BULK DENSITY AND ORGANIC MATTER CONTENT OF SOILS OF CONTRASTING TEXTURAL CLASSES IN UMUAHIA AREA OF ABIA STATE, SOUTHEASTERN NIGERIA.

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Abstract
Knowledge of bulk density (Bd) provides information on the status of soil compaction and aeration. Bulk density and organic matter (OM) content of soils of different textures were studied in Abia State, southeast Nigeria. Top soil samples (0-20 cm) were randomly collected at three points from each location comprising Michael Okpara University of Agriculture Umudike Farm (Umudike I) and Stadium (Umudike II), Ibere and Olokoro. A total of 12 auger and core samples were collected and analysed for particle size distribution, OM content and Bd of the soils. Descriptive statistic was used to determine variations in the soil properties. Correlation was used to determine the relationship between Bd and OM while regression analysis explained the control of OM over Bd. The textural classes identified were sandy loam (SL), sandy clay loam (SCL), silt loam (SiL) and clay loam (CL). Results showed that the SL soils were found in Olokoro, Umudike I and Umudike II. The SCL soil was observed in some areas of Umudike II, whereas the CL and SiL textures were all from Ibere. The highest Bd (1.52 Mg m^{-3}) was observed in SL soils whereas the lowest (1.20 Mg m^{-3}) was found in the CL soils. The Ibere SiL soil had the highest OM content (43.20 g kg^{-1}) while the Umudike I SL soil had the lowest (21.90 g kg^{-1}). Organic matter negatively correlated with Bd (R= -0.861**) and controlled about 79% of the variations observed in the Bd of the soils (R^2=0.793). The coarser the soil texture, the lower the OM content, and, the higher the Bd. Therefore, increasing soil volume through minimum tillage and application of OM reduces soil Bd thereby promoting soil aeration.

Keywords: bulk density, organic matter, texture.

INTRODUCTION

Soil organic matter content varies among and within soil types (Reicosky, 2005). Differences among types are primarily inherited, while differences within types are primarily due to soil management practices (Randy and Thompson, 2006). Usually, the larger the amount of residues returned over a period of several years, the higher the level of organic matter (OM) (Malgwi and Abu, 2011). Soil organic matter is represented by organic residues in various stages of decomposition (Reicosky, 2005). Distinction is made between two general groups of soil organic matter on the basis of differences in their properties (FAO, 2005). One of these, humus, the relatively stable end-product of organic residue decomposition, is sub-microscopic in size (colloidal) and exhibits electrical properties associated with surface active substances (FAO, 2005). The second group is organic materials at all stages of decomposition, which do not exhibit the properties of humus (FAO, 2005).

Humus exhibits its primary influence through its effect on bulk density. Bulk density of a given soil can be changed when the packing arrangement of soil aggregates is changed (Igwe, 2005). Packing arrangement is altered by changes in aggregate shape and size (Blaire *et al*., 2003). Humus binds soil particles together and thus changes their shape and size (Reicosky, 2005). To a less extent, bulk density can also change if organic material of low density replaces inorganic material of high density (Igwe, 2005). Bulk density which indicates whether the soil is compacted or not, determines total porosity. Porosity influences infiltration, permeability and surface flow, (Salako and Kirchhoff, 2003). Therefore, diverse behaviours exhibited by soils when bulk density and organic matter are considered are due to the differences in morphological, physical, chemical and mineralogical properties of the soil (Ukut *et al*., 2014).

Knowledge of the variation in bulk density and organic matter of texturally contrasting soils is imperative in the determination of the use to which soils may be put (Amusan *et al*., 2006) as well as the management strategies to be adopted. Therefore the objectives of this study were to determine:(i) variations in soil bulk density and organic matter content of texturally contrasting soils, (ii) relationship between organic matter and bulk density and iii) the extent to which organic matter will influence soil bulk density.

MATERIALS AND METHODS

The study area

The study was carried out in Abia State, Nigeria within latitudes 5° 25' to 5° 43'N and longitudes 7° 31' to 7° 52'E in Southeastern Nigeria (Nigeria Meteorological Agency, 2015). The climate is tropical with wet and dry seasons. The mean annual rainfall is 2250 mm (Nigeria Meteorological Agency, 2015). The rainfall is bimodal, starting in April and ending in October with peaks in June and September (Nigeria Meteorological Agency, 2015). Subsistent farming by resource-poor farmers for food crop production is prevalent in the area.

