Chapter 8
Effect of Climate Change on Soil Organic Carbon Storage in Four Land Use Types in Abakaliki, South Eastern Nigeria

J. E. Orji, C. A. Igwe, and P. I. Ezeaku

Abstract Soil organic carbon (SOC) has been found to negatively impact the environment due to its emission of carbon (iv) oxide (CO_2) a greenhouse gas with a serious effect on global climate change. A study was conducted to determine the effect of climate change on soil organic carbon storage in four land use types in the Abakaliki, south eastern Nigeria. The four land use types selected include managed forest plantation (MF), fallow land, grass land and continuously cultivated soil (CCS). Undisturbed and core samples were collected at three soil depths (0–20, 20–40 and 40–60 cm) and replicated five times for bulk density, total porosity, saturated hydraulic conductivity, particle size distribution, pH, organic carbon, total nitrogen available phosphorus and exchangeable acidity. The results showed that the soils in the area were predominantly sandy loam and sandy clay loam in texture. Bulk density values were lowest in the fallow land and highest in the continuously cultivated soil across the three depths. Saturated hydraulic conductivity values were highest in MF and lowest in CCS soil across the three depths. The pH of the soils was slightly acidic. Fallow land recorded the highest soil organic carbon (SOC), total nitrogen and available phosphorus while continuously cultivated soil had the lowest values for the soil nutrients at 0–20 cm. The result on total organic C storage showed that MF recorded the highest value (340.67 Mg C ha^{-1}), while CCS recorded the lowest value (151.49 Mg C ha^{-1}) across the three soil depths.

Keywords Climate change · Organic carbon · Storage · Land use · Soil

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Introduction

Soil organic matter (SOM) is known as a major component of soil that affects its physical, chemical and biological properties, and contributes greatly to its proper functioning on which human societies depend. SOM is made of organic compounds that are highly enriched in carbon (Murphy 2015; Chokor and Egborah 2018). Soil organic carbon, an integral part of soil organic matter is the component of soil obtained from dead living matter decomposed by soil microorganisms. It is a known source of nutrients for plants and energy for soil microorganisms. Soil organic carbon (SOC) levels are directly related to the amount of organic matter contained in the soil and SOC is often how organic matter is measured in soils (D'Amato et al. 2011). SOC levels result from the interactions of several ecosystem processes, of which photosynthesis, respiration and decomposition are key. Photosynthesis is the fixation of atmospheric CO_2 into the plant biomass (Powers et al. 2011).

The land use type, changes in land use and management practices influence the amount and rate of soil carbon losses (Guggenberger et al., 1995). Land use types affect the amount of soil carbon emission. Han et al. (2011) observed increase in soil organic carbon when arable crops were converted to grass land in China. Soil organic carbon plays an important role in supplying plant nutrients (N, P, S) enhancing cation exchange capacity, improving soil water retention and supporting biological activities (Dudal and Deckers 1993).

Soil comprises the largest pool of terrestrial C and through soil organic matter (SOM) cycling; it represents either an important sink in atmospheric CO_2 or a possible source of greenhouse gases. The concentration of carbon (iv) oxide in the atmosphere which encourages climate change is greatly influenced by the balance between soil organic carbon (SOC) inputs and outputs (IPCC 2007). Normally, the carbon pool in the soils is approximately twice as that in the atmosphere. The amount of soil organic carbon in the soil is controlled by several factors like climate (rainfall, temperature, etc.), parent materials and land use types (Akpan et al. 2018; Vose et al. 2012).

Forests, fallow and grass land vegetation contributions to the soil organic carbon pool include leaf litter, coarse woody debris, roots exudates and dissolved organic matters leached from the top (litter) layer (Nave et al. 2010; D'Amore and Kane 2016). The stabilization of these organic inputs in the mineral soil matrix (storage) or biodegraded and returned to the atmosphere as carbon (IV) oxide (CO_2) depends on complex, fine-scale interactions involving soil minerals, plants and soil organisms and organic components, and all these interactions are influenced by several factors such as climate, soil management practices and land use types (Johnson et al. 2009).

