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Original Article

Spatial Distribution of Soil Bulk Density, Organic Carbon and pH under Different Land Use Systems along Umuahia South Local Government Area of Abia State in South Eastern Nigeria

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Abstract

Information about spatial distribution of soil qualities in a given area is a fundamental piece of land surface prerequisites for ecological purposes, agriculture and other land use systems. The utilization of numerical methods to portray soil properties and upgrade objectivity in soil-related decision making, was applied to soil samples collected from soil under the land use systems; excavation site (EX), refuse dump site (RD), forest land (FL), continuously cultivated land (CC) and 4-year bush fallow (4-BF) along Umuahia South LGA of Abia State in south eastern Nigeria. Geostatistical technique was applied to estimate the spatial distribution and produce soil maps for each selected soil properties. Results revealed that excavation site (1.70 Mg m^{-3}) recorded a high bulk density, while the other land use systems had a moderate bulk density. The results showed that refuse dump site had a neutral soil reaction (7.02), slightly acidic reaction was recorded under 4-year bush fallow (6.00) and forest land (5.71). Continuously cultivated land had a moderately acidic soil reaction (5.41) and organic carbon content (1.48%). The result also revealed that forestland (2.97%) and refuse dump site (3.20%) had very high organic carbon content, while excavation site (0.38%) had very low organic carbon content. This study will help land owners/users in terms of choice and adoption of land for different uses in the area.

Keywords: geostatistical technique; land use systems; spatial distribution; soil map; soil properties

Introduction

Land use system is a process constrained by human activity, affected by natural, ecological and economic conditions (Oguike and Onwuka, 2018). The effect of land use systems on soil properties is profound (Skye, 2005). These impacts are apparent over a long period of time (Braimoh and Velk, 2004). Some land use systems consist of urbanization (which comprises of housing, industry, business ventures, roads, and so forth) (Eppink *et al.*, 2004), livestock ranching and forestry (Barlow, 2007), continuous cultivation and bush fallow system (Agoume and Birang, 2009), refuse dump site (Anikwe and Nwobodo, 2002) and excavation site (Mostafa and Nazor, 2012). Researchers have since a long time ago perceived the effects of land use systems on soil properties (Shepherd *et al.*, 2000; Braimoh and Velk, 2004; Neris *et al.***,** 2012; Oguike and Onwuka, 2017). Forestry has caused positive changes in the soil physical properties (Shepherd *et al.*, 2000) thereby resulting to the development of tree biomass (Versterdal *et al.*, 2002) and increased availability of plant nutrient (Mao *et al.*, 2010). The change of forest and pasture land into crop land is known to deteriorate soil properties, change the arrangement and stability of soil aggregates (Singh and Singh, 1996) and soils might become further liable to erosion since macro aggregates are distorted (Six *et al.*, 2000). Continuous cropping decreases aggregate stability of soils while increasing the bulk density (Celik, 2005). Excavation has caused a decrease in the accumulation of organic matter in the soil (Croke *et al.*, 2001), decreased soil porosity (Rab, 2003) and increased the bulk densities of soil (Rab *et al.*, 1992).

Soil maps provide a readily available source of soil property information that can be utilized to stratify and extrapolate soil properties across an area (Bouma, 1997). Every soil map shows simplified and organized information based on the underlying soil properties and its distribution across the study area (Skye, 2005). Soil map units are arranged according to the fundamental principles of soil taxonomy (Soil Survey Staff, 1996). New computer applications enhanced widespread development, use of more detailed analytical, and predictions techniques such as geostatistics (Skye, 2005). Geostatistics can be used to analyse any features that exhibits spatial dependence (Webster and Oliver, 2001). They provide a statistically

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robust technique for analyzing the spatial arrangement of soil properties at various locations and conditions (Skye, 2005). Using geostastics, statements that are more specific can be made about the changes in spatial distributions of soil properties (Chukwu *et al.*, 2007). Land use systems has been shown to change the variability of soil organic carbon, pH and bulk density (Oguike and Onwuka, 2017), while continuous cultivation was observed to increase the maximum distance of spatial dependence for soil organic matter and other properties (Cambardella *et al.*, 1994). Paz-Gonzalez *et al.* (2000) found that soils under continuously cultivated land were more homogeneous than soils under bush fallow and forestland, with reduced nugget effects of organic matter and pH.

