 ± 0.03 (0.08)a	0.42 ± 0.04 (0.09)a	0.39 ± 0.03 (0.08)a
	10 – 20	0.37 ± 0.03 (0.08)a	0.37 ± 0.03 (0.08)a	0.36 ± 0.04 (0.10)a
	20 – 30	0.32 ± 0.03 (0.08)ab	0.34 ± 0.03 (0.08)a	0.30 ± 0.04 (0.12)b
VMC (m^3 m^{-3})	0 – 10	5.85 ± 2.51 (0.43)a	5.12 ± 1.70 (0.33)a	9.80 ± 4.09 (0.35)b
	10 – 20	8.66 ± 2.85 (0.33)a	7.27 ± 1.86 (0.26)a	12.85 ± 3.11 (0.32)b
	20 – 30	11.50 ± 3.42 (0.30)a	9.30 ± 0.87 (0.15)a	17.18 ± 4.50 (0.29)b

Means in a row that do not share 'a' letter are significantly different. Where BD = Bulk Density, PT = Total Porosity, Mic = Micro Porosity, Mac = Macro Porosity and VMC = Volumetric Moisture Content

There was no significant difference ($p \leq 0.05$) in the bulk density distribution down the depths among the various land uses. It is noteworthy that bulk density is primarily affected by soil texture (Canarache, 1991) since well graded soils containing both fine and coarse particles results in a higher number of contact points than in a poorly graded soil (Kohnke and Franzmeier, 1995) but in the case where the sites are subjected to different land uses, the bulk density cannot be restrictive as observed in the study sites. This observation agrees with that of Vogelmann et al. (2010).

Soil porosities

Table 3 showed the variation of the total porosity, microporosity and macroporosity with depth at the various experimental sites. The total porosity varies from 0.47 $m^3 m^{-3}$ to 0.57 $m^3 m^{-3}$ with a mean value of 0.51 $m^3 m^{-3}$, standard deviation of 0.03 and coefficient of variation of 6 % in all the locations (Table 4). The estimated total porosity is inversely related to the bulk density. This observation agrees with the works of Olorunfemi and Fasinmirin (2012) and Vogelmann et al. (2010). The microporosity values ranged from 0.02 $m^3 m^{-3}$ to 0.17 $m^3 m^{-3}$ having a mean value of 0.06. The standard deviation of the surface horizon (0 – 10 cm) for the microporosity is 0.04 with coefficient of variation of 61 %. Likewise, the sites' macropores ranged from 0.31 $m^3 m^{-3}$ to 0.52 $cm^3 cm^{-3}$ having a mean value of 0.46 $m^3 m^{-3}$, standard deviation of 5 % and a low coefficient of variation of about 12 %. %). The total porosity, microporosity and macroporosity data down the soil depths differ significantly among the three soil layers. The total porosity and macroporosity decreases down the depth while the microporosity increases down the soil depth because of changes in soil texture, gravel content, and structure, and also because of reduced effect of soil tillage operations. Soil macro and microporosity have been used in important studies on soil aeration, soil water dynamics and soil compaction (Scardua, 1972; Freire, 1975; Primavesi et al., 1984).

Table 4. Analysis of variance of the segmented soil physical properties between land uses

Properties	Depths	Mean Square		F - Value	Significance
		Trt (Land use type)	Error		
BD ($Mg m^{-3}$)	0 – 10	0.001969	0.005867	0.34	ns
	10 – 20	0.010827	0.003643	2.97	ns
	20 – 30	0.001060	0.002936	0.36	ns
PT ($m^3 m^{-3}$)	0 – 10	0.000325	0.000813	0.40	ns
	10 – 20	0.001700	0.000546	3.11	*
	20 – 30	0.000317	0.000337	0.94	ns
Mic ($m^3 m^{-3}$)	0 – 10	0.002279	0.000224	10.18	***
	10 – 20	0.003193	0.000273	11.68	***
	20 – 30	0.004659	0.000341	13.64	***
Mac ($m^3 m^{-3}$)	0 – 10	0.000945	0.001181	0.80	ns
	10 – 20	0.000313	0.000975	0.32	ns
	20 – 30	0.003466	0.000775	4.47	*
VMC ($m^3 m^{-3}$)	0 – 10	52.153	6.314	8.26	***
	10 – 20	69.090	8.279	8.35	***
	20 – 30	135.97	11.13	12.22	***

*** = $P \leq 0.001$; ** = $P \leq 0.01$; * = $P \leq 0.05$ ns = not significant, Trt – treatment

Statistical analysis indicates significant ($p \leq 0.05$) difference in total porosity among the land uses at 5 – 10 cm soil depth indicating that not all the groups of the land uses resulted in the same total porosity value. Microporosity was significantly ($p \leq 0.001$) affected by land uses in all the soil depths while macroporosity was only significantly ($p \leq 0.05$) affected by land uses at 20 – 30 cm soil depth. High micropores in the natural forest may be due to the absence of tillage operations and continuity of pores. Tillage, especially plowing, creates macropores that cause saturated and near- saturated hydraulic conductivities to increase considerably, but also disrupts pore continuities that reduce hydraulic conductivities between plough layers and subsoils (Olorunfemi and Fasinmirin, 2012).

