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Effects of anthropogenic activities on soil carbon storage and compactness in coastal plain soil of tropical urban area.

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ABSTRACT: The study on the impact of anthropogenic activities of a tropical urban soil; effects of different land use on bulk density, relative bulk density and their capacity to store carbon were investigated using several key soil physical and chemical properties such as ammonium acetate methods used for determination of cation exchange capacity. Results obtained showed the soil textural class to be sandy in all the land used area. Moisture content and porosity were highest in the automobile servicing area. Bulk density (1.50g/cm3) and relative bulk density (0.82g/cm3) were highest in soil samples from commercial area. Automobile servicing area had the lowest soil pH (5.1), compared to other land use areas, which had it pH ranging from 6.2 – 7.5. The highest value of exchangeable base was obtained also from automobile servicing area compared to other anthropogenic active areas. There is a considerable variation in the total carbon storage from different land uses with the highest carbon storage obtained from automobile servicing area (570.5 g/cm3), this is followed by soil samples from commercial areas (370.0 g/cm3). The lowest value of carbon storage was obtained from institutional area. The major effect of anthropogenic activity is on soil organic matter (OM); therefore the degree of compactness was as a result of the impact on organic matter. Result of this present investigation shows that anthropogenic activities in urban environment affect the compactness and carbon storage of soil.

Keywords: Land use, urban soil, anthropogenic activities, soil compactness, relative bulk density

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1. INTRODUCTION

The rate of degradation of urban soil ecosystem resulting from anthropogenic activities remains a basic fact. However, much attention has not been given to it in recent time to cities in the developing countries. People migrate from rural areas to cities due to pull factors such as better job opportunities, better standard of living and access to social service; health care education, electricity, drinking water etc. About 75% of the world's total population has migrated and settled in urban areas [1], [2] and hence the report that urban areas are growing faster than any other land use [3]. It is expected that many more people will migrate to cities in developing countries come 2025, however, these cities lack resources to deal with urban problems associated with anthropogenic activities [4], [2]. Increase population in an area results in increased human activities such as; construction, expansion of residential, industrial and commercial areas, increase emission of gases, reduction in the use of social amenities, increased poverty, crime [5]. Generally, dense population such as those seen in urban areas in developing countries affects negatively local resource. Urban soil is

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made up of mixtures of mineral, organic material, living organisms (micro and macro) and water which all together support plant growth and other lives [6], [7] Urban Soil is also known for its ecosystem service; reduction in availability of pollutants, storage of carbon and other mineral nutrients [6], water infiltration and purification [9], supporting of urban vegetation [10], [6] and also formation and foundation of ecosystem process and interactions [11]. Urban soil is known to be the center stage in terrestrial ecosystem, however studies on impact of anthropogenic activities on urban soil have been sporadic, little studies on it were generally centered on managements, particularly agricultural soil and soil of other natural areas [12], [2]. There is therefore need to rigorously access the impact of anthropogenic activities on urban soil.

Anthropogenic activities, such expansion, and discharge of waste on urban soil are the major driving force in threats to soil ecosystem. Several studies have accessed the physical, chemical and biological properties of soil [12], [13]. Many have assumed that urban soils are highly compacted and are severely altered due to unrestrained activities carried out on them on daily bases. Increased bulk density and reduced porosity in soil due to urbanization [14], [6], [15]. Soil porosity is intimately related to bulk density as soil pore space is reduced due to severe compaction. The availability of soil water and nutrients to plant root uptake depends on the degree of compaction of that soil. Increase bulk density reduce water infiltration capacity, plant growth rate, promotes flooding and alters biogeochemical cycle [16], [15]. Urban soil in a bid to convert discharged waste also promotes soil carbon loss through microbial decomposition [17], [18]. Soil organic carbon pool is a function of the input of organic matter to ecosystem and average rate of decay of organic matter in hat system. Both are controlled by temperature and moisture content of the soil [19]. Anthropogenic activities increase soil temperature and decrease moisture storage in the soil [20]. Land use can affect the soil packing state directly (compaction due to agricultural field operations) and indirectly (land use effects on organic matter content) [21], [22], [23]. However, the storage of carbon in soil ecosystem is at risk because of human activities. The effects of anthropogenic activities on carbon storage in urban areas are important for managements and sustainability of urban soil for provision of ecosystem services. This study tends to access soil carbon storage under different anthropogenic activities and degree of soil compaction in urban areas.