Soil Sampling

Soils used for this study were collected from four (4) different locations as shown in Table 1. Coordinates of four sampled locations are shown in Table 1 below.

Table1: Locations, coordinates and elevations of the sampling points

Locations	Coordinates	Mean elevation
Umudike I	05° 28' 899"/05° 28' 804"N	116 m
	07° 31' 823"/07° 32' 366"E	
Umudike II	05° 28' 879"/05° 28' 904"N	126 m
	07° 31' 883"/07° 32' 386"E	
Ibere	05° 29' 290"/05° 30' 410"N	74 m
	07° 35' 340"/07° 35' 470"E	
Olokoro	05° 26' 490"/05° 32' 510"N	119 m
	07° 28' 390"/07° 33' 440"E	

Auger samples at a depth of 0 – 20cm were collected for particle size analysis and determination of organic matter. Core samples at 0 – 20cm were also collected for the determination of bulk density.

A total of 12 core and auger soil samples were collected across the locations. In each location, samples were randomly collected at three (3) different points.

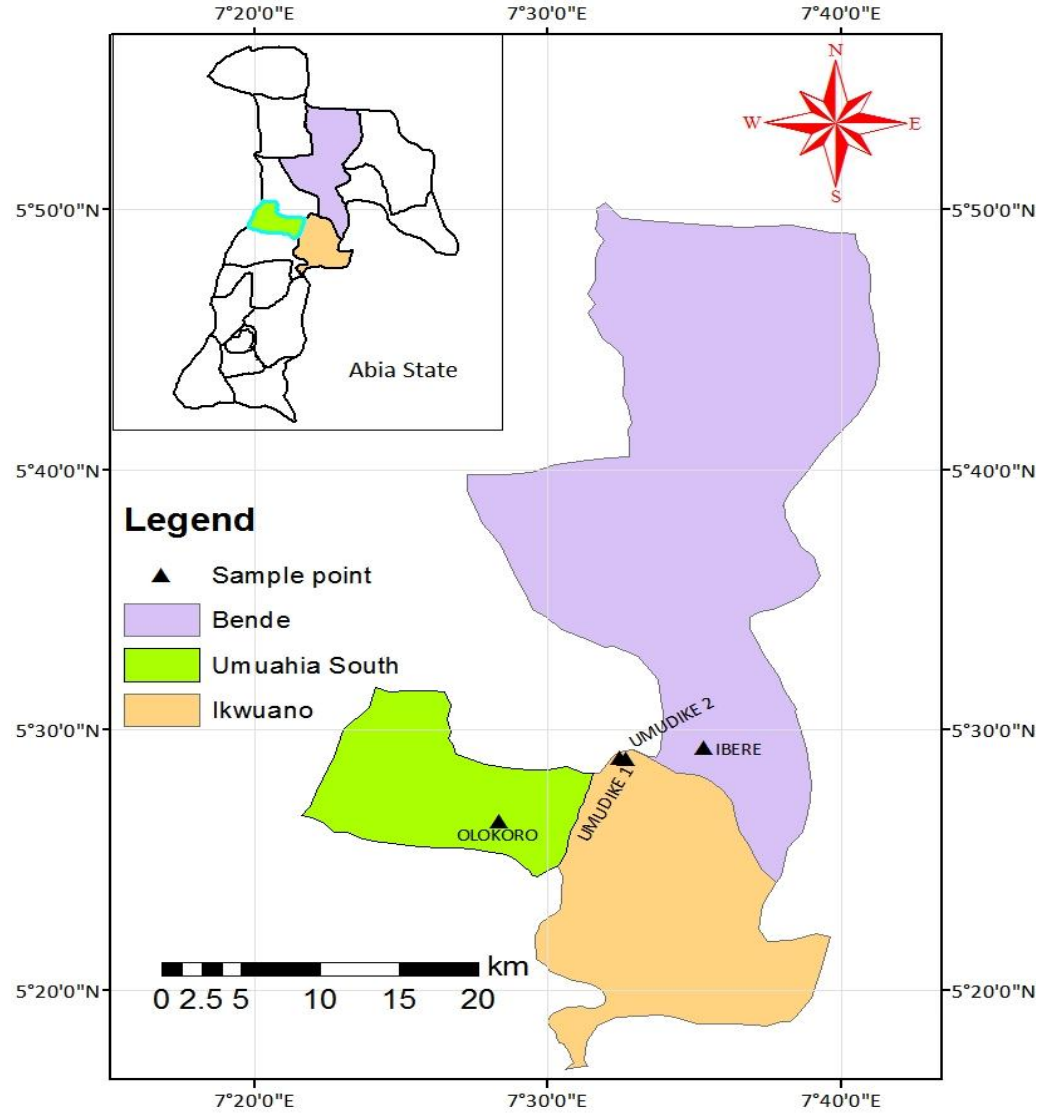

Fig 1: Location map of the study area.

Sample Preparation

The soil samples were air dried, passed through a 2-mm sieve and used for the determination of particle size distribution and organic matter. The core samples were weighed, oven dried and reweighed in order to calculate bulk density.

Laboratory analyses:

Particle size distribution analysis was by the hydrometer method as outlined by kettler *et al.*, (2001). Bulk density was determined by the method described by Blake (2003) while soil organic carbon (SOC) was determined by the Walkley and Black wet oxidation method as described by Nelson and Sommers (1996). The value of organic carbon obtained was multiplied by the Van Bemmelen Factor (1.72) to derive the exact value of soil organic matter (SOM).

Statistical analysis

Descriptive statistic was used to determine variations in the soil properties. Correlation was used to determine the relationship between bulk density and organic matter while regression analysis was used to ascertain the extent to which organic matter influenced bulk density.

RESULTS AND DISCUSSION

Particle size distribution

The particle size distribution of the soils is shown in Table 2. The Table showed that the textural classes of the soils were sandy loam (SL), sandy clay loam (SCL), clay loam (CL) and silt loam (SiL). The sandy loam (SL) textural class was observed in soils collected from Olokoro, Umudike I and two of the three parts of Umudike II locations. Sandy clay loam (SCL) texture was observed in the soil from one part of Umudike II while the soils with clay loam (CL) and silt loam (SiL) textural classes were from Ibere location.

The particle size distribution of the soils (Table2) revealed that total sand fraction varied from 644 to 744 g kg^{-1} in the sandy loam (SL) textural class across Olokoro, Umudike I and Umudike II while it covered 464 to 584 g kg^{-1} of the mineral fractions in the SiL and SCL textures in one of the three parts of Ibere and Umudike II, respectively. For the Ibere CL soil, the sand fractions did not vary at two sampling areas (284 g kg^{-1}). In the SL soil texture, silt fraction varied from 70 to 200 g kg^{-1} across Olokoro, Umudike I and Umudike II locations. The silt fraction occupied 160 and 300 g kg^{-1} of the mineral components of the SCL and SiL soils at Umudike II and Ibere locations, respectively. At Ibere location, silt fraction varied from 340 to 420 g kg^{-1} in the CL soil. The clay fraction in the SL soil ranged from 124 to 204 g $kg^{-1}$and from 296 to 376 g kg^{-1} in the CL soil. For the SCL and SiL textural classes, the clay fraction covered 256 and 236 g kg^{-1} of the soil mineral components, respectively. The highest sand content (744 g kg^{-1}) was recorded in soil of sandy loam (SL) texture while clay loam (CL) had the lowest (284 g/kg). Clay loam (CL) textured soil had the highest silt content (420 g kg^{-1}), while sandy loam (SL) recorded the lowest (70 g kg^{-1}). With regard to clay content, clay loam (CL) recorded the highest (376 g kg^{-1}) while sandy loam (SL) was observed to have the lowest (136 g kg^{-1}). The dominance of sand content in sandy loam (SL) and sandy clay loam (SCL) textured soils was a reflection of their coastal plain sands parent material (Chukwu, 2012). The dominance of silt and clay contents in clay loam (CL) and silt loam (SiL) textural classes indicated that the soils were formed from shale parent material (Chikezie *et al.*, 2009). Low clay content of soils with sandy loam (SL) and silt loam (SiL) textural classes may be attributed to sorting of soil materials by biological and /or agricultural activities, clay migration or surface runoff (Malgwi *et al*, 2000). The dominance of clay in sandy clay loam (SCL) and clay loam (CL) soils may be as a result of eluviation–illuviation processes as well as contributions of the underlying geology through weathering. The clayey nature of the soils suggested their capacity to hold more water and nutrients than other soils with sandy loam (SL) and silt loam (SiL) textural classes.

