

## Fertility Status of Soils in Eastern Jigawa State of Nigeria

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### Abstract

*The increasing demand for farmlands necessitated by growing population is becoming more intense in eastern Jigawa State in the face of declining soil quality and hence growing food insecurity. It is therefore pertinent to study soil fertility in the area so as to maximize utilization of available farmlands for enhanced agricultural production. Accordingly, composite surface (0 – 15 cm) soil samples were taken from locations/villages spread across the study area. Simple random (where there were no strata observed) and stratified (soil samples were taken where there were strata) soil sampling techniques were used to take the soil samples which were analyzed for routine soil fertility indicators using standard soil analytical procedures. Results indicated that the soils were generally sandy loam in texture showing strong alkalinity (10.10) to slight acidity (6.13) with low available P (4.0 – 0.56 mgkg<sup>-1</sup>), high total N (2.3 – 0.95 gkg<sup>-1</sup>) and exchangeable Na (10.15 – 4.92 Cmol (+) kg<sup>-1</sup>). The exchangeable Ca and organic C were low to medium and low to high with ranges of 3.32 – 1.28 Cmol (+) Kg<sup>-1</sup> and 17.00 – 6.20 gkg<sup>-1</sup> respectively. Exchangeable K (0.08 – 0.77 Cmol (+) Kg<sup>-1</sup>) and EC (2.12 – 6.18 dSm<sup>-1</sup>) ranged from low to high while medium to high exchangeable Mg and CEC showed ranges of 0.85 – 1.78 Cmol (+) Kg<sup>-1</sup> and 8.0 – 12.10 Cmol (+) Kg<sup>-1</sup> respectively. Generally, the soils were found to be moderately fertile but saline and or alkaline. Therefore, soil management practices aimed at reducing alkalinity/salinity such as drainage, leaching and incorporation of crop residues among others should be employed to reduce salt concentrations for improved and sustainable agricultural production in the study area.*

**Keywords:** Fertility, Soils, Eastern, Jigawa State, Nigeria.

### 1. Introduction

Eastern Jigawa State is located in the Sudan savanna ecological zone of Nigeria (Shehu *et al.*, 2015) within latitudes 9°3U and 12°31U N and longitudes 4° and 14°3U E covering an area of roughly 22.8 million hectares which represents about one quarter of Nigeria's geographical area as reported by Manyong *et al.*, (1995). Improved crop production in this zone needs a good knowledge of the soil fertility level to allow appropriate nutrient management strategies in the area.

Soil fertility refers to the inherent ability of soil to provide essential plant nutrients in adequate amounts to ensure optimum plant productivity including maximum economic benefit and minimum environmental degradation (Forth, 1990; Biswas and Mukherjee, 1994; Prasad and Power, 1997; Basak, 2000; SSSA, 2003). With time, with the increase of population and food demand, methods of agriculture and stress on soil have been accelerated simultaneously because of mismanagement of soil fertility. The increasing demand for farmlands necessitated by the growing population is becoming more intense, it is therefore very important to understand the limitations to agricultural productivity as related to soil quality and fertility (Biswaranjan and Kshudiran (2015). Biswaranjan and Kshudiran (2015) reported that with the increase of population and food demand, methods of agriculture and stress on soil have been accelerated simultaneously because of mismanagement of soil fertility.

Declining soil fertility has become a threat in agricultural productivity and agro-economic scenario (Biswaranjan and Kshudiram, 2015). Degradation of soil nutrients has been reported to be one of the most biogeophysical constraints to agricultural productivity in Sub-Saharan Africa (SSA) including Nigeria's Savanna Zone (Henao and Baanante, 2006). Most Nigerian Savanna soils are highly weathered and fragile with low



activity clays, thus making their fertility decline under continuous arable cropping (Jones and Wild, 1975; Lombin, 1987; FDALR., 1999; Odunze, 2006; FFD., 2012). Generally, soil productivity declines rapidly when vegetation cover is lost and inappropriate management practices are adopted (Lal, 1997), thereby resulting in soil organic matter depletion and reduced agricultural productivity and food security. The need for productive and sustainable agriculture, makes soil restoration and fertility management a priority. This was partly achieved in Nigeria through bush-fallow system and use of manures (Oyinlola and Chude, 2010; FFD., 2012). Demographic pressure and its associated factors have shortened the fallow periods, thereby minimizing its impact. The quantities of organic manure needed to meet the farmers' need are also not sufficient, even where it is available, transportation and labour costs limit its use on a routine basis. The Jigawa state population is dominated by farmers, in other words farming is the most important occupation which brings income and economic stability for most of Jigawa state populace including farmers in the study area.