Volumetric moisture content

Volumetric moisture content (VMC) distribution with depth among the land uses is presented in Table 3 with NF having the highest mean volumetric moisture content value. The volumetric moisture content of soils in all project sites ranged widely from 1.97 $m^3 m^{-3}$ to 14.02 $m^3 m^{-3}$ with a mean value of 6.41 $m^3 m^{-3}$ (± 3.00) at the soil superficial layer (0 – 10 cm), 4.48 $m^3 m^{-3}$ to 16.79 $m^3 m^{-3}$ with a mean value of 9.06 $m^3 m^{-3}$ (± 3.44) at the 10– 20 cm depth and from 6.49 $m^3 m^{-3}$ to 21.60 $m^3 m^{-3}$ having an average value of 11.94 $m^3 m^{-3}$ (± 4.30) at the 20 – 30 cm depth. The volumetric moisture content data differ significantly among the three soil layers down the soil depths. The volumetric moisture content was significantly higher in the lower layer (20 – 30 cm) than in the middle layer (10 – 20 cm), and the VMC of the middle layer (10 – 20 cm) was equally significantly higher than the VMC value of the upper layer (0–10 cm) respectively. This is in agreement with the work of Halfmann (2005) who noted that soil moisture increases with depth and that there was a significant increase in soil moisture at the 5-10 cm depth. Reduced aggregation, less pore space of the subsurface layers and increase bulk density down the soil layers compared to surface layers (USDA, 2008) equally lead to high volumetric moisture content.

Statistical analysis showed significant difference in VMC among the land uses down the soil layers (0 – 10 cm, 10 – 20 cm and 20 – 30 cm) indicating that not all the groups of the land uses resulted in the same VMC value*.* In this study, NF soils had significantly higher VMC than PA and CP and Tukey simultaneous 95% confident interval for the difference of means between the different land use types shows that the corresponding means between PA and CP are not significantly different down the soil depths. The high volumetric moisture content in NF may not be unconnected with the high micro porosity values. Very small pores pull water through capillary action in addition to and even against the force of gravity, while smaller pores offer greater resistance to gravity (Devore, 1995). The high VMC in the natural forest was also a reflection of its high soil organic matter content (SOM) and an indication of the affinity of organic matter for water (Oguike and Mbagwu, 2009). However, several studies have demonstrated no significant differences between the volumetric moisture content at field capacity of disturbed and undisturbed soils (Jusoff, 1989). Price et al. (2010) found consistent and significantly higher VMC at field capacity in forest than pasture and lawn soils, by a factor of nearly 20%. The observed results generally showed that the soils under different land uses may also differ in their water content at both FC and PWP because they vary in sand, silt and clay contents as rightly observed by Yeshaneh (2015).

Soil chemical properties

Soil organic carbon and organic matter

The soil organic carbon (SOC) of the soils of all the locations varies from 0.88 % to 2.36 %. Overall, the mean of the SOC of all soil sites is 1.42 % ± 0.38 with coefficient of variation of about 27 %. The organic carbon which is an index of the soil organic matter differs among the different land uses. In the natural forests, SOC varies from 1.24 % to 2.36 % having a mean value of 1.73 % ± 0.44 and coefficient of variation of 39 % (Table 5). The PA has organic carbon ranging from 0.88 % to 2.16 % with a mean value of 1.42 %. The coefficient of variation is about 41 %. In the same way, in the agricultural land organic carbon value has a maximum value of 1.74 % and a minimum value of 0.88 % averaging 1.26 % ± 0.28 with a coefficient of variation of about 32 % (Table 5). Soil organic carbon varied among the land uses studied (Table 5 and 6). The three land uses considered were significantly different ($F(2, 32) = 5.67$, $p \leq 0.01$) in soil organic carbon (Table 5 and 6). In this study, NF on the overall accumulated more organic carbon than PA sites and cultivated CP. The SOC is of the order NF > PA > CP. Natural forest naturally had the highest organic carbon value as forests play a vital role in the global carbon cycle. Forests absorb carbon through photosynthesis and sequester it as biomass, thus creating a natural storage of carbon. Croplands on the other hand had the least soil organic carbon. Much of this loss in soil organic carbon can be attributed to reduced inputs of organic matter, increased decomposability of crop residues, and tillage effects that decrease the amount of physical protection to decomposition (Post and Kwon, 2000). A great number of studies have reported similar observations. Paustian et al. (1996) observed that a greater frequency of cropping with associated increases in SOC is due to greater return of crop residues. Yimer et al. (2007) in Ethiopia also compared croplands, forestlands and grazing lands and found that soil organic C and total N decreased in croplands as compared to forestlands. Also, high temperature and high relative humidity, which favor rapid mineralization, might be responsible for decreasing order of magnitude of organic carbon (NF > PA > CP) in conformation with the finding of Senjobi and Ogunkunle (2011).