Table 2: Particle size distribution, texture, bulk density and organic matter content of soil studied

	Sand	Silt (gkg^{-1})	Clay	Texture	Bd ($Mg\ m^{-3}$)	OM (gkg^{-1})
			OLOKORO			
	684.00	120.00	196.00	SL	1.44	26.40
	744.00	70.00	186.00	SL	1.37	35.70
	644.00	200.00	156.00	SL	1.52	27.20
			UMUDIKE I			
	646.00	150.00	204.00	SL	1.40	22.60
	712.00	164.00	124.00	SL	1.45	23.10
	695.00	108.00	197.00	SL	1.42	21.90
			UMUDIKE II			
	664.00	140.00	196.00	SL	1.47	22.00
	704.00	160.00	136.00	SL	1.37	27.00
	584.00	160.00	256.00	SCL	1.43	28.20
			IBERE			
	464.00	300.00	236.00	SiL	1.33	43.20
	284.00	420.00	296.00	CL	1.24	41.40
	284.00	340.00	376.00	CL	1.20	40.20
Mean	592.42	194.33	213.25		1.39	29.91
Min	284.00	70.00	124.00		1.20	21.90
Max	744.00	420.00	376.00		1.52	43.20
%CV	43.46	54.85	37.47		5.28	25.58

Bd= bulk density, OM= organic matter, CL= clay loam, SCL= sandy clay loam, SL= sandy loam, SiL= silt loam, min= minimum value, max= maximum value, CV= coefficient of variation.

Bulk density and organic matter

Bulk density varied from 1.37–1.52 Mg m^{-3} in soils with sandy loam (SL) and sandy clay loam (SCL) textural classes and from 1.20–1.33Mg m^{-3} in soils with clay loam (CL) and silt loam (SiL) textural classes (Table 2). The highest bulk density (1.52Mg m^{-3}) was recorded in soil with sandy loam (SL) textural class, while clay loam (CL) textural class was observed to have the lowest bulk density (1.20Mg m^{-3}). The lower bulk density observed in soils of CL and SiL textural classes relative to that of SL and SCL had been reported by Chikezie *et al.* (2009). The possibility of migrating clay filling up the pore spaces in the supposedly well-structured pore arrangement may account for the high bulk density values in the soil (Idoga and Azagaku, 2005).

Organic matter ranged from 21.90 – 35.70 g kg^{-1} in soils of sandy loam and sandy clay loam textural classes (Table 2). The organic matter of soils of clay loam and silt loam textural classes ranged from 40.20 – 43.20 g kg^{-1}. The highest organic matter (43.20 g kg^{-1}) was recorded in soil of silt loam textural class while soil of sandy loam texture had the lowest (21.90 g kg^{-1}). In this study, the higher OM contents of soils of clay loam and silt loam textures compared to that of sandy loam and sandy clay loam (Table 2) agreed with Obasi (2004) who reported OM contents of soils with clay loam and silt loam textural class to be higher than those of sandy loam and sandy clay loam. These higher OM contents observed in soils of CL and SiL may be attributed to their finer textures and poor aeration (FAO, 2005) as well as litter fall (Hirabuki, 1991). Myravarapu *et al.* (2014) had earlier reported much of OM in soil closely associated with clay-sized particles. This is so because clay-sized minerals in soil are very reactive to external molecules owing to their tiny particle sizes, large surface area, and peculiar charge characteristics (Kaur *et al.*, 2002). High leaching potentials of sandy loam and sandy clay loam soils may also be responsible for the lower OM in these soils. Earlier report has revealed that sandy loam and sandy clay loam textured soils are characteristically low in OM content (Myravarapu *et al.*, 2014). The lower OM content of the soil in the sandy loam and sandy clay loam implied less bonding and a consequent lower aggregation of the soils.

