



Research article

Selected physical and chemical properties of soil under different agricultural land-use types in Ile-Ife, Nigeria



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ABSTRACT

This study examined changes in soil properties under different types of agricultural land-use. This was done with a view to extending knowledge on the nature of soil properties under long-term land-use practices. The study investigated six types of land-use: paddock, continuously cropped, secondary forest, teak, oil palm, and cacao plantations. Soil strength and saturated hydraulic conductivity were determined *in-situ* at two soil depths (0–15 and 15–30 cm) across the land-use types. Soil samples were collected to determine particle size distribution, bulk density, aggregate stability, pH, organic carbon, cation exchange capacity, total nitrogen, and available phosphorus. The data obtained were subjected to analysis of variance and Duncan's multiple range test was used to separate significant means at $p \leq 0.05$. The results showed that land-use types such as forest, cacao and continuously cropped had higher saturated hydraulic conductivity, while soil bulk density was highest under continuously cropped land-use type (1.55 g cm^{-3}). The soil aggregates of forest, teak, and oil palm land-use types were more stable, but soil under oil palm land-use had the highest soil strength (5.65 kg m^{-2}). Soil pH across the land-use types was slightly acidic to strongly acidic, while soil organic carbon was least in continuously cropped land (3.87 g kg^{-1}). The total nitrogen content of soil across the land-use types was high, but the available phosphorus was low. Paddock, cacao, and continuously cropped land-use types had higher cation exchange capacity. The results implied that continuous cultivation led to depletion in soil physical and chemical properties, whereas, afforestation and cultivation of tree crops conserved soil properties better. Therefore, the establishment of tree crop plantations and conservative soil management practices such as manuring, mulching, liming, and conservation tillage were suggested to prevent agricultural lands from degradation in areas with soils under similar conditions.

1. Introduction

Soil properties are reflections of the dominant factors of soil formation such as parent material, climate, organism, relief, and time. The influence of these factors on soil is distinct but has interdependent effects on soil, and it is their combined effect that gives rise to distinct soil type. The knowledge of soil properties is very useful in determining soil characteristics, quality, and productivity.

The conversion of natural forest to cultivated land is a leading cause of soil degradation. It leads to reduction in soil fertility, variation in soil moisture and aeration, affects the activities of soil fauna, and leads to increase in soil erosion (Bossuyt et al., 1999). Ashagrie et al. (2007) opined that cultivation of soil for agricultural production leads to the rapid decomposition of soil organic carbon (SOC). This may in turn affect

many soil functions that are either directly or indirectly related to SOC. Fageria (2012) reported that reduction of SOC below critical level resulted in the destruction of soil structure, reduction in water holding capacity, decrease in soil aggregation and aeration, and increase in soil bulk density. A positive relationship was established between grain yield and SOC (Logah et al., 2011), indicating that the yield of grain can be adversely affected by the reduction in SOC. More than 75% of SOC has been depleted in soils of tropical ecosystems, and agricultural practice has been reported to be the leading cause (Lal, 2004). Agricultural activities, especially deforestation and continuous cultivation, have been reported to be the second-largest human-induced carbon emission source (Lal, 2016). This has a negative impact on climate change.

Soil requires proper management to sustain agricultural production, maintain environmental health (Ashenafi et al., 2010), and for overall

