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Research Article

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Physical properties and organic matter content of the soils of Bade in Yobe State, Nigeria

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Abstract

The study was carried out to evaluate some physical properties of agricultural soils of Bade Local Government Area (LGA), Yobe State, Nigeria. One hundred and twenty soil samples, (0-20, 20-40, and 40-60cm depths) were randomly taken from four arable farms being cultivated for more than 30years in each of the 10 political wards of the LGA. The soil samples were analyzed for some physical properties and organic matter content using standard procedures. Results obtained showed that the soils were sandy loam in texture, slightly high bulk density (median (IQR) = 1.63Mgm^{-3}(1.60-1.65 Mgm^{-3})) with a median porosity of 39% and IQR of 38-40%. The structural stability showed that the soils are usually unstable with a mean weight diameter (MWD) (median = 0.78mm). The soil organic matter content is also very low (median =1.57gkg^{-3} and IQR (1.30-180)). Incorporation of organic residues and manure as well as conservation tillage practices to the soil will improve its physical properties and enhance productivity.

Keywords: Soil, Physical properties, Bade, Yobe

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Introduction

The most vital and essential common asset is soil. It is apparent that the production of sustenance to meet the requirement of people and animals is basically reliant upon agriculture which is dependent on soil (Lal, 1998). Soil properties vary spatially from a field to a larger scale influenced by both inherent and extrinsic factors (Cambardella and Karlen, 1999). The variation is a steady change in soil properties as a component of landforms, geomorphic components, soil forming variables and management (Boul et al*.,* 1997).). Physical properties of soil play important role in determining soils' suitability for agricultural, environmental and engineering uses.

The plant bolster, root penetration, seepage, air circulation, maintenance of moisture, and plant nutrients are connected with the physical state of the soil; they likewise impact the chemical and biological properties of soil. (Phogat et al, 2015). The physical properties of a soil as a feature of the numerous properties of soil are vital in deciding the way in which the soil can be utilized either for agricultural and non-agricultural purposes (Mandal, 2016). Information of the physical properties of soil is fundamental for characterizing as well as enhancing soil wellbeing to achieve optimal productivity for each soil/climatic condition.

Soil structure is one of the most important properties affecting crop production because it determines the depth that roots can penetrate, the amount of water that can be stored in the soil and the movement of air, water and soil fauna and overall soil fertility (Hermavan and Cameron, 1993; Cooper, 2011). Soil structure (aggregation) results from the rearrangement, flocculation and cementation of particles and is mediated by soil organic carbon (SOC), biota, ionic bridging, clay and carbonates (Bronick and Lal, 2005). MWD as a measure of aggregate stability is an index of erosion risk, surface crust, anaerobic condition and compaction (Cooper, 2011). Furthermore Garcia et al. (2010) added that maintaining high stability of soil aggregate is essential for preserving soil productivity, minimizing soil erosion and degradation, and thus minimizing environmental pollution as well.

The transformation and movement of materials within soil organic matter pools is a dynamic process influenced by climate, soil type, vegetation and soil organisms. Soil organic matter levels commonly increase as mean annual precipitation increases and field studies have shown that temperature is a key factor controlling the rate of decomposition of plant residues and accumulation (Bot and Banites, 2005)

There is a strong growing realization that yields are limited by the physical conditions rather than plant nutrient status in the soil and that among many climatic and edaphic crop production constraints, substantial reduction in the production capacity of rainfed areas could be attributed to soil physical constraints (Indoria et al., 2016). Knowledge of the nature of soil properties existing in any area is very vital in developing management systems for these soils. In view of that, this research was carried out to determine the status of some soil physical properties and organic matter of the soils of Bade Local Government Area, Yobe State, Nigeria.

