Responses of Selected Soil Properties to Mixed Tree Plantation and Cassava Land Use in Southern Nigeria

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Abstract

Responses of some selected soil properties to mixed tree plantation and cassava land use in southern Nigeria were evaluated in this study. The objectives were to examine variations in the selected soil properties among the different agricultural land use types; ascertain relationships between the soil properties; and evaluate cause-effect relationships between the soil properties. A total of 54 soil samples at 0-15 and 15-30 cm depths were collected from mixed tree plantation, cassava land use and secondary forest using transect sampling method. Soil samples were analysed for selected physical, chemical and biological properties following standard laboratory methods. The results revealed significant variations ($p \leq 0.05$) in the values of sand, silt, bulk density (BD), total porosity (TP), pH, total heterotrophic bacteria counts (THB) and total heterotrophic fungi counts (THF) in soils of the three land use types. The values of BD and TP did not exceed the respective critical limits of 1.75 g cm^{-3} and 40% for productive soils. However, pH, available phosphorous (Avail. P), soil organic carbon (SOC), soil organic matter (SOM), THB and THF responded negatively to mixed tree and cassava cultivation in the 0-15 cm soil depth as their values were lower than that of the control site. Significant positive (e.g., silt versus SOM/SOC/TN/Avail. P, and TP versus pH) and negative (e.g., clay versus SOC/SOM/Avail. P) relationships as well as significant cause and effect relationships (such as Avail. P versus silt/clay/TP/SOC/SOM/TN) were observed between some of the soil properties across the three land use types and soil depths. The study concluded that the examined soil quality indicators responded differently to the evaluated land use types.

Key words: cassava, land use type, mixed tree plantation, Odighi, response, soil properties

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Introduction

Scholars have argued that the physical, chemical and biological properties of soil respond differently to natural and anthropogenic activities (Tellen & Yerima, 2018; Mulat et al., 2021). Whereas the natural factors are associated with the underlying parent materials, the anthropogenic factors are linked with the dominant land use type which could be industrial, municipal or agricultural land uses. Soil degradation caused by inappropriate land use practices is a major global challenge that has attracted considerable critical attention in the quest for sustainable agriculture. The rapidly increasing human population and the attendant socio-economic needs put pressure on land resulting in unplanned land use changes, which may lead to the loss of soil nutrients. Land use change from forests to plantations and arable lands are widespread activities in Nigeria and this may degrade the soil physical, chemical and biological properties (Kerenku & Orkpe, 2017). Such land use changes are prevalent particularly in the lowland tropical rainforest areas where there is a high population density that depends directly on the exploration and exploitation of the land resources. Soil is therefore a major direct recipient of human actions which have led to a decline in soil quality, low agricultural yield and subsequently food insecurity in the country (Onwuka et al., 2020).

Most farming challenges especially in sub-Sahara Africa hinge on poor understanding of the impacts of different land use types on soil quality. The physical, chemical and biological properties of soils under intensive cultivation could vary from that which remains uncultivated for a long period of time (Gebreyohannes, 2001). During crop production, soil chemical nutrients are lost through crop harvesting resulting in declining soil quality. Guo et al. (2016) reported that land use change may negatively affect the composition of soil microbes (e.g., bacteria and fungi) which are essential for the maintenance of soil and plant productivity by altering the quality and quantity of litter in the soil. Thus, land use cover is a critical component of our ecosystem leading to natural increase in soil quality and enhanced biological community. Ritz et al. (2009) opined that the physical and chemical properties of soil are important in determining soil quality, however, some soil processes are driven by biological properties of the soil which respond rapidly to changes in land use. In preventing soil deterioration, empirical data on the physical, chemical and biological properties of soil under different land use types are very important in designing appropriate agricultural land use types and soil management measures. Therefore, soil physical, chemical and biological indicators have been recommended as key parameters for estimating the impact of different land use types on soil quality. This approach has been used by several scholars (Orobator & Ekpenkhio, 2021; Mulat et al., 2021; Ekpenkhio, 2022; Ugwa et al., 2022) to examine the impact of different land use types on soil quality in tropical environments.

Several scholars (e.g., Tellen & Yerima, 2018; Ekpenkhio, 2018; Tesfahunegn & Gebru, 2020; Kebebew et al., 2022) have investigated the effects of different agricultural land use types on soil properties. Some compared the impact of monocropped plantations on soil properties (Ugwa et al., 2016; Ota et al., 2019), while others such as Kerenku and Orkpe (2017) and Adebayo et al. (2018) examined soil properties solely under arable land use. These workers reported significant changes in some soil quality indicators. However, they did not examine the responses of some selected physical, chemical and biological properties of soil to mixed tree plantation and cassava land use specifically. Despite the growing interest in developing more sustainable agricultural land use types, soil biological analysis remains a largely neglected area of research (Jemal, 2020). There is limited empirical data of soil microbial population under different agricultural land use types in the humid tropical southern Nigeria. This study will add to the body of knowledge in soil science and serve as a scientific base for subsequent enquiries in similar agro-ecological environments. This research was limited to three agricultural land use types; mixed tree plantation, cassava land use and secondary forest in Odighi, Edo State because they give a good representation of mixed permanent and annual arable cropping land use types in southern Nigeria. This research used some selected soil physical, chemical and biological properties as key indicators of soil quality under the influence of the three land use types. Soil quality varies with soil depth, therefore this study was also based on assessing the quality of soils at both the upper soil (0-15 cm) and lower soil (15-30 cm) layers of each land use respectively. The objectives of the study were to; (i) examine variations in the soil properties among the different agricultural land use types, (ii) ascertain relationships between the soil properties, and (iii) evaluate cause and effect relationships between the soil properties.