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economic growth (Muche et al., 2015). Conversion of natural forest to agricultural use leads to land degradation which has resulted in hunger, poverty, and conflicts (FAO, 2020a). In order to achieve the Sustainable Development Goal (SDG) number 15 (Ensure conservation, restoration and sustainable use of land resources), understanding the changes in soil properties as a result of land-use (especially for agriculture) is of great importance (Tellen and Yerima, 2018). This will guide policy interventions that aim at addressing land degradation. Sustainable management of soil is very important, especially in developing countries where the economy is primarily based on agricultural production (IFPRI, 2010). In Nigeria, the economy is being diversified from oil-based to agricultural-based amongst others. By doing this, more forests (most of which are secondary forests) will be converted to agricultural land. Thus, there is a need for proper soil management to prevent the land from degradation. Few researchers have addressed the implication of the conversion of forest to cropland over time in tropical Southwestern Nigeria. Being a rainforest agro-ecological zone, the dominant land-use types in this region are tree crop plantations and arable farms. This study focused on continuously cropped land, paddock, cacao (*Theobroma cacao*), oil palm (*Elaeis guineensis*), and teak (*Tectona grandis*) plantations while, secondary forest was used as a reference. The Southwestern region of Nigeria accounts for about 60% of the total cocoa production in the country, and cacao plantation covers more than 650,000 ha of land (Sanusi and Oluyole, 2005). According to Olagunju (2008), oil palm plantation covers an estimated area of 1.65 million hectares in the southern part of Nigeria, out of which the southwestern region accounts for more than half. As far back as 1998, Nigeria has been identified as one of the leading countries in teak production in Tropical Africa (Pandey, 1998), and teak plantation in Nigeria was predicted to increase geometrically (Ball et al., 1999). At present, the exact number of hectares occupied by teak plantation in Nigeria is not known. Akpan-Ebe (2017) however suggested that the plantation is likely to increase over the years due to increase in artificial afforestation. The majority of animal production is localized to the northern part of Nigeria. Herders often move towards the southern part of the country during the dry season in search of water and pasture. This often results into clashes between crop cultivating farmers and herders. Recently, the Federal Government of Nigeria concluded plans to establish confined grazing areas within the southern part of the country to prevent conflict reoccurrence. This will result in an increase in the establishment of paddocks within this region. The most continuously cultivated crop in Southwestern Nigeria is maize (*Zea mays*). According to FAO (2020b), about 7 million hectares of land in Nigerian are cultivated with maize, majority of which are in the southern part of the country. The need to investigate changes in soil properties under long-term agricultural land-use practices informed this study. This study broadens existing knowledge on soil properties under long-term land-use practices in Southwestern Nigeria. It will serve as a guide for future land management practices. Hence, the main objective of this study is to examine the differences in selected physical and chemical properties of the soil resulting from long-term agricultural land-use types.

2. Materials and methods

The study was carried out at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. It lies on approximately Latitudes 7° 54' 277" N and 7° 56' 074" N and Longitudes 4° 54' 155" E and 4° 55' 861" E with an altitude of about 244 m above mean sea level. It is within the rainforest ecosystem of the Southwestern part of Nigeria with a mean annual rainfall of about 1500 mm which is bimodal in distribution with peaks in June and September. The soil in the sample site was derived from coarse-grained granite and gneiss (Okusami and Oyediran, 1985), it is highly weathered and highly leached. The soil was locally mapped as Iwo Association by Smyth and Montgomery (1962) and classified as Ferric Acrisol using IUSS World Reference Base (WRB) (2015). Six land-use types were investigated for this study, they were;

paddock (PL), teak (*Tectona grandis*) plantation (TL), oil palm (*Elaeis guineensis*) plantation (OL), cacao (*Theobroma cacao*) plantation (CL), secondary forest (SFL) and continuously cropped land (CCL) (Figure 1). Each land-use type is described as follows:

