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Land use Effects on Soil Properties and Carbon Stocks of Agricultural and Agroforestry Landscapes in a Rainforest Zone of Nigeria

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ABSTRACT

This study examined the impacts of land use on soil physical, chemical and biological properties along agroforestry and agricultural landscapes in a rainforest zone of Nigeria. The land use systems are forest, agroforestry, fallow and ornamental plant field in addition to permanent crop fields constituted by cocoa, oil palm and citrus and annual (arable) crop fields (maize). Profile pits were dug from the land use types from which samples were collected 0-20 cm and 20-50cm for laboratory analysis of soil properties. Undisturbed soil samples were also collected from the pits but opposite sides for soil bulk density and moisture content determination. Standard soil analytical procedures were followed in carrying out soil analysis. Results showed that among the land use types, soil physical properties: sand, clay, soil bulk density and chemical: soil pH, SOC total nitrogen, P, K, Ca, Mg and CEC differed significantly among the land use types. The bulk density of the soils, pH, SOC, total N and stocks of SOC and total N statistically differ along 0-20 and 20-50 cm soil depths. SOC and total N stocks increased downwards along depths sampled. Sandy loam was the dominant soil textural class. Permanent croplands including forest and agroforestry had higher SOC, total N, pH and CEC while arable crop land had relatively low amount of SOC, TN, pH and, P, K, Ca, Mg and CEC. In addition, the arable cropland had significantly lower soil C and N stocks in the top 50 cm (0.50 m) soil layer compared with the permanent crop fields. The lower values of these variables from maize field may be due to the effects of continuous tillage practices by the smallholder farmers in the area, and soil erosion may be responsible to the removal SOC and total N from soil surface (0 – 20 cm depths). Among permanent and annual crop fields, the SOC and total N stocks of the land uses for 0-20 cm depth ranged from 5.75 to 3.12 kg/m^2 for 0-20 cm depths and 2.44 to 1.93 kg/m^2 for 20-50 cm depth. Relative to forest soil, stocks of SOC in the surface soils (0-20 cm) decreased in the order: agroforestry > ornamental plant field > cocoa> fallow land > citrus > oil palm > annual cropping system. Following this decreasing order, soil deterioration indices are equivalent to 27 > 28 > 30 > 31 > 32 > 34 >38 % compared with forest soil respectively. Strong significant correlations ($p < 0.05$) were observed between SOC and TN stocks and some soil properties (bulk density, clay contents, pH and CEC) with R2 values ranging from 1.0 to 0.85. It is concluded that land-use and soil depth influenced soil physical, chemical (nutrient fluxes: organic carbon, N, P, K, Ca, Mg and CEC), biological properties and carbon storage potential in the study area.

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Highlights

The land use systems and vegetation cover affected soil physical and chemical properties and organic carbon stocks.

Soils of permanent land use systems: forest, agroforestry, ornamental plant field, fallow land, plantation crops had more favourable physical, chemical and biological properties.

Soil concentrations and stocks of organic carbon and total nitrogen differed among land use types Stocks of SOC organic carbon and total nitrogen were higher at 0-20 cm depths compared with 20-50 cm.

Introduction

In Sub-Saharan Africa (SSA), agriculture is major source of livelihood and in addition supplies food and raw materials for industries for economic development and foreign exchange earner. Agriculture contributes about 30 percent of the GDP to Nigeria economy, employs about 70 percent of the labour force and accounts for over 70 percent of non-oil exports, and provides over 80 percent of the food requirement of the country [1,2]. Nigeria has about 98.3 million hectares of land of which about 74 million hectares is useful for agriculture [2,3]. The cultivated lands occupies 44.7 percent of the land area out of which 37.3 and 7.4 percent consisting of arable land and permanent crops respectively while forest cover 9.5 percent and other land use take 12.6 percent [2,4].

In West Africa, common land use types are forest, fallow land, agroforesty, permanent (plantation) crop land, cultivated arable crops and grazing lands commonly managed by smallholder farmers. Land use and management practices have influence on the physical, chemical as well as the biological properties of the soils [5-8]. The influence of land use on soil chemical, physical and biological properties may be attributed to anthropogenic activities such as tillage, livestock trampling, harvesting, planting, application of fertilizer etc. On the other hand, land use also produces changes in soil properties, climate, population density, economic opportunities, cultural practices, and socio-economic factors [6,8]. Land use systems impact temporal and spatial variations of soil processes with consequences on the distribution of water, sediments and organic materials in the soil and organic matter stabilization [9-14].

Changes in land use and land cover transform landscapes and alter ecosystem processes (nutrient cycling, water use, evaporation, evapotranspiration and heat) and microclimate. Literature reports that ecosystem processes of carbon, water balance and energy fluxes in landscapes can change or affect land use, land cover, and vegetation dynamics [15-17]. Land use and agricultural practices are known for their environmental effects including biogeochemical processes including climate modifications. Land use and management practices have potential to resolve adaptation challenges to climate change and variability of weather events and provision of ecosystem services. It is therefore important to improve understanding of the effect of agricultural land use on biogeochemistry within the ecosystem, such understanding would promote sustainability of ecosystems and improve performance of agriculture and its relevance as strategy for climate change mitigation (adaptation and resilience building). There is inadequate information from the rainforest agroecology, the influence of land use practices (agroforestry, fallowing, plantation and arable/annual cropping) on vegetation land cover along agricultural and agroforestry landscapes.

Land use systems have potential to resolve adaptation challenges to climate change and weather variability in addition to provision of ecosystem services, functions and its sustainability. The continual evaluation of dynamics of soil properties under different management practices will foster the development of strategies for improving soil and crop productivity and sustainability.