Materials and Methods

Study area

Odighi community in Ovia North-East Local Government Area, Edo State, Nigeria (Figure 1) was chosen for this study because it is predominantly an agrarian community that is subject to different agricultural land use types. Odighi is located within the geographical coordinates of Latitudes 6° 37' 5.24" N to 6° 36' 46.97" N and Longitudes 5° 45' 53.88" E to 5° 45' 49.16" E. The general relief of the area is a plain, varying between 220 and 250 m above sea level. Odighi, which is approximately 37 km from the State capital (Benin City), possess similar climatic characteristics and is located within the lowland tropical rainforest area of southern Nigeria. This area experiences the typical rainforest zone climate with two distinct seasons: the rainy and dry seasons. Mean annual rainfall in Odighi vary between 2040 and 2500 mm while the average annual temperature varies between 22.5 and 31.2 °C (Odjugo, 2012). The soils in Odighi are classified as Typic Kandiudults with deep sandy horizons while the dominant soil type is Ultisol (Okoro et al., 2000). Although the area is located within the rain forest vegetation, typical of multi-layered high tropical forest with thick plant life, human activities such as logging and farming are fast depleting this natural vegetation.

Figure 1: Odighi community in Ovia North-East Local Government Area, Edo State, Nigeria

Sources: Esri, Garmin, USGS and Geospatial Links Company (2022)

Soil sampling

Plots under two different agricultural land use types: mixed tree plantation; comprised of gmelina (*Gmelina arborea* Roxb.) and teak (*Tectona grandis* L. f.) species, and cassava (*Manihot esculenta* Crantz) land use were identified as treatment sites in the study area. Part of the study area that is relatively undisturbed (secondary forest) was identified as the control site (Figure 2). The mixed tree plantation has been under cultivation for about 10-15 years. The cassava land use was between 7 and 10-year-old continuous cultivation while the secondary forest was 25 years old and above. A 100 m × 100 m sample area was mapped out at the centre of each site and three transects of 100 m each and at intervals of 25 m were laid on each sample area. Soil samples were collected from three sampling points at intervals of 50 m along each transect, and at the 0-15 and 15-30 cm soil depths in each of the three sample areas using a soil auger. The 0-15 and 15-30 cm soil depths were preferred for this investigation because the greatest abundance of plant roots, biological activities as well as the highest nutrient levels occur within these depths being the major recipient of plant litter, soil organic matter and nutrient cycling (Kummerow et al., 1982; De Oliveira and Valle, 1990). Altogether, 18 soil samples were collected from each site thereby giving a total of 54 soil samples. The study sites had similar soil forming environment in respect of parent materials, topography and macro-climatic conditions but differed in their respective agricultural land use types and soil management practices. During soil sampling, unusual areas such as eroded sections and furrows were avoided to prevent contamination of the soil samples.