In Abia State, land is put to numerous utilizations driven by the expanding interest for industrialization and development, thereby; studies are sparse on the impacts of land use on soil properties. Therefore, the present study was conducted to investigate and quantitatively delineate the spatial distribution of soil bulk density, organic carbon and pH under different land use systems.

Materials and Methods

Study area

The study was conducted in Umuahia South Local Government of Abia State, Southeastern Nigeria. The location of the study area (Fig. 1) is within latitude 5°25′0″-5°30′0″N and longitude 7°22′30″-7°32′30″E (Chigbu, 2015). The study area is highly populated having an average population density of 2600 inhabitants per square kilometre (Ukandu *et al.*, 2011) and a total area of 140 km^2 (Chigbu, 2015). The location of study has a mean annual bimodal rainfall of 2201.92mm (Nigeria Meteorological Agency, 2015). The rainfall starts in April and ends in October with peaks in June and September (Nigeria Meteorological Agency, 2015).

Within the location, refuse dump (RD), 4-year bush fallow land (4-BF), forestland (FL), continuously cultivated land (CC), and excavation sites (EX) were investigated. Those sites are located within Ubakala and Ohiya metropolis. The forest had existed for over 50 years with tress such as *Swietenia mahogani* (mahogany), *Milica excelsa* (iroko) and *Gmelina arborea* (gmelina), while the bush fallow land which had been under fallow for four years had trees such as *Dialium guineense* (mbacheleku), *Chromolaena odorata* (siam weed), *Anthonotha macrophylla* (ububa-iepa) and *Parinari congensis* (ahaba). The refuse dump site had been utilized for more than 12 years for dumping household municipal wastes while the excavation site has been used for over 7 years for mining of laterites for construction of road and housing. The continuously cultivated land has been used continuously for cultivation of crops such as melon, cassava, fluted pumpkin, and maize.

Soil sampling

Under each land use system, ten (10) sampling points were located randomly. Around each of the sampling points within each land use, soil samples were collected at the depths 0 - 20, 20 - 40 and 40 - 80 cm using soil auger and core sampler. This constituted a total of 30 samples for each land use and a grand total of 150 bulk and core samples for the 5 land uses.

Sample preparation

The auger soil samples were air-dried and sieved through 2 mm sieve size. The Samples for organic matter were crushed again after sieving with 2 mm sieve size. The base of the core samples were covered with a cheesecloth and saturated in water for determination of bulk density.

Laboratory analysis

Bulk density: This was determined by the method reported by Blake and Hartge (1986).

Organic carbon: The organic carbon content of the soil samples was determined as described by Walkely and Black method (Nelson and Summers, 1982).

Soil pH: Soil pH was determined using 1: 2.5 soil-water suspension ratio (McLean, 1982).

Statistical analysis

With the help of GIS, the soil variables (bulk density, organic carbon and pH) were exposed to exploratory analysis. It involved plotting coordinates in a global positioning system (GPS) data file using ArcGIS software. The GPS coordinates were plotted on a map with a base map. The GIS has the flexibility to pick out applicable transformation methodology for each data set.

