Evaluation of physical and chemical properties of soils in selected parts of Yobe State, Nigeria

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Abstract

The experiment was carried out in 2019 with the objective to evaluate the physical and chemical properties of soils in selected parts of Yobe State, Nigeria. The study locations were Potiskum, Nangere and Fika Local Government Areas of the state. A composite soil sample was collected at a plough layer of 0-15 cm from four different farm plots across the locations while the adjacent uncultivated soil to each location was used as the control. All the soil samples collected were analyzed at the laboratory to see if there were significant differences in the soil physical and chemical properties across the locations. The textural classes are sandy clay loam. The sand values ranged from 42-47 %, silt values ranged from 15-17 % while clay values ranged from 40-48 % across the locations and their control plots. The bulk density (Bd) values across the locations ranged from 1.3-1.6 gcm-3. Total porosity (Pt) values for Potiskum, Nangere and Fika ranged from 43-46 %, 53-60 % and 50-53 % respectively. Similarly, hydraulic conductivity (Ksat) values across the study locations ranged from 0.4-0.6 cmhr-1. Bd, total pore spaces as well as Ksat values across the study locations and their control plots were rated as moderate and were considered favourable for optimum crop yield but with continuous crop growth and animal trampling that is common across the locations, there may be poor aeration, movement of water and soil physical degradation. In order to avoid these problems, animal trampling should be controlled since this could lead to increased in Bd, reduced pore spaces and Ksat. The soil pH values across the experimental locations could be considered appropriate for plant growth and development. The pH was positively and significantly correlated with CEC. The CEC in all study locations and their control plots is predominantly low, and this low in CEC may be attributed to the low OM, TN, and available P content of the whole soil samples collected. Application of organic residue and proper soil management practices are important in reversing the trend of nutrient depletion in soils across the study locations.

Key-words: Study, Soil samples, Properties, Locations, Analysis, Results, Reports, Recommendations

Introduction

Agricultural practices require sustainable use and management of soil resources. The soils may easily lose their nutrients and qualities within a short period of time under poor management and land use (Yakubu, 2010). Soil properties describe the physical and chemical characteristic behaviour of soils including the nutrient status (Usman, 2017). The need for basic knowledge and assessment of changes in soil properties and their fertility status with time to evaluate the impact of various soil management practices has become necessary for sustainable agriculture in Nigerian savanna zones. Similarly, for sustainable soil nutrient management in these zones,
there is also need for an understanding of how soil responds to agricultural practices over time (Oyedele et al., 2014). One of the major important components of agricultural management and sustainability as well, a goal of most farmers in the tropics is the maintenance of soil nutrients and qualities. This according to Mallo (2010) provides avenue for measuring levels of crop productivity. Soil properties reveal soil quality which measures the levels of soil fertility. This means that assessing soil quality also involves measuring and evaluating soil properties for optimum crop yield. Soil properties may have influence on various processes that are suitable for agricultural practices, though the dynamic soil nature describes the condition of a specific soil due to management practices.

The knowledge of soil properties in Nigerian savanna is necessary in addressing the problem of low fertility status and to ensure optimum food production. However, there is lack of information on the physical and chemical properties of the soils in study locations specifically with reference to availability of nitrogen and phosphorus which are known to limit performance of most crops and are often not supplied adequately by inorganic fertilizer in the areas. Thus, the objective of this study was to evaluate the physical and chemical properties of soils in Potiskum, Nangere and Fika Local Government Areas of Yobe State, Northeastern Nigeria.

Material and methods

Study locations

The study was carried out in 2019 with the objective to evaluate the physical and chemical properties of soils in selected parts of Yobe State, Nigeria. The study locations were Potiskum, Nangere and Fika Local Government Areas of the state. The Potiskum study location falls on latitude 11°42' N to 11° 43’ N and longitude 10° 04' E to 11° 06’ E. Similarly, Nangere study location falls on latitude 11° 50’ N to 11°51’ N and longitude 11°04'E to 11°11’ E while Fika study location is on latitude 11°00' N to 11°17’N and longitude 11°18’E to 11°29’ E (YSGN, 2008). All the study locations fall within the Sudan Savanna Zone of Nigeria with mean rainfall of about 800 mm per annum and temperature of 39-42 °C. The two vegetation zones in Yobe State are the Sahel in the North and the Sudan Savanna in the Southern part where all the experimental sites are located.