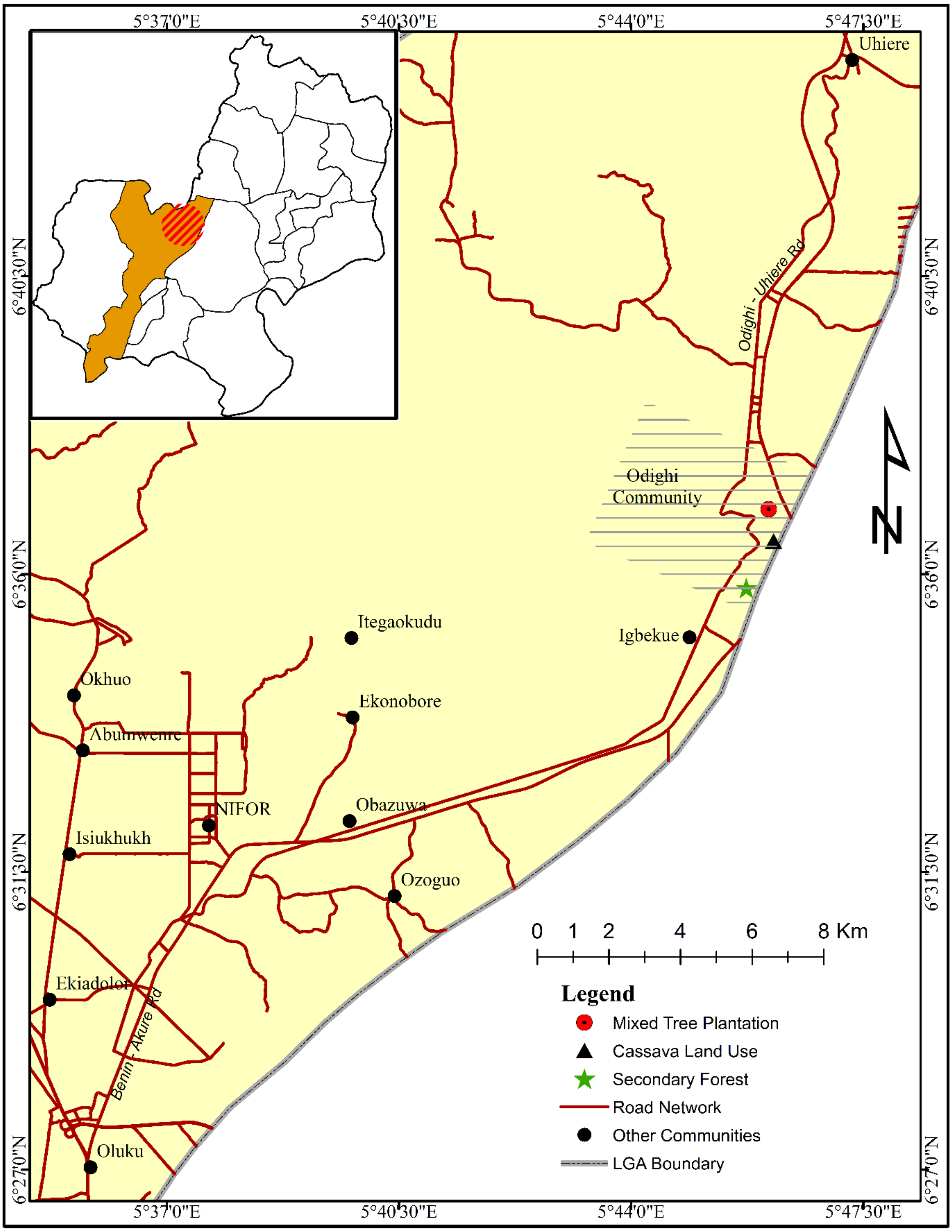

Figure 2: Odighi community showing the three land uses

Sources: Esri, Garmin, USGS and Geospatial Links Company (2022)

Soil laboratory analysis

Soil texture was analysed using the hydrometer method (Bouyoucos, 1962). Bulk density was determined from undisturbed soil samples using core method (Black and Hartge, 1986). Undisturbed soil samples were collected at 0-15 and 15-30 cm soil depths respectively from each sampling point and land use type, oven-dried and weighed. The bulk density was thereafter computed using the formula: bulk density = dry weight (g) / volume (cm^{-3}). The total porosity of soil samples was calculated from the values of bulk density (BD) and particle density (PD) using the formula: percentage pore space = [1 - (BD / PD)] × 100. The average PD of mineral soils which is 2.65 g cm^{-3} (Brady & Weil, 2007) was used for computation. Soil pH was measured in 1:1 (soil to water), using a glass electrode pH meter. The micro-Kjedahl procedure was used to determine the concentration of total nitrogen, while available phosphorous was measured following Bray II method (Lindsay & Norvell, 1978). Walkey-Black wet oxidation procedure modified by Nelson and Sommers, (1982) was used to determine soil organic carbon whose values were multiplied by the Van Bemmelen conversion factor (1.7240) to estimate soil organic matter (Heaton et al., 2016). Enumeration of the viable bacterial and fungal population of the soil samples as per the total heterotrophic bacteria counts and total heterotrophic fungi counts were carried out by pour-plating of 0.1 ml of the appropriate soil dilution (10^{-6}) on nutrient agar plates. Inoculated plates were incubated for 24 hours at 30 °C and the microbial load was determined as a colony forming units (cfu g^{-1}) in each sample (Phil-Eze, 2010).

Data analysis

Data were analysed in the IBM SPSS version 16 and Microsoft Excel for both descriptive and inferential statistics. Range, mean, standard deviation (SD) and coefficient of variation (CV) were computed for all the soil quality indicators across land use types and soil depths. Wilding (1985) classification scheme was used to assess variability of soil properties in which CV values < 15, 15 to 35 and > 35 % indicated low, moderate and high variation respectively. The permissible limits for selected soil properties (Table 1) were used to determine the status and quality index values of the soil properties. Analysis of variance (ANOVA) was used to test for variations in the soil properties among the three land use types. Pearson product-moment correlation was tabulated to identify relationships between the soil properties while multiple regression was used to determine cause-effect relationships between the soil properties at the 0.05 level of significance.