Correlation of some soil properties

Correlation of the soil properties is shown in Table 3. The sand fraction negatively, and significantly correlated with silt (R=-0.916**) and clay (R=-0.531*). Bulk density negatively, and significantly correlated with organic matter (R= -0.861**). The indication was that sand content decreased with increase in silt and clay contents while bulk density increased with decrease in organic matter content. This observation was similar to the findings of De Preez *et al.* (2011) who reported that soil organic matter reduced bulk density through the adhesive and bonding properties of OM such as bacterial waste, organic gel, etc. A correlation of soil organic carbon with bulk density has been reported (Igwe, 2005). FAO, (2005) reported a reduced bulk density and an enhanced porosity as soil organic matter content increased. This is because OM enhances aggregation and also ensures increase in pore spaces thereby promoting soil aeration.

Table 3: Correlation matrix of soil properties

	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	OM (g kg^{-1})	Bd (Mg m^{-3})
Sand(g kg^{-1})	-				
Silt(g kg^{-1})	-0.916**	-			
Clay(g kg-1)	-0.531*	0.147	-		
OM(g kg^{-1})	-0.279	0.386	-0.128	-	
BD(Mg m^{-3})	-0.117	0.074	0.132	-0.861**	-

Influence of organic matter on bulk density

Organic matter was observed to influence the variations in bulk density. The regression analysis (Fig 1) showed that organic matter influenced the variability of bulk density by 79.3 % (R^2= 0.793). Organic matter was observed to have an inverse control on the bulk density of the soils. This trend, showing an inverse relationship between organic matter and bulk density (Igwe, 2005), indicated that a reduction in organic matter will result to an increase in bulk density (Agbede *et al*., 2008).

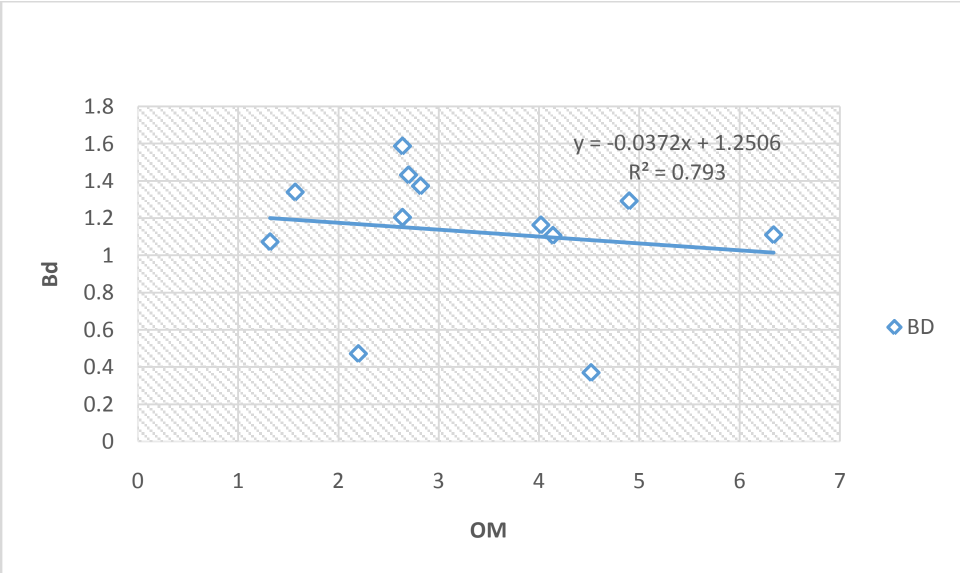

Fig 1: Regression of organic matter and bulk density.

CONCLUSION

Bulk density and organic matter varied among and within the soils although, variability was slight. Regarding bulk density as an index, the soil with the greatest tendency to compact was the SL soil located at Olokoro with a Bd of 1.52 Mg m^{-3} whereas the least (1.20 Mg m^{-3}) was the CL soil at Ibere. Correlation of organic matter and bulk density was high and inverse with bulk density reducing as organic matter increased. Organic matter influenced the variations in bulk density by about 79%. Hence, the lower the organic matter, the more compact the soil becomes. However, the values for the bulk densities would still permit good plant growth with no restrictions to root development. The values exceeded no threshold for the different soils.

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