Various studies had highlighted the capacities of tropical soils to store carbon and nitrogen, the potentials of rainforest soils for carbon sink and sequestration under various land use systems that are poorly reported [18,19]. Also, information is inadequate from the rainforest agroecology, the influence of land use practices (agroforestry, fallowing, plantation and arable/annual cropping) on vegetation land cover along agricultural and agroforestry landscapes. In particular, the influence of some land use types such as forest, fallow, ornamental plant field, cocoa, citrus, oil palm, agroforestry and maize on soil physical, chemical and biological properties of the rainforest zone of Nigeria is not adequately researched and reported. It is necessary to continually evaluate changes in soil properties under various widely practiced smallholder land use and different management to foster development of strategies for improving soil and crop productivity and ecosystem sustainability and to explore the potential of land use practices to resolve adaptation challenges to climate change and weather variability in addition to provision of ecosystem services.

The objectives of the present study are to evaluate the effects of land use and vegetation cover patterns on soil physical and chemical properties, on the stocks of soil organic carbon and total N, and soil fertility deterioration of agricultural and agroforestry landscapes.

Materials and Methods

The land use systems are forest, agroforestry, fallow and ornamental plant field in addition to permanent crop fields constituted by cocoa, oil palm and citrus and annual (arable) crop fields (maize) in Akure, a rainforest zone of Nigeria. Akure, study site is geographically geo-referenced on coordinate lines of 734393E, 808614N; on the western flank of meridians. The effects of land use on soil properties (physical, chemical and biological properties) and weather conditions along agricultural and agroforestry landscapes.

Soil Sampling and Analysis

Soil profile pits were dug from the land use types and samples were collected from two soil depths: 0 to 20 and 20-50 cm for physical and chemical analysis. Soil samples were collected at depths by inserting a core sampler into the wall of the pits; the lowest first and the top soil at last to avoid contamination between the two layers. Approximately, 1 kg of sample from each soil depth were collected and air-dried at room temperature, crushed, homogenized, and passed through a 2mm sieve and further sieved at 0.5mm for total nitrogen before laboratory analysis.

Laboratory Analyses

Total nitrogen content was determined following the Kjeldahl method, was used to estimate total nitrogen (TN) [20]. The available phosphorus content of the soil was analyzed using 0.5M sodium bicarbonate extraction solution (pH: 8.5) following the method of Olsen et al. [21]. The exchangeable basic cations (K+, Ca2+, Mg2+, and Na+) were extracted with 1 M ammonium acetate at pH (7.0). The CEC of the soil was determined from ammonium acetate saturated sample. The excess ammonium acetate was removed by washing with ethanol. Exchangeable Ca2+ and Mg2+ in the ammonium acetate leachate were measured by atomic absorption spectrophotometry (AAS), and K+ and Na+ were determined by flame photometer. Hydrometer method was used for the determination of soil particle size distribution. The soil pH was measured using a glass combination pH meter in the supernatant solution of 1:2.5 soil to water solution ratio. Soil organic carbon determinations was made following the wet oxidation method of Walkley and Black [22]. The soil pH was measured using pH meter in 1:2.5 soils to water solution ratio. Bulk density and moisture content were determined from undisturbed soil samples collected using manual core sampler at soil depth (0-20 and 20-50 cm). Soil-water content determined by standard procedures described for the gravimetry method after oven drying to a constant weight at 105º C. Bulk density was determined using core method after oven drying wet undisturbed soil samples at temperature of 105◦ C for 30 hours. Bulk density was calculated by dividing the weight of oven-dried soil with the volume of the core.

Soil hydrological properties were calculated using soil water characteristic equations derived by Saxton et al. and modified by Saxton and Rawls [23,24]. The variables of soil texture and soil organic matter were deployed in the calculation based on the relationships for tensions and conductivities and the effects of density, gravel, and salinity. These variables were used to form predictive system of soil water characteristics for agricultural water management and hydrologic analyses. The programmed for a graphical computerized model of the predictive system for rapid solutions available at: http://hydrolab.arsusda.gov/soilwater/Index.htm.

Soil Organic Carbon Stocks

Soil carbon stock (Mg C. ha $^{-1}$) for each sample depth was computed following the method of Milne.

Carbon stock (kg. m^2) = [% C * BD * Depth in (m) * 10^4 m^2 ha ^{1}] / 100 …………

where BD is bulk density (g/cm3) of each sample depth, where percentage C was the Walkley-Black carbon [22]. Subsequently, SOC and TN stock in each soil layer was summed up to determine total SOC and TN stock for each land-use type.

Carbon to nitrogen ratio (C:N ratio) was calculated as the ratio of carbon to nitrogen for each soil sample with the formulae below:

C:Nratio=SOC(%)TN(%)…………

Where C:N ratio is carbon to nitrogen, SOC represents the concentration of carbon (%) in a soil sample, and TN is the concentration of total nitrogen (%) in the soil sample.

Bulk density refers to bulk density of the fine soil component, and CF is the volumetric coarse fragment content.

Bulk mass (g) -coarse fragment (g)
Bulk density = --- …………
Bulk soil volume (cm^3) - coarse fragment volume (cm^3)

Soil Deterioration Index (SDI)
Soil deterioration indices were calculated on the assumption that the status of individual soil properties under the identified land-use types (woodland savannah, grassland, fallow, and cropland) were once the same as adjacent soils under natural forest (well-stocked soils) before conversion. The differences between mean values of individual soil properties were compared with values of soil properties under well-stocked natural forest (100%), computed and expressed as a percentage of the mean value of individual soil properties using Equation.

