

ASSESSMENT OF SELECTED SOIL QUALITY INDICATORS IN BENIN CITY, NIGERIA

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Abstract

The research assessed selected soil quality indicators in Benin City, Nigeria. Eleven soil samples (0 - 15 cm) were collected randomly from selected urban land use areas (market, fuel filling station, cattle lairage, abattoir, sawmill, waste dumpsite, granite dump, carwash, scraps metal dump, auto-mechanic workshop and horticultural garden). Soil texture, bulk density (BD), pH, organic matter (SOM) and cation exchange capacity (CEC) were determined using standardized procedures. Soil parameters were interpreted using US EPA (2011) threshold values. The results established that urban land use had varied (good condition, moderate and severe) extent of impacts on the investigated urban soil quality indicators in the study area. Taking into consideration the observed severed status of BD, CEC and SOM in the urban soils, compost applications are recommended.

Keywords: Urban, Land use, Impact, Soil quality, Topsoil.

INTRODUCTION

Land is a prerequisite for several uses both in the urban and rural ecosystems. Beniston (2013) stated that cities now use unoccupied plots of land for the social and ecological services that green spaces can offer. Zhao et al. (2013) observed that land use have marked effects on soil quality, ecological processes and soil functions due to the modification of soil physical and chemical properties. Soil is a significant component in urban ecosystems and urban areas have intensive human activities; the most common uses are residential, commercial, transportation, food production and recreational uses such as parks, forests and green lands (Oktaba et al., 2018). Pickett and Cadenasso (2009) cited in Beniston (2013) claimed that urban land use effect on soils is so pronounced that Jenny's (1941) model of soil formation must be modified considerably to interpret pedogenesis in urban areas. They submit that disturbance, changed resources as well as spatial heterogeneity of social and ecological processes make up an extra level of soil forming processes that frequently surpass the traditional soil forming factors. Urban soils show a great variety, mainly due to the way they are used and the various functions they perform. Li et al. (2013) opined that urban soils are often dramatically altered by human activities (construction, compaction, degradation, land filling, mixing, etc.), and that

urban land uses are important factors affecting soil nutrients.

The effects of urban land use on soils more often, are more than the effects of rural land use. The increasing burden of expanding urban areas, attendant need for infrastructure and accommodation of greater human population densities results in alteration of urban soil properties (Pouyat et al., 2015). The issue has grown in importance; hence, Zhao et al. (2013) stated that rapid urban expansion and human disturbance intensely altered soil biochemical processes and soil qualities of the unsealed green space through land use. Earlier investigations of Jim (1998) and Wang et al. (2011) had reported decreased content of organic matter, variation of soil microbial biomass and soil pollutions for park, roadside and tree land uses. Pouyat et al. (2015) stated that characteristics of urban soils vary widely and are dependent on both direct (grading, irrigation, trampling etc.) and indirect (urban heat island, atmospheric deposition etc.) effects resulting from land use.

Soil texture, bulk density, pH, organic matter and cation exchange capacity are significant soil quality indicators which, according to Jin et al. (2011), reflect various aspects of soil fertility properties, such as nutrient availability, soil moisture retention, sorption capacity, soil resistance to pollution and thermal properties. Therefore, knowledge

of these properties is important, especially as soils of urban areas play a significant role in the day-to-day lives of the individual inhabitants. da Silva et al. (2017) affirmed that several urban-related activities voluntarily or involuntarily compact the soil. Land use has emerged as a prime predictor for soil quality properties in urban areas (Beniston, 2013). However, little or no information is available on the consequences of urban land use on soil texture, bulk density, pH, organic matter and cation exchange capacity in the study area.

The justification for selecting these particular soil quality properties is hinged on their significant influence on soil utility, other soil fertility parameters and nutrient cycles. For instance, Asabere, Zeppenfeld, Nketia and Sauer (2018) noted that soil organic matter (SOM) stock is a vital pointer to urban ecosystem performance due to its effects on soil fertility and biogeochemical cycles. Mao, Sang, Liu and Jia (2014) reported that excesses in acidity or alkalinity will alter the nutrients accessible and lead to element disproportions in plants. Brady and Weil. (2004) stated that soil texture influences nearly every aspect of soil use and management. In addition, comprehending the extent these specific soil properties are influenced by specific urban land use is vital for bringing urban soils into dynamic use for the rapidly increasing urban population. Therefore, following the fundamental principle in urban ecology theory that anthropogenic activities impacts urban soil quality properties which is vital for urban ecosystems functioning (Alberti, 1999), we investigated selected soil quality indicators in Benin City, Nigeria. The findings of the research could offer reference evidence for making better urban soil management and sustainable strategies in Nigerian cities.