2. MATERIALS AND METHODS

Description of study area

The city of Owerri provides a good example of environmental impact due to urbanization. Owerri is the state capital of Imo State since 1976; it covers an area of approximately 100square kilometer (40 sq. m) [24] and it is located on the Southeastern part of Nigeria with Longitudinal and latitudinal coordinates of 6^{O} 32^{1} – 7^{O} 11^{1}E and 6^{O} 21^{1} – 6^{O} 35^{1}N. Owerri is relatively a city that has experienced expansion and population growth in few decades. It lies on an area of flat agricultural land converted to residential, industrial, commercial and institutional areas. In this city, workshops especially artisans' workshops, stores, and other work places are scattered all over the area. This makes the area very busy with human activities. Owerri has a tropical climate characterized by type A W in the Kopper-Geiger classification of wet and dry climate with an annual rainfall of 2250 -2500mm [25]. Given the close relationship between climate and vegetation, the location of the study area coincided with the rain-forest belt. Soils are derived from coastal plain sand [26]. This type of soil has good drainage and is well aerated causing it to dry out quickly. This study area shows a high population density being about 104 people per 1km. this population density could be as a result of activities of these labor force and their relatives [27].

Collection of soil samples

Soil samples were randomly collected from different land use areas; institutional residential, commercial automobile land use area. The soil samples were collected from the depths of 0 - 20cm using an auger of approximately 7.5cm diameter and taken to the laboratory for studies. These soil samples were air-dried and sieved using a 2 mm sieve. However, 12 core samples were collected for bulk density determination.

Laboratory Studies: Particle size analysis was determined by hydrometer method [28]. Bulk density was estimated by core procedure [29]. Soil pH was measured using a pH meter in a soil water ratio 1:2:5 [30], cation exchange capacity (CEC) was determined by ammonium acetate method [31]. Soil organic carbon was estimated by wet digestion [32].

Reference bulk density ($Pb_{\text{-ref}}$) as needed for the calculation of relative bulk density $Pb_{\text{-rel}}$ was computed using the equation proposed by Jones [33] for the lower limit of critical bulk density:

$$Pb_{\text{-ref}} = 1.882 - 0.0083 \text{ Clay}$$

And the relative bulk density was calculated as following [34]:

$$Pb_{\text{-ref}} = \frac{\text{Pb}}{Pb_{\text{-rel}}}$$

Soil carbon sequestration was calculated by multiplying bulk density, soil organic carbon and thickness of horizon that is carbon sequestration; BD (Mg/m^3) x soil organic carbon (SOC) (g/kg) x thickness of horizons (m)… [35].

Data Analysis: Soil data was analyzed using SAS statistics package for analysis of variance (ANOVA) [36]. Significant difference between soil organic carbon stocks between land uses was analyzed using simple correlation analysis.

3. RESULTS AND DISCUSSION

Results

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Table 1.0: Impact of Land use on some selected physical properties in the studied soil

Anthropogenic activities	Parameters	Mean	Standard Deviation STD	Minimum	Maximum	CV
Institutional Area	p*b*(Mgm^{-1})	1.28	0.05	1.23	1.33	3.91
	P*b*- rel	0.69	0.02	0.67	0.71	2.90
	Clay (%)	4.03	0.05	3.98	4.08	1.24
	Sand (%)	87.2	1.9	85.3	89.1	2.18
	Silt (%)	9.10	0.19	8.91	9.29	2.09
	Moisture Content(%)	8.01	0.03	7.98	8.04	0.37
	Porosity	22.4	0.26	22.2	22.3	1.15
Commercial Area	p*b*(Mgm^{-1})	1.50	0.09	1.41	1.59	6.0
	P*b*- rel	0.82	0.05	0.77	0.87	6.10
	Clay (%)	5.10	0.31	4.79	5.41	6.08
	Sand (%)	89.2	1.9	87.3	91.1	2.13
	Silt (%)	6.25	0.34	5.91	6.59	5.44
	Moisture Content(%)	6.28	0.18	6.10	6.46	2.87
	Porosity	25.0	0.30	24.7	25.3	1.2
Residential Area	p*b*(Mgm^{-1})	1.32	0.03	1.29	1.35	2.27
	P*b*- rel	0.71	0.02	0.69	0.73	2.82
	Clay (%)	3.15	0.14	3.01	3.29	4.44
	Sand (%)	90.2	2.65	87.5	92.8	2.94
	Silt (%)	7.13	0.15	6.98	7.28	2.10
	Moisture Content(%)	7.96	0.28	7.68	8.24	3.52
	Porosity	21.9	1.1	20.8	23.0	5.02
Automobile servicing Area	p*b*(Mgm^{-1})	1.39	0.01	1.38	1.40	0.72
	P*b*- rel	0.74	0.09	0.65	0.83	12.16
	Clay (%)	1.76	0.23	1.53	1.99	13.07
	Sand (%)	95.8	2.00	93.9	97.7	2.09
	Silt (%)	2.4	0.25	2.15	2.65	10.42
	Moisture Content(%)	14.7	0.5	14.2	15.2	3.40
	Porosity	51.3	0.4	50.9	51.7	0.78

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Table 2: Impact of Land use on some selected chemical properties in the studied soil

Chemical Property	Institutional Area	Commercial Area	Residential Area	Automobile Servicing Area	Mean	STD	CV
pH	7.3± 0.06	7.5	6.7	5.1	6.7	1.09	16.3
Total Nitrogen	0.02	0.03	0.3	0.10	0.11	1.13	1027.3
Phosphorus	12.30	18.6	15.2	20.9	16.75	3.78	22.57
ECEC	0.18	1.02	0.96	10.67	3.21	4.99	155.5
E/A	0.70	0.62	0.85	0.25	0.61	0.26	42.62
E/B	1.09	2.57	1.29	9.8	3.69	4.13	111.9
Organic Carbon	0.22	0.60	0.30	5.3	1.61	2.47	153.4
O/M	0.32	1.02	0.52	9.1	2.76	4.24	153.6

Key; ECEC: Effective Cation Exchange Capacity, E/A: Exchangeable Acidity, E/B: Exchangeable Base, O/C: Organic Carbon, O/M: Organic Matter.

Table 3: Impact of land use on carbon storage in a tropical urban soil

	Bulk Density	Carbon Density	Carbon Sequestration
Institutional Area	1.28	2.14	42.8
Commercial Area	1.5	18.54	370.0
Residential Area	1.32	4.12	82.4
Automobile Servicing Area	1.39	284.98	570.0

Table 4: Correlations between bulk density (ρb), relative bulk density (ρb-rel.) and intrinsic soil properties

	Sand	Clay	Silt	Bulk density	Bulk density relative	OM/Clay
Sand	1					
Clay	0.69**	1				
Silt	0.94***	0.44	1			
Bulk density	0.05	0.22	0.22	1		
Bulk density relative	0.012	0.21**	0.12	0.99***	1	
OM/Clay	0.89***	0.65***	0.84***	0.02	0.001	1

** and *** stands for significant correlation at 95 and 99%

Table 5: Correlations between bulk density (ρb), Carbon density and Carbon Storage.

	Bulk Density (ρb)	Carbon density	Carbon Storage
Bulk Density (ρb)	1		
Carbon density	0.06	1	
Carbon Storage	0.50***	0.71***	1

*** Stands for significant correlation at 95%

Discussion

The result of effects of anthropogenic activities on institutional, commercial, residential and automobile servicing areas are shown on Table 1. The results showed the textural class of soils from study area is sandy. All soils were classified as sandy. The urban land use differed in both silt and clay content, the highest silt content was obtained from institutional area while the smallest values was obtained from automobile mechanic servicing area. The urban land uses did not differ in sand as all the samples showed relatively high values of sand. Anthropogenic activities did not affect the sandy nature of the study areas. [37] made similar observation, however [38] reported the sandy nature of the samples as one of the peculiarities of soils of this region. Sandy soils have been reported to have less aggregation and as such the rate of infiltration is high [39]. Infiltration is important in relation to the intensity of rainfall as it helps to drain excess rain off the soil surface.

The lowest value of bulk density was observed in soil from institutional, this is followed by that obtained from agricultural soil (Table 1). However, the highest value was obtained in soil within the commercial areas. Soil bulk density in residential and automobile mechanic servicing area was not significantly different. Pouyat [40], reported soil bulk density values in urban soils to range from very low (<0.8 g/cm^3) to high (<1.85 g/cm^3). Hagan [2] also reported that bulk density affects the rate at which water filters into the soil and it is associated with the resultant pool and water generation in urban areas. It is important to note that average bulk density of agricultural soil is in the range of 1.1 – 1.5 gcm^{-3} for organic soil. Soil bulk density values obtained in these study areas, were within the range bulk density result obtained by some researchers [41], [8], [2]. Pouyat, [19] reported that bulk density can serve as indicator of soil disturbance and soils with low surface bulk density values have the greatest potential to contribute infiltration.

Soil porosity from automobile mechanic servicing area recorded the highest values. Meanwhile, the porosity content of other urban land use was not significantly different from each other. Increase bulk density and porosity observed in this study could be due to anthropogenic disturbances on soil. Porosity measures the size and number of spaces in the substrate. This result is in agreement with the finding of [42]. Similarly, higher porosity is advantageous to plant because of ease of movement of oxygen, water and nutrients in the soil matrix [43]. It is observed that such movement is inhibited in soil from automobile mechanic servicing center. Pollution from unregulated automobile waste discharged in and around their vicinity can affect to a greater extent the total percentage porosity of such sites. The difference pore sizes distribution observed in this study might be due to different degrees of swelling and shrinkage done by human activities [44], [40].

The percentage moisture content of urban land use is shown in Table 1, the result obtained showed the percentage moisture content was the same in institutional, commercial and residential areas, however, the values increased double times in soils from automobile mechanic servicing area. The increase in moisture content observed in the automobile servicing area could be attributed to infiltration caused by waste discharged in the surrounding environment. Soil moisture content determines the potential for growth, abundance and distribution of plants and animal life with the inclusive of fungi and bacteria. Soil moisture increases the microbial population and activity [45], [17]. Fungal and bacterial communities influence soil fertility and plant growth by regulating nutrient availability and turnover [46], [47].

The pH of soils in different land uses is presented in Table 2; Mean soil pH in automobile servicing area (5.1) was significantly lower than other land use (6.2 – 7.3). The low pH observed in automobile mechanic servicing center is an indication of high acidity in that soil. Accumulated trace metals discharged from automobile waste in that area could be the reason for that acidity. The magnitude of soil increase in soil pH was in the order of automobile mechanic servicing area > residential > institutional > commercial soil and the pH was high in less acidic soil.

Hagan [2] also reported soil pH of 6.1 – 6.4 in areas with low population density, however in this report, soil pH of 6.7 was obtained in the study area which has relatively high population density by any standard. Soil pH obtained in both institutional and commercial area of this study areas were higher compared to that reported by Hagan [2]. Addition of urban deposit such as carbonate and weatherable materials in the dust from atmosphere can also increase soil pH. Similarly, Sharenbroch, [41] reported a soil pH of 6 – 7 with minimal difference among urban landscape. Soil exchangeable base of the study area is shown on Table 2. Result obtained showed a decrease in exchangeable acidity in soils from institutional, residential and commercial area by 1.09, 1.29 and 2.57gkg^{-1} respectively. In automobile mechanic servicing area, exchangeable base was higher (9.8 gkg^{-1}). This increase could be as a result of pollutant load on the soil surface. Such pollutant as hydrocarbon products such as spent engine oil, gasoline, diesel etc that can accumulate on the soil surface of the study area [48]. Urbanization can cause inhibition of water and nutrients exchange thereby affecting proper functioning of the soil [49]. Higher values of exchangeable acidity were recorded institutional, commercial, residential areas, while lower values were recorded in automobile mechanic servicing areas.