The percentage values were averaged across all soil properties in land uses to calculate the soil deterioration index (SDI) following the method as adopted by Adejuwon and Ekanade [25].

$$DI(\%) = \left[P_{SL} - P_{RL} \quad P_{RL} \right] \times 100 \ldots\ldots$$

Where PSL is the mean value of individual soil property (P) under specific land use (SL), P_{RL} is the mean value of individual soil property (P) under reference land use (RL), and DI is deterioration index. The cumulative sum obtained gave an SDI for the identified land-use types. The higher the total value, the better the quality and/or health of soil for a particular land-use system.

Data collected on the physical, chemical properties and soil carbon and total N stock of the various land use practices were subjected to statistical analysis (analysis of variance (ANOVA). When the results of the analysis showed significant differences ($P \leq 0.05$) among the land uses and soil depths for each parameter, treatment means were separated using Tukey's pair wise comparisons (Tukey Honestly Significance Difference: HSD) test at 5 % level of probability. Pearson correlation coefficient was used to test the relationship among soil properties Multiple comparison of means for each soil variable among land-use, clay, bulk density, pH, SOC and TN were conducted using the Duncan test at $\alpha = 0.05$.

Results

Effect of Land use Type on Soil Physical and Hydrologic Properties

Soil Physical, Chemical and Hydrologic Properties

The effect of land use type on soil physical properties (Sand, Clay and Silt) is presented in Table 1 Cocoa field had the highest sand percentage, followed by oil palm, maize, ornamental plant field, agroforestry, citrus and fallow land. The results showed that the soils textural class is mainly sandy-clay-loam (Table 1).

Table 1: Soil Physical Properties with Textural Classes

Land use	Sand	Clay	Silt	Textural Class
GFF	16.80	63.20	20.00	Clay loam
OPF	56.80	27.20	16.00	Sandy clay loam
CF	58.00	27.00	15.00	Sandy clay loam
CTF	52.20	27.80	20.00	Sandy clay loam
AF	54.80	25.20	20.00	Sandy clay loam
MF	36.80	43.20	20.00	Clay loam
CSF	56.80	27.20	16.00	Sandy clay loam
OF	56.80	27.20	16.00	Sandy clay loam

GFF: Grass Fallow, OPF: Oil Palm, CF Cocoa, CTF: Citrus, AGF: Agroforestry, MF: Maize, CSF: Cassava, OF: Ornamental Plant Field

Bulk density range around 1.40 to 1.47 while lowest values were found for permanent crop fields and values were recorded for MF and OPF. Soil porosity values above 50 % were found for OPF and MF and approximately 50 % for most others. The highest porosity was recorded for oil palm followed by citrus, cocoa, agroforestry, fallow land and maize. Porosity values would have follow from soil compaction indicated by bulk density (Table 2). Field capacity (Fc) moisture was highest for oil palm followed by Maize, Ornamental, citrus, Cassava and Cocoa and agroforestry while the least values was obtained for fallow. High field capacity (FC) water content (0.47) was recorded for OPF closely followed by MF land use (0.36). lower values ranging between 0.22 and 0.27 were recorded for other land use types. Permanent wilting point (PWP) was highest for oil palm followed by Maize, Citrus, Cassava, Cocoa, Agroforest and fallow fields. Permanent wilting percentage of the soil under the land use types range between 0.13 to 0.34. highest value was obtained for oil palm followed by maize with lowest under agroforestry (Table 2) Plant available water (AW) value was lowest for forested and agroforestry and oil palm and values were close for other land use types. The permanent crop fields had lower bulk density values compared with arable crop field in addition to hydraulic conductivity which had implications for PWP and FC moisture contents and thus plant available water contents of the land use types (Table 2 and Figure 1) Hydraulic conductivity (Ks) values was highest for fallow land followed by agroforestry, Cocoa, Citrus, Ornamental, Oil palm and Maize field respectively. The available water (AW) in soil was highest for Oil palm followed by ornamental plant field, Agroforestry, Maize, Cocoa and Citrus field (Figure 1). Highest values of hydraulic conductivity (indicator of soil water transmission property) above 70 % were for four of the land use types and lowest for MF and OF (less than 30 %).

Table 2: Soil Hydrological Properties of the Land use Classes

	Soil Hydrological Properties					
Land Uses	**Porosity**	**PWP**	**FC**	**Ks**	**AW**	**BD**
CTF	0.469	0.150	0.257	0.563	0.107	1.407
CF	0.461	0.136	0.245	0.786	0.109	1.430
MF	0.512	0.244	0.355	0.163	0.111	1.294
OPF	0.542	0.337	0.469	0.226	0.132	1.215
AF	0.460	0.131	0.244	0.836	0.113	1.432
GFF	0.446	0.127	0.220	0.937	0.094	1.470
CSF	0.465	0.135	0.251	0.727	0.117	1.418
OF	0.476	0.155	0.267	0.458	0.112	1.389
LSD (0.05)	0.053	0.013	0.008	0.035	0.003	0.026

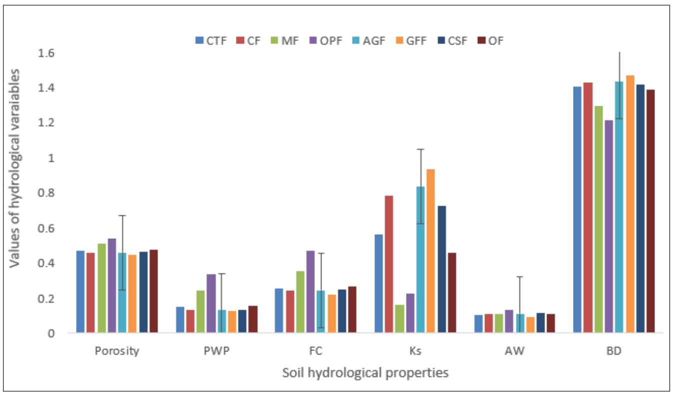

Figure 1: Hydrological Properties of Soils of the Land use Types. PWP (permanent wilting percentage), FC (field capacity moisture), ks (hydraulic conductivity), AW (available water), BD (bulk density)