Soil sampling and laboratory analysis

A composite soil sample was collected at a plough layer of 0-15 cm from four different farm plots across the locations while the adjacent uncultivated soil to each location was used as the control. All the soil samples collected were analyzed at the laboratory to see if there were significant differences in the soil physical and chemical properties across the locations.

Particle size distribution (PSD) of the samples was determined by the Bouyoucos hydrometer method (1951) while the soil textures were determined by the use of USDA textural triangle. Core method was used to determine the soil dry bulk density (Bd). The total porosity (Pt) of the soil samples was determined by calculating the relationship below:

\[ \% P = \left(1 - \frac{Bd}{Pd}\right) \times 100 \]

Where\( P = \) porosity
\( Bd = \) bulk density g/cm\(^3\)
\( Pd = \) particle density of the soil estimated at 2.65 g/cm\(^3\)

The constant head method was used to determine saturated hydraulic conductivity (Ksat).

Electrometric method was used to determine the soil pH in water (1:1) and in KCl (1:1). The wet oxidation method of Walkley and Black (1934) was used to determine the organic carbon (OC) content of the soil samples while Total nitrogen (TN) was determined by the Macro-Kjeldahl digestion method (Jackson, 1965). Neutral, 1N Ammonium acetate method was used to determine Cation Exchange Capacity (CEC). As for Available Phosphorus, Bray-1 method was used to determine the extractable phosphorus (Bray and Kurtz, 1945). EDTA titration method was used to determine the Exchangeable Bases (Ca and Mg) (Jackson, 1965). Similarly, Sodium (Na) was determined by the EDTA extracts of Na, and Potassium (K) was determined with flame photometer. Effective Cation Exchange Capacity (ECEC) was determined by summing up the exchangeable bases plus the exchangeable acidity. Percentage Base Saturation was determined by dividing the sum of exchangeable bases by CEC and multiplying by 100.

Results and Discussion

The results obtained for particle size distribution across the study locations are presented in Table 1 and
further demonstrated in a graph (Fig. 1-3). Different textural compositions of the soils are presented in Table 1. The textural classes are sandy clay loam. The sand values ranged from 42-47 %, silt values ranged from 15-17 % while clay values ranged from 40-48 % across the study locations and their control plots (Fig. 1-3). According to Hillel (1980), textural classes serve as intrinsic soil properties and are adequately permanent and are also used to describe physical properties of soil. The control soils (uncultivated) across the study locations had higher clay content compared with some of the cultivated soils (P1 and P4) in Potiskum and Fika (Table 1). This is in line with the position of Troech and Thompson (1993) who stated that proper management of soil increased the content of clay and improved productivity level though, may not affect the soil textural class.