Governments had been making strenuous efforts to improve agricultural productivity either through the supply of fertilizers. However, the use of fertilizers remain low which is directly related to low crop yields. The use of mineral fertilizer in Nigeria has been often low with an average application of nutrient per hectare of arable land estimated at 5.7 kg, compared to the world average of 133.5 kg (World Bank, 2010). FAO (1985) reported that the use of fertilizers in Africa is as low as 8 kg/ha per year compared with a global annual average of 90 kg/ha.

It is therefore pertinent to study soil fertility in the area so as to maximize utilization of available farmlands for enhanced agricultural production. The results of this research may provide a panacea to the existing problems and design corrective measures for improved and sustainable crop production in the study area.

## **2. Materials and Methods**

### **2.1 Site Descriptions and Climate of the Study Area**

Jigawa State, North Western Nigeria, lies between latitudes 12<sup>0</sup> 00' to 13<sup>0</sup> 00' north and longitudes 100 00' to 100 13' east, within a climatic zone of Sudan in the central, and Sahel savannah at the extreme northeast, with a rainfall of 680mm per annum. The ecology of the entire state is grassland with a mean annual temperature of 28.20 °C. The geology on the highland is mostly residual / aeolian. In lowland areas, characterized with rivers soil formation is mostly alluvial /residual.

### **2.2 Soil Sampling and Preparation**

In order to take soil samples that is representative of the study area, a total of eight (8) locations/villages namely Auyo, Birniwa, Guri, Hadeja, Kafin Hausa, Kaugama, Kirikasamma and Malam Madori (Figure 1) spread across the study area were identified for soil sampling. In each location, composite surface (0 – 15 cm) soil samples were taken. Each composite sample composed of 8-10 sub samples. The sub samples were thoroughly mixed and then reduced to the required quantity through the quartering process. Simple random (in a “W” shape sampling framework) and stratified soil sampling techniques were used to take the soil samples. The latter was employed in areas with occurrence of rivers/floodplains. The soil samples were air dried and ground to pass through a 2 mm sieve before laboratory analyses.



Figure 1. Map of Jigawa State Showing Eastern Part and Soil Sampling Locations (in yellow).

### 2.3 Soil Analytical Procedures

Soil particle size was determined by hydrometer method as described by Bouyoucos (1951). Fifty (50g) of a 2 mm sieved soil was weighed into a 250 ml plastic container and 50 ml of sodium hexametaphosphate (calgon) was added to the soil and shaken for 15 minutes. The suspension was transferred into a 1000 ml measuring cylinder and made up to mark with distilled water. The suspension was thoroughly stirred using a plunger and a hydrometer was inserted immediately. Readings were recorded at 40 seconds and at 2 hours. A blank of the reagent was also run. The percentage of clay, silt and sand were determined using the appropriate formula. Soil pH was determined in soil water ratio of 1:2.5 by using an electrode pH meter (Maclean, 1965). Ten (10 g) of air-dried soil sample was weighed and poured into a 50 ml beaker, after which 10 ml of distilled water was added and stirred while the suspension was allowed to stand for 15 minutes. The partly settled suspension was stirred again occasionally with the glass rod for 15 minutes. The pH meter was calibrated with buffer 4 and 7 and finally the pH electrode was inserted into the partly settled suspension and the pH was measured. The result was reported as "soil pH measured in water" pH (H<sub>2</sub>O).

Electrical conductivity meter was used to determine the EC of soil (Bower and Wilcox, 1965). Ten (10 g) air-dry soil (< 2-mm) was weighed and later placed into a 50 ml glass beaker. 50 ml of distilled water added. After which the combination was mixed well with a glass rod, and allow to stand overnight.

Total nitrogen was determined using micro-Kjeldhal digestion method as described by (Bremner, 1965). One (1g) of an air-dried soil sample was poured into a 100 ml calibrated digestion tube. Followed by 2 g catalyst mixture, a few pumice boiling granules and 10 ml of concentrated H<sub>2</sub>SO<sub>4</sub> which was carefully swirled. The tubes were later placed in digestion block and slowly the temperature was increased to 370°C. The solution later changed its color to light blue after 3 hours of heating. Later the tubes were carefully removed from the digestion block and then placed on the tube rack holder, which was then allowed to cool to a room temperature. Slowly 20 ml of distilled water was added to the tubes slowly while shaking. The tube was swirled to bring any insoluble material into suspension and was then transferred into a 120ml container. However, the suspension was rinsed several times with distilled water to complete the transfer. 10 ml of boric acid was added to a 100 ml conical flask and the flask was placed under the condenser of the distillation apparatus in such a way that the end of the condenser dips into the solution. Nonetheless, 10 ml of 40% NaOH solution was added into the kjeldahl