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by the soil microbes as the decay occurs (Brady, 1990). The results of the soil organic matter (SOM) of all the 35 locations show that the percentage organic matter of the different land uses ranged from 1.52 % to 4.07 % with an average of 2.46 % ± 0.66. The coefficient of variation of SOM is about 29 %. The three land uses considered (Croplands, Plantations and Natural forests) were significantly different ($F(2, 32) = 5.63$, $p \leq 0.01$) in soil organic matter content. Tukey HSD showed that SOM was significantly higher in the natural forests as compared with that in the croplands. The highest SOM value of 4.07 % was recorded in the natural forests, while the lowest value of 1.52 % was found in the croplands. Soil organic matter ranged from 2.14 % to 4.07 % in the natural forests with an average value of 2.98 % ± 0.79. The spatial variability of the SOM of the natural forests is about 27 %. The organic matter of the plantation agriculture showed a variability of 24.5 % ranging from 1.62 % to 3.72 %. It has an average value of 2.46 % with a standard deviation of 0.6. The organic matter content value of CP ranged from 1.52 % to 3 % averaging 2.17 % ± 0.48 and with a variability of 22.33 %. In all, the NF has the highest average organic matter content; this may be due to findings that soils underlying native vegetation (e.g., undisturbed natural forest) generally feature high SOM, as a result of ample litter cover, organic inputs, root growth and decay, and abundant burrowing fauna (Price et al., 2010). The CP have the least average SOM, as cropping of the soils may have led to erosion and leaching of soil nutrients which in turn, adversely affects the physico – chemical properties of the soils (Oguike and Mbagwu, 2009). Also, Sombroek et al. (1993) reported a 20–50% reduction of SOM as a result of clearing tropical forests and their subsequent conversion into farm land. The clearing of forests for annual crop production invariably resulted in a loss of soil organic matter because of the removal of large quantities of biomass during land clearing, a reduction in the quantity and quality of organic inputs added to the soil and increasing soil organic matter decomposition rates. These higher decomposing rates are due to enhanced biological activity caused by soil mixing from tillage and higher temperatures from increased soil exposure (Barber, 1995). Furthermore, Lal (1986) and Oguike and Mbagwu (2009) reported that with continuous cultivation, physical properties and productivity of many soils commonly decline due to decrease in SOM and soil pH. However, the level of response to changing management practices differs across eco-regions and strongly interact with local climate, land use, farming systems and soil/crop management systems (Post and Kwon, 2000).

Table 5. Summary statistics for surface soil chemical parameters under different land uses

Land uses	Croplands	Plantations	Forests
Statistics	Mean ± STD (CV)	Mean ± STD (CV)	Mean ± STD (CV)
Soil pH	5.93 ± 0.30 (0.05)a	5.90 ± 0.41(0.07)a	6.06 ± 0.72 (0.01)a
Available Phosphorus (ppm)	18.43 ± 11.11 (0.60)a	23.76 ± 13.12 (0.55)a	24.03 ± 14.19 (0.59)a
SOC (%)	1.27 ± 0.28 (0.22)a	1.48 ± 0.38 (0.26)ab	1.78 ± 0.44 (0.25)b
SOM (%)	2.19 ± 0.48 (0.22)a	2.59 ± 0.65(0.25)ab	3.06 ± 0.76 (0.25)b
SON (%)	0.065 ± 0.015 (0.24)a	0.072 ± 0.018 (0.26)ab	0.089 ± 0.022 (0.25)b
CEC (cmol+kg^{-1})	5.98 ± 1.79 (0.30)a	6.54 ± 2.22(0.34)ab	8.08 ± 1.42 (0.18)b
SAR	0.084 ± 0.023 (0.27)a	0.079 ± 0.016 (0.21)ab	0.058 ± 0.022 (0.37)b
ESP (%)	2.11 ± 0.78 (0.37)a	1.94 ± 0.55 (0.28)ab	1.29 ± 0.54 (0.41)b
BS (%)	81.80 ± 10.94 (0.13)a	81.83 ± 9.16(0.11)a	88.75 ± 3.17 (0.04)a
ASP (%)	11.33 ± 5.73 (0.51)a	12.01 ± 3.92(0.33)a	7.36 ± 1.90 (0.26)a

Means in a row that do not share a letter are significantly different. Where SOC = Soil organic Carbon, SOM = Soil Organic Matter, SON = Soil Organic Nitrogen, CEC = Cation Exchange Capacity, SAR = Sodium Absorption Ratio, ESP = Exchangeable Sodium Percentage, BS = Base Saturation and ASP = Aluminum Saturation Percentage

Soil organic nitrogen

The soil organic nitrogen (SON) in all 35 sites varies from 0.044 % to 0.118 %. It has an average value of 0.071 % ± 0.02 with a coefficient of variation of 27.5 % (Table 5). The NF soils have the highest mean organic nitrogen of 0.09 % while the croplands have the least average value of 0.06 %. Difference in SON among the land uses were statistically significant ($F(2, 32) = 4.49$, $p \leq 0.05$) (Table 6). The mean SON of NF is significantly higher than that of CP while mean SON of PA soils did not differ significantly from that of NF and CP ($p \leq 0.05$). This can be attributed to the land use and management system as roughly 95% of soil organic nitrogen is found in soil organic material in undisturbed, natural soils (Walworth, 2013). Soil organic material in the naturals soils are as a result of ample litter cover, organic inputs, root growth and decay, and abundant burrowing fauna (Price et al., 2010). Al-Kaisi et al. (2005) investigated soil carbon and nitrogen changes as influenced by tillage and cropping systems in some Iowa soils and discovered No-tillage increased total nitrogen content by 9.1% (0.3 Mg ha $^{-1}$) over chisel plowing averaged across five soil associations at the 0–15 cm soil depth. Increase in the intensity and frequency of tillage operations which produces more soil disturbance decreased total nitrogen contents (Franzluebbers et al., 1999). Meysner et al. (2006) reported that there are variations in mineral nitrogen leaching between farming systems due to differences in production mix within farm types. Previous findings by Havlin et al. (1990), Franzluebbers et al. (1995) and Halvorson et al. (2002) have shown that soil can be managed to increase soil organic carbon and nitrogen storage from a long- term (>10 years) perspective. This can be achieved by implementing conservation soil and crop management practices such as conservation tillage.