- i. Paddock: It was established about 20 years before this study and it had been under sheep and goat grazing since then. The land is predominantly covered with grasses, mainly guinea grass (*Panicum maximum*) and shrubs; e.g. siam weed (*Chromolaena odorata*), goat weed (*Ageratum conyzoides*), prostrate globe-amaranth (*Gomphrena celosioides*), and legumes; mainly *Centrosema* spp.
- ii. Teak (*Tectona grandis*) plantation: It was established about 35 years before this study. The soil surface is covered with weeds such as; siam weed (*Chromolaena odorata*), khaki weed (*Alternanthera pungens*), haemorrhage plant (*Aspilia africana*), blackjack (*Bidens pilosa*), etc. These weeds are controlled by manual slashing. Tree climber plants are common in the plantation example of which are; loofah gourd (*Luffa cylindrica*) and African cucumber (*Momordica charantia*).
- iii. Oil palm (*Elaeis guineensis*) plantation: It was established about the same time as the teak plantation. Predominant weeds in this land-use are guinea grass (*Panicum maximum*), siam weed (*Chromolaena odorata*), haemorrhage plant (*Aspilia africana*), white-flowered haemorrhage plant (*Aspilia bussei*), etc. These weeds are constantly slashed by tractor-mounted slasher and occasionally controlled by herbicides.
- iv. Cacao (*Theobroma cacao*) plantation: This plantation has also been established about 35 years prior to this study. Weeds here are sparsely distributed which could be due to the cacao tree's dense canopy and the surface of the soil covered with leave litters. Some of the weeds present are silver bush (*Peperomia pellucida*), cock's comb (*Heliotropium indicum*), lesser round weed (*Hyptis brevipes*), broad sword fern (*Nephrolepis bisserata*), etc. These weeds are controlled by manual slashing.
- v. Secondary forest: The forest has been left undisturbed for over 35 years. It is composed of various species of trees such as *Baphia nitida*, *Teclea afzeli*, *Eucalyptus camaldulensis*, *Hura crepitans*, etc., shrubs such as false thistle (*Acanthus montanus*), climbing fern (*Stenochlaena palustris*), giant sensitive plant (*Mimosa invisa*), tropical nettle weed (*Laportea aestuans*), etc. and bushes such as Christmas bush (*Alchornea cordifolia*).
- vi. Continuously cropped land: The land had been tilled (to the depth of 15 cm) continuously every year for about 20 years using disk plough and harrows. It has been continuously cropped with maize (*Zea mays*). The application of fertilizer (urea and NPK) is constantly carried out. Weed control is mainly by the application of herbicides. Pesticide is used to control pests. The common weeds are guinea grass (*Panicum maximum*), prostrate globe-amaranth (*Gomphrena celosioides*), tridax (*Tridax procumbens*), finger grass (*Chloris pilosa*), torpedo grass (*Panicum repens*), siam weed (*Chromolaena odorata*), etc.

Each land-use type was divided into three based on its physiography unit into upper, middle, and lower slopes, with each unit serving as a pseudo-replicate (hereafter block). Soil sampling and *in-situ* determination of some physical parameters were randomly carried out within each block, and the number of measurements and samples from each block is described in the next two paragraphs.

Soil saturated hydraulic conductivity was measured using a Guelph permeameter. A dynamic cone penetrometer (UK DCP 2.2) with a 20 mm cone diameter and 60° angle was used to measure the soil strength, while the bulk density was determined using the cylindrical core method, the volume of the core was 101 cm³. These measurements were taken randomly on three different spots in each block of each land-use at 0–15 cm and 15–30 cm soil depth.