distillation apparatus and distillate was titrated with 0.025N HCl to the colour of the indicator. Organic carbon was determined by wet oxidation method as described by Nelson and Sommers (1982). One (1 g) air-dry soil was weighed into a 500 ml beaker after which 5 ml 1N potassium dichromate ( $K_2Cr_2O_7$ ) solution was added using a pipette along with 10 ml concentrated  $H_2SO_4$  using a dispenser, and swirling the beaker to mix the suspension. Later, the suspension was allowed to stand for 30 minutes. 100 ml of distilled water was added and 5 drops of O-phenanthroline-ferrous indicator was added and it was titrated with 0.5N Ferrous sulphate solution. Available phosphorus was determined in the soil extract using ascorbic acid method (Bray and Krutz, 1945). The P in solution was determined calorimetrically by the use of colorimeter.

After extraction, exchangeable Ca and Mg were read using Atomic Absorption Spectrophotometer while exchangeable K and Na was determined using Flame photometer. Cation exchange capacity was estimated by the neutral ammonium acetate procedure (Anderson and Ingram, 1998).

## 2.4 Statistical Analysis

Where there means showed significant differences they were separated using analysis of variance (ANOVA) using the SAS statistical package.

## 3. Results and Discussions

Table 1 presents the soil physical and chemical properties in the study area. The sand content ranged from 49.36 (Kaugama) to 74.86% (Birniwa) while the silt and clay contents ranged from 8.82 (Birniwa) to 28.32% (Kaugama) and from 13.21 (Kafin Hausa) to 27.77% (Malam Madori) with mean values of 64.23, 15.59 and 22.08 respectively. Generally there were no significant differences in the distribution of the soil particle sizes in the study area (Table 1). The soil was found to be sandy loam in the study area except at Kaugama. The variation in soil texture at Kaugama compared to all other locations may be due to the fact that Kaugama is located close to a floodplain which normally shows variations in soil physical properties as reported (FAO, 1991; Akamigbo *et al.*, 2005). The high sand content may not be unconnected with the aeolian nature of the parent materials in the study area.

The pH ( $H_2O$ ) and electrical conductivity ranged from 7.26 (Malam Madori; slightly alkaline) to 10.10 (Kafin Hausa; strongly alkaline) and  $2.12 \text{ dSm}^{-1}$  with mean values of 8.0 and  $4.11 \text{ dSm}^{-1}$  respectively. The strong alkalinity is probably due to the high concentration of exchangeable Na (Table 1). The soil was saline as expressed by the high mean value of the EC. Landon (1991) reported that soils with EC greater than  $4.0 \text{ dSm}^{-1}$  are rated saline. The soil did not show variations in both pH and EC across the study area.

There were significant ( $P = 0.05$ ) differences in the contents of organic carbon and exchangeable potassium across the study area (Table 1) with values ranging from 6.20 (Guri) to  $17.00 \text{ gkg}^{-1}$  (Kaugama) and 0.08 (Birniwa) to  $0.77 \text{ cmol (+) kg}^{-1}$  (Kaugama) with mean values of  $9.87 \text{ gkg}^{-1}$  and  $0.24 \text{ cmol (+) kg}^{-1}$  respectively. The soil was generally rated moderate in the contents of both organic carbon and exchangeable potassium as expressed by their respective mean values. The high content of organic carbon observed at Kaugama may probably be due to its location close to a floodplain which receives fresh sediments and hence regularly rejuvenated. These sediments are reported to be high in organic matter (FAO, 1991; Omar, 2011). Similarly, Imam (2014) reported variations as well as high organic carbon in Maigatari, which is located very close to the study area. The moderate content of exchangeable K in the soils in all the locations is in agreement with the findings of Carroll and Klinkenberg (1972) in which he observed that floodplain soils in North-eastern Nigeria were observed to have moderate content of exchangeable potassium. The moderate content might not be unconnected with heavy presence of muscovite which is an important source of K in wet soils (Singer and Munns, 1996). It has been observed during the collection of soil samples that they contain white shiny particles later identified as muscovite. Muscovite glitter in wet soils (Singer and Munns, 1996).

Mean values of total nitrogen and available phosphorus were found to be  $1.30 \text{ gkg}^{-1}$  and  $1.83 \text{ mgkg}^{-1}$  respectively with both showing no variation across the study area (Table 1).

