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Assessment of Physical and Chemical Properties of Soils for Agriculture in Yandev, Gboko, Benue State, Nigeria

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ABSTRACT
The physical and chemical properties of the soils at Akperan Orshi College of Agriculture, Yandev (AOCAY) (longitudes $8^{0}36'$ and $8^{0}45'$E and latitudes $7^{0}45'$ and $8^{0}00'$N) that have been under continuous cultivation (Rainfed and irrigated agriculture) were studied. Soil samples were taken from 0 – 30 cm depth for laboratory analysis and subjected to fertility related parameters. The research was carried out in July, 2018. The soils of the study area were of dominantly loamy sand textures at western and eastern school farms located within the school premises, while southern school farm was of sandy loam texture. The soils are deficient in nitrogen (0.27 – 0.32 %), phosphorus (2.70 – 3.01 mg/kg), potassium (0.23 – 0.30 Cmol/kg), calcium (2.70 – 3.10 Cmol/kg), magnesium (2.40 – 2.90 Cmol/kg) and low cation exchange capacity (6.54 – 7.62 Cmol/kg) due to low levels of organic matter (0.62 – 1.75 %). These soils could be rated moderate in fertility status due to their high base saturation (84.60 – 86.70 %). The soils indicate no salinity problem as the values of pH (6.8 – 7.3), electrical conductivity (0.72 – 0.86 ds/m), sodium (0.20 – 0.31 Cmol/kg), exchangeable sodium percentage (3.62 – 4.07 %) and sodium absorption ratio (0.13 – 0.18) fall within the tolerable limit. Crop residue and farm yard manure application and adequate and timely application of fertilizers by burying has been recommended as management practices for sustainable use of the soils under continuous cropping.
Keywords: Soil properties, fertility, tolerable limit, residue, sustainability

INTRODUCTION
Soils are indispensible resources that have been exploited for thousands of years for several purposes resulting in their degradation (Eswaran *et al*., 2001; Junge and Skowronek, 2007). Degradation of soils is encouraged through farmers' practices of burning of farm residues, use of cereal stalk as fuel wood and for fencing, non return of household wastes and annual wastes to the farmland, scarcity of fertilizer at affordable prices (Odunze, 2006). In Nigerian Savanna region, nitrogen is reported as the most limiting nutrient for crop production (Muhr *et al*., 2001; Odunze, 2006) and this problem has been compounded in recent times by difficulties farmers faced in obtaining nitrogen fertilizers. These reasons made the effort by farmers to replenish soil fertility in the Nigerian Savanna area low, thereby encouraging continued degradation of soils. This is manifested by their decline in yields, low fertility, Salinization, increasing erosion and deforestation (FAO, 2000). Therefore, there is need for development of sustainable land use management strategy that will conserve these soil resources. However, knowledge of the physical and chemical properties of any soil is an integral part of soil quality studies, necessary for the development of a sustainable soil management programme (Ogunwole *et al*., 2001; Junge and Skowronek, 2007; Konrad *et al*., 2001).

The soils around Akperan Orshi College of Agriculture, Yandev have been exposed to continuous cultivation. This is associated to increase in human population that have resulted in increasing intensities of soil cultivation to meet the challenges of food security.

Soil information on the study area is largely on reconnaissance level. There is scanty of information on the physical and chemical characteristics of these rather important agricultural soils. Therefore, the purpose of the study is to assess the physical and chemical properties of the soils around Akperan Orshi College of Agriculture, Yandev (AOCAY) with a view to recommending better management strategies that will enhance sustainable use of the soil resources under continuous cultivation (rainfed and irrigated agriculture) in the area.

MATERIALS AND METHODS

Study Areas

The research was carried out at three selected locations around the school farming areas viz: western, eastern and southern parts Akperan Orshi College of Agriculture, Yandev. Akperan Orshi College of Agriculture, Yandev is located at about 4 km north – east from Gboko Town along Gboko – Makurdi road in Gboko Local Government Area of Benue State. The study area is bounded by longitudes $8^0$36’ and $8^0$45’E and latitudes $7^0$45’ and $8^0$00’N (Fig. 1).