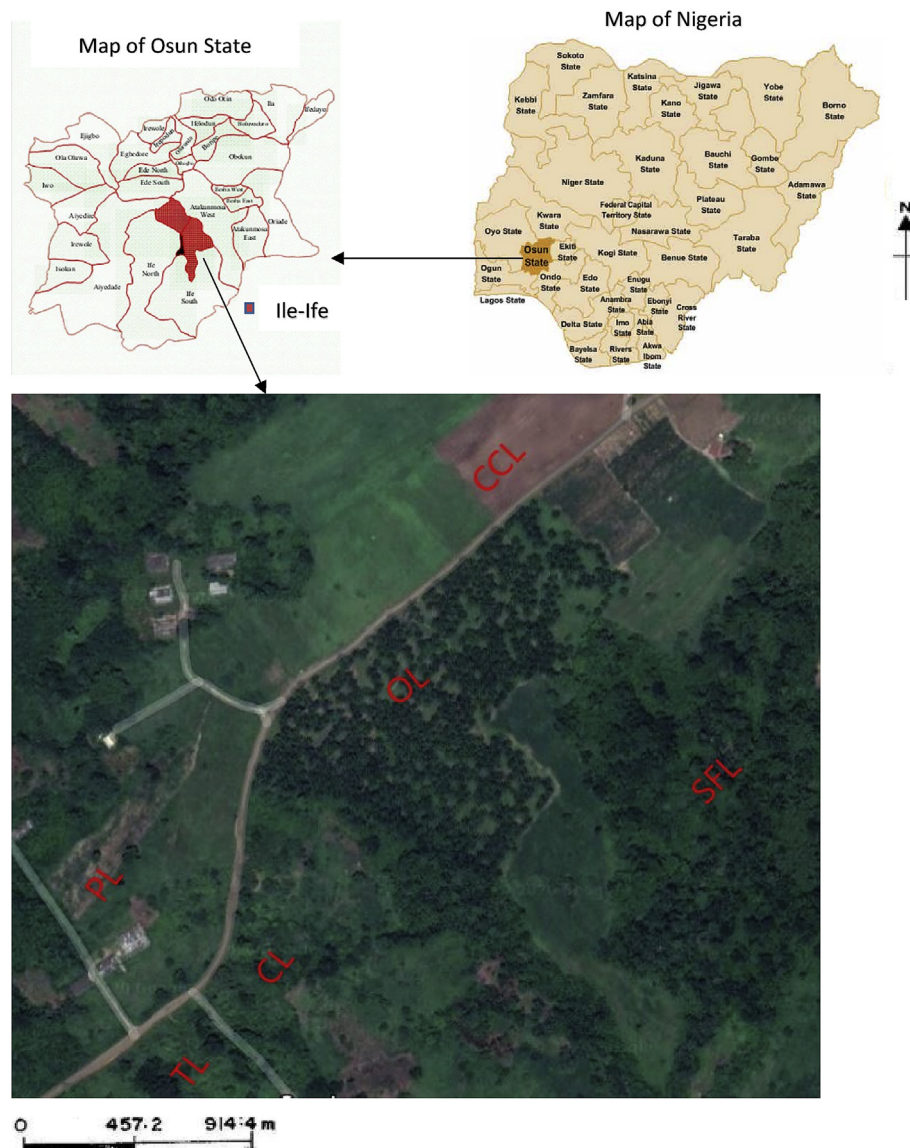


Figure 1. Satellite image of the Teaching and Research Farm Obafemi Awolowo University, Ile-Ife, Nigeria, showing the land-use types. PL = Paddock land-use, OL = Oil palm land-use, TL = Teak land-use, SFL = Secondary forest land-use, CL = Cacao land-use, CCL = Continuously cropped land-use.

Soil samples were collected from two depths (0–15 and 15–30 cm) from each land-use type. Ten samples were randomly collected from each block using a sampling tube. They were bulked, air dried, gently crushed, and sieved through 2 mm sieve. The following analyses were carried out on each soil sample: particle size distribution using modified hydrometer method (Gee and Or, 2002); soil aggregate stability by wet sieving method using a wet sieving apparatus (Eijkkelkamp, Agrisearch equipment, a Royal Eijkkelkamp Company, Art no.: 08.13); soil pH by digital pH meter (Walk lab Ti 9000) in a 2:1 0.01 M CaCl_2 solution to soil suspension; cations exchange capacity using 1 N NH_4OAc solution at pH 7 (Sumner and Miller, 1996); organic carbon by colorimetric method (Nelson and Sommers, 1996); total nitrogen by micro-Kjeldahl method (Bremner, 1996); and available phosphorus using Bray-1 method (Kuo, 1996). The data obtained were subjected to analysis of variance in a randomized complete block design, sources of variation were block, land-use, soil depth, and their interaction. Duncan's multiple range test was used to separate significant means at $p \leq 0.05$.

3. Results

3.1. Soil physical properties

The soils across the six types of land-use and the two depths were classified as sandy loam except for the surface soil (0–15 cm depth) of TL, surface and subsoil (15–30 cm depth) of CL, and the surface soil of PL (Table 1). The soil bulk density on the land-use types ranged from 0.94 g cm^{-3} to 1.55 g cm^{-3} in the 0–15 cm depth, and 1.40 g cm^{-3} to 1.63 g cm^{-3} in the 15–30 cm depth (Table 2). Continuously cropped land had the highest value at both soil depth (1.55 and 1.63 g cm^{-3} in 0–15 and 15–30 cm depth respectively). The soil strength (cone index) of the surface soil was significantly highest under OL (5.65 kg m^{-2}), SFL had the least (2.24 kg m^{-2}) which was not significantly different from that of CCL (2.71 kg m^{-2}) (Table 2). The land-use types had statistically similar soil strength in the subsoil with OL having the highest value (11.05 kg m^{-2}). The surface soil of SFL had the highest value of saturated hydraulic conductivity (K_{sat}) (0.022 cm s^{-1}) which though not significantly

Table 1. Soil particle size distribution for each land-use type at the two soil depths.