### Table 1. Physical and chemical properties of soil at the study locations.

| Locations /Plot | Particle Size Distribution | pH | Org | Org | Bray-1 | Exch. Cations (CmolKg⁻¹) | Base Saturation (%) |
|----------------|-----------------------------|----|-----|-----|--------|-------------------------|--------------------|
|                | Sand (%) | Silt (%) | Clay (%) | Textural Class | H₂O | KCl | C (%) | M (%) | N (%) | P (mg kg⁻¹) | Ca | Mg | K | Na | CEC |                |
| Potiskum       |           |           |           |               |     |     |       |       |       |             |    |    |   |    |      |                |
| P1             | 47.0      | 15.0      | 38.0      | SCL           | 6.50 | 5.70 | 0.88  | 1.52  | 0.077 | 4.20        | 3.29 | 1.51 | 0.26 | 0.65 | 6.40 | 89.10          |
| P2             | 43.2      | 17.8      | 39.0      | SCL           | 6.65 | 5.90 | 0.90  | 1.56  | 0.070 | 3.50        | 3.01 | 1.30 | 0.21 | 0.52 | 6.10 | 88.60          |
| P3             | 46.0      | 15.0      | 39.0      | SCL           | 6.45 | 5.65 | 0.74  | 1.28  | 0.091 | 3.10        | 2.96 | 1.26 | 0.21 | 0.50 | 5.80 | 87.40          |
| P4             | 44.2      | 17.8      | 38.0      | SCL           | 6.60 | 5.85 | 0.90  | 1.56  | 0.077 | 4.60        | 2.77 | 1.30 | 0.23 | 0.48 | 5.20 | 90.20          |
| Control        | 43.8      | 17.2      | 39.0      | SCL           | 6.65 | 5.90 | 0.92  | 1.59  | 0.088 | 4.00        | 3.80 | 1.60 | 0.30 | 0.71 | 6.00 | 86.70          |
| Nangere        |           |           |           |               |     |     |       |       |       |             |    |    |   |    |      |                |
| P1             | 45.0      | 15.0      | 40.0      | SCL           | 6.70 | 5.95 | 0.87  | 1.51  | 0.091 | 3.30        | 3.57 | 1.37 | 0.26 | 0.58 | 6.22 | 88.50          |
| P2             | 42.2      | 17.8      | 40.0      | SCL           | 6.45 | 5.65 | 0.77  | 1.33  | 0.079 | 4.50        | 3.11 | 1.40 | 0.22 | 0.50 | 6.30 | 87.60          |
| P3             | 45.0      | 15.0      | 40.0      | SCL           | 6.75 | 5.96 | 0.91  | 1.57  | 0.070 | 3.70        | 3.46 | 1.55 | 0.24 | 0.57 | 6.50 | 89.30          |
| P4             | 42.2      | 17.8      | 40.0      | SCL           | 6.58 | 5.90 | 0.86  | 1.49  | 0.090 | 3.60        | 4.12 | 1.70 | 0.30 | 0.76 | 6.70 | 90.40          |
| Control        | 46.0      | 16.0      | 40.0      | SCL           | 6.71 | 5.94 | 0.93  | 1.61  | 0.086 | 3.10        | 3.85 | 1.54 | 0.27 | 0.69 | 6.52 | 88.80          |
| Nangere        |           |           |           |               |     |     |       |       |       |             |    |    |   |    |      |                |
| P1             | 46.0      | 15.0      | 39.0      | SCL           | 6.48 | 5.70 | 0.73  | 1.26  | 0.088 | 3.80        | 3.08 | 1.40 | 0.24 | 0.43 | 6.27 | 89.00          |
| P2             | 42.2      | 17.8      | 40.0      | SCL           | 6.60 | 5.93 | 0.91  | 1.57  | 0.080 | 3.50        | 2.71 | 1.20 | 0.20 | 0.40 | 5.10 | 90.30          |
| P3             | 45.0      | 15.0      | 40.0      | SCL           | 6.40 | 5.70 | 0.88  | 1.52  | 0.077 | 2.90        | 4.20 | 1.86 | 0.33 | 0.75 | 6.77 | 87.80          |
| P4             | 43.2      | 17.8      | 39.0      | SCL           | 6.55 | 5.86 | 0.86  | 1.49  | 0.091 | 3.30        | 4.11 | 1.81 | 0.31 | 0.68 | 6.60 | 88.10          |
| Control        | 42.1      | 17.9      | 40.0      | SCL           | 6.58 | 5.90 | 0.86  | 1.49  | 0.090 | 3.60        | 4.12 | 1.70 | 0.30 | 0.76 | 6.70 | 90.40          |