The study area relief ranges from 90 to 262m above mean sea level (a.m.s.l). The study area is undulating plains. The climate of the study area is tropical savanna. The minimum temperature is 25^0C and maximum is 33.5^0C. The mean monthly temperature is 27.3^0C. The total annual rainfall varies between about 900 and 1200mm. The study area has distinct dry and wet seasons. Rainy season starts in March/April and ends in October/November.

The vegetation in the study area is Guinea Savannah type, characterized by grasses with few scattered shrubs and trees. The land in the study area is used for cultivation of crops such as yam, cassava, guinea corn, maize, millet, groundnut, soyabean, benniseed, rice, melon, and other vegetable crops. Trees crops such as mango, palm trees, citrus, cashew and other economic trees are also found in the area. The study areas are underlain by the rock units of the undifferentiated basement complex and sandstone.

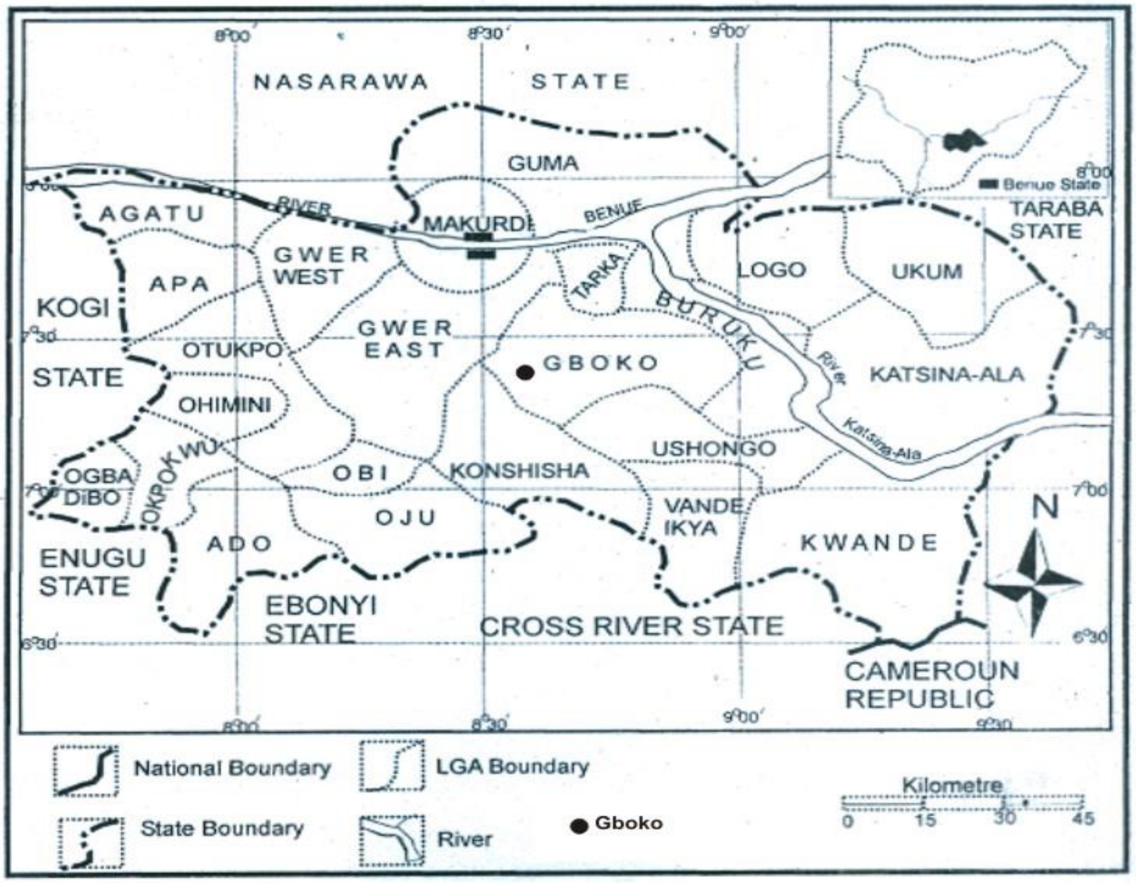

Figure 1. Map of Benue State showing Gboko
Source: Ministry of Land and Survey, Makurdi (The National Atlas of the Federal Republic of Nigeria, 1978)