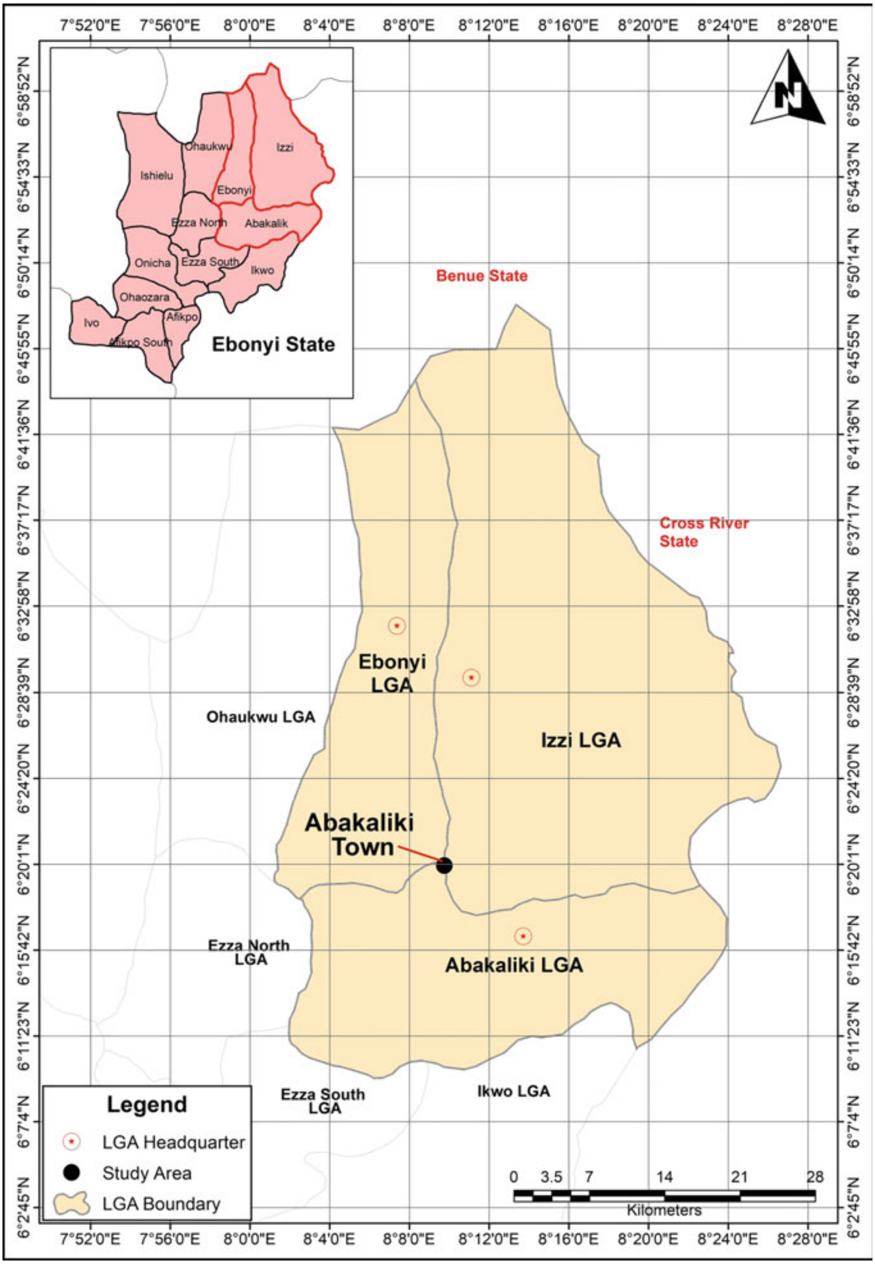
Soil organic carbon is lost and released to the atmosphere when trees are felled and soils ploughed (tillage). Among the emitted greenhouse gases which encourage global warming that results to climate change, carbon (iv) oxide contributes 72% of the total gases emitted (IPCC 2007). Regular disturbances on soils through tillage operations during crop production result to loss of soil organic carbon to the atmosphere as CO_2. Therefore, to reduce atmospheric carbon (iv) oxide in order to mitigate the effect of climate change, the existing atmospheric carbon must be captured and stored in soils and plant biomass. However, relatively little is known about the effect of climate change on carbon storage in different land use types in the Abakaliki, South eastern Nigeria. The objective of the study, therefore, is to determine the effect of climate change on carbon storage in four land use types in the Abakaliki, South eastern Nigeria.

Materials and Methods

Site Description

The study was carried out at four locations with a particular land use type situated in the Abakaliki Ebonyi State, South Eastern Nigeria in 2019 cropping season. The Abakaliki in Ebonyi State lies between Latitude 06° 25 N and longitude 08° 3′ E and altitude of 170 m. The rainfall ranges from 1700 to 2000 mm with mean annual rainfall of 1800 mm (ODRNI 1989). The mean annual temperature ranges from 27 to 31 °C throughout the year. The relative humidity is high 80% during rainy season but declines to 65% in the dry season (ODRNI 1989).

The relief of the area is generally undulating and no location exceeds 200 m above sea level. Geologically, the soil of the area is underlain by sedimentary rocks derived from successive marine deposits. According to FDALR (1987), the Abakaliki agricultural zone lies within Asu River and is associated with brown olive shales, fine grained sandstone and mudstone. The soils of the area being basically clayey loam underlain with laterite are particularly suitable for the cultivation of rice, yam, cassava, maize, etc. The soil is shallow with unconsolidated parent material up to 1 m depth belonging to the order ultisol classified as Typic Haplustult (FDALR 1987). The major vegetation of the area is derived savanna characterized by growth of shrubs, herbs, dispersed large trees and common tropical grasses.



The map of Ebonyi state, showing Abakaliki the study area (the Abakaliki area covers three local government areas viz*: Abakaliki, Ebonyi and Izzi).*

The four land use types and their land use history are described below as follows;

Managed Forest Plantation (MF): Artificial *Gmelina arborea* was established at Azugwu Abakaliki during the colonial era for preservation of forestry resources spanning for 50 years (Nwite et al. 2018). Other species of trees and shrubs are also found growing in the plantation. Hunting and farming activities are prohibited although poaching is not completely eliminated as people still encroach in the forest for farming related activities. The land area for the study was measured 100 × 100 m which is equivalent to 1 ha.