Land-use	0–15 cm				15–30 cm			
	Sand (g kg ⁻¹)	Silt (g kg ⁻¹)	Clay (g kg ⁻¹)	Textural class	Sand (g kg ⁻¹)	Silt (g kg ⁻¹)	Clay (g kg ⁻¹)	Textural class
PL	680e	60d	260a	Sandy clay loam	720d	80c	200c	Sandy loam
OL	730b	90c	180d	Sandy loam	780a	70d	150d	Sandy loam
TL	700d	110a	190c	Sandy loam	720d	70d	210b	Sandy clay loam
SFL	740a	100b	160e	Sandy loam	770b	90b	140e	Sandy loam
CL	660f	100b	240b	Sandy clay loam	560e	100a	340a	Sandy clay loam
CCL	720c	100b	180d	Sandy loam	740c	60b	200c	Sandy loam

PL = Paddock land-use, OL = Oil palm land-use, TL = Teak land-use, SFL = Secondary forest land-use, CL = Cacao land-use, CCL = Continuously cropped land-use. Means with the same alphabet on a column are not significantly different at 5% probability according to Duncan's Multiple Range Test. Ten samples were randomly collected from each of the three sampling block (replicate) to obtain the mean.

Table 2. Effect of land-use types on selected soil physical properties at two depths.

Land-use	0–15 cm				15–30 cm			
	Db (g cm ⁻³)	cone index (kg m ⁻²)	Ksat (cm s ⁻¹)	WSA (%)	Db (g cm ⁻³)	cone index (kg m ⁻²)	Ksat (cm s ⁻¹)	WSA (%)
PL	1.14c	4.02b	0.004b	81.07c	1.48ab	8.37a	0.014b	76.91b
OL	1.34b	5.65a	0.006b	90.02b	1.45b	11.05a	0.004b	89.03a
TL	1.12c	3.38bc	0.009b	94.23ab	1.45b	5.34a	0.003b	91.20a
SFL	1.04cd	2.24d	0.022a	95.77a	1.40b	5.39a	0.02a	75.24b
CL	0.94d	3.19bc	0.012a	80.69c	1.51ab	6.48a	0.002b	70.17bc
CCL	1.55a	2.71cd	0.020a	69.65d	1.63a	9.04a	0.002b	62.76c

PL = Paddock land-use, OL = Oil palm land-use, TL = Teak land-use, SFL = Secondary forest land-use, CL = Cacao land-use, CCL = Continuously cropped land-use, Db = Bulk density, Ksat = Saturated hydraulic conductivity, WSA = Water stable aggregate. Means with the same alphabet on a column are not significantly different at 5% probability according to Duncan's Multiple Range Test. Ten samples were randomly collected from each of the three sampling block (replicate) to obtain the mean.

different from that of CL (0.012 cm s⁻¹) and CCL (0.020 cm s⁻¹) (Table 2). At the soil subsurface, the Ksat of SFL (0.02 cm s⁻¹) was significantly the highest, while other land-use types were not significantly different from one another. The stability of soil aggregates under SFL was the greatest (95.77%) at the surface soil, though not significantly different from that of TL (94.23%) (Table 2). At the subsoil, soil aggregates of TL (91.20%) and OL (89.03%) were not significantly different from each other, and they were significantly more stable than others. Soil aggregates under CCL were least stable (69.65 and 62.76% at 0–15 and 15–30 cm soil depth respectively).