Soil Sampling

Soil sampling in the school farms (western, eastern and southern parts of the school) was conducted in July, 2018. The random sampling technique was used to collect soil samples from six (6) different points in each location. Soil auger was used for collection of the soil samples. Composite soil samples were taken at the depth of 0 – 30cm at the three locations. The 6 samples in each location (distance) were air dried, bulked accordingly and gently crushed. A total of 3 soil samples from the three locations were sieved using 2.0mm sieve for physical and chemical analysis

Laboratory Analyses

The relative proportion of the soil separates was determined by hydrometer method of Bouyoucos (1951) (Udo *et al*., 2009). The glass electrode method was used to determine the soil pH (Udo *et al*., 2009). Organic carbon (OC) content of the soil samples were determined by the chromic acid oxidation procedure of Walkley – Black (Udo *et al.*, 2009). Electrical conductivities (EC) of the soil samples were measured with electric conductivity meter in a paste of 1:5 soil/water (Udo *et al*., 2009). Cation exchange capacity (CEC) of the soils was determined by Summation (TEB + EA) method (Udo *et al*., 2009). Extractable bases were determined using the ammonium acetate extract. Sodium and potassium were determined using the flame photometer. Calcium and magnesium were determined using atomic absorption spectrophotometer (AAS) (Udo *et al*., 2009). Total nitrogen was determined using the standard Macro-Kjeldahl method (Udo *et al*., 2009). Bray – I method was used to determine the available phosphorus. Exchangeable acidity (EA) was extracted using the titrimetric method (Udo *et al*., 2009). Exchangeable base (EB) was obtained by summation of the values of bases [EB = $\sum$ (K, Na, Mg, Ca)].

Exchangeable sodium percentage (ESP) of the ionic concentration (in meq/100g) of the soils was calculated using the formular;

$$ESP = \frac{\text{Exchangeable } Na^{+}}{EB} \times 100\%$$

The base saturation (BS) value of the soils was calculated in percentages using the formular;

$$BS = \frac{\text{Total Exchangeable bases}}{CEC} \times \frac{100}{1}$$

Sodium adsorption ratio (SAR) was calculated to determine the concentration of cation in soil as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

The chemical properties of the soils were compared with USDA soil degradation standards (USDA, 2001) and discussed under fertility related parameters.

RESULTS AND DISCUSSION

Soil Particle Size Distribution of the Study Area

The particle size distribution of the soils of the study area is presented in Table 1. The soils of the study area were of dominantly loamy sand textures at the school farms located at west and eastern sides of the school premises, while southern part of school was of sandy loam texture. The soils in these locations have a proportion of sand ranging from 78 to 83 %, silt from 10 to 12 % and clay from 7 to 10 %. The sand dominant fractions in the three locations indicate low water holding capacity and rapid water and air transmission. The soils possess good drainage and aeration. The soils are moderately suitable for crop production but may be prone to drought. Also, with continuous cultivation, loss of organic matter (OM) will be high due to crop utilization and rapid mineralization without replacement.

Table 1. Mechanical Composition of Soils of the Study Area

Location	Depth (cm)	Particle size Distribution (%)			Textural Class
		Sand	Silt	Clay	(USDA)
AOCAY West	0 – 30	83.0	10.0	7.0	Loamy Sand
AOCAY East	0 – 30	81.0	11.0	8.0	Loamy Sand
AOCAY South	0 – 30	78.0	12.0	10.0	Sandy Loam

Chemical Properties of the Soils of the Study Area

The data related to chemical properties are presented in Table 2. The highest values of soil nutrients were obtained at Southern parts of the school followed by Eastern and Western parts where the school farms are located.