Cation exchange capacity (CEC)

The CEC of all the sampled soils (which is a measurement of its ability to bind or hold exchangeable cations) shows a variability of about 32 % ranging from 3.43 $cmol_c.kg^{-1}$ to 11.97 $cmol_c.kg^{-1}$ with PA having the highest mean value and CP having the least mean value (Table 6). The soils of all the sites have an average CEC value of 6.53 $cmol_c.kg^{-1}$ ± 2.01. The statistics of the CEC with respect to land uses shows that average values of the CEC for the different land uses are 8.08 $cmol_c.kg^{-1}$ ±1.42, 6.38 $cmol_c.kg^{-1}$ ± 2.26 and 5.98 $cmol_c.kg^{-1}$ ± 1.79 for NF, PA and CP, respectively (Table 5). In the NF, CEC vary from 5.53 $cmol_c.kg^{-1}$ to 10 $cmol_c.kg^{-1}$ with a coefficient of variation of 17.6 %. The Croplands CEC values ranged from 3.43 $cmol_c.kg^{-1}$ to 9.58 $cmol_c.kg^{-1}$ with a higher coefficient of variation of 30 % while in the PA, it varied from 4.28 $cmol_c.kg^{-1}$ to 11.97 $cmol_c.kg^{-1}$ with the largest coefficient of variation (37 %).

Table 6. Analysis of variance of the surface soil chemical properties between land uses

Properties	Mean Square		F - Value	Significance
	Trt (Land use type)	Error		
Soil pH	0.05943	0.10165	0.58	ns
Available phosphorus (ppm)	129.1	153.3	0.84	ns
SOC (%)	0.6388	0.1126	5.67	**
SOM (%)	1.9036	0.3379	5.63	**
SON (%)	0.00141	0.00032	4.49	*
CEC ($cmol^{+}kg^{-1}$)	11.107	3.591	3.09	*
SAR	0.001666	0.000433	3.85	*
ESP (%)	1.6858	0.4528	3.72	*
BS (%)	140.03	90.07	1.55	ns
ASP (%)	56.62	21.97	2.58	ns

*** = $P \le 0.001$; ** = $P \le 0.01$; * = $P \le 0.05$ ns = not significant, Trt – treatment.

There was a statiscally significant difference ($p \le 0.05$) in CEC among the treatments (Table 6). Comparisons of means by Tukey procedure was used to determine which pairs of the three treatments means differed. The results indicate that the mean CEC of NF and CP are significantly different. In absolute term, NF has highest average CEC of 8.08 $cmol_c.kg^{-1}$ (± 1.42) which may be due to their high organic matter content while croplands have the least average CEC of 5.98 $cmol_c.kg^{-1}$ (± 1.79). The lowest CEC under the cultivated lands may be due to the depletion of organic matter which is as a result of intensive cultivation and this is in agreement with findings from previous researches (Abebe, 1980; Gao and Chang, 1996).

Characterizing soils cation exchange capacity (CEC) is of utmost importance as it can be a good indicator of soil productivity and is also useful for making recommendations of phosphorus, potassium, and magnesium for soils of different textures. The results of the correlation analysis between CEC (%) and Clay percentage (r = 0.36, N = 35, p ≤ 0 .05) and also CEC (%) and SOM (%) (r = 0.54, N = 35, p ≤ 0 .001) in all the sites revealed a significant and positive relationship (Table 7). From our observation, high CEC values were found in soils with high organic matter content and clay particles. This shows that CEC is mainly dependent on soil clay minerals and organic matter (Martel et al., 1978; Manrique et al., 1991; Harada and Inoko, 2012) and silt to a lesser extent (Rashidi and Seilsepour, 2008). There is a strong correlation between the CEC values, and the amount of organic matter present in the soil as Organic matter is a major source of negative electrostatic sites. The research findings conform to the works of Bayer and Bertol (1999); Vogelmann et al. (2010) and Fasinmirin and Olorunfemi (2012) who all reported that soil samples with higher values of CEC were found to have high levels of organic matter and pH levels. Likewise, in any given soil, soil pH; type, size and amount of clay; and amount and source of the organic material influenced the number of exchange sites (Kamprath and Welch 1962; Parfitt et al., 1995; Miller, 1970; Rashidi and Seilsepour, 2008).