Effects of anthropogenic activities on carbon storage

Results of total carbon density and carbon storage are presented in Table 3. The result obtained showed the total carbon density and carbon storage were significantly higher in soils of automobile mechanic servicing area (570.0 g/cm^{-3}), followed by soils from commercial area (370.0 g/cm^{-3}), the lower values were obtained from soils of institutional and residential area (2.14 and 42.8 g/cm^{-3}) respectively. Strong positive correlation was observed between carbon storage and bulk density (R^2 = 0.50***), Similarly, positive correlation was also observed between carbon density (CD) and carbon storage (R2 = 0.70***) in all the different land uses. Increase carbon density and carbon storage in soils of automobile mechanic servicing area and commercial area could be attributed to the type of waste generated and dumped in such areas. Residential wastes such as organic waste deposited without a regulation promotes microbial activities and these activities contributes carbon and nutrients in the soil [50], [51] (Sun, *et al.*, 2011; Sun, *et al.*, 2014). Waste of a tropical urban environment includes, organic/biomas, papers, oil of all types, polyethylene materials, empty containers/metals, food stuff /garbage, glasses, papers, chemical substances [52]. Though it has been reported that the content of urban waste differs between developing and developed countries, and the large proportion of organic waste are found in developing countries than developed [53]. Organic /biomass waste contributes 65% of the total waste generated and deposited in urban centers [54]. Increase carbon storage in automobile mechanic servicing centers of the study area may have resulted from wastes deposited in such vicinity. Such waste includes spent engine oil, diesel, gasoline, brake fluid, grease, old spare parts, carbide, batteries, bulbs and glasses. Carbon content of these wastes particularly those containing hydrocarbon can increase carbon content of soil. High organic carbon content in soil is an indication of soil instability [42]. Infiltration resulting from pollution can contribute to increase concentration of organic carbon in soils [6]. Decrease in soil carbon storage as observed in the study area could be attributed to physical disturbances from urbanization. Such activities as removal of plant, tree leaves and other organic debris can reduce microbial activities and input of soil organic carbon pool [41]. [55] also reported that urbanization induce large decrease in carbon pool, as such soils beneath impervious surfaces contain less carbon and have a reduced carbon sequestration capacity.

People have migrated from rural areas to cities for a better and higher standard of living, such as better job opportunities, access to social amenities (health care and educational services, electricity, good drinking water and good roads). These have brought half of the world's population to settle in the cities [2]. Report has it that while population growth in cities of temperate region has reduced, urban population in tropical and subtropical areas continue to increase. It is expected that the population increase in tropical areas will reach four billion by 2025

[56]. Cities in these areas particularly in developing countries lack the resources to tackle environmental challenges resulting from anthropogenic activities [57]. Anthropogenic activities are the driving force influencing negatively, environmental qualities and it is presenting serious challenges to the use of local resources. Urban soil is one of the local resources that provide numerous ecosystem services; e.g. storage of carbon and other mineral nutrients [6], water infiltration and purification [58], [59], reduction in availability of pollutants and support to urban vegetation [6]. Construction, expansion and discharge of waste are majors to urban soil ecosystem services, however little is relatively known about the effects of urbanization on soil properties and processes [2]. Several studies have been carried out on the physical, chemical and biological properties of temperate urban soil [12], [6], [2]. Most of these studies reported that the urban soil properties were severely altered, for instance bulk density in those studies showed significant variations; the values obtained ranged from very low 0.8g/cm^3 to high (> 1.8g/cm^3) [41], [6]. However, many of these studies were carried out in temperate urban soil where anthropogenic activities are regulated and the effects of anthropogenic activities are minimal compared to those obtained in developing countries. Another important interesting function of urban soil is it ability to store carbon. The effects of anthropogenic activities of urban population on soil carbon storage of different land use are given on Table 3. Results obtained showed that the highest levels of carbon were obtained from automobile servicing area; this is followed by values obtained from commercial areas. Increase organic carbon have earlier been reported by researchers and are attributed to microbial mineralization of pollutants in the soil [60], [61]. Waste from automobile servicing area include amongst all products of hydrocarbon, which are mainly carbon. Studies have shown that the ability of soil to store carbon depends on the changes in soil organic carbon [62]. Scharenbroch [41] reported that the removal of grass clippings, tree leaves, and other organic debris can reduce inputs to the soil organic matter pool. Such anthropogenic activities must have induced loss of soil carbon in both institutional and residential areas. Also correlation matrix between bulk density and carbon storage is given in Table 5, which showed a strong negative correlation existing between carbon storage and bulk density. [63], [64] had similar results and suggested that the degree of compactness is controlled mainly by organic matter.

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