The soil pH is the most important factor influencing crop performance. It influences the rate of organic matter decomposition, microbial activities, forms and extent of nutrient availability and nutrient uptake by crop. The soil pH values of the school farm sites were generally slightly alkaline at Western (7.2), Eastern (7.3) and slightly acidic at the Southern (6.8) areas in the wet season (Table 2). Acidity in the wet season was due to the leaching of appreciable quantities of exchangeable base-forming cations (Ca, Mg, K and Na) from the surface layers of the soils and high buffering capacity. In the slightly alkaline areas (Western and Eastern sites), there was a comparatively high degree of saturation with base-forming cations and low buffering capacity due to loamy sand nature of the soils. Soil can be easily overlimed in the drought prone areas due to low buffering capacity (Agbede, 2009). The soil pH in the sand dominant areas that are drought prone may be lowered by the application of light irrigation but at frequent intervals. This would keep the soil moisture, dilute salts and lessen the toxic and osmotic effects of salts in the soil. The soil quality in the three study sites for agriculture is moderate as the soil pH is within the normal range (5 - 8.5 for most arable crops). The soils are non-saline and therefore, moderately suitable for crop production.

The soil organic matter content of the catchment areas ranged from as low as 1.07 % in the soils of Western part of school to 1.75 % (South). This is because there was rapid rate of organic matter decomposition due to moisture and dominant sandy nature of the soils in the wet season which brought about decline in its content in the soils. The values of organic matter in the soils of the study areas were generally low to moderate. The organic matter of most soils ranges from 1-5% mostly in the top 25cm of soil (Agbede, 2009). The soil is considered moderately suitable for crop production and irrigation due to appreciable quantities of organic matter contents of the soils. Water holding capacity, granulation, cation exchange capacity, supply and availability of nutrients would improve if organic matter is added or maintained in the field. In view of the low organic matter content of the soils, incorporation of crop residue and farm yard manure is suggested. The crop residue is however currently used as feed, bedding and as roofing materials and usually little of it is returned to the soil (Kparmwang *et al*., 2001; Odunze *et al*., 2003). For any successful cropping there is need to add organic manure and fertilizers (N, P and K) in adequate quantity and preferably buried at a shallow depth adjacent to the plant root.

The nitrogen content of the soils of the study sites ranges from 0.27 – 0.32 % (Table 2). The low N content in the soils could be as a result of rapid rate of organic matter decomposition, excessive leaching of nutrients down the soil profile, and crop removal and erosion during the rainy season. Most savannah soils of Nigeria have very low total N content (0.04 – 0.05%) as against the normal range of 1 – 6% N (Adetunji and Adepetu, 1990). The soil is considered suitable for agriculture even though they are low in N content but due to moderate organic matter content in the soils, N would be supplied through decomposition of organic matter.

The available P content of the soils ranges from 2.7 – 3.01 mg/kg. The moderate level of phosphorus content of the soils is due to available organic matter content, parent material and degree of weathering. The availability of P might have been slightly affected by phosphate fixation under acid conditions. Liming of the soils is however not recommended because of poor buffering ability of phosphorus and micro nutrients (Havlin *et al*., 2005).

The exchangeable bases are generally moderate in all the soils of the three locations. Calcium (Ca) and magnesium (Mg) are the dominant cation in all the soils with a values ranging from 2.7 – 3.1 Cmol/kg and 2.4 – 2.9 Cmol/kg in the surface horizon respectively. Potassium (K) and sodium (Na) are low in concentration with values ranging from 0.23 – 0.30 and 0.2 – 0.31 Cmol/kg in the surface horizon respectively (Table 2). The ratio of Ca/Mg is greater than one. Therefore, potential effect of sodium is reduced. The SAR and ESP would also decrease.

The total exchangeable bases range from 5.53 – 6.61 Cmol/kg (Table 2). The generally low content of the exchangeable bases especially K and Na might be attributed to intensive cropping of the soils and crop removal without replacement resulting in chemical deterioration as also reported by Tarawali *et al.* (2001) and Odunze (2006). Fertilizers containing these elements will be required to be applied timely in adequate quantity and by burying to remedy the deficiency.