3.2. Soil chemical properties

The pH of the 0–15 cm soil depth ranged from 4.71 to 6.01, while that of 15–30 cm ranged from 4.64 to 5.76 (Table 3). Soil organic carbon (SOC) in the study area ranged from 3.9 to 17.0 g kg⁻¹ within the 0–15

cm depth, and from 3.5 to 7.6 g kg⁻¹ within the 15–30 cm depth (Table 3). The SOC in the land-use types were not statistically different from one another across the two depths except for CCL in the surface soil. The cation exchange capacity (CEC) of the land-use types ranged between 2.32 to 3.18 cmol kg⁻¹ in 0–15 cm depth, and 2.69–3.09 cmol kg⁻¹ in 15–30 cm depth (Table 3). Unexpectedly, the CEC under SFL (2.44 cmol kg⁻¹) along with TL (2.63 cmol kg⁻¹) and CCL (2.69 cmol kg⁻¹) were significantly lowest. However, the CEC was not significantly different across all the land-use types within 15–30 cm soil depth. The total soil nitrogen content (TN) of the land-use types ranged from 2.68 to 4.35 g kg⁻¹ in the 0–15 cm depth, and from 2.49 to 3.55 g kg⁻¹ in the 15–30 cm depth (Table 3). Within the 0–15 cm depth, PL (4.35 g kg⁻¹) and CCL (3.76 g kg⁻¹) had the significantly highest TN content. However, within 15–30 cm depth, the TN contents of the land-use types were not significantly different from one another. The available phosphorus (P) in the land-use types ranged from 4.13 to 7.60 mg kg⁻¹ within the 0–15

Table 3. Effect of land-use types on selected soil chemical properties at two depths.

Land-use	0–15 cm					15–30 cm				
	pH	SOC (g kg ⁻¹)	CEC (cmol kg ⁻¹)	TN (g kg ⁻¹)	Avail. P (mg kg ⁻¹)	pH	SOC (g kg ⁻¹)	CEC (cmol kg ⁻¹)	TN (g kg ⁻¹)	Avail. P (mg kg ⁻¹)
PL	5.28ab	10.47a	3.18a	4.35a	4.78bc	5.05b	5.00a	2.87a	3.23a	4.73b
OL	4.72b	7.10a	2.32c	3.09bc	4.13c	4.64b	5.23a	3.05a	2.49a	4.77b
TL	5.51ab	11.53a	2.63bc	3.40bc	5.61abc	5.16ab	4.97a	2.69a	3.55a	5.40b
SFL	5.85a	17.00a	2.44c	2.88c	6.49ab	5.76a	7.63a	2.69a	3.15a	5.86b
CL	6.01a	15.60a	3.05ab	2.68c	7.60a	5.24ab	3.53a	3.15a	2.82a	6.97a
CCL	4.71b	3.87b	2.69abc	3.76ab	7.39a	4.87b	4.70a	3.09a	3.29a	5.06b

PL = Paddock land-use, OL = Oil palm land-use, TL = Teak land-use, SFL = Secondary forest land-use, CL = Cacao land-use, CCL = Continuously cropped land-use, SOC = Soil organic carbon, CEC = Cation exchange capacity, TN = Total nitrogen, Avail. P = Available phosphorus. Means with the same alphabet on a column are not significantly different at 5% probability according to Duncan's Multiple Range Test. Ten samples were randomly collected from each of the three sampling block (replicate) to obtain the mean.

depth, and from 4.74 to 6.98 mg kg⁻¹ within the 15–30 cm depth (Table 3).

4. Discussion

4.1. Soil physical properties

The predominance of sandy loam soil under the land-use types is inherited from the parent material of the study area which is coarse-grained granite and gneiss (Okusami and Oyediran, 1985). The textural composition of soil is highly influenced by parent material (Oguike and Mbagwu, 2009). It is an inherent property of the soil that is not influenced over a short period of time (Kiflu and Beyene, 2013).

