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EVALUATION OF SOME SELECTED SOIL PROPERTIES IN THE GUINEA SAVANNAH OF NIGERIA

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Abstract
Inadequate information on current soil properties is a major factor limiting agricultural production in Nigeria. The study was conducted in Kaduna state and soil was sampled from the two regions in the state; Southern Guinea Savanna and Northern Guinea Savanna. In each region, sampling was carried out from two different locations and ten soil samples were collected making a total of forty samples. The samples were subjected to standard laboratory analytical methods to determine the physical and chemical properties of the soils, and standard fertility ratings were used to interpret the results obtained. The results obtained showed that most of the soils were dominantly sandy loam, slightly acidic to strongly acidic with low exchange acidity. Cation exchange capacity was observed to range from low to moderate, high total Nitrogen, low available phosphorus and low to high exchangeable potassium.
Key Words: *particle size density, organic carbon, pH CEC soil*

Introduction

Agriculture is the predominant economic activity in Nigeria and these creates a demand in basic information necessary to create functional soil classification schemes, and assess soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa *et al.,* 2004). Savanna soils were often characterized as weak, highlyweathered and fragile with low activity clays, poor water infiltration capacity, high rate of erosion, run-off, low soil organic carbon, pH, CEC, highly dominated by Al^{3+} and Fe^{2+} (Ibrahim *et al.,* 2016; