Influence of Land Use on Soil Organic Carbon and Microbial Biomass in Sokoto Area, Nigeria

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ABSTRACT: The influence of land use on soil organic carbon and microbial biomass distribution in some selected areas of Sokoto Nigeria was investigated. Four different types of land use were selected (irrigated area, permanent crop area, windbreak area and arable area). Four profile pits were excavated and described from each of the four different land use types. Soil samples were collected from each horizon for laboratory analysis and total microbial biomass determination by the use of Nutrient Agar. The results shows that variation exists in the soil organic carbon (SOC), pH, particle size distribution and microbial biomass from the different land use types. Irrigated area was found to have the highest soil organic carbon (30.17gkg^{-1}) followed by permanent crop area (28.97gkg^{-1}). The bacteria population was found to be higher in the arable land area (1.2 x 10^8 cfu/g) followed by windbreak area (1.0 x 10^8 cfu/g). The pH of the soils ranged from very strongly acid (4.63) to moderately acid (6.05). The textures of the soils in all the four (4) land use areas were sandy and loamy sand. The study provides some baseline information regarding the causes of variation in soil organic carbon and microbial biomass from different land use types in this environment. However further research is required for in-depth understanding of the underlining processes that regulate soil microbial biomass and organic carbon variation as influenced by land use.

INTRODUCTION

Soil is the largest pool of terrestrial organic carbon in the biosphere, storing more carbon than is contained in the atmosphere. Soil also plays an important part in global carbon cycle as it contains about 1550 Pg of organic carbon and 750 Pg of inorganic carbon within 0100cm depth. Similarly, Soil organic matter is a large reservoir of C that can act as a sink or source of atmospheric CO_2 (Lugo and Brown, 1993). It is also an important source of inorganic nutrients for plant production in natural and managed ecosystems. Moreover, soil organic matter (SOM) governs structural stability and cation exchange capacity of soils either directly, through its chemical structure and or indirectly as a source of energy and nutrients for soil biota (Zech et al., 1997). These effects are especially important in cultivated tropical soils where SOM is frequently related to soil fertility. The magnitude of soil organic carbon (SOC) pool is a product of complex interactions among climate, topography, texture, and land-use practices (Parton et al., 1987, Burke., et al., 1989; Pennock and Van Kessel, 1997; Tan et al., 2003). Land use type is also believed to greatly influence organic matter distribution in soils, for instance conversion from natural to agricultural ecosystems decreases SOC pools and the magnitude of the decrease depends on land use, management, and ecological factors. Quantification of the loss of SOC by conversion to agricultural land use provides a reference point with regards to the potential of re-sequestration of SOC through improved management. Change in land use impacts soil organic carbon (SOC) pools and fluxes. Houghton (1995) estimated that 120 Pg carbon has been released to the atmosphere due to change in land use throughout the world since 1850. Change in land use typically results in differing rates of erosion, aggregate formation, biological activity, and drainage, which all have a significant impact on SOC accumulation and carbon dioxide evolution. Losses of SOC result in the decrease in soil moisture, atmospheric and soil quality. Different land uses have variable impact on SOC pool and dynamics. Agricultural, forested and pastured lands make up the most land area and have a potential to sequester large amounts of carbon. About 77.3% of all land use change is due to removal of forests and conversion of grasslands for arable land use (Lal et al., 1997).

The importance of organic matter in agriculture can not be over-emphasized as reveal from the numerous functions it serves in the soil. Understanding the variation in organic carbon and microbial distribution in soils under different land use types is therefore of paramount importance. Considering the fact that not much studies of this nature have been conducted particularly in Sokoto environment, the present study is of valuable importance in this direction.

The objective of this study is to determine the variation of soil organic carbon pools and the microbial biomass in different land use types in Sokoto, semi arid, Nigeria.

MATERIALS AND METHODS

Description of the Study Area

This research work was carried out in the permanent site of the Usmanu Danfodiyo University Sokoto, located in the northwestern part of Nigeria between latitude 11^0 30' and 13' 50' N and Longitude 4^{o}0' to 6^{o}0'E (SSGD, 2003). The vegetation type is Sudan Savannah characterized by scattered trees such as Acacia nilotica, Acacia albida, Adansonia digitata etc. and shrubs such as Colotropis procera (Iloeje, 1981). Sokoto State enjoys semiarid climate characterized by a long dry season and short rainy season. The mean annual rainfall varies from 380 mm to 899 mm decreasing northwards (SADP, 1992). The maximum and minimum temperatures of the area are 40^{o}C and 15^{o}C respectively (Arnborg, 1988).

Field Study

For the purpose of this study four pedons (all >100 cm depth) were excavated in each of the land use types identified (irrigated area, permanent cropped area, windbreak area and arable area). Soil samples were taken from various horizons after describing the profiles using a soil profile description manual (FAO, 1977). The soils have been classified as Typic Ustifluvents (irrigated and permanent cropped areas) and Typic Ustipsmments (windbreak and arable area) by Noma and Yakubu (2002). Samples from the pedons were taken to the laboratory, air dried and sieved to remove materials coarser than 2mm prior to chemical analyses.

Crops grown in the filed under study include onions, tomatoes and other vegetables in the irrigated areas, mango trees, pawpaw, and banana, in the permanent crop areas, neem trees, Acacia and arable crops in the windbreak area and millet, cowpea and sorghum in the arable land.

Physical and Chemical Analysis

Particle size distribution was determined by use of hydrometer method (Bouyoucos, 1936). Organic carbon was determined by Walkley-Black method (Walkley and Black, 1934). The soil pH was determined in 1:2 (soil: water) using Glass Electrode pH meter.

Microbial Analysis

Media preparation

The culture medium used was Nutrient Agar (NA) and was prepared according to the manufacturer's manual. Twenty eight (28) grams of this medium was poured in a conical flask containing 1000mls of distilled water. The content was vigorously shaken till homogenous suspension was obtained. It was then heated using hot plate to ensure complete dissolution and sterilized by autoclaving at 121^0C for 15 mins. It was allowed to cool to about 45^0C before dispensing 20ml portion into each sterilized Petri dish and allowed to solidify. The plates were incubated at 37°C for 24 hours to check for sterility of the medium. Plates showing no bacterial growth were used.

Determination of total plate count

The soil samples collected were subjected to the following:

1 gram of each soil sample was placed separately in a sterile conical flask and 10mls of sterile distilled water was added to each conical flask. All the conical flasks were mechanically shaken for 30 minutes to ensure that microorganisms are brought to suspension in water. Serial dilution was carried out by pipetting 1 ml from the conical flask into 9ml of sterilized distilled water; this made 1:10 dilution. From 1:10 dilution tube, another 1 ml was transferred into tube 2. This was repeated until tube 6 making dilutions of $1:10^{-1}$, $1:10^{-2,}$ $1:10^{-3,}$ up to $1:10^{-6}$. Using a fresh and sterilized pipette 0.2ml of dilution from 10^{-6} was inoculated in duplicates using surface plating technique. A bent glass-rod was used to spread the inoculums over the surface of the plates. The plates were then incubated at 37^0C for 24 hours. Plates showing little or no growth were further incubated for 48 hours before discarding.

After incubation, plates showing between 300-500 colonies were counted. Each plate was divided into 4 quadrants. Only one quadrant was counted and the result multiplied by 4. This gives the total number of colonies per plate. To get the number of bacteria in 1gram of the soil sample, the dilution factor (10^{-6}) from which aliquots were plated is used. The volume plated was also used. Total number of bacteria was calculated in colony forming units (cfu) as follows:

A x (0.2) x 5 x dilution factor, where A is the total number of colonies in the plate.

Direct count method was employed in determining the bacterial density in the soil. The mean count of colony forming unit (cfu/g) was conducted using reaction to stain, shape of cell, arrangement of cell as well as colonial appearance.

RESULTS AND DISCUSSION

Particle Size Distribution

The result of particle size analysis is presented in Table 1. Percentage sand ranged from 84-93% in the soils of the irrigated land, 78-94 % in the soils of the permanent cropped area, 76-94 % in the soils of the wind break area and 93-95% in the soil of the arable land area. The weighted average value of sand is 89 % in irrigated area, 84 % in permanent cropped area, 79 % in the wind break area and 92 % in the arable land.

Table 1: Particle Size Distribution of the Soils

Pedon	Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
1(Irrigated Area)	Ap	0-43	84	15	01	Sand
	AB	43-59	90	09	01	Sand
	BC	59-80	93	06	01	Sand
	C	80-109	92	07	01	Sand
W. ave.			**89**	**10**	**01**	
2(Permanent Cropped area)	Ap	0-12	94	05	01	Sand
	AB	12-34	82	16	02	Sand
	Bw	34-45	78	14	08	Loamy Sand
	C	45-105	84	08	07	Sand
W.ave.			**84**	**09**	**04**	
3 (Wind break Area)	A	0-18	94	03	04	Sand
	AB	18-43	92	06	02	Sand
	B	43-59	85	14	01	Sand
	BC1	59-78	81	09	09	Loamy Sand
	BC2	78-93	78	11	11	Loamy Sand
	C	93-112	76	15	09	Loamy Sand
W.ave.			**79**	**10**	**06**	
4. (Arable Land Area)	Ap	0-30	95	04	01	Sand
	AC	30-56	85	06	01	Sand
	C	56-180	93	05	01	Sand
W. ave.			**92**	**05**	**06**	

W. ave. Weighted average

From all the soil profiles the percentage sand is higher compared to that of silt and clay but more sand was found in arable land area. The variation in the amount of the various soils separates from the different land use types may be due to differences in level of cultivation and other cultural practices. The variation in particle size distribution determines the water holding capacity of soil and hence microbial population. Agehara and Warncke, (2005), reported that soil moisture content and temperature affects N release because of the effect on microbial population.

Chemical Properties of the Soil

Organic Carbon and Soil pH

The values of organic carbon in soils from the pedons under the different land use types ranged from 15 to 33 gkg^{-1} (Table 2).

Table 2: Organic Carbon Content of the Soil

Pedon	Horizon	Depth (cm)	Organic Carbon (gkg^{-1})
1(Irrigated Area)	Ap	0-43	28
	AB	43-59	28
	BC	59-80	33
	C	80-109	32
W. ave.			**30**
2(Permanent Cropped area)	Ap	0-12	30
	AB	12-34	28
	Bw	34-45	30
	C	45-105	28
W.ave.			**29**
3 (Wind break Area)	A	0-18	21
	AB	18-43	29
	B	43-59	22
	BC1	59-78	26
	BC2	78-93	24
	C	93-112	23
W.ave.			**24**
4. (Arable Land Area)	Ap	0-30	23
	AC	30-56	15
	C	56-180	27
W. ave.			**24**

W. ave. Weighted average

The values obtained from irrigated land (Pedon 1) ranged from 28 to 33 gkg^{-1}, in the permanent cropped area (Pedon 2) it ranged from 28 to 30 gkg^{-1}, in the wind break area it ranged from 21 to 26 gkg^{-1} and for arable land area (Pedon 4) the value ranged from 15 to 27 gkg^{-1}.

The weighted average values obtained from the different pedons under various land use type were in decreasing order of 30 gkg^{-1}, 29 gkg^{-1}, 25 gkg^{-1} and 24 gkg^{-1} for irrigated soil area, permanent crop area, arable land and wind break area respectively. The organic carbon content varies within each pedon in an irregular manner. This may probably be due to differences in cultural practices such as tillage, harrowing, weeding etc. adopted in each of the land use type. Jackson *et al.,* (1996) reported that plant production and decomposition determine carbon inputs to the soil profile, and plant allocation above and below ground and between shallow and deep roots may leave distinct imprints on the relative distribution of soil carbon with depth.

Organic carbon content in the soils under different land use types is in the decreasing order of irrigated land > permanent cropped area > wind break area > arable land. The variation in organic carbon content between land use types may be due to the differences in the amount of plant residues deposited on/in the soil surface which later undergoes certain microbial decomposition. Feigl *et al.,* (1995) reported that pasture establishment in the tropics may maintain or even increase the soil organic carbon content especially where grass species with high percentage of below ground biomass production are used. The results of this study are in agreement with the above findings since organic carbon

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	C	45-105	28
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Similarly, the low organic carbon content experienced in the arable land could be associated to continuous cropping, the area has been experiencing over the years.