Fallow Land (FL): The fallow is located behind All Saints Cathedral, Abakaliki near Ogoja road. It lies between latitude 06° 19′ 17N and longitude 08°06′ 23E (Google map 2019). The fallow has lasted for more than 10 years. There are different types of vegetation covering the land but among major ones are scattered trees, herbs, shrubs and grasses like guinea grass (*Panicum maximum),* wire grass (*Sporobulus pyramidalis*), goat weed (*Ageratum conyzoides*)*,* stubborn weed *(Sida acuta).* The land area of 100 × 100 m equivalent to 1 ha was measured for the study.

Grass Land (GL) is located at Bishop Otubelu College Abakaliki. The grass land is periodically undercut especially the area that serves as field for games, some parts of the land is used to graze animals. The grass land has existed over 20 years. The land is grown with herbs but dominated by grasses such as *Tridax*, giant star grass, guinea grass, wire grass, goat weed *and* stubborn weed. The land area for the purpose of the study is measured 100 × 100 m equivalent to 1 ha.

Continuously Cultivated Soil (CCS) otherwise known as arable land is located behind Law Faculty of Ebonyi State University Abakaliki. The land is the experimental farm of the Department of Soil Science and Environmental Management, Faculty of Agriculture, Ebonyi State University, Abakaliki. The area has been under yearly cultivation for more than 18 years by students and staff of the department. It has been subjected to conventional tillage operations, use of chemicals (like fertilizers, herbicides and pesticides), organic amendments and other cultural practices. Common crops grown in rotation include yam (*Dioscorea spp*), cassava (*Manihot spp*), maize (*Zea mays* L), vegetables, cucumber and leguminous crops. The land area measured out for the purpose of the research is 100 × 100 m equivalent to 1 ha.

Soil Sampling Procedure

Soil samples were collected from the four (4) selected land use types. Undisturbed samples were randomly collected from all the four land use types at three different depths (0–20, 20–40 and 40–60 cm) using open-faced coring tube of 6 cm height and 5 cm diameter for determination of physical properties of the soil. Within each land use type, two (2) core and an auger samples of the soils were collected from each of the three depths and replicated five times for physicochemical properties determination of soils of the land use types.

The experiment was laid out in a randomized complete block design (RCBD) with four treatments (the four land use types viz: Continuously cultivated soil, fallow land, grass land and managed Gmelina plantation), three sub treatment was the soil depths (0–20, 20–40 and 40–60 cm) and replicated five times.

Laboratory Methods

The disturbed soil samples were air dried and sieved through 2 mm mesh. The undisturbed core samples were used for bulk density, total porosity and hydraulic conductivity determinations only. The samples <2 mm were used for the determination of particles size distribution (in water and calgon), soil pH, soil organic carbon, total Nitrogen, available phosphorus, exchangeable acidity according to the standard analytical procedures. Particle size distribution was determined using Bouyoucous hydrometer method as described by Gee and Bauder (1986). The textural class of the soil was determined using the textural triangle.

Bulk density was determined using core sampling method after oven drying the soil samples to a constant weight at temperature of 105 °C for 24 h ((Blake and Hartage 1986; Grossman and Reinsch 2002). Total porosity was calculated from soil bulk density using as assumed particle density of 2.70 gcm^{-3}. Saturated hydraulic conductivity (Ksat) was determined by core method as described by Klute and Dirksen (1986). Soil pH was determined both in water and 0.1 N potassium chloride solution at the ratio 1:2.5 soil/water suspension using standardized glass electrode pH metre (Udo et al. 2009).

Soil organic carbon content of the soil and aggregate-associated carbon was quantified by Walkley and Black wet oxidation method as described by Nelson and Sommers (1998). Total nitrogen content of the soil (<2.00 mm) was determined by the Micro Kjeldahl digestion method using $CuSO_4$ (Copper sulphate) and Na_2SO_4 (Sodium sulphate) catalyst mixture (Bremner and Mulvanney 1982). Available phosphorus was determined using Bray II bicarbonate extraction method (Bray and Kurtz 1945) using 0.03 N ammonium fluoride with 0.1NHCl. The phosphorus in the extract was determined with a photo-electric colorimeter. Exchangeable acidity (EA) was calculated by summing the values of exchangeable aluminium and hydrogen; $EA = Al^{3+} + H^{+}$.

Soil carbon storage ($MgCha^{-1}$) was quantified as the product of fractional mass of carbon, soil depth (m), soil bulk density (mg/m^3) and land area/ha (m^2/ha) thus.

$MgC\ ha^{-1} = [\%\ C \times BD \times d \times 10^4 m^2]/100$ (Lal et al. 1998).
where $MgC\ ha^{-1}$ = mega gram carbon per hectare ($1\ Mg = 10^6$ g).
%C = percentage of carbon given by laboratory result.
Bd = soil bulk density (gcm^{-3}).
d = depth in metres.