Results and Discussion

Bulk density

Fig. 2 shows the spatial distribution of bulk densities across the different land use systems. The Figure showed that excavation site had a high bulk density with a mean value of 1.70 Mg m^{-3}, while refuse dump site (1.25 Mg m^{-3}), continuously cultivated land (1.47 Mg m^{-3}), 4-year bush fallow (1.37 Mg m^{-3}) and forestland (1.33 Mg m^{-3}) had moderate bulk densities. Table 1 showed that the bulk density increased as the depth increased. The variation in bulk density may be due to the level of organic matter in the soil (Oguike *et al.*, 2018). The high bulk density observed under excavation site may be attributed to the loss of vegetative cover from the soil and the large-scale use of machineries on the sites, which led to the loss of organic matter thereby resulting to the high bulk density. This high bulk density was similar to the findings of Musah (2013). The moderate bulk density observed under refuse dump site may be attributed to the high organic matter content of the site. This finding concurred with that reported by Okolo *et al.* (2013) who observed that the high level of organic matter in the refuse dump sites of Abakaliki led to high total volume, moderate bulk density and favoured transmission of water under saturated conditions. The variation in bulk density observed under continuously cultivated land may be because of the mechanical disturbance of pore arrangements by tillage (Celik, 2005). The moderate bulk densities of 4-bush fallow and forestland may be because of their high organic matter contents (Oguike *et al.*, 2006; Oguike and Mbagwu, 2009). Oguike *et al.* (2018) observed that soil organic matter reduced bulk density through the adhesive and bonding properties of organic matter such as bacterial waste.

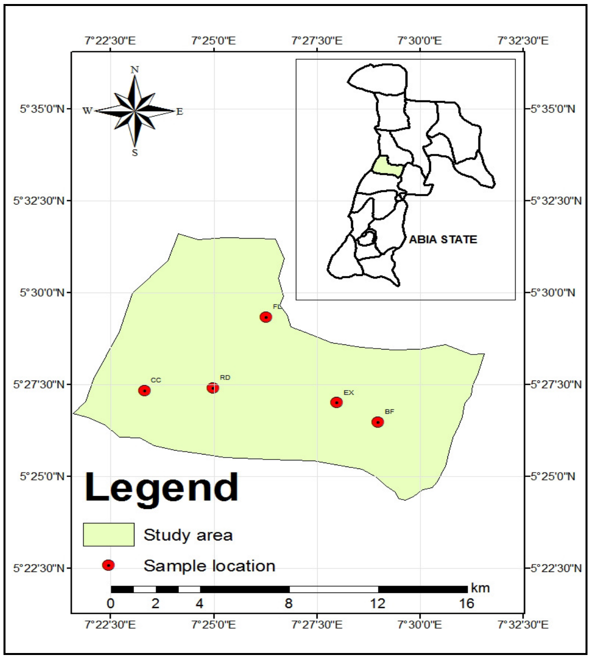

Fig. 1. Map of the study area showing the sample location

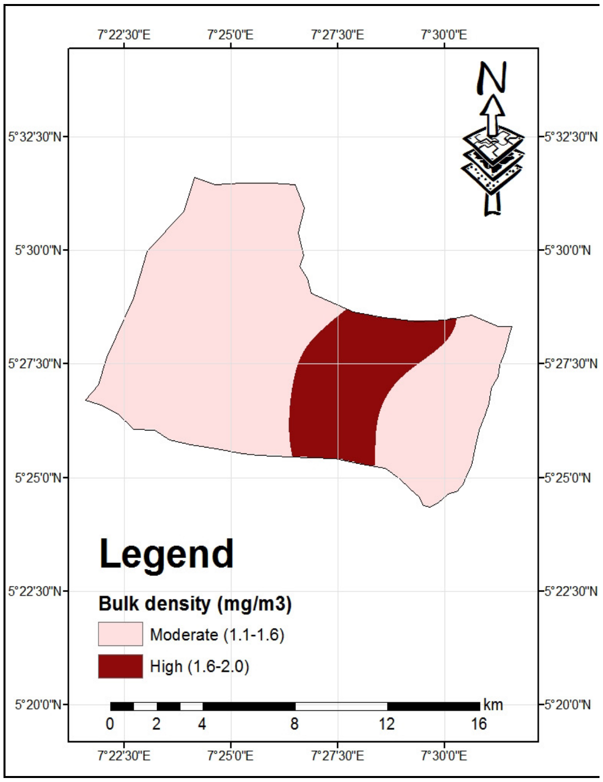

Fig. 2. Soil map showing the spatial distribution of bulk density among the land use systems studied