MATERIALS AND METHODS

Study Area

Benin City lies between Latitudes 6° 10' and 6° 30'N to Longitude 5° 30' and 5° 45' E in the southern part of Edo State, Nigeria (Figure 1). Multifaceted hydrogeological situations and strong human influence in the city are the prime environmental pressures in the Benin urban area. The investigation was piloted at carefully chosen urban land uses in the study area, which were selected to show the different extent of anthropogenic effect on urban soils quality.

Benin City falls within the rainforest zone of southern Nigeria and has a monthly rainfall of above 2000 mm with a mean monthly temperature of 28°C. The soils were made from complex basement rocks and are rich in iron which accounts for their characteristic red color (Orobator and Odjugo, 2016).

Soil Sampling

Soils occurring in areas representing eleven urban land uses were examined in Benin City. The selected land uses include; market (6° 20 58'' N, 5° 39 35'' E), fuel filling station (6° 22 58'' N, 5° 42 33'' E), cattle lairage (6° 24 19'' N, 5° 41 48'' E), abattoir (6° 21 06'' N, 5° 35 46'' E), sawmill (6° 21 44'' N, 5° 35 36'' E), waste dumpsite (6° 27 58'' N, 5° 36 32'' E), granite dump (6° 26 29'' N, 5° 35 50'' E), carwash (6° 25 51'' N, 5° 36 31'' E), scraps metal dump (6° 20 36'' N, 5° 37 16'' E), auto-mechanic workshop (6° 20 16'' N, 5° 36 57'' E) and horticultural garden (6° 19 55'' N, 5° 36 06'' E). Soil samples were collected randomly from each of the land uses with the aid of a soil auger from the topsoil (0 - 15 cm). On arrival to the laboratory, the soil samples were gradually air dried preceding the process of homogenization with an analytical sieve of 2 mm mesh size (Tresch et al., 2018). Global Positioning System (GPS) was used to geolocate the soil sampling points in the studied urban land uses.

Determination of Selected Soil Parameters

Adopting the methods of Jim (1998), bulk density was analyzed for each soil sample and reported in Mg m⁻³. Sand, silt and clay contents were determined following the procedures of Rajj et al., (2001). Soil carbon content was determined using wet digestion method and percent soil OM was attained by multiplying percent soil OC by a factor of 1.724 (Walkley and Black, 1934). Soil pH was measured in a 1:2.5 (soil: water ratio) mixture with a glass electrode (Zhao et al., 2013). Cation exchange capacity was extracted by using sodium acetate at a pH 8.2 (Chapman, 1965).

Data Analysis

Descriptive statistical tools and U.S. EPA (2011) threshold levels were used to analyze the data for the investigation. To determine the extent of urban land use impact on soil pH, texture (sand, silt, and clay), bulk density, CEC and soil organic matter, U.S. EPA (2011) urban

land use threshold levels of soil quality indicators were utilized (Table 1).

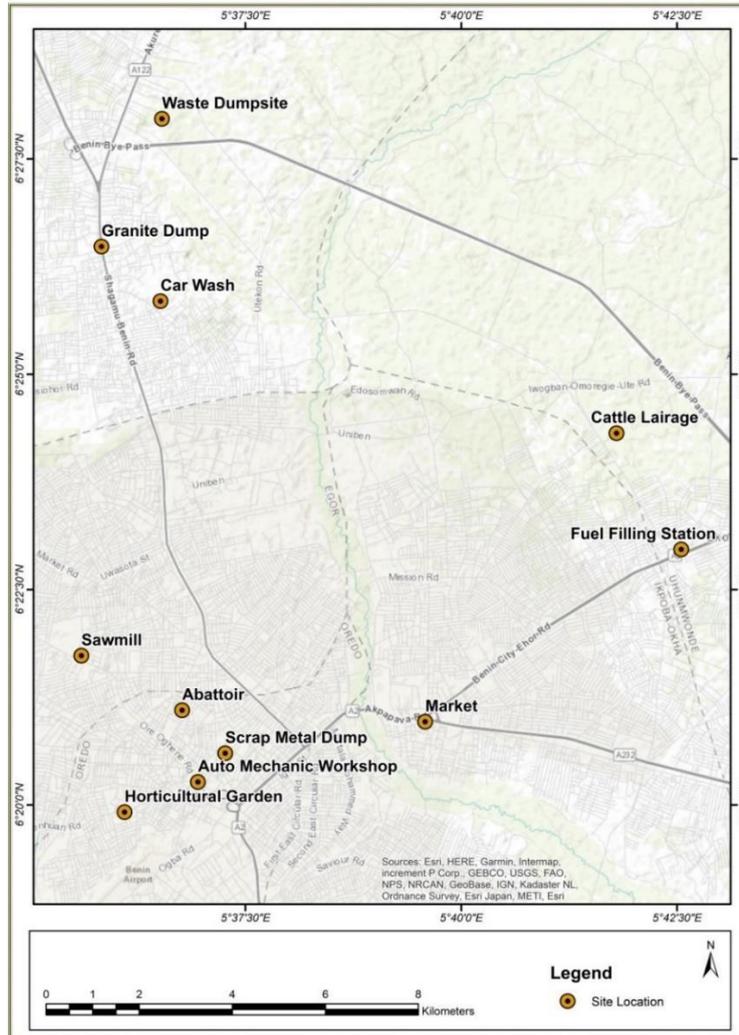


Figure 1 Benin City showing the examined urban land uses

Table 1 Urban land use threshold levels of soil quality indicators

Soil Quality Indicators	Good Condition- No Limitations	Threshold for Moderate Impacts	Threshold for Severe Impacts
Sand (gkg ⁻¹)	*	>75	>90
Silt (gkg ⁻¹)	*	*	*
Clay (gkg ⁻¹)	*	>50	>65
BD (Mg m ⁻³)	<1.3	>1.5	>1.6
pH	6-7	< 6	< 4
CEC(cmol kg ⁻¹)	*	<5	<3
SOM (gkg ⁻¹)	*	*	<1
SOC (gkg ⁻¹)	>5	<1	<0.5

Adapted from U.S. EPA (2011)

* = Not available

RESULTS AND DISCUSSION

Soil Texture

Texture is one of the most important soil characteristics determining other soil properties (Wang et al., 2010). Sand contents among the different land uses vary from 54.79 to 77.94 gkg⁻¹ (Table 2). The result revealed that the soils in the study sites were dominated by sand. This implies that the soils could display poor nutrient holding capacity due to the relatively large pore spaces between sand particles (Pearson, 2019). Among all the land use types analyzed, only soils in abattoir land use had the highest sand contents (77.94 gkg⁻¹). The value was above the threshold of 75 gkg⁻¹ and this infers that the soils were moderately impacted (Table 1) in abattoir land use. None of the soils in all the

investigated land uses were severely impacted as the values of sand were < 90 gkg⁻¹ which is the threshold value for severe impacts according to U.S. EPA (2011). SOM conditions the soils' texture and porosity, thereby improving water and nutrient retention as well as resilience of soils against mechanical stress (Brock et al., 2017). Also, anthropogenic activities on the investigated land uses were also reflected in the observed different sand fraction of the soils. The action of humans release various materials such as household and construction waste, including metal, plastics, textiles etc. into the soils and the abundance of these materials is the most observable direct result of urban land use on the soils (Asabere et al., 2018).

Table 2 Summary of selected soil quality indicators

Soil Quality Indicators	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Sand (gkg ⁻¹)	63.24	71.98	57.32	77.94	60.25	60.21	69.07	63.86	72.24	54.79	69.32
Silt (gkg ⁻¹)	19.76	17.81	6.87	13.95	11.78	29.26	23.45	30.66	18.69	14.33	22.65
Clay (gkg ⁻¹)	17.00	10.21	35.81	8.11	27.97	10.53	7.48	5.48	9.07	30.88	8.03
BD (Mg m ⁻³)	0.17	0.14	2.99	0.08	2.45	0.15	0.07	0.16	0.07	1.51	0.07
pH	5.36	5.11	5.41	5.58	5.55	5.76	5.63	6.21	5.09	5.47	5.14
CEC (cmol kg ⁻¹)	0.32	0.26	6.95	0.15	4.63	0.29	0.14	0.31	0.14	2.85	0.13
SOM (gkg ⁻¹)	0.98	7.31	4.90	10.20	5.26	10.90	9.34	0.83	5.58	3.08	11.32
SOC (gkg ⁻¹)	0.57	4.25	2.85	5.93	3.06	6.34	5.43	0.48	3.42	1.79	6.58

Note: I = market; II = fuel filling station; III = cattle lairage; IV = abattoir; V = horticultural garden; VI = saw mill; VII = waste dumpsite; VIII = granite dump; IX = car wash; X = scrap metal dump; XI = auto mechanic workshop.

Bulk Density (BD)

Table 2 shows the values of BD across the different urban land use systems. Bulk density (BD) varies from 0.07 to 2.99 Mg m⁻³. The highest BD value of 2.99 Mg m⁻³ was observed in cattle lairage soils. The result of the study infers that BD had been severely impacted in cattle lairage soils (Table 1). The value of BD in cattle lairage soil was > 1.6 Mg m⁻³ which according to U.S. EPA (2011) is the threshold for severe impacts of BD in urban soils. This may be attributed to the trampling effects of cattle on the soils and suggests that the capacity of cattle lairage soils for water storage and their biodiversity are at risk (FAO & ITPS, 2015). The attendant decreases in water infiltration in

this land use may lead to reduced soil moisture and lower degrees of groundwater recharge (Beniston, 2013). The lowest value of BD (0.07 Mg m⁻³) was observed in waste dumpsite, car wash site and auto-mechanic land uses. This implies that BD has good condition and no limitation status (< 1.3 Mg m⁻³) in these land use types (Table 1). The variability in bulk density concentrations in these different urban land use soils can be attributed to the exposure of these soils to different urban influences, including anthropogenic compaction and deposition, which could also lead to upsurge in surface run-off and erosion, and consequently boost soil degradation (Labrière et al., 2015).

Also variations in BD values among the different urban land uses may be due to the level of organic matter in the soil. Oguike and Ndifreke (2016) noted that soil organic matter reduced bulk density through the adhesive and bonding properties of organic matter such as bacterial waste.

Soil pH

Soil pH is a causal factor for chemical reactions in the soil and the processes of soil acidification boost for the movement of some elements (Barrales et al., 2007). Urban soil pH ranged from 5.09 to 6.21 among the different land uses and all the soil samples fell lower than pH neutrality value of 7 (Table 2). The soils in car wash site were the most acidic (5.09) while the least acidic soils were found in granite dump (6.21). The acidic status of soils in the car wash may be due to the effect of leaching activated by the constant presence of water. Among all the investigated urban land uses, only the pH for granite dump soils' was within the good condition and no limitation range of 6-7 (Table 1). This deduces that pH was least impacted on granite dump. The gravels (crushed rock fragments) on the soil surface might have enhanced the higher pH level on granite dump soils. Zhang et al. (2010) affirmed that this also could largely be due to alkalizing products such as calcium-magnesium carbonate or calcium carbonate in gravel and atmospheric particulate deposition.

However, Li et al. (2013) observed a higher pH value of 8.76 while only 8 % of the soils fell below neutrality. In contrast, Asabere et al. (2018) reported that pH values were higher than 7, reaching up to a maximum of 8.6. Possible reasons for the high pH (>7) in the urban soils include the release of alkaline leachates from calcareous materials and decomposing organic waste (Jim, 1998). The acidic state of the soils under the other land uses could be ascribed to release of high exchangeable bases (Alemayeha and Sheleme, 2013). This may advance reasons why soil pH for other land uses was moderately impacted as their pH values were less than 6 (Table 2). Their acidic nature may also be attributed to the presence of acidic oxides of anthropogenic origin which could be partly explained by extraneous processes and materials such as inappropriately disposed lubrication oil, scrap metals and fuel leakages into the soil.

Soil Organic Matter (SOM)