Soil pH

The results of the chemical properties of the sample soils are presented in Table 6. The average pH value of all the locations is 5.95. The pH level of the soil directly affects soil life and the availability of essential soil nutrients for plant growth. Factors such as parent material, rainfall, and type of vegetation are dominant in determining the pH of soils. Under cultivation, however, organic acids from plant roots, repeated use of acid-forming fertilizers, plant removal, and replacement of calcium and magnesium by hydrogen eventually lowers the pH of topsoil. The pH value for the NF soils ranged from 5.96 to 6.17 with an average value of 6.06 ± 0.07 while in the PA, the max. and min. pH value are 6.36 and 4.95 respectively with an average pH value of 5.90 ± 0.43. Likewise, the CP have a pH value ranging from 5.46 to 6.31 with an average value of 5.93 ± 0.30. In all the sites, there was no definite sequence in the distribution of their degree of acidity and alkalinity but in general the soil pH values fall within the acceptable limit for maximum utilization of soil nutrients (Soil Survey Staff, 2009). Analysis of variance of the soil properties between land uses showed that the pH distribution is homogenous ($p \le 0.05$) among the different treatments. Inherent factors affecting soil pH such as climate, mineral content and soil texture cannot be changed. The slightly lower average value of soil pH under the cropland and plantations may be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution lowers its soil pH value (Chimdi et al., 2014).

Available Phosphorus

The available phosphorus of all sites ranged from 3.92 ppm to 43.54 ppm. The available phosphorus was not significantly different among the land uses. Croplands slightly have lower values than soils under PA and NF. This may be due to soil organic matter being the main source of available Phosphorus (Mamo and Haque, 1987). The availability of phosphorus under most soils decline by the impacts of fixation, abundant crop harvest and erosion (Yeshaneh, 2015).

However, it was observed that 45.71 % (16 experimental sites) of the soil sites showed low phosphorus availability (<20 ppm) compared with the critical level of 10 – 16 ppm (Adeoye and Agboola, 1985) while the rest 54.29 % (19 experimental sites) fall in the medium category (20 ppm – 40 ppm). Availability of Phosphorus is maximized when soil pH is between 5.5 and 7.5 (Mullen, 2004) which happen to be the ideal pH range for optimal availability of plant nutrients for most crops. Also soils with inherent pH values between 6 and 7.5 and by moist, warm conditions are ideal for P-availability, while pH values below 5.5 and between 7.5 and 8.5 limits P-availability to plants due to fixation by aluminum, iron, or calcium, often associated with soil parent materials (Soil Survey Staff, 2009).

Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP)

There was a significant difference ($P < 0.05$) for SAR and ESP among the three land use types. SAR was highest in CP (0.084 %), followed by PA (0.079 %) and least in forest (0.058 %). Likewise, ESP was highest in CP (2.11 %), followed by PA (1.94 %) and least in NF (1.29 %). Soils that have more than 6% ESP are considered to have structural stability problems related to potential dispersion (van de Graaff and Patterson, 2001).

Total base saturation (BS) and aluminium saturation (ASP)

In all sites, the base saturation ranged from 57.73 % to 94.49 % (Table 6). It has an average value of 83.10 % ± 9.64 with a coefficient of variation of about 12%. Soils with 70% or greater BS are unlikely to limit agronomic crop growth due to acidity. The values of the base saturation showed no definite sequence in their distribution among the different land uses in the study sites. Likewise, the percentage of aluminium saturation in all the locations ranged from 2.70% to 23.32 % with an average percentage of 10.85 % ±4.9 and coefficient of variation of 45.2 %. The average aluminium saturation percentages across the different land uses showed that NF have the least ASP (7.37 % ± 1.9) while soils of PA have the highest ASP (12.33 % ± 3.94). Croplands have average ASP of 11.34 % ± 5.74. The total base saturation (BS) and aluminium saturation (ASP) were not significantly or highly affected by land use systems.

Correlation between base saturation (%) and aluminium saturation (%) showed that base saturation (%) correlated negatively and significantly with aluminium saturation (%) ($r = -0.70$, $N = 35$, $p = 0.001$) indicating that higher values of base saturation are associated with lower levels of aluminium saturation (Table 7). The correlation was strong in strength and higher values of base saturation (%) were also associated with lower values of aluminium saturation (%). The soils that have high base saturation were found having low aluminium saturation and high pH values and vice versa. This is in agreement with the findings of Streck et al. (2008), who reported that low saturation of bases could be traced to high Al saturation and low pH in Oxisols and Alfisol. Vogelmann et al. (2010) also reported low base saturation in Paleodult and Hapludox, which together had low pH and high Al saturation in their research to identify and determine the hydro-repellency of soils of Rio Grande do Sul, Southern Brazil. Higher values of base saturation were associated with higher levels of soil pH. The base saturation is inversely related to aluminum saturation and directly related to the levels of organic matter, pH and CEC as reported by Vogelmann et al. (2010). High base saturation in soils are associated with high CEC (Souza and Alves, 2003). Zalamena (2008) also observed similar findings especially in the lower horizons.

The results of the correlation analysis between base saturation (%) and soil pH at $p < 0.05$ revealed a significant difference and positive correlation. Correlation analysis between aluminium saturation (%) and soil pH revealed a negative relationship for all the experimental sites. In all, higher values of base saturation were associated with lower levels of soil pH (negative correlation).