Soil pH

The spatial distribution of soil reaction across the different land use systems is shown in Fig. 3. The figure showed that refuse dump site had a neutral soil reaction with a mean value of 7.02, whereas 4-year bush fallow (6.00) and forestland (5.71) were slightly acidic. However, continuously cultivated land with a mean value of 5.41 was moderately acidic while excavation site (4.59) was very strongly acidic in reaction. The soil pH decreased with increase in depth (Table 1). The neutral and slightly acidic nature of the soils under refuse dump sites, 4-year bush fallow and forestland might be due to release of high exchangeable bases from municipal wastes, litter fall and roots (Alemayeha and Sheleme, 2013). The moderate acidic nature of the soil under continuously cultivated land and very strong acidic nature of excavation sites could be the increase in clay contents resulting from the removal of vegetation and top soil from the area. This increased the tendency of the clay contents to supply hydrogen ions from clay colloidal surface to the solution thereby reducing soil pH (Oguike and Onwuka, 2017).

Organic carbon

Spatial distribution of organic carbon among the land use systems studied was quantitatively delineated in Fig. 4. From the figure, it was observed that soil under excavation site had very low organic carbon content with a mean value of 0.38%, while continuously cultivated land (1.48%) was observed to have a moderate organic carbon content. However, forestland (2.97%) and refuse dump site (3.20%) had very high organic carbon contents, while 4-year bush fallow land (1.91%) recorded high organic carbon content. The organic carbon content of the soil decreased as the depth increased (Table 1).

Table 1. Bulk density, organic carbon and pH of soils studied

Land use	Soil properties		
	Bd (Mg m^{-3})	OC (%)	pH
	0-20 cm		
EX	1.61	0.38	4.90
RD	1.15	3.20	7.06
CC	1.38	1.48	5.70
4-BF	1.27	1.91	6.21
FL	1.20	2.97	5.93
	20-40 cm		
EX	1.69	0.21	4.57
RD	1.24	2.92	6.58
CC	1.45	1.30	5.51
4-BF	1.36	1.62	6.02
FL	1.29	2.08	5.71
	40-80 cm		
EX	1.81	0.18	4.30
RD	1.36	2.10	6.16
CC	1.57	0.98	5.02
4-BF	1.48	1.03	5.76
FL	1.51	1.68	5.48
Mean	1.42	1.60	5.66

EX = excavation site, RD = refuse dump site, CC = continuously cultivated land, 4-BF = 4-year bush fallow land, FL = forest land.

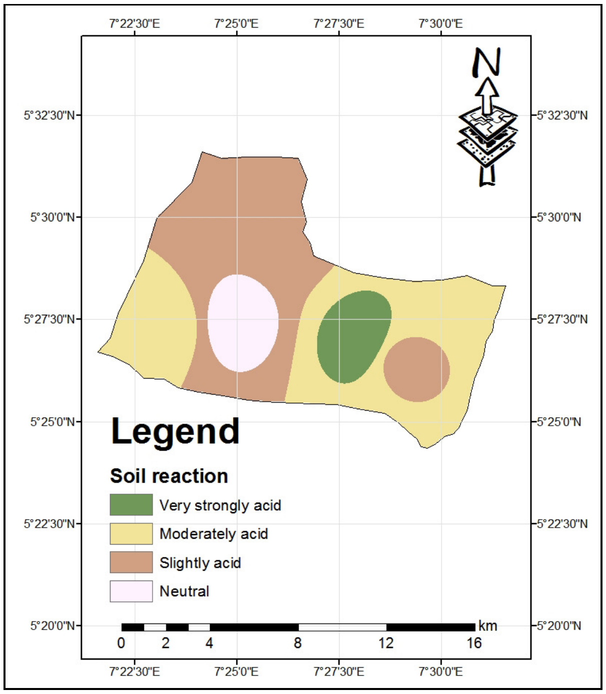

Fig. 3. Soil map showing the spatial distribution of soil pH among the land use systems studied