Data Analysis

An analysis of variance (ANOVA) of each soil properties within each depth and land use type was performed on the soil data generated from laboratory using the Genstat Discovery Software, edition 4. Mean separation was done using the Fisher's least significant difference (FLSD) at 5% level of probability. Descriptive statistics (mean, range and coefficient of variation) was used to assess the variability in soil physicochemical properties across the land use types. Coefficients of variation were ranked according to Aweto (1980) as follows: $CV < 20\%$ low variation, $CV = 20–50\%$ moderate variation and $CV = 50\%$ and above high variation.

Results and Discussion

Physical Properties of Soils of the Different Land Use Types

The results in Table 8.1 show the physical properties of the soils of the four land use types studied. The result revealed that the sand fraction was significantly different ($P < 0.05$) among the land use types and varied from 620 to 740 gkg^{-1} with coefficient of variation (CV) of 5.0% at 0–20 cm depth, 580 to 640 gkg^{-1} with CV of 6.0% at 20–40 cm depth and, 580 to 680 gkg^{-1} (CV: 7.0%) at 40–60 cm. The sand fraction decreased generally with depth in all land use types except at 40–60 cm depth in FL which could be attributed to the selective movement of soil particles from one horizon to another by erosion and variations in weathering intensity (Kolo 2019). The sand fractions are similar in variation irrespective of different land use types as evidenced by their CV values ($CV \leq 7.0\%$). The general decrease in sand fraction with depth was reported by Thomas and Oke (2018). The silt fraction was found to be significantly different ($P < 0.05$) among the four land use types. Silt fraction varied from 90 to 190 gkg^{-1} with CV of 11.0%, 70 to 170 gkg^{-1} with CV of 39.0% and 70 to 150 gkg^{-1} with CV of 39.0% for 0–20, 20–40 and 40–60 cm depths, respectively (Table 8.1). The distribution of silt fraction was irregular with depth across the land use types. Although in CCS, FL and GL land use types, silt fractions decreased with increase in depths but the reverse was the case with MF which could be as a result of loessial deposit on soils of managed Gmelina plantation (Maniyunda and Gwari 2016; Maniyunda 2018). According to Sharu et al. (2013) the development of soils in-situ is responsible for the irregular distribution of silt down the soil depths.

The clay fraction varied from 130 to 230 gkg^{-1} (CV: 30.0%) at 0–20 cm depth, 250 to 270 gkg^{-1} (CV: 4.0%) at 20–40 cm depth and 230 to 310 gkg^{-1} with CV of 13% at 40–60 cm depth. The clay fraction was found to be significantly different ($P < 0.05$) among the four land use types. According to the result, clay fraction increased with depth at 0–20 and 40 cm but varied at 40–60 cm depth. Continuously cultivated soil (CCS), fallow land (FL) and grass land (GL) land use types recorded higher values of clay fractions at the sub soil (20–40 cm and 40–60 cm) depths compared to the top

Table 8.1 Physical properties of soils of the four land use types

Land use	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	TC	Bd (gcm^{-3})	TP (%)	Ksat (cmh^{-1})
0–20 cm							
CCS	680	190	130	SL	1.75	36.41	15.52
FL	740	110	150	SL	1.51	46.50	25.75
GL	740	130	130	SL	1.69	36.60	1854
MF	680	90	230	SCL	1.58	43.49	2453
MEAN	710	130	160		1.63	40.75	21.09
CV (%)	5.0	11.0	30.0		6.0	12.0	23.0
FLSD (0.05)	6.29	58.35	6.29		0.15	2.26	8.73
20–40 cm							
CCS	580	170	250	SCL	1.65	36.79	13.05
FL	640	90	270	SCL	1.35	50.00	16.92
GL	660	70	270	SCL	1.68	36.60	13.74
MF	640	110	250	SCL	1.68	36.60	28.41
MEAN	630	110	260		1.59	40.00	18.04
CV (%)	6.0	39.0	4.0		9.0	17.0	39.0
FLSD (0.05)	25.94	34.09	50.71		0.89	15.73	1.89
40–60 cm							
CCS	580	150	270	SCL	1.62	38.52	5.80
FL	680	70	250	SCL	1.33	50.97	7.09
GL	620	70	310	SCL	1.64	38.30	17.10
MF	640	130	230	SCL	1.65	38.35	14.20
MEAN	630	105	265		1.56	41.54	11.05
CV (%)	7.0	39.0	13.0		9.0	15.0	50.0
FLSD (0.05)	15.41	62.90	3.15		0.99	5.03	4.40

TC—Textural class Bd—Bulk density, TP—Total porosity, Ksat—Saturated hydraulic conductivity, CCS = Continuously cultivated soil, FL = Fallow land, GL = Grass land, MF = Managed Gmelina plantation. CV = Coefficient of variation

soils (0–20 cm) (Table 8.1). This might be attributed to the selective transport of finer soil particles into lower soil depths by eluviation/illuviation processes (Akamigbo et al. 2001; Mustapha et al. 2003; Osuaku et al. 2014; Amuyou and Kontigo 2015). The higher clay on the upper depth (20–40 cm) of MF land use type might be attributed to clay accumulation from the selective dissolution of more soluble minerals (Boul et al. 2003).