Land use and Soil Chemical Properties

The differences among the land uses for soil pH were not significant ($P \geq 0.05$) although highest soil pH value was recorded for ornamental plant field followed by cocoa , agroforestry, maize, citrus, cocoa and oil palm fields respectively while the least mean value was recorded for grass fallow (Table 3) There were also no significant differences among the land uses for total N, however, soil N was highest for Citrus followed by Ornamental, Maize, Cocoa field, Agroforestry, Cassava and Oil palm fields had the least mean N. The highest value of K was recorded on Ornamental field followed by Maize, Grass fallow, Cassava, Citrus, Cocoa and Agroforestry respectively while the least mean value was recorded on Oil palm tree (Table 3).

The highest P value was recorded on Citrus followed by Agroforestry, Ornamental, Maize and cassava, Cocoa and oil palm field respectively while the least mean value was recorded on grass fallowed field.

Cocoa field had highest Ca followed by Citrus field, Ornamental field, Grass fallowed field, Maize field, Agroforestry and Cassava field respectively. Oil palm field had the least mean value. There was no significant difference ($P = 0.05$) as well (Table 3).

Cocoa field also had highest Mg in soil followed by Citrus field, Agroforestry, Grass fallowed field, Ornamental field, Maize field and Citrus field respectively. However, Citrus field had highest value, followed by Cocoa field, Maize field, grass fallowed field, Cassava field, Ornamental field and Agroforestry respectively while the least mean value was recorded on Oil palm field (Table 3) Soil pH differed significantly among land use types, soil pH were highest for of, CSF MF and AF and lowest values for GFF and close values for OPF and CF. soil organic matter (SOM) values also differed significantly among land use types. CTF, MF. And OF recorded highest SOM whereas lowest values were found for OPF and CF. Similar trends was observed for SOM, total N in soils differed among land use types. CTF recorded highest values followed by OF, MF and CF while lowest were found for GFF and OPF. The records of soil K values differed from those of SOM, significantly higher K was obtained for OF, values were close for CF, CTF and AF and lowest for oil palm field. Total P in soil were significantly different among land use types. Significantly higher values were recorded for cocoa, agroforestry and oil palm which had close values while lowest soil P were found for oil palm field.

Calcium contents of soil under the land use types differed, CF and CTF were not different, OF, GFF and MF were not different while lowest Ca values were recorded for OPF and CSF. Soil contents of Mg differed among land uses, CF and CTF were not different in values and lowest were recorded for oil palm. CEC of soils of land use types had highest value for CTF while values were close for agroforestry, cocoa and maize fields (Table 3).

The effect of season was significant on soil chemical properties of land use types. In the rainy season, pH of soil under the land uses was lower significantly compare with values for the dry season. SOM follow the observations on soil pH for the seasons while values for soil N, K and P, Ca and Mg and CEC occurred in contrast to those of soil pH and SOM, the rainy season recorded higher values compare with the dry season for these nutrient elements. Soil pH, OC, SOM and total N were higher in values for permanent cultivation compared to arable (annual crop) fields. however, soil K was higher for arable fields. Other measured chemical variables had higher values for permanent cultivation.

Table 3: Land use Effects on Soil Chemical Properties

	Chemical Properties									
Land use	**pH(1:2 in H_20)**	**OC (%)**	**OM (%)**	**N (%)**	**K(cmol kg)**	**P (mg/kg)**	**Na(cmol/kg)**	**Ca(cmol/kg)**	**Mg(cmol/kg**	**CEC (cmol/kg)**
GFF	5.296[a]	0.94[a]	1.632[a]	0.182[a]	0.556[a]	8.680[a]	0.411[a]	3.650[a]	1.381[a]	8.999[a]
OPF	5.471[a]	1.04[a]	1.805[a]	0.232[a]	0.343[a]	9.240[a]	0.4219[a]	3.004[a]	1.098[a]	8.189[a]
CF	5.453[a]	1.52[a]	2.627[a]	0.385[a]	0.448[a]	10.090[a]	0.430[a]	3.892[a]	1.618[a]	9.848[a]
CTF	5.504[a]	1.79[a]	3.094[a]	0.472[a]	0.487[a]	12.440[a]	0.455[a]	3.813[a]	1.532[a]	12.260[a]
AF	5.738[a]	1.54[a]	2.671[a]	0.346[a]	0.445[a]	12.090[a]	0.441[a]	3.417[a]	1.415[a]	8.840[a]
MF	5.672[a]	1.68[a]	2.909[a]	0.407[a]	0.604[a]	11.069[a]	0.539[a]	3.621[a]	1.249[a]	9.522[a]
CSF	5.812[a]	1.58[a]	2.729[a]	0.308[a]	0.518[a]	10.530[a]	0.507[a]	3.242[a]	1.166[a]	8.921[a]
OF	5.886[a]	1.68[a]	2.906[a]	0.434[a]	0.671[a]	11.940[a]	0.513[a]	3.730[a]	1.332[a]	8.897[a]
LSD (0.05) 0.095 0.214 0.242 0.026 0.113 0.723 0.009 0.057 0.07 0.4268										