Materials and Methods

The Study Area

Bade is a Local Government Area in Yobe State, Nigeria. It has an area of 809.661 km² with a population of 139,804 (NPC, 2010). The major vegetation type is the Sahel savannah. It consists of open thorny savannah with short

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trees and grasses. The trees are about 5 to 10 m high. The LGA comprises ten (10) agricultural and political areas namely: Dagona, Gwio-Kura, Katuzu, Lawan-Fannami, Lawan-Musa, Sabon-Gari, Sarkin-Hausa, Sugum-Tagali, Usur-Dawayo, and Zango. They are predominantly farmers and mostly depend on trading of agricultural produce for livelihoods.

The study was conducted between October to November 2017 in the ten agricultural areas of Bade LGA, Yobe State, Nigeria (The areas are Dagona, Gwio-Kura, Katuzu, Lawan-Fannami, Lawan-Musa, Sabon-Gari, Sarkin-Hausa, Sugum-Tagali, Usur-Dawayo and Zango). The LGA is located between longitudes 10° 02' and 11° 11'E and latitudes 12° 48' and 12° 88' N. It is situated in the Sudan savanna ecological zone of Nigeria. The climate is characterized by high temperature and seasonal rainfall. The mean minimum temperature ranges between 10 -12°C in December/January, while the mean maximum is about 34-37°C in March-May. The mean rainfall is between 300-500 mm per annum and is unimodal and lasts mostly from June to September while the dry season starts from October to May (NEAZDP, 2015). Jalloh et al. (2011) had classified the soils of the area as Lixisols.

Soil Sampling and Handling

At each location, soil samples (N = 12) were collected from the top layer (0-20 cm) of the soil and two subsurface layers (20-40cm and 40-60 cm depths). The soil samples were collected from randomly selected cultivated farms using bucket auger, packaged and separately stored in polythene bags according to depth and location.

Laboratory Analyses

The samples were air-dried separately, ground using a porcelain pestle and mortar, and sieved through a 2 mm sieve for particle size analyses.

Particle size distribution was determined by the hydrometer method (Gee and Or, 2002). Total soil porosity was calculated assuming particle density 2.65 g cm^{-3} using the following equation (Bhogal *et al*., 2009). Total soil porosity was determined using the expression = [1- (bulk density/2.65)] 100%. Oxidizable organic carbon was determined by the Potassium Dichromate method and converted to soil organic matter using the conversion factor of 1.72 as described by Ryan *et al*. (2001)

Mean weight diameter was determined by the wet-sieving method of Le Bissonnais (1996). The mean weight diameter (MWD) was calculated as follows:

$$MWD = \sum_{i=1}^{n} x_i . w_i$$

Where: x_i is the mean diameter of the size fraction i that corresponds to the mean aperture of the adjacent sieves, and w_i is the proportion of the total sample weight remaining on each sieve after sieving.

Data Analyses

Shapiro-Wilk test for normality was applied to the data distribution among the sites, which indicated non normal distribution. The variability of the properties by location were evaluated by non-parametric test of Independent samples, where the effect was significant, pairwise comparison were carried out with Nemenyi-dunn test using 'PMCMR' package of R version 3.1.3 (R, 2017)

Results and Discussion

Particle size distribution

Table 2 presents the results of some physical properties of the soils of Bade according to the sampling locations. The soils of all the areas showed dominance of sand particles and they all belong to the textural class of sandy loam. The sand content ranged from 552.20 to 706.23 g/kg, with a median (interquartile range) of 627.70 (583.00 – 653.20 g/kg), the values at Lawan-Fannami and Sabon-Gari areas were above the 3rd quartile and only at Sugum-Tagali the value was below the 1st quartile. The silt content was higher at 378.17g/kg at Sugum-Tagali and lower at Sabon-Gari (222.33g/kg) with a median of 317.30 (IQR = 282.80 – 352.20 g/kg). Clay content also showed marked difference between the 10 locations ranging from 54.30 to 71.43g/kg, with a median of 61.90 (IQR = 55.10 – 65.80 g/kg); about 40% of the locations had values above 3rd quartile. The presence of high level of sand particle across the sampling sites recorded in the study was corroborated by findings of Ohu *et al*. (1989) for soils of Yobe and Borno States and Vonciret al. (2008) reported that the dominance of sand contents in Northern Nigerian soils is as a result of sorting of materials by clay eluviation and surface wind erosion.