None of the soil bulk values density were above the critical value of 1.63 g cm⁻³ at which hindrance to root penetration and seed emergency are likely to occur (De-Geus, 1973). The high bulk density of soil under CCL could be resulting from compaction, due to traction and weight of machinery, and activities of individuals during cultivation and management (Tellen and Yerima, 2018). It could also be due to exposure of the land to agents of erosion that removed the less dense fine particles leaving behind coarse particles made up of heavier sand minerals. The result of this study corroborates the findings of Amusan et al. (2006), and Tellen and Yerima (2018) who both reported the highest bulk density for continuously cultivated plots. Emadi et al. (2008) investigated forest, pasture, and cropland land-use types, they reported that cropland had the highest bulk density. The increase in bulk density with increase in depth could be due to the reduction in organic matter, soil fauna activities, and pore space distribution as the soil depth increases, and compression of soil trapped between growing plant roots (Singh et al., 2015).

The high soil strength under OL could be due to the fibrous root nature of oil palm which holds the soil closely packed, thereby, compressing it (Singh et al., 2015). Mature roots might also physically impede the drive of the penetrometer. The lower cone penetrometer resistance values under SFL could be due to less disturbance, low bulk density, high organic carbon content, and possibly higher activities of soil fauna (this was not measured). Despite its high bulk density and low organic carbon content, the low soil strength observed under CCL could be as a result of soil pulverization during land preparation which has led to the loss of clay minerals that are capable of binding the soil particles together (to agents of erosion) plus attendant less coherent soil. It was however observed that the penetrometer resistance increased with the increase in soil depth confirming the reports of Chen and Tessier (1997), Doan et al. (2005), and Shittu et al. (2017).

The high Ksat value in surface soils of SFL and CL could be linked to their higher organic matter contents and activities of soil fauna (this was not measured) which would have contributed to the development of more macropores. Macroporosity causes the hydraulic conductivity to increase and reflects the drainage level of a given soil (Heard et al., 1988). The high value of Ksat under CCL could be as a result of loose, less coherent, and structureless nature of the soil due to soil pulverization during tillage operations. This might have increased the soil macropores and consequently, higher drainage. These findings confirmed the reports of Nwite (2015) and Amanze et al. (2017); who both reported high Ksat for cultivated soils.

The aggregate stability test revealed more stable soil aggregates in soils under forest and tree crops. This could be due to minimal disturbance (Six et al., 1998; Oyedele et al., 1999) and higher SOC (Puget and Drinkwater, 2001) in these land-use types. In addition, the fibrous root nature of OL might exert a positive effect on its aggregate stability. Physical disturbances such as during tillage activities and low SOC can be suggested as the reason for low soil aggregate stability under CCL. The result of this study corroborates the findings of Shittu and Amusan (2015) who observed better soil aggregation in land management with improved SOC content. It also corroborates Kalhoro et al. (2017) who found less disturbed soils to be of better aggregation than highly disturbed soils. Generally, the observed variation in soil aggregate

stability across the two depths could be due to the effect of the rooting systems (Angers and Caron, 1998), type of soil organisms present and their activities (Bignell and Holt, 2002), or the presence of SOC in quantity and forms (Shein and Milanovskii, 2003).

4.2. Soil chemical properties

Based on the classification of Adepetu et al. (2014), the pH across the land-use types and at the two soil depths ranges between very slightly acidic to strongly acidic levels. This is probably due to the acidic nature of the highly weathered and leached soil. The strongly acidic soil under CCL could be because of frequent application of acidic fertilizer and intensive cultivation leading to prolonged uptakes of basic cations (Tegenu et al., 2008). Amusan et al. (2006) reported a similar pH range for soils of the study area. The result of this study agrees with the findings of Muche et al. (2015) who reported the pH of cultivated land to be more acidic than the other land-use types they investigated. They mentioned factors such as poorly managed cultivation, inappropriate use of ammonium-based fertilizers, and accelerated erosions as the probable cause.

The SOC content across the land-use types was within low to medium class of organic carbon content in the soil, as classified by Adepetu (1990). It however, appeared that the higher the amount of litter produced under a land-use type, the higher the SOC. Consequently, SFL and CL had higher values of SOC. Amusan et al. (2006) observed a similar trend in their study, they reported the lowest SOC content in the cultivated plot. Jamala and Oke (2013) reported 8% and 15% higher SOC under natural forest compared with cropped land and fallow land respectively. The result of this study agrees with other studies that land-use type can markedly affect SOC content (Houghton, 2003; Li et al., 2014; Alcantara et al., 2016).