The particle size distribution result is in tandem with the general trend in particle size distribution sand > clay > silt, this was also observed by Asadu and Akamigbo

(1983) in most soils of southeastern, Nigeria. The dominance of sand fraction in the soils may be attributed to high content of quartz mineral in the parent material. Lawal et al. (2013) and Osujieke et al. (2016) reported that sand dominated the mineral fraction due to quartz rich parent material, clay migration, surface erosion and geological sorting of soil materials by biological activities in their field of study. Low silt fraction observed in the soils could be attributed to leaching and nature of the parent material (Nsor 2017). The textural class of the soils of the different land use types varied from sandy loam to sand clay loam (Table 8.1). The textural variation across the land use types might be attributed to the selective removal of soil particles from one location to another by agents of soil erosion and variation in weathering intensity (Kolo 2019).

Across the soil depths (0–60 cm), the value of bulk density was significantly different ($P < 0.05$) among the land use types and ranged from 1.33 to 1.75 gcm^{-3}. The highest (1.75 gcm^{-3}) and lowest (1.51 gcm^{-3}) bulk density values at 0–20 cmsoil depth were recorded at continuously cultivated soil (CCS) and fallow land (FL), respectively. The values of bulk density ranged between 1.33 and 1.65 gcm^{-3} with CV of 9.0% (mean = 1.63 gcm^{-3}) at 0–20 cm depth, 1.35 and 1.68 gcm^{-3} (CV 9.0%; mean = 1.59 gcm^{-3}) at 20–40 cm depth and 1.51 and 1.75 gcm^{-3} with CV of 6.0% (mean = 1.56 gcm^{-3}) at 40–60 cm depth (Table 8.1). Fallow land recorded the lowest bulk density among the land use types across the depths which ranged from 1.33 to 1.50 gcm^{-3} which has advantage of increased porosity (Brady and Weil 2010; Vogelmann et al. 2010) with accompanied adequate aeration. The increase in bulk density with depth may be attributed to compaction caused by the weight of the overlying horizons and decrease in organic matter with depth. This agrees with the reports of Chaudhari et al. (2013) and Fedaku et al. (2018) as they reported increasing bulk density with depth due to changes in organic matter content, porosity and compaction.

The mean values of total porosity ranged from 40.00 to 41.54% for the different land use types and across the depths defying a particular trend. Total porosity values of the soils were significantly different ($P < 0.05$) among the land use types. Total porosity varied from 38.30 to 50.90% with CV of 15% at 0–20 cm depth, 36.60 to 50.00% with CV of 17% at 20–40 cm depth and 36. 41 to 46.50% with CV of 12% at 40–60 cm depth. The trend in enhancement of total porosity by the different land use types at 0–20 cm depth is FL > MF > GL > CCS. Increase in bulk density reduces pore spaces (Okolo et al. 2015). Also, continuous traffic and agricultural activities on land (Akamigbo et al. 2001). The decrease in total porosities with depth might be attributed to the decrease in organic matter content with depth (Hassan and Shuaibu 2006).

The values of hydraulic conductivity of the soils were significantly different ($P < 0.05$) among the land use types The result showed that Ksat ranged from 15.52 to 25.75 cmh^{-1} with CV of 39.0% at 0–20 cm, 13.05 to 28.41 $cmhr^{-1}$ (CV: 39.0%) at 20–40 cm and 5.80 to 17.10$cmhr^{-1}$ (CV: 50.0%) at 40–60 cm. The wide variation (23.0, 39.0 and 50.0%) observed in Ksat might be due to variation in particle size distribution and moisture content (Shelton 2003; Obalum et al. 2011). Hydraulic conductivity increases with decrease in bulk density, increase in porosity and organic matter content (Anikwe 2000). The values of Ksat were found to be lower in sub soil when compared with the top soils suggesting low rate of water transmission in the former due to accumulation of clay (Ezeaku et al. 2015). At 0–20 cm depth, fallow land recorded the highest value (25.75 cmh^{-1}) when compared with other land used types. In all, 0–20 cm recorded the highest mean value when compared with the other depths and the trend of the decrease in the mean values was 0–20 > 20–40 < 40–60 cm (Table 8.2). Antonio et al. (2001) and Bagarello and Lovino (2003) reported high Ksat on top soils due to higher water content and smaller pores.