Bulk density and Porosity

The bulk density value were relatively high with a median value of 1.63Mg/m^3 (IQR = 1.60 – 1.65 Mg/m^3) as shown in Table 2.this could be attributed to the soil texture and very low organic matter content of the soils. It is reported that sandy soils usually have higher bulk densities (1.3–1.7 g/cm^3), and that bulk densities greater than 1.6 g/cm^3 tend to restrict root growth (McKenzie *et al.*, 2004). Therefore practices like reduced tillage, organic manure application, crop rotation and mixed cropping should be imbibed by the farmers to decrease the high bulk density which may affect the distribution and movement of water, plant nutrients availability and even uptake by plants which may ultimately affect overall plant growth (Marshall and Holmes, 1988; Ishaq et al., 2001).

The porosity ranged between 37.67 and 39.67% with a median value of 39.00% (IQR = 38.00 – 40.00). The total porosity is typical of sandy soils as reported that the total porosity of sandy soil ranged between 30 – 45% (Phogat *et al*, 2015). The low values of porosity is a reflection of high bulk density recorded in all locations, this could be attributed to continues cultivation as reported by Malgwi and Abu (2011) indicating that continuous cultivation led to increased bulk density, reduced porosity, organic carbon, aggregate stability and water retention capacity.

Mean weight diameter (MWD) as one of the measures of soil aggregate stability is one of the key soil physical quality indicators that integrates physical, chemical, and biological information into a single measurement (Tisdall, 1996). The MWD median (interquartile range) of the soils across all sites within the LGA is 0.78 (0.60 – 1.06 mm). This result fall within unstable (0.4-0.8mm) to medium (0.8-1.3mm) category of the stability grouping of Le Bissonnais (1996). Similarly Maduakor (1991) reported that the unstable structure of these soils may be due to weak binding of the aggregates caused by low organic matter content especially in the soils formed from aeolian deposits found across the Sahel region. The soil organic matter across the LGA was low (median 1.57gkg^{-1} and IQR (1.30-1.80). Generally, the soils were low in OM, this could be attributed to low vegetative cover which is a result of low rainfall that characterize such savannas (Nyalemegbe et al., 2011). Similarly the low organic matter content of the soils in all areas could be attributed to factors such as continuous cultivation, frequent burning of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil (Sharu *et al*., 2013). The study area is characterized by low precipitation and high temperature, this may also contribute to low level of OM as reported to have effect on low of organic matter accumulation (Hamza and Anderson, 2010).

Soil properties as affected by depth (cm)

Physical properties of surface and sub-surface soils are presented in Table 3. The sand and clay contents showed a slight decrease with depth. The decrease in clay with depth is an indication that subsoil is more weathered than the surface, Similar results was reported on the soils of Sokoto State by Sharu *et al*. (2013). Low silt content in all the surface soils is in line with the report of Adegbenro *et al*. (2011). Bulk density and porosity showed significant differences by depth. As the bulk density increases downward the porosity decreases. This could be attributed to less organic matter and decreased aggregation and corroborates the work of Abdullah et al. (2018) whose findings showed that bulk density increased with soil depth thus, giving good porosity for soil water movement and cation exchange capacity to hold the nutrients necessary for microbial activity.

Conclusion

This study showed that the soils of Bade LGA are Sandy loam, high in bulk density, low porosity, weak structure and very low in organic matter content. In order to improve on these properties, practices such as minimum tillage, incorporation of crop residues and organic matter into soil should be encouraged.