The CEC is low in all soils of the study area and ranged from 6.54 – 7.62 Cmol/kg (Table 4). The low CEC was as a result of the combined effect of the organic matter, total exchangeable bases and exchangeable acidity of the soils. The CEC of the soils were low. The CEC values are less than 12 Cmol/kg soil considered minimum values for fertile soil (kparmwang *et al.*, 2001). However, the CEC increased in the soil at the Southern part of the school was in a similar manner to those of the exchangeable bases. The low CEC of the soils implies that with continuous cultivation (rainfed and irrigated agriculture), the soils would undergo rapid degradation physically and chemically. The incorporation of organic matter and addition of bases under fertilizer programme would raise CEC of these soils.

The base saturation of the soils of the study areas is generally high and ranges from 85 to 87 %. Base saturation values greater than 50% indicate fertile soils while values less than 50% indicate low fertility (FAO – UNESCO, 1998). Based on this, the soils of three farm sites could be considered fertile.

The exchangeable sodium percentage (ESP) values ranged from 3.62 to 4.07 % in the surface horizon. The values of ESP were below the critical limit of 15% which is the acceptable limits for sodic soils. The soils were rated as no sodic. The results of the soil pH, electrical conductivities and ESP showed that the soils were non-saline and non-sodic, however, under irrigation cautions have to be taken as it often leads to salt build –up.
Electrical conductivity of the soils (ECe) of the three areas ranged from 0.72 to 0.86 ds/m. The values are generally low and show that the soils are non-saline according to the limits set by Schoeneberger *et al.* (2002). All the soils have ECe values of less than 2 ds/m. Sodium absorption ratio (SAR) of the soils ranged from 0.13 – 0.18. The study area has low SAR. The SAR of the soils falls below USDA standard value of 0 – 15.

Table 2. Chemical Properties of the Soils of the School Farms

Parameters	AOCAY West	AOCAY East	AOCAY South	USDA Soil Standard Ranges
pH (H_2O)	7.2	7.3	6.8	5.5 – 8.5
O.C (%)	0.62	0.82	1.01	1.0 - >2.0 %
O.M (%)	1.07	1.41	1.75	2.0 – 20
N (%)	0.27	0.30	0.32	0.2 - >1.0 %
P (mg/kg)	2.70	2.81	3.01	8 – 20 mg/l
K (Cmol/kg)	0.23	0.27	0.30	0.2 – 2 Cmol/kg
Na (Cmol/kg)	0.20	0.25	0.31	0.1 – 2 Cmol/kg
Mg (Cmol/kg)	2.40	2.60	2.90	0.3 – 8 Cmol/kg
Ca (Cmol/kg)	2.70	2.80	3.10	2 – 20 Cmol/kg
CEC (Cmol/kg)	6.54	6.92	7.62	6 – 40 Cmol/kg
BS (%)	84.60	85.50	86.70	20 – >80 %
ESP (%)	3.62	4.22	4.07	<15 %
EC (ds/m)	0.72	0.81	0.86	0 – 2 ds/m
SAR	0.13	0.15	0.18	0 – 15

CONCLUSION

The effect of continuous cultivation declined soil fertility as shown by changes in soil chemical properties. The chemical properties of the soils were inherently low in their natural fertility in respect to N, P and K. The low CEC implies that the soils were prone to physical and chemical deterioration. For any successful cropping, fertilizers containing basic cations (Ca, Mg, K), N and P have to be supplied and organic need to be incorporated into the soils.
The salinity and sodicity indices such as pH, CEC, and ESP showed that the soils are non-saline and non-sodic in their present status. The salinity and sodicity of the soils will need to be monitored on a regular basis to check the rate of salt build up.
Therefore, in view of the low organic matter content of the soils, incorporation of crop residue and farm yard manure is suggested. The crop residue is however currently used as feed, bedding and as roofing materials and usually little of it is returned to the soil. For any successful cropping there is need to add organic manure and fertilizers (N, P and K) in adequate quantity and preferably buried at a shallow depth adjacent to the plant root.

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