Table 8.2 Chemical properties of soils of the land use types

Land use	pH (H_2O)	pH (KCl)	OC	TN	Av.P (mgkg^{-1})	H^+	Al^{3+} cmolkg^{-1}	EA
0–20 cm								
CCS	6.20	5.00	4.74	0.98	4.89	1.60	0.20	1.80
FL	6.40	5.20	11.37	1.68	11.99	1.40	0.60	2.00
GL	6.90	5.60	6.58	1.40	5.60	1.20	0.00	1.20
MP	5.60	4.20	10.27	1.54	9.40	1.20	1.00	2.20
Mean	5.38	5.00	8.24	1.40	7.97	1.45	0.55	1.90
CV (%)	10.0	12.0	38.0	21.0	38.0	14.0	113.0	26.0
FLSD (0.05)	0.06	0.37	0.07	0.26	0.72	0.37	0.27	0.39
20–40 cm								
CCS	5.60	4.30	3.29	0.70	3.86	1.60	0.80	2.40
FL	5.90	4.70	5.69	1.12	10.93	1.60	1.00	2.60
GL	6.40	5.20	5.53	0.84	4.20	1.00	0.80	1.80
MP	5.50	4.30	7.11	0.98	8.80	1.40	1.20	2.60
Mean	5.85	4.63	5.41	0.91	6.95	1.40	1.05	2.35
CV (%	7.0	9.0	29.0	19.0	32.0	20.0	35.0	9.0
FLSD (0.05)	0.19	0.17	0.02	0.13	0.14	0.52	0.32	0.09
40–60 cm								
CCS	5.60	4.30	2.37	0.70	3.30	1.40	1.00	2.60
FL	6.00	5.00	4.19	0.98	9.60	1.40	1.20	2.60
GL	6.80	5.70	3.56	0.70	3.58	1.20	0.20	1.00
MP	5.60	4.30	6.72	0.84	7.18	1.60	0.20	1.80
Mean	6.00	4.83	4.21	0.81	5.92	1.35	1.10	2.45
CV (%)	9.0	14.0	47.0	17.0	40.0	7.0	35.0	12.0
FLSD (0.05)	0.41	0.43	0.06	0.09	0.25	0.17	0.14	0.34

OM: organic matter; TN: total nitrogen; Av. P available phosphorus; H^+: exchangeable hydrogen; Al^{3+}: exchangeable aluminium; CV: coefficient of variation. CCS = Continuously cultivated soil, FL = Fallow land, GL = Grass land, MF = Managed Gmelina plantation

Chemical Properties of Soils of Various Land Use Type

The chemical properties of the soils of the various land use types are presented in Table 8.2. The soil pH in H_2O and KCl ranged from 5.60 to 6.90 and 4.20 to 5.20 with CV of 10.0 and 9.0%, respectively, 5.50–6.40 and 4.30–5.20 with CV of 7 and 9%, respectively, at 20–40 cm. At 40–60 cm depth, pH in H_2O and KCl ranged from 5.60 to 6.80 and 4.30 to 5.7 with CV of 10 and 14%, respectively. The soil pH was significantly different ($P < 0.05$) among the land use types. Generally, the pH values both in H_2O and KCl were rated moderately acidic to slightly acidic according to the ratings of Enwezor et al. (1989), Fasina et al. (2000), Raji and Mohammed (2007) and Adeputu et al. (2014). This level of soil reaction may be attributed to the influence of the parent materials, continuous cultivation, application commercial fertilizers and loss of exchangeable bases through leaching (Brady and Weil 2002; Havlin et al. 2006; Maniyunda 2018).

Soil organic carbon (SOC) was significantly different ($P < 0.05$) among land use types across the depths. The highest (11.37 gkg^{-1}) and lowest (4.74 gkg^{-1}) values of SOC were recorded at fallow land (FL) and continuously cultivated soil (CCS) at 0–20 cm. Soil organic carbon varied from 4.74 to 11.37 gkg^{-1} with CV of 38.0% (mean = 8.24 gkg^{-1}) at 0–20 cm, for soils at 20–40 cm, SOC varied from 3.29 to 7.11 gkg^{-1} with CV of 29.0% (mean = 5.41 gkg^{-1}) and 2.37 to 6.72 gkg^{-1} with CV of 43.0% (mean = 4.21 gkg^{-1}) at 40–60 cm depths. Generally, SOC contents in the soil under different land use types significantly decreased with depths giving the least values at 40–60 cm depths. The trend of soil organic carbon content under different land use types at 0–20 cm depths is FL > MF > GL > CCS and in the depth intervals the trend is as follows: 0–20 > 20–40 > 40–60 cm (Table 8.2).

Low values of SOC recorded in soils of the various land use types might be attributed to the low content of organic matter in the soils. Mbah and Idike (2011) observed that organic manure like poultry manure has the capacity of improving the nutrient condition of soils. Soil organic carbon had the highest values at the depths of 0–20 cm, with fallow land recording the highest value (11.37 gkg^{-1}) while the lowest (4.74 gkg^{-1}) was obtained in continuously cultivated soils. These variations might be due to high level of humification of organic matter in the top soils as reported by Nsor et al. (2014). Vegetation cover was observed to encourage high organic carbon and organic matter contents of the soils as observed by Chokor and Egborah (2018). The studied soils had generally low content of organic carbon since the SOC of the soils were below the critical value (<17.0 gkg^{-1}) (as reported by Loveland and Webb 2003 and Emmanuel et al. 2018). This could be attributed to leaching and washing effects of high erosivity in the region (Igwe 2005).