Soil Carbon and total Nitrogen Stocks of Land use Types

Agroforestry recorded the highest SOC stocks followed by Maize, Oil palm, Citrus, Cocoa, fallow land and maize. Significantly higher SOC values were obtained for agroforestry, ornamental plant and oil palm fields compared with cocoa, citrus and fallow land. Maize field recorded significantly higher SOC compare with citrus, cocoa, cassava and grass fallow. Significantly higher SOC values were obtained for agroforestry and oil palm while maize field recorded significantly higher SOC compare with citrus, cocoa, cassava and grass fallow. Significant differences in SOC and total N stocks were obtained between forest based and permanent crop fields compared with the annual (maize) field (Table 4) and within 0 - 20 cm compare with 20-50 cm soil depths. A Among permanent and annual crop fields, the SOC and total N stocks of the land uses for 0-20 cm depth ranged from 5.75 to 3.12 kg/m2 for 0-20 cm depths and 2.44 to 1.93 kg/m2 for 20-50 cm depth (Table 4) Nitrogen stocks for the subsoil (20-50 cm depths) among the land use types followed similar trend with what was observed for 0 - 20 cm depth. Permanent crop lands had the highest total N stocks compared to annual cropland, highest values were recorded for 0 - 20 compared with 20 - 50 cm soil depths. Soils from forested and fallow land, and agroforestry and permanent crop fields had the highest soil organic carbon and total nitrogen and stocks compared with the annual cropland (Table 5). Relative to forest soil, stocks of SOC in the surface soils (0-20 cm) decreased in the order: agroforestry > ornamental plant field > cocoa> fallow land > citrus > oil palm > annual cropping system (Table 5).

Table 4: Soil Chemical Properties of 0-20 and 20-50 cm Depth of Land use Types

Land use	Soil depth (cm)	Soil organic carbon (SOC) (%)	Carbon stocks (kg/m^2)	Total N (%)	Total N stocks(kg/m^2)	C:N ratio	Soil pH (water)	Clay	Bulk density
Forest soil	0-20	2.33	8.14	0.28	8.51		6.53	28.4	1.20
	20-50	0.01	3.67	0.14	5.13		6.13	35.8	1.31
Fallow land (Grass spp. dominant)	0-20	1.07	6.12	0.16	7.22		5.62	33.2	1.28
Oil palm	20-50	0.59	2.83	0.06	3.84		5.21	42.4	1.33
	0-20	1.04	5.75	0.25	6.33		5.48	30.2	1.32
Cocoa	20-50	0.56	2.44	0.12	3.05		5.11	41.5	1.43
	0-20	0.93	4.25	0.12	6.53		5.53	30.3	1.30
Citrus	20-50	0.42	2.11	0.74	2.84		5.15	40.4	1.42
	0-20	0.95	4.46	0.15	6.71		5.51	37.1	1.33
Agroforestry	20-50	0.46	2.14	0.78	3.08		5.08	44.2	1.44
	0-20	1.73	6.52	0.18	7.91		5.74	31.3	1.29
Crop land	20-50	0.68	3.33	0.08	4.32		5.27	38.6	1.41
	0-20	1.21	3.12	0.10	4.13		5.45	34.3	1.37
	20-50	0.53	1.93	0.63	1.82		5.06	40.4	1.45
Ornamental field	0-20	1.71	6.44	0.19	8.12		5.89	32.2	1.33
	20-50	0.65	3.31	0.08	4.44		5.33	37.8	1.44

GFF: Grass Fallow, OPF: Oil Palm, CF Cocoa, CTF: Citrus, AGF: Agroforestry, MF: Maize, CSF: Cassava, OF: Ornamental Plant Field

Table 5: Soil Hydrological Properties (Permanent and Agricultural Land uses)

Soil depth (cm)	SOC (%)	Carbon stocks (kg/m²)	Total N (%)	Total N stocks (kg/m²)	C:N ratio	Soil pH (water)	Clay	Silt	Sand	Bulk density
0-20	1.25	8.14	0.21	7.18		6.47	17.65	19.3	60.27	1.28
20-50	0.11	3.67	0.13	4.13		6.27	22.34	21.6	51.34	1.43

Regression analysis showed significantly strong correlations between SOC stocks and some soil physical (clay and bulk density) and chemical (pH and CEC) properties. Strong but negative relationship was obtained between bulk density and SOC (0.63; $p = 0.05$) while positive relationships between SOC and clay content, pH and CEC were positive and highly significant (Table 6).

Table 6: Correlation Equations and Coefficients of some Soil Physical and Chemical Properties

Variables	Equations	R2
SOC vs Clay	$y = 0.3689x - 9.1896$	0.92
SOC vs TN	$y = 0.8449x - 0.4857$	0.91
SOC vs CEC	$y = 1.9833x - 14.703$	0.92
SOC vs pH	$y = 5.5791x - 25.987$	0.95
TN vs pH	$y = 5.4477x - 24.086$	0.85
SOC vs BD	$y = -18.208x + 28.88$	0.50
TN vs BD	$y = 18.703x - 19.829$	0.41

Soil Deterioration Indices

Relative to forest soil, stocks of SOC in the surface soils (0-20 cm) decreased in the order: agroforestry > ornamental plant field > cocoa> fallow land > citrus > oil palm > maize crop field.

Soil deterioration indices of were 0 %, -27, -28, - 30, - 31, - 32, - 34 and -38 % for forest, agroforestry, ornamental plant, cocoa, fallow land, citrus, oil palm and maize crop fields. Hence, the results showed that the stock of SOC in the 0 to 50 cm soil layers were 73, 72, 70, 69, 68, 66 and 62 % for the land use types evaluated (Figure 2).