Table 1. Permissible limits for selected soil properties

Soil property	Very low	Low	Moderate	High	Very high
Total porosity (%)	< 2	2 - 5	5 - 15	15 - 40	> 40
pH		< 5.5	5.5 - 7.0	> 7.0	
Soil organic matter (g kg^{-1})		< 4	4 - 10	> 10	
Soil organic carbon (g kg^{-1})		< 1	1 - 5	> 5	
Total nitrogen (g kg^{-1})	< 0.1	0.1 - 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Available Phosphorous (mg kg^{-1})		< 8	8 - 20	>20	

Source: National Special Programme for Food Security, Federal Ministry of Agriculture and Rural Development (NSPFS, 2004); Food and Agriculture Organization of the United Nations (FAO, 2006).

Results and Discussion

Effects of land use types on the selected soil properties

Soil physical properties

Table 2 revealed that the soils in all the examined land uses and soil depths were dominated by sand fractions. However, they cannot be classified as sandy soils because their respective mean values were less than 700 g kg^{-1} (Brito-Vega et al., 2018). Soil textures were mainly sandy clay loam, loam and sandy loam for mixed tree plantation, cassava land use and secondary forest respectively. Soils under mixed tree plantation contained more sand fractions at both 0-15

(601.11 g kg^{-1}) and 15-30 cm (647.77 g kg^{-1}) soil depths than in the other two land uses. This change may suggest that the examined land use types are on different soil types. It could also be attributed to the high precipitation that promotes illuviation of clay and silt particles below the 15-30 cm soil depth in the study area. Differences in mean sand values among the three land uses may have accounted for the significant variations detected in both soil depths (Table 2). Similar results were reported by Ota et al. (2019).

The values of silt were significantly higher ($p \leq 0.05$) under cassava land use both in the 0-15 (336.66 g kg^{-1}) and 15-30 cm (350 g kg^{-1}) soil depths (Table 2). This may be due to agronomic practices undertaken in this land use. However, silt may have been eroded to have recorded low values in soils of mixed tree plantation. This result is inconsistent with the work of Onwudike et al. (2016) who observed insignificant effect of cassava and maize cultivation on silt contents. The values of clay contents were generally low in all the soil samples as their mean values were less than 250 g kg^{-1} (Table 2). Clay increased with increasing soil depth in mixed tree plantation and cassava land use. This connotes that their lower soil layers were finer in texture than the respective upper soil layers. This is most likely an indication of clay migration from the upper soil layer to the lower soil layer through illuviation and elluviation processes. This finding is not surprising since the study area is located within the tropical rain forest characterized by consistently heavy rainfall. Similar results were reported by Ugwa et al. (2016).

Table 2: Variations in the soil physical properties as affected by mixed tree plantation, cassava land use and secondary forest

Soil property	Depth (cm)	Mixed tree plantation				Cassava land use				Secondary forest				*p*-value
		Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	
Sand (g kg^{-1})	0 - 15	500 - 680	601.11	66.41	11.04	350 - 500	444.44	46.39	10.43	450 - 700	544.44	84.57	15.53	0.00*
	15 - 30	500 - 780	647.77	82.42	12.72	350 - 500	416.66	55.90	13.41	500 - 720	596.66	84.26	14.12	0.00*
Silt (g kg^{-1})	0 - 15	40 - 300	223.33	93.27	41.76	200 - 450	336.66	83.51	24.81	200 - 350	283.33	55.90	19.74	0.02*
	15 - 30	20 - 250	110.00	82.46	74.96	200 - 450	350.00	75.00	21.42	100 - 350	238.88	69.72	29.18	0.00*
Clay (g kg^{-1})	0 - 15	100 - 280	175.55	57.03	32.48	100 - 350	218.88	82.68	37.77	100 - 200	172.22	36.32	21.09	0.22
	15 - 30	200 - 280	242.22	25.87	10.68	100 - 450	233.33	96.82	41.49	100 - 200	153.33	36.74	23.96	0.00*
BD (g cm^{-3})	0 - 15	1.47 - 1.66	1.53	0.06	4.17	1.47 - 1.66	1.52	0.08	5.29	1.51 - 1.85	1.68	0.11	7.13	0.00*
	15 - 30	1.47 - 1.72	1.54	0.07	4.96	1.47 - 1.72	1.56	0.09	5.95	1.47 - 1.85	1.66	0.12	7.32	0.02*
TP (%)	0 - 15	37 - 45	42.11	2.66	6.33	37 - 45	42.78	3.38	7.91	31 - 43	36.78	4.17	11.36	0.00*
	15 - 30	35 - 45	42.11	3.01	7.17	35 - 45	41.00	3.74	9.13	31 - 45	37.22	4.52	12.15	0.03*