Total nitrogen (TN) showed significant difference ($P < 0.05$) among the land use types. Total N at CCS (0.98 gkg^{-1}); FL (1.68 gkg^{-1}); GL (1.40 gkg^{-1}) and MF (1.54 gkg^{-1}) at 0–20 cm. On the other hand, TN recorded 0.70, 1.12, 0.84 and 0.98 $gkg^{-1}$for CCS, FL, GL and MF, respectively, at 20–40 cm soil depth. Similarly, at 40–60 cm the values of TN across the various LUTs are 0.70, 0.98, 0.70 and 0.84 $gkg^{-1}$for CCS, FL, GL and MF, respectively. Total N at 0–20, 20–40 and 40–60 cm varied from 0.98 to 1.68 gkg^{-1} with CV of 21.0%, 0.70 to 1.12 gkg^{-1} with CV of 19.0% and 0.70 to 0.98 gkg^{-1} with CV of 17.0%, respectively. Total nitrogen was generally low, (Maniyunda 2018) which according to Enwezor et al. (1989) could be rated very low to low. The content of TN recorded low variation in its distribution across the land use types with CV ranged from 17 to 21%. The highest TN value (1.68 gkg–^{1}) and the lowest value (0.98 gkg^{-1}) were obtained at 0–20 cm in fallow land and continuously cultivated soil, respectively. The low values of total nitrogen obtained might be attributed to low organic matter content of the soils as OM accounts for 93 to 97% of total nitrogen (Meysner et al. 2006). Total nitrogen of the soils of various land use types decreased with increase in depths with 0–20 cm recording the highest values. Njoku (2012) and Uzoho et al. (2014) attributed low TN to losses through run-off, low organic matter, high N mineralization and crop removal. The higher TN content values in surface soils when compared with the sub-surface soils of the different land use types might be due to nutrient recycling through litter fall (Egbuchua and Ojobor 2011).

The results of available phosphorus showed that the values ranged between 4.89 and 11.99 $mgkg^{-1}$ with CV of 3.0% at 0–20 cm; 3.86 to 10.93 $mgkg^{-1}$ 32.0% at 20–40 cm and 3.30 to 9.60 $mgkg^{-1}$ with CV of 44.0% at 40–60 cm (Table 8.2). Available phosphorus values were rated low to high with content values between 4.89 and 11.99 $mgkg^{-1}$ when compared to the critical value of 10–16 $mgkg^{-1}$ as reported by Adeoye and Agboola (1985); Chokor and Egborah (2018). The CV values of available phosphorus varied between 32 and 40% and considered to be moderately high (Tabi and Ogunkule 2007; Maniyunda 2018). The value of available P at 0–20 cm depths of the soils of FL land use type was higher than 10 $mgkg^{-1}$ critical limit recommended for most commonly cultivated crops whereas others are below. This agrees with the observations of Uponi and Adeoye (2000), Aduayi et al. (2002) and Obigbesan (2009) that reported that the critical limit of available P recommended for most commonly cultivated crops is 10 $mgkg^{-1}$.

Available P decreased with increasing soil depths in all the soils of the land use types with 40–60 cm recording the lowest values. At 20–40 cm FL recorded the highest values (10.93 $mgkg^{-1}$) above the critical limit for available P (10 $mgkg^{-1}$) when compared with other land use types which recorded low values that fall below the critical limit of 10 $mgkg^{-1}$ (Table 8.2). The low values of available P recorded at the sub soils might partly be due to the nature of the parent material and as well due to the ease with which phosphorus undergoes fixation with iron and aluminium oxides under well drained acidic medium (Onyekwere et al. 2001; Nuga et al. 2006). According to Amhaklian and Osemuota (2012), tropical soils are generally low in available P due to low apatite content of the soil forming materials.

Exchangeable acidity (EA) was significantly different ($P < 0.05$) among the various land use types. The values of EA in CCS = 1.80 $cmolkg^{-1}$, FL = 2.00 $cmolkg^{-1}$, GL = 1.20 $cmolkg^{-1}$ and 2.20 $cmolkg^{-1}$ at 0–20 cm depth. At 20–40 cm the values of EA include 2.40, 2.60, 1.80 and 2.60 $cmolkg^{-1}$ for CCS, FL, GL and MF, respectively. Similarly, at 40–60 cm the values of EA include 2.60, 2.60, 1.00 and 2.60 $cmolkg^{-1}$ for CCS, FL, GL and MF, respectively. The exchangeable acidity ranged between 1.40 and 2.60 $cmolkg^{-1}$ with CV of 26.0% at 0–20 cm, 2.20 and

2.60 cmolkg^{-1} with CV of 9.0% at 20–40 cm and 2.20 and 2.80 cmolkg-^{1} with CV of 12.0% at 40–60 cmsoil depths.