Exchangeable cations and acidity of the land uses

The means of the exchangeable cations and exchangeable acidity are presented in Table 4 and 5. The five (5) most abundant cations in soils are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}) and in strongly acid soils, aluminium (Al^{3+}). These are summed up to give an approximate value of CEC called effective CEC. The individual cations can be expressed as a percentage (%) of the effective CEC (Abbott, 1989). The exchangeable bases (K, Ca, Mg and Na) in all the land uses were dominated by calcium and magnesium. The exchangeable calcium (Ca^{2+}) varied from 1.2 $cmol_c.kg^{-1}$ (240 ppm) to 6.3 (1260 ppm) $cmol_c.kg^{-1}$ with an average value of 3.35 $cmol_c.kg^{-1}$ ±1.27. It has a variability of 38 %. The mean percent base saturation of calcium (50.46 %) of all the sites falls within the ideal base cation saturation ration (BCSR) of 50 % – 70 % for calcium which is ideal for pH range of 5.8 to 6.5 (www.hill-laboratories.com) but less than that (60 % - 70 %) recommended by Albrecht (1975). Calcium is rarely deficient when soil pH is adequate and in a soil where calcium is deficient, the soil will require an application of lime ($CaCO_3$) to increase the base saturation of Ca before it will be a productive soil. In the natural forest, the exchangeable calcium ranged from 3 $cmol_c.kg^{-1}$ (600 ppm) to 6 $cmol_c.kg^{-1}$ (1200 ppm) with a mean value of 4.51 $cmol_c.kg^{-1}$ ± 0.94 (903 ppm) and coefficient of variation of 21 %. The average exchangeable calcium of the plantation agriculture is 3.13 $cmol_c.kg^{-1}$ ± 1.24 (626 ppm) with a higher variability of 40 % ranging from 2 $cmol_c.kg^{-1}$ (400 ppm) to 6.3 $cmol_c.kg^{-1}$ (1260 ppm). The exchangeable calcium of the croplands varied from 1.2 $cmol_c.kg^{-1}$ (240 ppm) to 5.6 (1120 ppm) $cmol_c.kg^{-1}$. It has an average value of 3.01 $cmol_c.kg^{-1}$ ± 1.18 (602 ppm) with a variability of 39 %.

The exchangeable magnesium of all soil sites ranged from 0.5 $cmol_c.kg^{-1}$ (61 ppm) to 3 $cmol_c.kg^{-1}$ (363 ppm) which is within the medium (0.5–2.5 $cmol_c.kg^{-1}$/ 60 – 300 ppm) and high (>2.5 $cmol_c.kg^{-1}$ / >303 ppm) categories of exchangeable magnesium for crop production (Horneck et al., 2011). Overall, the mean of exchangeable magnesium of all soil sites is 1.43 $cmol_c.kg^{-1}$ ± 0.59 (173 ppm) with a coefficient of variation of 41 %. The overall mean of the exchangeable magnesium cation falls within the range (100 ppm – 250 ppm) given as the optimum magnesium levels for crop production. The amount of magnesium adequate for crops can be further determined by its base saturation, which should be between 10 -20 % (Albrecht, 1975; Young, 1999). The mean base saturation of magnesium of all soils sites is 21. 44 % which is very slightly higher than the recommended range. Soils having a magnesium base saturation in excess of 30 - 35 % may exhibit serious problems, such as soil crusting and restricted root development. In respect to the different land uses, the magnesium in the NF ranged from 1.1$cmol_c.kg^{-1}$ (133 ppm) to 2.2 $cmol_c.kg^{-1}$ (266 ppm) with a mean value of 1.83 $cmol_c.kg^{-1}$ ± 0.39 (221 ppm) and coefficient of variation of 21 %. Likewise, the PA has a mean value of 1.45 $cmol_c.kg^{-1}$ ± 0.65 (175 ppm) ranging from 1 $cmol_c.kg^{-1}$ (121 ppm) to 3 $cmol_c.kg^{-1}$ (363 ppm) with a variability of 45 %. The exchangeable magnesium of the croplands varied from 0.5 $cmol_c.kg^{-1}$ (61 ppm) to 2.6 $cmol_c.kg^{-1}$ (315 ppm). The average magnesium is 1.26 $cmol_c.kg^{-1}$ ± 0.56 (152 ppm) and the coefficient of variation is 44 %.

The exchangeable sodium of all sites indicates the degree of which the soil exchange sites are saturated with Sodium. The exchangeable sodium of all sites ranged from 0.03$cmol_c.kg^{-1}$ (6.9 ppm) to 0.16 $cmol_c.kg^{-1}$ (36.8 ppm) with an average value of 0.11 $cmol_c.kg^{-1}$ ± 0.02 (25.96 ppm). The variability of exchangeable sodium in all soil sites is 22 %. Sodium (Na), though is not an essential element for plant growth, but is important for diagnosing problem soils that may contain high amounts of sodium. High levels of exchangeable sodium affect soil structure, soil permeability and may be toxic to sensitive plants (Horneck et al., 2011). Sodium levels are evaluated based on exchangeable sodium percentage (ESP) which is the percent of the CEC occupied by sodium (Na). The exchangeable sodium percentage (ESP) of all sites ranged from 0.42 % to 4.27 %. The average ESP of the soil samples of all the locations (1.89 % ± 0.72) with a variability of 38 % falls within the recommended range (0.5 - 3% Na) given by Albrecht (1975) and also within the ideal sodium base saturation level (1-2 %) (www.hill-laboratories.com). The mean ESP of the different land uses are 1.29% ± 0.53, 1.94% ± 0.55 and 2.11% ± 0.78 for NF, PA and CP respectively which are within the recommended range. Exchangeable sodium greater than 2.5% may cause adverse physical and chemical conditions to develop in the soil that may prevent plant growth. Sodium base saturation values over 7% can represent a water permeability problem. When the estimated exchangeable sodium exceeds 15%, the soil is considered “sodic,” but crop production problems may occur at lower levels (Espinoza et al., 1996). Reclamation involves establishment of drainage followed by gypsum application and leaching with low-sodium water (Horneck et al., 2011).