There was significant effect ($p \leq 0.05$) of land uses and soil depths on BD (Table 2). The highest mean BD value (1.68 g cm^{-3}) recorded in secondary forest is an indication of higher soil compaction probably due to timber harvest and other associated anthropogenic activities in the forest. Brady & Weil (2007) argued that forest ecosystem function is sensitive to increase in BD and that timber harvest compacts between 20 and 40% of forest soils. The mean BD value (1.52 g cm^{-3}) recorded in 0-15 cm of cassava land use could be due to regular manual tillage leading to soil loosening. Bulk density values of all the soils were lower than the critical limit (1.75 g cm^{-3}) for sand dominated soils as described by Arshad & Martin (2002). Bulk density values above this critical limit may inhibit plant root growth and penetration, movement of soil moisture and air as well as disrupt biological activities within the soil. The ecological implication of this finding is that there is no hard pan layer that can mechanically impede plant root growth and penetration induced by the respective land use types.

Unlike in the work of Jemal (2020), total porosity (TP) in this study was significantly impacted ($p \leq 0.05$) by the different land uses and soil depths with lower mean values observed in both soil layers of secondary forest (Table 2). Using the FAO (2006) classification of total porosity, the mean TP values recorded in all the test soils are classified as high to very high. Such TP values less than 40% are unsatisfactory for crop production (Essoka & Esu, 2003). Therefore, soils in mixed tree plantation and cassava land use are more porous and favorable to aeration and free water movements than in secondary forest. The significant variations ($p \leq 0.05$) of TP among the land uses and soil depths may be ascribed to variances in soil organic matter contents and earthworms that play important roles in decomposition of organic materials.

Soil chemical and biological properties

Results of the impact of the different land use types and soil depths on soil chemical and microbial properties are presented in Table 3. pH exhibited significant interaction effects with the land uses and soil depths ($p \leq 0.05$). pH values declined as soil depth increased in both mixed tree plantation and cassava land use. These values were rated as slightly acidic (Foth & Ellis, 1997). The lower pH values recorded in cassava land use may be attributed to intensive cultivation of the soil which increases water infiltration, run off and leaching of basic cations. However, this pH status is acceptable for crop cultivation in the tropics where the soil may be subjected to regular leaching of bases and often replenished by crop residues. These pH values suggest that the soils in the three land uses are suitable for agricultural use (Brito-Vega et al., 2018).

Table 3: Variations in the soil chemical and biological properties as affected by mixed tree plantation, cassava land use and secondary forest

Soil property	Depth (cm)	Mixed tree plantation				Cassava land use				Secondary forest				*p* - value
		Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	
pH	0 - 15	5.80 - 6.80	6.34	0.28	4.53	6.00 - 6.90	6.48	0.27	4.21	6.60 - 7.60	6.96	0.30	4.32	0.00*
	15 - 30	5.70 - 6.60	6.12	0.25	4.15	5.40 - 6.90	6.12	0.53	8.71	6.90 - 7.90	7.31	0.34	4.66	0.00*
SOC (g kg^{-1})	0 - 15	2.09 - 4.90	3.29	0.94	28.64	2.55 - 4.41	3.39	0.69	20.63	2.44 - 4.55	3.54	0.73	20.93	0.82
	15 - 30	2.50 - 4.41	3.29	0.78	23.93	2.78 - 4.65	3.64	0.72	19.86	1.40 - 5.49	2.98	1.38	46.33	0.40
SOM (g kg^{-1})	0 - 15	3.61 - 8.45	5.68	1.62	28.64	4.40 - 7.60	5.83	1.20	20.60	4.20 - 7.83	6.09	1.27	20.90	0.82
	15 - 30	4.30 - 7.60	5.67	1.35	23.94	4.79 - 8.02	6.27	1.24	19.90	2.41 - 9.45	4.73	2.00	42.49	0.13
TN (g kg^{-1})	0 - 15	0.14 - 0.35	0.23	0.06	30.25	0.18 - 0.31	0.24	0.04	21.02	0.10 - 0.31	0.22	0.06	29.40	0.92
	15 - 30	0.18 - 0.31	0.23	0.05	22.37	0.19 - 0.33	0.25	0.05	22.50	0.10 - 0.39	0.19	0.0	43.28	0.19
Avail. P (mg kg^{-1})	0 - 15	3.84 - 8.80	5.63	1.78	31.77	4.05 - 8.20	5.86	1.47	25.22	3.84 - 8.12	6.14	1.62	26.49	0.80
	15 - 30	4.01 - 7.60	5.48	1.55	28.44	4.30 - 8.20	6.16	1.40	22.74	2.40 - 9.52	4.73	2.03	28.44	0.22
THB (× 10^{-6} cfu g^{-1})	0 - 15	0.26 - 1.50	0.85	0.44	52.07	0.84 - 2.20	1.54	0.51	33.56	1.02 - 2.24	1.66	0.51	31.07	0.00*
	15 - 30	1.20 - 0.28	0.81	0.50	62.44	0.58 - 5.20	1.82	1.37	75.54	0.18 - 5.00	1.34	1.42	106.40	0.21
THF (× 10^{-6} cfu g^{-1})	0 - 15	2.20 - 0.60	1.77	0.82	46.50	1.60 - 4.20	2.88	0.75	26.34	2.00 - 4.10	3.12	0.63	20.37	0.00*
	15 - 30	0.80 - 3.40	2.02	1.06	52.50	1.20 - 3.10	2.19	0.76	34.98	1.60 - 9.00	2.96	2.31	78.44	0.40