Exchangeable hydrogen was significantly different ($P < 0.05$) among the land use types and ranged from 1.20 to 1.60 cmolkg^{-1} with CV of 14.0%. At 20–40 cm H^+ varied from 1.00 to 1.60 cmolkg^{-1} with CV of 20.0%. Exchangeable H^+ varied from 1.20 to 1.40 cmolkg^{-1} with CV of 7.0% at 40–60 cm soil depth. Exchangeable aluminium ranged between 0.00 and 1.4 cmolkg^{-1} with CV of 113.0% at 0–20 cmsoil depth. At 20–40 cm Al^{3+} ranged between 0.80 and 1.20 cmolkg^{-1} with CV of 35.0%. Exchangeable Al^{3+} ranged from 0.20 to 1.20 cmolkg^{-1} with CV of 35% at 40–60 cm soil depths. Exchangeable acidity values were rated low to relatively high according to the rating of Enwezor et al. (1989). Higher values (2.60 cmolkg^{-1} each) were observed in soils of the CCS and FL land use types at 40–60 cm. This might be attributed to the presence of iron and aluminium oxides at the sub soils. The high values of EA could be attributed to the application commercial fertilizer, uptake of basic cations and leaching (Orji Uzor and Obasi 2015; Mohammed 2017). Mustapha et al. (2003) and Fasina et al. (2005) attributed higher values of EA on subsoil to the solubility and movement of exchangeable acidity down to the soil from surface soils. The variation of EA across the soil depth is low with a CV range between 15.0 and 24.0% according to Aweto (1980).

Carbon Storage on Soils of the Four Land Use Types Across the Three Soil Depths

The results of carbon storage across the land use types are presented in Table 8.3. The result showed that carbon storage ranged between 29.28 and 126.88 MgCha^{-1} at 0–20 cmsoil depth, 47.41 and 135.48 MgCha^{-1} at 20–40 cm soil depth and 42.54 and 78.32 MgCha^{-1} across the land use types (Table 8.3). The total carbon storage across the depths showed that 0–20 cm recorded the highest value (352.18 MgCha^{-1}) whereas 40–60 cm recorded the lowest value (265.97 MgCha^{-1}) which implies that carbon storage decreased with increase in depth. The highest value (126.88 MgCha^{-1}) for carbon storage was obtained in managed forest plantation, and the lowest value (29.28 MgCha^{-1}) was obtained in continuously cultivated soil at 0–20 cm soil depth. The mean values of carbon storage across the soil depths ranged from 66.49 to 88.05 MgCha^{-1} whereas the coefficient of variation varied between 25.0 and 60.0%.

The total carbon storage across the land use types is as follows; CCS = 151.49 MgCha^{-1}, FL = 217.08 MgCha^{-1}, GL = 195.92 MgCha^{-1} and MF = 340.67 MgCha^{-1} (Table 8.3). The trend for increase in total carbon storage across the land use types is MF > FL > GL > CCS. This could be attributed to the ability of forest trees to sequester and store carbon in soil through the litter fall which increases SOM and in turn encourages carbon storage. Many researchers (Nowak et al. 2010; Mbah and Idike 2011; Nowak and Greenfield 2012) have reported that

Table 8.3 Carbon storage on soils of the four land use types across the three soil depths

Carbon storage (MgCha^{-1})				
Land use	0–20 cm	20–40 cm	40–60 cm	Total
CCS	29.28	47.41	74.81	151.49
FL	95.05	51.72	70.31	217.08
GL	100.98	52.41	42.54	195.92
MF	126.88	135.48	78.32	340.67
TOTAL	352.18	287.01	265.97	905.16
Mean	88.05	71.76	66.49	226.29
CV (%)	48.0	60.0	25.0	

CCS = Continuously cultivated soil, FL = Fallow land, GL = Grass land, MF = Managed forest plantation, CV = Coefficient of variation.

natural undisturbed forests store high quantity of carbon. On the other hand, the low carbon storage observed in CCS during the period of study could be as a result of tillage operation, run-off, leaching and nutrient uptake. The observation corroborates with the reports of previous studies that tillage adversely affects carbon storage in soils (Anikwe 2006; Mbah and Idike 2011). Similarly, Bationo et al. (2007) in their study of soil organic carbon dynamics, functions and management in West African agro-ecosystems observed rapid decline of SOC levels with continuous cultivation.

Conclusion

The study showed that physical and chemical properties of soils of the various land use types including carbon storage were significantly higher in managed forest plantation, fallow land and grass land than in continuously cultivated soil due to the effect of climate change. The trend in carbon storage was as follows: managed forest plantation > fallow land > grassland > continuously cultivated soil. The soil physicochemical properties including total carbon storage were significantly higher at 0–20 cm soil depth than 20–40 and 40–60 cm soil depths. In all the land use types, managed forest plantation had the highest carbon storage while continuously cultivated soil had the lowest. Therefore, in the face of climate change, the land uses such as managed forest plantation, fallow land and grassland should be encouraged in order to capture and store the existing atmospheric carbon into the soil and biomass to mitigate the effect of climate change while continuous cultivation should be discouraged since it encourages carbon emission into the atmosphere which promotes climate change. It is, therefore, recommended that continuous cultivation which exposes the soil and hinders carbon storage should be discouraged especially now climate change is ravaging the global ecosystem rather managed forest plantation, fallow land and grass land should be encouraged in order to mitigate the effect of climate change.

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