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Table 1. Soil sampling locations (wards) in Bade LGA of Yobe State

S/no.	Wards	Latitude	Longitude	Altitude(m)
1	Dagona	12.856473	10.763133	366
2	Gwio-Kura	12.704625	11.100117	361
3	Katuzu	12.862674	11.041934	369
4	Lawan- Fannami	12.864131	11.041636	365
5	Lawan-Musa	12.891682	11.049198	366
6	Sabon-Gari	12.874008	11.030397	355
7	Sarkin-Hausa	12.864152	11.041625	334
8	Sugum-Tagali	12.813096	10.659087	373
9	Usur-Dawayo	12.875244	10.985060	359
10	Zango	12.883993	11.037897	357

Table 2. Some physical properties and organic matter content of the soils of the ten wards in Bade LGA

Wards	Sand	Silt	Clay	TC	B D	Porosity	MWD	SOM
	←	g kg⁻¹	→		(Mg m^{-3})	(%)	(mm)	g kg^{-1}
Dagona	606.50bc	330.33abc	63.17abcde	SL	1.62bc	39.33ab	0.87ab	1.60abc
Gwio-Kura	596.20cd	341.17abc	62.63abcde	SL	1.61bc	39.33ab	0.93a	1.64ab
Katuzu	616.47bc	329.23abc	54.30e	SL	1.65a	37.67c	0.58bc	1.22de
Lawan- Fannami	649.50b	293.17cd	57.33cde	SL	1.63ab	38.33bc	0.56bc	1.32cde
Lawan-Musa	653.43b	276.07d	70.50ab	SL	1.63abc	39.33ab	0.99a	1.84a
Sabon-Gari	706.23a	222.33e	71.43a	SL	1.63abc	38.67abc	0.94a	1.54abcd
Sarkin-Hausa	597.23cd	346.50ab	56.27de	SL	1.63abc	38.67abc	0.53c	1.20e
Sugum-Tagali	552.50d	378.17a	69.33abc	SL	1.60c	39.67a	1.04a	1.82a
Usur-Dawayo	619.43bc	321.83bcd	58.73bcde	SL	1.64ab	38.33bc	0.78abc	1.48bcde
Zango	636.53bc	295.13bcd	68.33abcd	SL	1.63ab	38.00c	1.09a	1.71ab
K-W ($p \leq 0.05$)	0.001	0.001	0.001		0.001	0.001	0.002	0.001
Mdn	627.70	317.30	61.90		1.63	39.00	0.78	1.57
IQR	583 - 653.2	282.8 - 352.2	55.1 - 65.8		1.60 - 1.65	38.0 - 40.0	0.60 – 1.06	1.30-180

TC = Textural class, BD = Bulk density, MWD = Mean weight diameter, SOM = Soil organic matter, K-W = Kruskal Wallis test @ 0.05 significance level, Mdn = Median and IQR = interquartile range

Table 3. Some soil physical properties and organic matter content by depth (cm)

Depth (cm)	Sand	Silt	Clay	Bulk Density	Porosity	MWD	SOM
	←	g kg⁻¹	→	(Mg m^{-3})	(%)	(mm)	g kg^{-1}
0 – 20	636.36	296.00	67.64	1.61b	39.10a	0.89	1.58
20 – 40	626.73	311.73	61.54	1.64a	38.40b	0.83	1.54
40 – 60	607.12	332.45	60.43	1.63ab	38.70ab	0.77	1.48
K-W ($p \leq 0.05$)	0.097	0.067	0.435	0.001	0.014	0.693	0.435
Mdn	627.70	317.30	61.90	1.63	39.00	0.78	1.57
IQR	583 - 653.2	282.8 - 352.2	55.1 - 65.8	1.60 - 1.65	38.0 - 40.0	0.60 – 1.06	1.30-180

MWD = Mean weight diameter, SOM = Soil organic matter, K-W = Kruskal Wallis test @ 0.05 significance level, Mdn = Median and IQR = interquartile range

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