The concentration of SOC in cassava land use increased as soil depth increased (Table 3). This infers that cassava crop absorbed organic carbon more from the upper soil layer than the lower soil layer. Comparatively, the non-significant lower SOC value found in the upper soil layer of cassava land use (3.39 g kg^{-1}) than secondary forest (3.54 g kg^{-1}) may be due to continuous cassava cultivation that aggravate organic carbon loss. On the other hand, the high SOC values in secondary forest may be due to accumulation and decomposition of litter from below- and above- ground plant biomass. This finding corroborates Woldeamlak & Stroosnijder (2003) who observed a decline in SOC concentrations after conversion of forested land to agricultural land. The similar mean SOC values may have accounted for the insignificant variation ($p >$

0.05), implying non-effect of the land uses and soil depths on SOC. Generally, the values of SOC in all the soils of the investigated land uses were moderate as they were between 1 and 5 g kg^{-1}.

Table 3 reveals that the higher SOM mean value found in 0-15 cm of secondary forest (6.09 g kg^{-1}) compared to the other land uses may be due to the high rate of litter fall and decomposition. More nutrients may have been stored in the upper soil layer of secondary forest than in the other land uses. This finding is in agreement with the investigation of Kerenku & Orkpe (2017) who reported high SOM values in forested land compared to cultivated land. Inversely, continuous cropping, which increases soil aeration and rapid loss of SOM may have contributed to the low SOM values recorded in 0-15 cm depth of mixed tree plantation (5.68 g kg^{-1}) and cassava land use (5.83 g kg^{-1}). This means that SOM responded negatively to mixed tree and cassava cultivation in this soil layer. It could also be implied that the insufficient inputs of organic substrate from cassava land use due to residue removal and zero crop rotation may have caused low levels of SOM. The concentrations of SOM in all the evaluated land use types and soil depths were within adequate and permissible limits.

Total nitrogen (TN) responded positively to cassava cultivation as higher mean values were recorded in the upper (0.24 g kg^{-1}) and lower (0.25 g kg^{-1}) soil layers compared to the other land uses (Table 3). This outcome may be related to the presence of SOM as it is a major source of TN in soils (Adejuwon & Adesina, 2004). Since SOM was higher in the lower soil layer of cassava land use, TN was expected to show a similar trend. The reduction of TN values as soil depth increased in secondary forest agrees with the observations of Gbadegesin et al. (2011) who attributed this decrease to declining humus with depth. The concentrations of total nitrogen in all the evaluated land use types were within moderate range. Available phosphorous (Avail. P) declined as soil depth increased in all the land uses except in cassava land use. The higher Avail. P mean values found in cassava land use than in mixed tree plantation may possibly be due to the residue ash arising from the dominant slash and burn method of land preparation prior cultivation which enhances the concentrations of available phosphorous. However, concentrations of Avail. P in all the soils was very low as they were less than 8 g kg^{-1}. Following the pattern of soil microbial properties, the total heterotrophic bacteria (THB) counts found in 0-15 cm of secondary forest were significantly higher than the other land use types ($p \leq 0.05$). This may be attributable to the high concentrations of SOC in this depth. Pereg et al. (2018) asserted that higher SOC concentrations support greater bacterial abundance. Similarly, the total heterotrophic fungi count in the upper soil layer of secondary forest was significantly higher ($p \leq 0.05$) compared to the other land uses. Benitez et al. (2006) and Orimoloye et al. (2012) observed that soils developed under organic management generally present greater biological activities than those under integrated or conventional cultivation.

Relationships between the selected physical versus chemical or biological soil properties

Arshad & Martin (2002) opined that soil properties interrelate with one another hence, the value of one is influenced by one or more of the other properties. As shown in Table 4, significant relationships were observed between some soil physical versus chemical or biological properties. For instance, in 15-30 cm soil depth of mixed tree plantation, significant positive correlations were observed between silt versus SOM/SOC/TN/Avail. P; and TP versus pH. This infers that as silt content increased, there was a corresponding increase in SOM, SOC, TN and Avail. P, and that the soil became more alkaline with increased pore spaces. On the other hand, significant negative correlations were observed between sand versus SOC/SOM/TN/Avail. P; and BD versus pH. In 0-15 cm soil depth of cassava land use, significant positive relationships were detected for silt versus SOC/SOM/TN/Avail. P while significant negative associations were observed between clay versus SOC/SOM/TN/Avail. P; and TP versus pH. In the 15-30 cm soil depth, significant positive correlations were observed between THB versus clay; and THF versus silt/pH. At 0-15 cm soil depth of secondary forest significant positive associations were observed between TP versus TN/THB but significant negative correlations were observed between BD versus TN/THB. At 15-30 cm depth, a significant positive relationship was observed between THB versus TP, while BD versus THB indicated significant negative relationship.