The CEC falls within the classification range of very low, as classified by Adepetu et al. (2014). This can be attributed to the kaolinitic nature of the soils of this area. The unexpected trend the CEC content followed (especially in the surface soil) could inform further studies into the mineralogy of the clay present across the land-use types and other factors that affects CEC. Cation exchange capacity has been established to increase and decrease with SOC content (Kiflu and Beyene, 2013). Further, continuous cultivation and the use of acidic inorganic fertilizers have been reported to deplete the CEC of continuously cropped land-use (Wakene and Heluf, 2003). Factors such as leaching, low content of basic cations in the parent material, and proportion of clay (Muche et al., 2015) might have contributed to the variation in the CEC of this study. Earlier studies have shown that land-use type influences the CEC of soils (Awdenigest et al., 2013; Muche et al., 2015). Tellen and Yerima (2018) conducted a study in the Northwestern region of Cameroon, they did not find significant difference in the CEC of the six land-use types (natural forest, natural savanna, grazing land, afforested land, farmland, and Eucalyptus plantation), even though the values were numerically different.

The total nitrogen (TN) content of the land-use types was found to be high based on the classification of Adepetu (1990). This implies that nitrogen is not a limiting factor for plant growth in the study area. The high TN in PL could be attributed to animal waste (faeces and urine) containing high amount of nitrogen (McNaughton et al., 1997), while that of CCL can be attributed to the continuous application of nitrogen-based fertilizer. This result contradicts the findings of Tellen and Yerima (2018) who in a similar study reported that land-use types did not significantly influence total nitrogen. It is however in agreement with the findings of Emadi et al. (2008), Kiflu and Beyene (2013), and Muche et al. (2015), who reported significant variations in soil total nitrogen with land-use type.

Available soil P content in all the land-use types falls into the low range class, as classified by Adepetu (1990) for soils of the area. This substantiates previous findings (Dawit et al., 2002) that reported that acidic soils were deficient in available P. The continuously cropped land

(CCL) had higher value of available P which could be attributed to the continuous application of P-based fertilizer. This is similar to the observation of Tellen and Yerima (2018) who reported the highest value of available P in farming land-use.

In summary, twenty years of continuous cultivation in the study area significantly reduced soil's physical and chemical qualities compared to the uncultivated secondary forest. This is demonstrated by reduced nutrient and SOC contents, increased soil compaction, and increased soil acidity. Thus, liming and soil amendment with organic manure would be needed to restore and sustain the soil's productivity. The soil properties under tree crop cultivation compared favourably with the undisturbed secondary forest, implying that the forest could be successfully converted to economic trees cultivation (oil palm, cacao, and teak) without negatively impacting the soil properties. Moreover, cacao cultivation improved SOC and soil bulk density over the undisturbed secondary forest.

5. Conclusion

This study aimed at assessing the differences in selected physical and chemical properties of the soil resulting from long-term agricultural land-use types in Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. Although there are limitations due to the selected soil properties, the number of land-use considered, depth of sampling (0–15 cm and 15–30 cm), and years of establishment of the land-use types, nevertheless, the study has important managerial implications. The findings showed that about 20 years of continuous cultivation with conventional tillage practices significantly degraded soil physical properties, SOC, and soil fertility. Soil conservation measures such as manuring, mulching, and conservation tillage should be adopted to improve the soil properties. Also, the conversion of forest to continuous arable agricultural land further increased the soil's acidity and will require soil liming and application of P-based fertilizer to maintain or improve the soils' productivity. However, the physical and chemical properties (except soil CEC) of the soils under long-term afforestation with teak, oil palm, and cacao compared favourably with long-term native secondary forest. Thus, instead of leaving the land to native fallow, planting of the studied economic crops on this soil will not negatively impact its quality.

Declarations

Author contribution statement

Bamikole Peter Akinde, Abiodun Ojo Olakayode: Performed the experiments; Analyzed and interpreted the data; Contributed analysis tools or data; Wrote the paper.

Durodoluwa Joseph Oyedele, Fatai Oladapo Tijani: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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