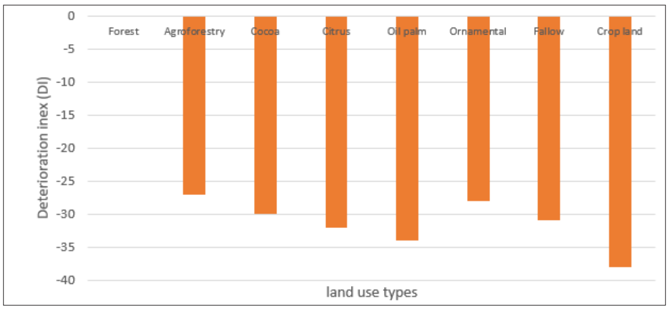

Figure 2. Soil deterioration Indices (0-20 cm) of land use types of the study area

Discussion

Land use Effects on Soil Physical Properties

The soil particle size analysis showed that the soil type at the experimental area were predominantly Sandy clay loam. This result is consistent with those of Omotade and Alatise, and Agele et al. that the textural class of the soil of the study area is sandy loam [26].

The results showed that irrespective of land use type, soil particle sizes did not differ significantly. Soil texture is highly influenced by the parent material and topography from which the soil was derived, the high sand fractions in the area could be attributed to the parent material. The study area is characterized by high rainfall that promote illuviation or leaching of silt and clay particles thus may contribute to high sand fractions of soil under the land use types.

Land use Effects on Soil Hydrological Properties

Soil hydrological properties are parameters that determine soil quality and its capacity to sustain plant growth s and ecosystem services [27]. The results showed that soil porosity were close in values among land use types This result supported the findings of Mefin and Mohammed, Theobald et al. and Nnaji et al. that the porosity of permanent crop fields was higher than cultivated lands [28,29].

Field capacity, available water, permanent wilting point and hydraulic conductivity were higher in values compare with the cultivated/agricultural land uses. These results conformed with the findings of Oguike and Onwuka, that permanent land use types had higher soil moisture at field capacity, permanent wilting point, available water and hydraulic conductivity [30]. The findings from the present study were in contrast to the report of Mandel et al. that cultivated land uses were better in soil hydrological properties compared to agroforest and forested land and permanent crop fields [31]. The contradictions can be attributed to soil type and climatic conditions of the sites of study. The bulk density of the soils showed that the permanent land uses had a lower values compare to annual crop lands. This result conformed with the findings of Ryan et al. that forest and agroforestry soils had lower bulk density compared with other land use types and crop production activities of annual (arable) crops such as tillage [14]. The agronomic practices under the land use types differed which can explain differences in soil bulk density, soil total porosity and gravimetric moisture contents. These activities have consequences for soil density, porosity, moisture contents of the agricultural cultivated land uses [28]. Also, the soil textural class of the study site appeared to have contributed to observations of the physical properties of soils of the various land uses. Soil hydrological properties are important parameters that determine soil quality and function within the ecosystem [27].

The magnitudes of hydraulic conductivity (K) recorded for permanent land uses can be linked to lower disturbance, improved soil structure and organic matter contents, activities of soil fauna which would have contributed to the development of more micropores. Microporosity has been reported to cause increase in hydraulic conductivity to increase and reflects the drainage level *of given soil. The lower value of K under arable land uses could also be as a result of loose, less coherent and structureless nature of the soil due to soil disturbance during land/seedbed preparation and other farm activities (soil tillage operations) [32,33]. However, Mander and Meyer, reported that cultivated land was better in soil hydrological properties compared to agroforestry-based land uses.

Soil bulk density represents a measure of soil compaction and health. Kakaire et al stated that a higher soil bulk density means that less amount of water is held in the soil at field capacity while a lower soil bulk density means soil are less compacted and are able to retain more water. The bulk density of the study site showed that the permanent land uses had a lower value compare to agricultural land uses. Ryan et al. obtained lower bulk density for forested soils compare with agricultural land uses [14]. The high bulk density of soil under arable land use could be attributed to compaction from traction (man and machine: weight of machinery) and other a activities involved in cultivation and management. The high bulk density on cultivated land use could also be due to exposure of land to agents of erosion that removed the less dense fine particles [28]. The observations on soil moisture, porosity and bulk density may be explained based on the intensities of agricultural activities on the study site. The bulk density values among the land use types were not above 1.63 gcm^{-3}. such value would not constitute sever hindrance to root penetration and seed germination [28,34]. It is therefore important to report that soil under more stable permanent land uses such as agroforestry, cocoa and oil palm fields can be adduced to minimal disturbance and higher soil organic carbon of soil of these land uses [35]. Bulk density of soil determines nature of other soil physical properties and processes such as soil-water dynamics, aeration, mechanical resistance to root growth and development. These explain the significantly high soil bulk density of annual crop field compared to forest-based land use types, which may stem from the intensities of ploughing plus harrowing/ridging and the impact of raindrops on unprotected soil which enhances soil water erosion [34]. Bulk density values were higher in subsoils compared to the topsoil among the land uses. The redistribution of soil carbon by tillage operation and increased soil evaporation of cropland could cause an upward movement of dissolved inorganic C from the subsoil to the surface soil due to soil moisture evaporation in the crop growing season [36].