Potassium is the third most important plant nutrient along with nitrogen and phosphorus. The potassium of all soil sites ranged from 0.18 $cmol_c.kg^{-1}$ (70 ppm) to 1.69 $cmol_c.kg^{-1}$ (659 ppm falling within the low (< 0.4 18 $cmol_c.kg^{-1}$ / 150 ppm), medium (0.4 – 0.6 18 $cmol_c.kg^{-1}$ / 150 – 250 ppm) and high (0.6 – 2.0 18 $cmol_c.kg^{-1}$ / 150 – 800 ppm) potassium categories for crop production (Horneck et al., 2011). The potassium is 0.62 $cmol_c.kg^{-1}$ ± 0.36 (243 ppm) on average with coefficient of variation of 58 %. The average potassium of all the soil sites falls within the Medium category regarded as the optimum level. Soils commonly contain over 20, 000 parts per million (ppm) of total potassium. Nearly all of this is a structural component of soils mineral and is unavailable to plants. Plants use only the exchangeable potassium on the surface of soil particles and potassium dissolved in the soil water and this often amounts to less than 100 ppm (Schulte and Kelling, 2011). The potassium can also be evaluated based on the potassium base saturation level. The potassium base saturation level of all soil sites ranged from 3.98 % to 20.14 % with a mean value of 9.03 % ± 3.91 and a variability of 42 %. The mean potassium base saturation of all soil sites is above the recommended range of 2 – 5 % (Albrecht, 1975; Young, 1999). The NF exchangeable potassium ranged from 0.51 $cmol_c kg^{-1}$ (199 ppm) to 1.1 $cmol_c kg^{-1}$ (429 ppm), PA ranged from 0.28 $cmol_c kg^{-1}$ (109 ppm) to 1.46 $cmol_c kg^{-1}$ (569 ppm) while that of CP varied from 0.18 $cmol_c kg^{-1}$ (70 ppm) to 1.69 $cmol_c kg^{-1}$ (659 ppm).

The exchangeable cations can be divided into two groups: bases and acids. The soil pH will be affected by whichever cations predominate on these exchange sites. The more base cations present, the more alkaline the soil (i.e. the higher soil pH will be), whereas the more acid cations present, the more acidic the soil (i.e. the lower the pH). Hydrogen and Aluminium are acid cations which increase soil acidity and therefore lower pH. The hydrogen cation in all soil sites ranged from 0.05 $cmol_c kg^{-1}$ to 1.31 $cmol_c kg^{-1}$ with a mean value of 0.37 $cmol_c kg^{-1}$ ± 0.35. The coefficient of variation is 95 %. Evaluating the hydrogen base saturation levels, it varied widely from 0.59 % to 24.62 % with a mean value of 6.05 % ± 6.26 and coefficient of variation of 103 %. The recommended range of hydrogen base saturation is 10 – 15 % (Young, 1999).

The descriptive statistics of the hydrogen cation of the different land uses showed that the H^+ of the NF ranged from 0.59 $cmol_c kg^{-1}$ to 6.07 $cmol_c kg^{-1}$. It has an average value of 3.89 $cmol_c kg^{-1}$ ± 2.00 and a variability of 51 %. The H^+ in the PA showed the highest variation of 113% ranging from 0.91 $cmol_c kg^{-1}$ to 22.20 $cmol_c kg^{-1}$ with an average value of 6.17 $cmol_c kg^{-1}$ ± 6.99. The CP demonstrated an H^+ variability of 101 %. The H^+ of the CP ranged from 0.82 $cmol_c kg^{-1}$ to 24.62 $cmol_c kg^{-1}$. It has an average value of 6.86 $cmol_c kg^{-1}$ ± 6.96.

Correlation between soil properties

There was a considerable degree of correlation between the physical properties and the various chemical properties measured (Table 7). The linear correlation analysis of the 11 soil physico-chemical properties for the study area, showed a significant correlation among 70 of the 190 soil attribute pairs ($P \leq 0.01$; $P \leq 0.05$) (Table 7). Increasing soils ability to retain water (i.e increasing micropores) reduces their water transmitting ability. The micropores are small enough that the adhesive and cohesive forces holding the water to the pore wall are stronger than the gravitational force trying to drain the soil. The data collected revealed that soil texture influences the water retention capabilities of soils of the experimental locations. We observed a significant and positive relationship (r = 0.54**, N = 35) between WHC (%) and Clay percentage in all the sites. This shows that soils with high clay percentage tends to have high water holding capacity. Likewise, soil with very high proportion of sand have very low water holding capacity due to large pore spaces between the particles which enables the water to move freely (relatively higher hydraulic conductivity) into deeper layers leaving upper layers practically dry. Increases sand and silt content in soil texture increases ratio of macro porosity in total porosity (Gülser and Candemir, 2014). According to Hillel (1998), "a sandy soil will absorb water more rapidly during infiltration, but clay can sustain the evaporation process longer." Clay can hold a large volume of water per volume of bulk material, but they do not release water rapidly. Clay soil, on the other hand, due to very small size of the pore spaces (fine capillaries) retained more water in the capillary spaces as capillary water and as a result, water does not transmit easily.