The very low organic carbon observed in excavation sites could be attributed to the soil disturbance which may had altered soil profile by destroying vegetation, roots, soil microbes and soil horizon (Musah, 2013). Those excavation activities increased the vulnerability of the soil surface to wind and water erosion. Similar observation had reported that the very low organic carbon might be due to the removal of litter and top soil (Rab, 2003). The very high organic carbon observed under refuse dump sites may be attributed to the use of the sites for dumping wastes (Anikwe and Nwobodo, 2002). Amos-Tauta *et al.* (2014) in their work on the assessing some heavy metals and physicochemical properties in surface soil under municipal open waste dump sites in Yenegoa, made similar observations with the study on very high organic carbon content of refuse dumpsites. They reported that the high organic carbon could have been due to the presence of degradable and compostable refuse wastes. The moderate organic carbon observed in continuously cultivated land could have been due to the effects of continuous cultivation that aggravates organic carbon oxidation (Wakene, 2001; Malo *et al.*, 2005; Alemayeha and Sheleme, 2013). The high organic carbon under 4-year bush fallow and very high organic carbon in forestland may be attributed to the continuous input and decomposition of litter falls and roots (Kleber *et al.*, 2011; Wu *et al.*, 2011). This was in agreement with the findings of Urisotle *et al.* (2006) on possibility of high organic carbon content in soil due to presence of roots of grasses and trees and the hyphae of fungi under bush, fallow and forestland.

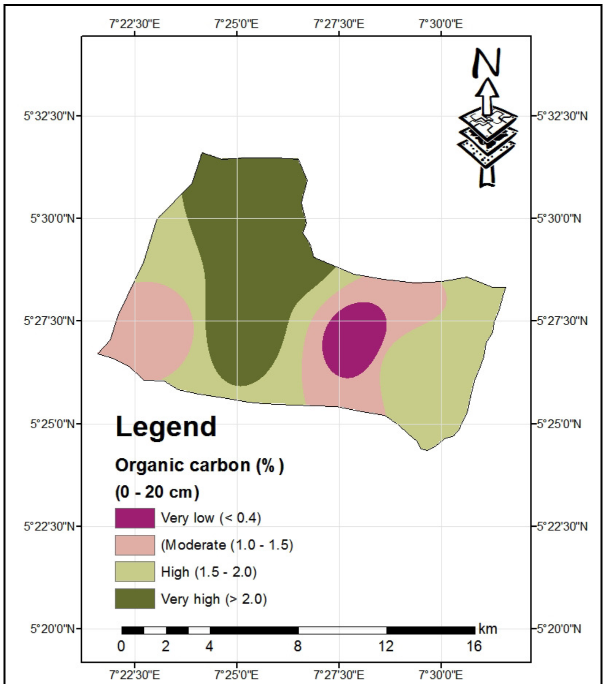

Fig. 4. Soil map showing the spatial distribution of soil organic carbon among the land use systems studied

Conclusions

The selected soil properties were spatially distributed among the different land use systems. Bulk density varied across the different land use systems under the impact of organic carbon. Higher soil bulk density was observed under excavation site than other land use systems studied. The hydrogen ion concentration of the soils studied was within moderately acidic to very strongly acidic. Organic carbon was generally very low in excavation site and moderate in continuously cultivated land, but very high in refuse dump site and forestland. The delineated spatial distribution of the selected soil properties in the area will guide land users in soil management strategies, in terms of choice and adoption of land for different uses in the area.

Conflict of Interest

We declare that there is no conflict of interest between authors.

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