**Key:** P1-4 = Farm Plot 1-4, SCL = Sandy Clay Loam.

**Fig. 1.** Particle size distribution of soil samples in Potiskum location.
Bulk density (Bd) values across the study locations ranged from 1.3-1.6 g cm$^{-3}$ (Fig. 4-6). Total porosity (Pt) values for Potiskum, Nangere and Fika ranged from 43-46 %, 53-60 % and 50-53 % respectively. Similarly, hydraulic conductivity (Ksat) values across the study locations ranged from 0.4-0.6 cm hr$^{-1}$. The Bd tended to increase in P1 and P4 across the study locations. This may probably be due to illuviation of clay leading to poor structural development and compaction (Malgwi et al., 2000; Brady and Weil, 2005). According to Donahue (1990), Bd values ranged below 1.4 and 1.6 g cm$^{-3}$ are good for optimum yield of crop in clay and sandy soils respectively. Bd values above 1.4 and 1.6 g cm$^{-3}$ in clay and sandy soils have been reported to inhibit root penetration (Malgwi et al., 2000). This means, root penetration may be inhibited in p1 and P4 across the study locations due to high Bd. This according to Brady and Weil (2005) will lead to poor aeration, slow movement of plant nutrients as well as building up of toxic gases. Bd, total pore spaces as well as Ksat values across the study locations and their control plots were rated as moderate based on the report by Maniyunda and Malgwi (2011) and were considered favourable for optimum crop yield but with continuous crop growth and animal trampling that is common across the study locations, there may be poor aeration, movement of water and soil physical degradation. In order to avoid these problems, animal trampling should be controlled since this could lead to increased in Bd, reduced pore spaces and Ksat.
The pH of the soils (Table 1) ranged from 5.95-6.75 across the study locations. The Nangere soil (P3 and P2) had the highest and lowest pH value of 6.75 and 5.65 respectively. The values could be considered appropriate for plant growth and development in the study locations (Usman, 2017). The pH was significantly related with values of CEC across the locations.
The values for organic matter (OM) (1.26-1.90 %) across the study locations are low compared with the values (2.5- 2.6 %) as reported by Prasad and Singh (2000) for optimum crop production. The results thus showed that soil amendment would be required in accordance with Agboola (1975) who reported that adequate soil amendments are required by farmers in Africa for optimum crop growth as a result of low inherent soil fertility. However, the lowest value of OM (1.26 %) was obtained from P1 at Fika location while the highest value of OM (1.90 %) was obtained from P1 at Potiskum. The total nitrogen (TN) values ranged from 0.070 % at (P2 Potiskum) and (P3 Nangere) to 0.091 % at (P3 Potiskum), (P1 Nangere) and (P4 Fika). The available P values ranged from 2.90 mgkg\(^{-1}\) at P3 Fika to 4.60 mgkg\(^{-1}\) at P4 Potiskum.

The values for cation exchange capacity (CEC) in all study locations and their control plots are predominantly low, it ranged from 5.10-6.77 Cmolkg\(^{-1}\) across the locations (Table 1) and this low in CEC values may be attributed to the low OM content of the whole soil samples collected. According to Lal and Kang (1982), the higher the OM content of the soil, the higher the CEC. Similarly, Lombin et al. (1991) opined that OM content was a major contributor to the CEC of the soil. The relationship in values between OM and CEC was significant, which is in line with the above observation. The soils were therefore tended to be low in available P and TN. This is also in accordance with the observation of Balasubramanian et al. (1984). The base saturation (BS) of the soil across the study locations increased from 86.70 % in control plot at Potiskum to 90.40 % in P4 Nangere and control plot at Fika. This indicates the differences in the balance between acid and base cations adsorbed by the CEC of soils in study locations.

**Conclusion**

The study was carried out in 2019 with the objective to evaluate the physical and chemical properties of soils in selected parts of Yobe State, Nigeria. The textural classes are sandy clay loam. The values of bulk density, total pore spaces as well as hydraulic conductivity across the study locations and their control plots were rated as moderate and were considered favourable for optimum crop yield but with continuous crop growth and animal trampling that is common across the locations, there may be poor aeration, movement of water and soil physical degradation. In order to avoid these problems, animal trampling should be controlled since this could lead to increased in Bd, reduced pore spaces and Ksat.

The values of soil pH across the experimental locations could be considered appropriate for plant growth and development. The pH was positively and significantly correlated with CEC. The values for CEC in all study locations and their control plots are predominantly low, and this low in CEC values may be attributed to the low OM, TN, and available P content of the whole soil samples collected. Application of organic residue and proper soil management practices are important in reversing the trend of nutrient depletion in soils across the study locations.

**Conflict of interest:** All authors declare no conflict of interest.

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