**Table 1: Soil Physical and Chemical Properties in Eastern Part of Jigawa**

Locations	Sand (%)	Silt (%)	Clay (%)	pH H <sub>2</sub> O	EC dSm <sub>1</sub> <sup>-1</sup>	O.C gkg <sup>-1</sup>	TN gkg <sup>-1</sup>	P mgkg <sup>-1</sup>	K	Ca	Mg	Na	CEC
										Cmol(+)kg <sup>-1</sup>			
Auyo	64.12	11.65	24.23	8.96	2.77	9.167 <sup>bc</sup>	0.993	0.567	0.356 <sup>ab</sup>	1.557	1.770	7.79	11.27
Birmiwa	74.86	8.82	17.53	8.48	2.12	8.500 <sup>bc</sup>	1.525	2.00	0.085 <sup>b</sup>	2.065	1.780	4.92	11.25
Guri	63.24	17.65	19.11	8.04	4.23	6.200 <sup>c</sup>	1.067	1.743	0.093 <sup>b</sup>	3.323	0.950	8.13	11.83
Hadejia	60.83	14.99	24.19	8.67	4.05	7.930 <sup>c</sup>	2.300	4.056	0.123 <sup>b</sup>	2.070	1.010	6.57	9.67
Kafin Hausa	71.68	16.32	13.21	10.10	3.23	8.100 <sup>bc</sup>	1.200	1.255	0.250 <sup>ab</sup>	2.080	1.090	7.18	10.55
Kaugama	49.36	28.32	25.77	6.41	6.18	17.00 <sup>a</sup>	0.950	1.410	0.770 <sup>a</sup>	2.050	0.930	8.48	12.10
Kirikasama	63.45	17.65	24.83	6.13	5.79	7.23 <sup>c</sup>	1.133	0.876	0.137 <sup>b</sup>	1.760	0.940	10.15	11.47
Malam Madori	66.36	9.32	27.77	7.26	4.58	14.90 <sup>ab</sup>	1.300	2.810	0.200 <sup>ab</sup>	1.280	0.850	5.74	8.00
p-value	0.486	0.341	0.924	0.455	0.550	0.003	0.729	0.265	0.001	0.316	0.215	0.358	0.908
SE±	4.928	3.553	6.701	1.076	1.193	0.881	0.611	0.871	0.063	0.469	0.259	1.195	1.707

Based on the mean values, the concentration of total nitrogen and available phosphorus in the soil was observed to be high and low respectively. The high total nitrogen may be connected with the medium content of organic carbon in the soil as reported earlier. High level of total nitrogen has been associated with high level of organic matter (Mustapha, 2000). Concentrations of exchangeable calcium, magnesium and sodium did not vary significantly across the study area. Mean values 2.02 cmol (+) kg<sup>-1</sup> (Ca), 1.16 cmol (+) kg<sup>-1</sup> (Mg) and 7.37 cmol (+) kg<sup>-1</sup> (Na) indicated medium, high and high content respectively. These high values are expected due to the high value of the cation exchange capacity observed (Table 1).

The cation exchange capacity did not vary significantly in the soils across the study area. However, Kaugama 8.48 (cmol (+) kg<sup>-1</sup>) and Kirikasama (10.15 cmol (+) kg<sup>-1</sup>) recorded one of the highest concentrations of exchangeable sodium which corresponded with high levels of electrical conductivity as indicated in Table 1. This probably related to the alkalinity of the soils as earlier observed.

The cation exchange capacity of the soils ranged from 8.0 (Malam Madori) to 12.10 (Kaugama) cmol (+) kg<sup>-1</sup> with a mean value of 10.76. Thus it is rated as low to high. The high values recorded may be due to the high concentrations of the exchangeable bases (Table1). Generally the soils were found to be of relative fertility as expressed by the moderate soil fertility parameters appraised. The relative fertility may probably be connected to that fact that the soil samples were taken mostly from virgin lands.

#### 4.0 Conclusion and Recommendations

Generally the soil was found to be of relative fertility as expressed by the moderate soil fertility parameters appraised showing no significant differences in soil particle size distribution and concentrations of exchangeable calcium, magnesium and sodium across the study area. However, the soil varied significantly in contents of organic carbon and exchangeable potassium. Concentration of available phosphorus was low. The soil was found to be dominated by a sandy loam texture. The high concentration of exchangeable sodium and most of the other exchangeable cations made the soil to be slightly alkaline and saline respectively.

Soil management practices aimed at reducing alkalinity/salinity such as drainage, leaching and incorporation of crop residues among others should be employed to reduce salt concentrations for improved and sustainable agricultural production especially at Kaugama and Kirikasama.



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