The pH values obtained are slightly acid in Pedons 1 and 2 (irrigated land and permanent cropped area). The values ranged from 5.8 to 6.1 (weighted average of 5.9) and 5.9 to 6.1 (weighted average of 5.8) in Pedons 1 and 2 respectively. The values obtained from Pedon 3 (wind break area) show very strongly acid to moderately acid with values range of 4.6 to 5.9 with weighted average of 5.8. In Pedon 4 (arable land) the pH is very strongly acid to strongly acid and ranged from 5.1 to 5.4 with weighted average of 5.2. Based on the weighted average value of soil pH, soils of irrigated area, permanent cropped and wind break are rated slightly acid while soils of Arable land area are strongly acid.

Table 3: The pH of the soils from different land use types

Pedon	**Horizon**	**Depth (cm)**	pH Value
1(Irrigated Area)	Ap	0-43	6.0
	AB	43-59	5.8
	BC	59-80	6.1
	C	80-109	5.8
W. ave.			**5.9**
2(Permanent Cropped area)	Ap	0-12	6.1
	AB	12-34	5.9
	Bw	34-45	6.0
	C	45-105	6.0
W.ave.			**5.9**
3 (Wind break Area)	A	0-18	5.9
	AB	18-43	5.9
	B	43-59	5.5
	BC1	59-78	4.6
	BC2	78-93	5.6
	C	93-112	5.6
W.ave.			5.8
4. (Arable Land Area)	Ap	0-30	5.4
	AC	30-56	5.4
	C	56-180	5.1
W. ave.			**5.2**

W. ave. Weighted average

Microbial Count

The total microbial count varies in the four different land use types investigated. The variation was found both within profile and between profiles across the different land use types. In the irrigated soil area and permanent crop soil area the mean count ranges from $2.1 x 10^7$-$4.7 x 10^7$ cfu/g and $2.9 x 10^7$-$4.1 x 10^7$ cfu/g respectively (Table 4), with mean counts of 3.010^7 cfu/g and $3.5 x 10^7$ cfu/g respectively. In wind break soil area (Pedon 3)

the range count was from 2.2×10^7-2.1×10^8 (cfu/g) with a mean of 1.0×10^8 cfu/g. In arable land area (Pedon 4) the range count was from 2.8×10^7-1.6×10^8 cfu/g with mean count of 1.2×10^8 cfu/g. On average the arable soil area (Pedon 4) had the highest value of bacteria population of 1.2×10^7 cfu/g followed by wind break area (1.0×10^8 cfu/g The variation in the bacterial population may be due to the difference in available nutrients and amount of litter materials deposited by the plants. Many authors have reported that cultivation affects the distribution and activities of microorganisms in the soils (Za'ady et al, 1996; Hopper and Vitousk, 1998; Jones, 1998; Chen and Stark 2000; Abbas, 1996).
These findings are in agreement with the current research when considering variations from the different land use areas. The reaction of gram staining indicated about all the bacteria is gram positive with few gram negative.

Table 4: Results of Total Viable Plate Counts of Bacteria (cfu/g) from Different Types of Land Use

Land use type	Total count	Range	Mean (SD)
1. Irrigated land	1.23×10^7	$2.1\text{-}4.7 \times 10^5$	3.08×10^6 (11.44)
2.Permanent cropped	1.51×10^7	$3.2\text{-}4.1 \times 10^5$	3.78×10^6 (3.95)
3. Wind break land	6.22×10^7	$2.2\text{-}21.4 \times 10^5$	1.04×10^7 (78.52)
4. Arable land	3.27×10^7	$2.8\text{-}16.8 \times 10^5$	1.09×10^6 (72.09)

CONCLUSION

Variations were observed in organic carbon distribution and microbial biomass from the different land use types studied. This could serve as a basis for the management of soils under different land use for increased yield and sustainability in Sokoto area.

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