Soil organic matter is a significant soil parameter that sustains and shields soil nutrients from environmental loss (Scharenbroch et al., 2005). The values of SOM among the different land use range from 0.83 to 11.32 gkg⁻¹ (Table 2). The observed higher SOM contents in abattoir (10.20 gkg⁻¹) sawmill (10.90 gkg⁻¹) and auto mechanic workshop (11.32 gkg⁻¹) sites could be ascribed to elemental carbon (EC) also referred to as black carbon (BC), which is produced, by the incomplete combustion of fossil fuel (Schmidt and Noack, 2000). The lowest concentrations of SOM were observed in granite dump (0.83 gkg⁻¹) and market (0.98 gkg⁻¹) land uses. The results show that SOM in market and granite dump soils were severely impacted. The values of SOM in both land uses (Table 2) were < 1 which is the threshold for severe impacts (U.S. EPA, 2011). This may be ascribed to the accumulation of municipal solid waste, construction materials and rock fragments which dilute SOM (Asabere et al., 2018). Also, in an effort to prepare the land for use, trees, fallen leaves, grass clippings and other organic residues are repeatedly removed which further reduce organic matter input to the soil (Li et al., 2013). However, the different SOM values obtained for this study could be attributed to the presence of anthropogenic substrates, such as coal, charcoal, char, plastics or different pollutants, e.g., polycyclic aromatic hydrocarbons in the land uses (Oktaba et al., 2018). The findings of the current study do not support the previous research of Zhao et al., (2013) who reported that the highest value of SOM was observed in the roadside-tree soils. They argued that this may be probably be due to human management.

At global and continental scales, Yesilonis and Pouyat (2012) asserted that soil C pools are a function of the inputs of soil organic matter (SOM) to the ecosystem. Soil organic carbon is broadly acknowledged to boost and increase a varied range of properties and processes in the soil biota, including: increasing soil water and nutrient reserves, improving soil structure and increasing invertebrates and microbes, improving water quality by absorbing and filtering contaminants (Lal, 2007). Urban soils are created through physical disturbance, directly modifying the biogeochemical alteration of C through the synergistic outcome of vital soil and organism

processes (Reichert, 2014). The concentrations of SOC among the investigated land use types are indicated in Table 1. The values of SOC ranged from 0.48 - 6.58 gkg⁻¹ in the different land uses.

One major component that may also lead to increased concentrations of SOC is the deposition of black carbon (BC) (Edmondson et al., 2015). In auto – mechanic workshops, diesel powered vehicles and vehicle emissions are the dominant sources of BC. BC is very stable in the environment and has strong sorption properties (Oktaba et al., 2018). The varied SOC concentrations observed in the examined land uses depicts the manner of land use impacted on SOC. The contents of SOC differ in urban soils and can be large or small subject to land use history and site management practices (Lorenz and Lal 2009).

Cation Exchange Capacity (CEC)

CEC is a measure of the soil's capability to hold positively charged ions. Dan et al. (2018) opined that it is very significant as it impacts soil structure stability, nutrient accessibility, soil hydrogen contents (pH) as well as the reaction of soil to fertilizers and other ameliorants. Urban soil cation exchange capacity ranged from 0.13 to 6.95 cmol kg⁻¹ among the different land uses (Table 2). The highest value of CEC was observed in cattle lairage soils (6.95 cmol kg⁻¹). This may be ascribed to the occurrence of highest clay contents in soils under cattle lairage (35.81 cmol kg⁻¹) and implies that eluviation will be less on this land use (Scharenbroch et al., 2005). CEC was severely impacted in market, fuel filling station, abattoir, saw mill, waste dumpsite, granite dump, car wash site and auto mechanic workshop as their values were less than 3 cmol kg⁻¹ (U.S. EPA, 2011 threshold for severe impacts). Previous study of Oktaba et al., (2018) demonstrated that lawns had the highest values of CEC with a value of 36.5 cmol kg⁻¹. CEC values in granite dump (0.31 cmol kg⁻¹) could be greatly attributed to the influence of gravel on the soil which is an important source for building materials (Huang et al., 2015). The different levels of CEC in the examined land uses reveal the degree of anthropogenic impacts on it. Also, Yones et al. (2012) noted that the varied concentrations of CEC in the investigated land uses showed that CEC depends on the content of SOM and clay amount in the soils.

CONCLUSION

The research has provided data on selected soil quality indicators in Benin City, Nigeria. Sand content was moderately impacted in abattoir land use. Bulk density in cattle lairage soil was severely impacted whereas CEC was severely impacted in market, fuel filling station, abattoir, saw mill, waste dumpsite, granite dump, carwash site and auto mechanic workshop. Soil pH in granite dump was within the good state and no constraint range while it was impacted moderately in other investigated land uses. SOM in market and granite dump soils were severely impacted. The study resolves that the observed status of the urban soil quality properties is suggestive of the degree of influence by the examined urban land uses. The study recommends the application of compost to the severed soil parameters as a reconditioning measure. There is a need to carry out investigation on indigenous local knowledge of urban land use effects of soil quality indicators. Also, researches should be undertaken on managing and enhancing urban soil quality so that urban soils can adequately offer the essential ecosystem functions.

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