Generally, the correlation coefficients (Table 4) indicate that BD had an inverse relationship with TP in all the examined land use types and soil depths, thus implying the negative influence of BD on TP. This implies that at higher BD values, TP of soils declined. SOC, SOM, TN and Avail. P indicated significantly positive relationships among one another in both 0-15 and 15-30 cm of each land use. Hence, an increase in any of these soil nutrients will trigger a corresponding increase in the other soil properties. This could be a function of the similar parent material of soils in the study area. SOM is the soil nutrient pool and its fluctuations will upset the quality and quantity of soils (Fisher & Binkley, 2000).

Table 5 revealed cause-effect relationships between the physical versus chemical or biological soil properties in the respective land use types and across soil depths. In the 0-15 cm soil depth of cassava land use, there exist a significant causal relationship between Avail. P versus silt/clay/TP/SOC/SOM/TN with R^2 value of 0.98. This indicate that in predicting Avail. P in cassava soils, valuation of silt, clay, TP, SOC, SOM and TN may provide optimal information. Similarly, in 15-30 cm, a significant cause-effect relationship between THF versus silt/pH, and between Avail. P versus SOC/SOM/TN/THF with R^2 values of 0.91 and 0.99 were detected respectively. These results show that silt and pH had a strong contribution in predicting fungal count while the combination of SOC, SOM, TN and THF predicted the concentration of Avail. P. Fisher & Binkley (2000) affirmed that SOC, SOM and TN may be the most influencing property affecting soil processes. SOM content, which is typically measured in the form of SOC content, is commonly regarded as a key indicator of soil quality (Liu et al., 2015). Table

5 also indicated a causal relationship between THB versus BD/TP in both 0-15 and 15-30 cm depths with R^2 values of 0.85 and 0.95 of secondary forest respectively. This implies that BD and TP are important influencing factors of THB.

Table 4: Pearson correlation matrix between the selected physical versus chemical or biological soil properties in the 0-15 cm (above diagonal) and 15-30 cm (below diagonal) soil depths