Soil Chemical Properties

The results of the present study showed that agroforestry, cocoa. citrus and oil palm including fallow land recorded higher soil chemical properties such as soil pH, exchangeable bases and CEC. This could be attributed to little ecosystem disturbance, litter retention, enhanced biological population and activities under permanent. Smallholder farmers in the study area commonly use fertilizers (including livestock manure and plant residues, domestic wastes (ash from firewood and bush burning) and other biodegradable materials. Ash serves as a good liming material and thus, the high soil pH recorded which will enhance availability of exchangeable bases among the land use types especially for arable crops Soil pH values across the land uses for this study showed that the soil is slightly acidic. This result agreed with the findings of Olubanjo and Ayoola reported soil pH of soils of the study area in the range of 5.65 and 5.72 [37]. Hassan et al, reported that favourable pH enhances availability of nutrients in the soil [38]. Soil pH for most crops lies within 6.0 and 7.0 within which nutrient availability in soil is enhanced. This result showed that the study area was fairly suitable for plant growth as the pH values fall around the optimum value of 6.0. The organic matter of soils of the land use types differed This result confirmed h the findings of Olubanjo and Ayoola tah the organic matter of the study site varied from 2.88% to 3.97% [37]. Theobald et al. who opined that cultivated crop fields tend to produce lower Organic matter compare to permanent crop land uses [28]. This observation also conformed to those of Biernbaum that the organic matter in sandy clay loam soil ranges from 1% (low) to average of 2 to 4% [39]. Kizilkaya and Panwar et al. opined that organic matter modifies water retention capacity and other physical soil properties thereby contributes to more carbon into the soil pool [40,41].

Nitrogen, phosphorus, potassium, calcium and cation-exchange capacity did not differ significantly among the land use types. This observation agreed with the findings of Theobald and Akintokun and Owoeye that soil chemical properties of soil cultivated for arable crop production are lower than under permanent land uses [28,42]. The land use types had undergone different practices involving engagement of tractorized operations for tillage, sowing and agrochemical application. White and Haddaway et al. reported the effects of such activities on the mineralization of nutrient in soil [43,44]. Among the land use types, citrus field had highest value of organic matter, N and P in addition to high cation exchange capacity, the high contents of nutrient elements of citrus soil can be adduced to the abundance of elephant grass (Pennisetum purpurem Schum.) on the field. Elephant grass has been known for soil erosion prevention and enhancement of soil fertility [45]. Results showed that soil acidity is higher in dry season than the wet season which would influence soil nutrients availability for crop use [46]. This study therefore showed that nutrients were available during the wet season than the dry season. This observation conforms with those of Guizani et al. that rain remove significant amount of salts that accumulate in the soil during previous cultivation period from the soil. Hence the low nutrient status of soils during the rainy season (leaching losses) [47]. From this study, it is observed that permanent land uses recorded higher values of the essential nutrient elements for plant growth enhancement compared with arable crop field [11,19,48].

Effect of Land use on the Soil Organic Carbon Stocks

Results from this study showed land use types differed in SOC and total N stocks. Agroforestry and oil palm fields had highest SOC stock. Oladoye et al. reported that forest soil had high carbon stocks and will thus sequester higher carbon than other land uses especially arable land cultivation for annual cropping [49]. However, Nyawira et al. reported high SOC stocks of land use with good soil management such as reduced or no tillage soil management [50]. The permanent crop lands (cocoa, citrus, oil palm) including agroforestry ecosystem are associated with high biodiversity and ability to sequester carbon in the soil than frequently cultivated (arable crops) crop lands [51]. The mechanisms of SOC stabilization appear to differ among the land use types and can be linked to soil and crop management intensity. Soil management practices is significant to SOC dynamics and global carbon [52].

Soil organic carbon (SOC) stocks was calculated from organic carbon concentration (g/kg) soil bulk density [53]. Result from this study showed land uses differed in SOC stocks. Agroforestry and oil palm field had highest SOC stock respectively. Oladoye et al. reported that forest land soil sequester higher carbon than other land use [49]. Nyawira et al. opined that SOC stocks can be increased for agricultural land uses with good soil management such as reduced/minimum or no tillage soil management practice [50]. Maize field from this study had high SOC stocks not significantly different from other land uses. This can be attributed to soil management practiced over the years [54]. Agroforestry is an example of ecosystem with high biodiversity has ability to sequester more carbon in the soil than those with reduced biodiversity [51]. Therefore, understanding mechanisms of SOC buildup of land uses and management intensity adopted are relevant for understanding their carbon sequestration and contributions to global C cycle [52].

The study showed that soils under forest and permanent croplands had significantly higher SOC and total nitrogen stocks than annual cropland soils. Soil carbon concentration influences the retention of nutrients, buffer pH, microbial activity, structure (formation of micro-aggregate and water infiltration and retention. Higher litter accumulation promotes build up in permanent crop fields which can be attributed to high above and below-ground biomass (root biomass) and lower litter breakdown (decomposition) rate. The findings of this study are consistent with the studies of Delelegn et al. and Girmay and Singh [55,56]. The low SOC and TN values recorded under cropland may be due to the magnitude of organic material brake down via high oxidation rates caused by tillage and soil water erosion. In addition, the susceptibility of micro-aggregate organic carbon to microbial degradation due to seasonal shift in moisture and temperature regimes would have promoted SOC loss on arable lands. In the forest, the favourable micro-climate would have enhanced nutrient transformation and accelerated decomposition of organic matter Delegan et al. reported that fine root biomass from forest and tree crops are the primary source of carbon and nitrogen additions to the soil making huge contributions to SOC and total N stocks in soils. The high plant root turnover via exudates of mycorrhizal fungi and the rhizosphere in forest ecosystem is known [56,57]. This process contribute to nutrient build-up in soils.