Cation exchange capacity showed positive correlation with soil pH (r = 0.441**), SOC (r = 0.580**), SOM (r = 572**), WHC (r = 0.580**) and clay content (r = 0.356 *) respectively amongst all the soil samples in the experimental locations (Table 7). It was observed that soils with high organic matter content and clay particles demonstrated high CEC values. The reason for this observation has been stated earlier. Organic matter being a major source of negative electrostatic sites in soils; therefore, there is a strong correlation between CEC value and amount of organic matter present in the soil. Soil water holding capacity correlated positively with clay content (r = 0.539**) and negatively with sand content (r = - 0.517**). Results of the correlation analysis between WHC (%) and SOM (%) revealed a significant and positive relationship (r = 0.584**, N = 35). Olorunfemi and Fasinmirin (2017) reported that soils having high proportion of sands are associated with low WHC. The result also shows that increase in clay and organic matter contents increased the water holding capacity of the soil (FAO, 2005). This observation conformed to the findings of Senjobi and Ogunkunle (2011) who reported that water holding capacity of soils increase with increase in clay content of soils in their study to assess the extent to which different land use types influences land degradation and productivity in Ogun State, Nigeria.

Table 7. Correlation matrix among the different parameters

	Sand	Silt	Clay	Silt/Clay	BD	PT	MIC	MAC	VMC	WHC	pH	P	SOM	SOC	SON	CEC	BS	ASP	SAR	ESP
Sand	1																			
Silt	-.366*	1																		
Clay	-.794**	-.275	1																	
Silt/Clay	.266	.772**	-.794**	1																
BD	.049	-.039	0.077	-.078	1															
PT	-0.16	.093	-.044	.091	-.975**	1														
MIC	-.409*	.282	.238	.036	.056	.007	1													
MAC	.283	-.135	-.205	.041	-.721**	.693**	-.716**	1												
VMC	-.417*	.270	.255	.018	.161	-.098	.993**	-.785**	1											
WHC	-.517**	-.008	.539**	-.306	-.031	.117	.596**	-.347*	.583**	1										
soil pH	.088	.065	-.134	.085	-.181	.139	-.074	.155	-.092	.152	1									
P	.195	-.132	-.115	.012	-.247	.282	.107	.117	.067	.106	-.068	1								
SOM	-.339*	-.137	.440**	-.347*	.070	-.003	.316	-.229	.306	.584**	.139	-.095	1							
SOC	-.363*	-.140	.467**	-.370*	.051	.015	.338*	-.232	.327	.610**	.128	-.089	.993**	1						
SON	-.352*	-.122	.443**	-.344*	.052	.016	.312	-.213	.303	.602**	.116	-.093	.975**	.981**	1					
CEC	-.281	-.101	.356*	-.252	-.027	.089	.297	-.149	.294	.569**	.441**	-.090	.572**	.580**	.543**	1				
BS	-.201	.144	.114	.088	-.192	.245	.179	.048	.159	.462**	.426*	.102	.206	.206	.227	.510**	1			
ASP	.253	-.078	-.210	.045	.061	-.139	-.311	.121	-.306	-.591**	-.254	.035	-.351*	-.370*	-.381*	-.700**	-.824**	1		
SAR	.374*	.105	-.455**	.365*	.120	-.150	-.345*	.144	-.326	-.526**	-.216	-.136	-.485**	-.512**	-.487**	-.633**	-.369*	.526**	1	
ESP	.326	.167	-.446**	.395*	.036	-.073	-.354*	.203	-.346*	.530**	-.251	-.079	-.534**	-.555**	-.523**	-.756**	-.311	.550**	.961**	1

Conclusion

This research evaluated and characterized physiochemical properties of soils of similar geological substrate and climatic conditions but under different land uses (i.e croplands, plantation agriculture and natural forests) in Southwestern Nigeria. Bulk density showed a regular increase with depth (i.e. higher bulk density at the lower soil cores) and has no definite sequence in their distribution across the different land uses. The high volumetric moisture content in natural forest may not be unconnected with their high micro porosity values. The high VMC in the NF was also a reflection of its high soil organic matter content (SOM) and an indication of the affinity of organic matter for water. Water holding capacity of the soils increases with increase in clay and soil organic matter (SOM) content of the soil. Organic carbon and organic matter accumulation follows the order NF > PA > CP. Soils with high organic matter content and clay particles demonstrated high CEC values. Natural forest naturally had the highest organic carbon value as forests play a vital role in the global carbon cycle. In all, the natural forest has the highest average organic matter content; this may be due to findings that soils underlying native vegetation (e.g., undisturbed natural forest) generally feature high SOM, as a result of ample litter cover, organic inputs, root growth and decay, and abundant burrowing fauna. The clearing of forests for annual crop production invariably resulted in a loss of soil quality because of the removal of large quantities of biomass during land clearing, a reduction in the quantity and quality of organic inputs added to the soil and increasing soil organic matter decomposition rates. Land uses and soil management appear to be good predictor of soil fertility status. Success in soil management depends on the understanding of how the soil responds to agricultural practices over time. Reliable knowledge on soil fertility and other soil properties under different land uses and evaluation of the land use systems affecting them can be of great interest in understanding the influences of human activities on soil fertility and possible implications for livelihoods in consideration of increasing food insecurity and soil degradation changes.

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