Variables	Sand	Silt	Clay	BD	TP	pH	SOC	SOM	TN	Avail. P	THB	THF
						Mixed tree plantation						
Sand	-	-0.796*	0.137	0.134	-0.135	-0.009	-0.175	-0.175	-0.173	-0.260	0.496	0.418
Silt	-0.951**	-	-	0.127	-0.127	0.171	0.184	0.186	0.197	0.245	-0.038	-0.044
Clay	-0.156	-0.158	-	-0.363	0.365	-0.268	-0.098	-0.100	-0.121	-0.098	-0.516	-0.414
BD	0.554	-0.306	-	-	-	-0.344	-0.511	-0.510	-0.493	-0.581	0.146	0.008
TP	-0.531	0.281	0.797*	-	-	0.351	0.519	0.519	0.502	0.586	-0.147	-0.027
pH	-0.607	0.496	0.353	-0.712*	0.714*	-	0.184	0.185	0.177	0.233	0.045	0.203
SOC	-0.856**	0.917**	-0.197	-0.219	0.189	0.425	-	1.000**	0.999**	0.987**	-0.020	-0.050
SOM	-0.857**	0.919**	-0.197	-0.221	0.191	0.426	1.000**	-	0.999**	0.987**	-0.019	-0.048
TN	-0.785*	0.894**	-0.349	-0.030	0.005	0.314	0.975**	0.975**	-	0.984**	0.007	-0.034
Avail. P	-0.854**	0.920**	-0.210	-0.231	0.204	0.447	0.991**	0.991**	0.973**	-	-0.076	-0.034
THB	0.333	-0.490	0.499	-0.226	0.212	0.079	-0.243	-0.245	-0.359	-0.291	-	0.835**
THF	0.341	-0.527	0.594	-0.297	0.288	0.091	-0.300	-0.302	-0.426	-0.346	0.988**	-
						Cassava land use						
Sand	-	-0.296	-0.262	-0.165	0.150	-0.011	-0.018	-0.017	-0.009	0.052	-0.586	-0.662
Silt	0.075	-	-0.844**	-0.211	0.236	0.210	0.801**	0.800**	0.788*	0.778*	-0.204	0.421
Clay	-0.635	-0.818**	-	0.306	-0.323	-0.206	-	-	-0.791*	-	0.535	-0.054
BD	0.252	0.323	-0.396	-	-	-0.073	-0.656	-0.658	-0.654	-0.658	0.237	0.523
TP	-0.239	-0.312	0.380	-	-	-	-0.073	-0.656	-0.658	-0.654	-0.658	0.237
pH	-0.098	0.328	-0.198	0.190	-0.188	-	0.002	0.004	0.058	-0.078	-0.003	-0.124
SOC	-0.664	0.163	0.258	-0.168	0.171	0.287	-	1.000**	0.996**	0.979**	-0.291	0.080
SOM	-0.665	0.162	0.258	-0.170	0.174	0.287	1.000**	-	0.996**	0.979**	-0.293	0.077
TN	-0.552	0.045	0.284	-0.004	0.000	0.193	0.905**	0.904**	-	0.961**	-0.281	0.074
Avail. P	-0.618	0.199	0.203	-0.105	0.111	0.452	0.978**	0.977**	0.852**	-	-0.385	0.009
THB	-0.514	-0.504	0.687*	-0.116	0.104	0.560	0.342	0.342	0.306	0.430	-	0.611
THF	0.005	0.773*	-0.601	0.524	-0.515	0.680*	0.413	0.412	0.303	0.526	-0.014	-
						Secondary forest						
Sand	-	-0.947**	-0.870**	0.295	-0.322	0.358	-0.092	-0.094	-0.208	-0.092	-0.566	-0.578
Silt	-	-	0.667**	-0.112	0.143	-0.496	-0.019	-0.017	0.006	-0.028	0.433	0.522
Clay	-0.355	-0.081	-	-0.513	0.531	-0.070	0.244	0.245	0.475	0.259	0.651	0.544
BD	-0.291	0.058	0.038	-	-0.998*	-0.029	-0.098	-0.099	-0.698*	-0.138	-0.789*	-0.576
TP	0.238	-0.031	-0.020	-	-	-0.009	0.104	0.105	0.675*	0.147	0.811**	0.614
pH	0.054	-0.047	0.077	0.333	-0.375	-	-0.206	-0.206	0.049	-0.178	0.001	-0.393
SOC	0.306	-0.230	0.040	-0.128	0.105	0.362	-	1.000**	0.617	0.979**	-0.028	0.493
SOM	0.353	-0.144	-0.246	-0.257	0.238	0.166	0.854**	-	0.617	0.979**	-0.026	0.496
TN	0.365	-0.154	-0.248	-0.262	0.242	0.152	0.859	1.000**	-	0.634	0.309	0.441
Avail. P	0.339	-0.133	-0.234	-0.243	0.220	0.251	0.880**	0.994**	0.993**	-	0.015	0.536
THB	-0.330	0.436	0.054	-0.677*	0.726*	-0.473	0.124	0.255	0.254	0.223	-	0.708*
THF	0.366	-0.108	-0.554	-0.045	0.011	-0.278	-0.428	-0.393	-0.379	-0.397	-0.360	-

* = correlation is significant at the 0.05 level (2-tailed), ** = correlation is significant at the 0.01 level (2-tailed)

Table 5: Summary of multiple regression analysis of the physical versus chemical or biological soil properties in mixed tree plantation, cassava land use and secondary forest

Land use types	Soil depth (cm)	Soil variables description	R	R^2	*p* - value
Mixed tree plantation	0 - 15	THF versus THB	0.85	0.72*	0.02
	0 - 15	Avail. P versus SOC, TN	0.98	0.97*	0.00
	15 - 30	THF versus THB	0.99	0.99*	0.00
	15 - 30	THB versus THF	0.99	0.99*	0.00
Cassava land use	0 - 15	Avail. P versus Silt, Clay, TP, SOC, SOM, TN	0.99	0.98*	0.00
	15 - 30	THF versus Silt, pH	0.95	0.91*	0.00
	15 - 30	Avail. P versus SOC, SOM, TN, THF	0.99	0.99*	0.00
Secondary forest	0 - 15	THF versus THB	0.87	0.77*	0.01
	0 - 15	THB versus BD, TP	0.92	0.85*	0.01
	15 - 30	THB versus BD, TP	0.98	0.96*	0.00

* = significant at 0.05 (2 tailed)

Conclusions

Most of the investigated physical, chemical and biological soil properties (sand, silt, clay, BD, TP, pH, THB and THF) varied significantly in response to the different land use types and soil depths. All the soils were moderate in SOM, SOC, TN and Avail. P concentrations, although pH, Avail. P, SOC, SOM, THB and THF responded negatively to land use change. Significant positive (such as silt versus SOM/SOC/TN/Avail. P, and TP versus pH) and negative (e.g., clay versus SOC/SOM/Avail. P) relationships as well as significant causal relationships (e.g., Avail. P versus silt/clay/TP/SOC/SOM/TN) were observed between some of the soil properties across the three land use types and soil depths. Therefore, the study concluded that the examined soil properties responded differently from the conversion of natural forest to cultivated land. Conservation agriculture and organic farming practices such as minimum tillage, permanent soil cover and diversified crop associations and rotations that will improve Avail. P, SOC and SOM in the continuously cultivated cassava farm should be adopted.

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