The SOC and total N stocks in the topsoil of the land use types (forest, permanent and annual croplands) decreased with depth. The larger N stock in forest and permanent crop fields can be adduced to deep root systems of tree crops which may promote porosity and nutrient transfer processes in soil [57,58]. The large differences observed between C and N stocks among land use types may be attributed to shorter fallow periods of soils under annual croplands. It is reported that soil physical properties influence organic carbon by affecting soil aggregate particle-size fraction, bulk density, and soil moisture content [59]. Soil organic carbon plays important roles in the soil along with provision of other ecosystem services (such as carbon sequestration, climate, and greenhouse regulations), nutrient cycling, and provision food, fiber, fuel, and water [59]. Land use, soil properties, geographical area, climate variability, and the dominant vegetation composition on a soil landscape are known for their contributions to the stabilization of SOC and TN stocks in landscapes [60,61]. Other factors are climate and vegetation which are important soil-forming factors influencing C and N storage in an agroecology [62]. The high stocks of SOC and total N between the forest and permanent crop lands, and annual (arable) croplands can be attributed to high litter decomposition, and carbon turnover which may serve as carbon sinks.

Relations of land use, SOC and total nitrogen concentration and stocks

A correlation matrix was computed to establish the relationship between measured soil nutrients. Results showed that SOC and total nitrogen stocks were positively correlated with clay. However, negative correlation with bulk density and SOC. Also, the negative correlation of SOC and total nitrogen concentrations and stocks with bulk density. This indicated that low bulk density and high clay content which associate with high SOC, resulting in the accumulation of carbon Yu et al. [63]. These observations are consistent with the findings of Tsui et al. and Seifu et al. who reported that high soil compaction is detrimental to SOC and hence soil organic matter accretion possibly due to reduction in soil water infiltration and drainage capacity and consequent aeration-related challenges in the soil [60,64].

Soil Deterioration Index (SDI)

The results of this study showed that soil quality properties (physical, chemical and biological) deteriorated differently under forest and permanent compared with annual croplands especially, via degradation of SOC and TN stocks and other essential nutrients. Soil deterioration index (SDI) values for the land use types compared with forest soil showed net degradation of soil C and N stocks. Low SDI was observed on annual cropland compared to permanent cropping systems, this observation affirmed the that most smallholder farmers practice results in soil quality degradation [64,65]. Land use change significantly alters vegetation biomass stock and plant species diversity, such is attributable to the various input of organic residues and hence, soil C stock and soil C storage potential [66]. This affects the potential of cropland to sequester and/or capture atmospheric carbon, which can mitigate climate change in the long term [58]. Adoption of sustainable land use and management options incorporating climate-smart agriculture practices can enhance the potential of smallholder land use systems to sequester carbon, thereby reducing emissions in the atmosphere [67]. Needed are sustainable practices and strategies to increase smallholder farmers' adaptation capacity under the changing climate [61]. The potential of smallholder farming and land use practices to sequester carbon need to be boosted also for climate change mitigation. Strategies may include re-carbonization (enhancing soils capacity for carbon storage) of soils of agroecosystems using sustainable restoration management strategies to reintegrate smallholder agricultural activities into the global produce and carbon market and for policymakers at local and national levels and international community (UN, WTO, etc.) [68].

Conclusions

The physical, chemical and biological properties of soils under the land use types were measured (soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, soil bulk density, moisture content and porosity). There were differences between the permanent land use types (forest land, agroforestry, fallow land, cocoa, citrus, oil palm, ornamental plant field) and arable (annual) crop fields for soil organic matter, available nitrogen, bulk density and clay content. It was observed that irrespective of land use type, soil particle sizes did not differ significantly among land use types. However, differences were found for concentration of SOC, total N, P, K, Ca, Mg for oil palm plantation, cocoa and citrus orchards, agroforestry, fallow land and maize field. Soil pH was highest for forest and permanent crop fields compared to other land uses, and the soils under forest and permanent crop fields had higher SOC, total nitrogen, available P, carbon and nitrogen stock compared to annual crop fields. The land use types influenced soil C and N contents and stocks in a addition to other physical and chemical properties. Soil organic carbon and total nitrogen contents and stocks of the land use types differed within soil depths (0 - 20 and 20 - 50 cm) Higher values of soil organic carbon and total nitrogen contents and stocks were found for upper soil layers (0-20 cm) compared with lower soil depths (20-50 cm). There were significant differences in clay content, SOC and total nitrogen stocks among land use types and soil depths. Soil bulk density was significantly higher for maize field compared with forest and permanent crop lands. high bulk density indicate soil compaction soil due to intensive tillage in maize field. Generally, the permanent land use systems (agroforestry and permanent crop lands) had more favourable soil biophysical and chemical properties, while annual (arable) cropping degrade the soil (physical, chemical and biological properties). Decreasing order of SOC and total N stocks were: forest>agroforestry>fallow>ornamental plant field > cocoa, citrus>oil palm >maize field within 0-50 cm. Lower SOC and TN under maize field indicate soil fertility depletion under this land use, where as the higher soil nutrients and stocks of SOC and total nitrogen under forest and permanent crop field soils suggest the importance of this land use types for addressing soil nutrient depletion and carbon storage in soil.

Strategies for restoration of degraded lands or avert trends of soil degradation may benefit form findings from this study which will have applications for improving soil nutrient and carbon storage and for enhancing sustainable land use and landscape management. The low input continuous cultivation of annual crops (such as maize), would require soil conservation and fertility management measures to address the trends of soil degradation and nutrient depletion. Mitigating the loss of soil nutrients and degradation of soil properties under continuous cropping (eg, maize) cultivation through the retention of crop residues, manure use, crop rotation practice. These practices that will increase soil pH and organic matter and SOC and N stocks especially in maize farm and will improve soil carbon sequestration.

Carbon markets for ecosystem services can contribute additional income and/or incentives to resource-poor farmers to invest in soil management. The estimation of C stocks can be traded. This can serve as a baseline to establish a large-scale inventory of SOC database for Nigeria to assess funds from the Clean Development Mechanism (CMD). The carbon sequestration potentials of forest-based land use systems will serve as emission reduction targets for developed and/or industrialized countries under article 12 of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) [69-120].

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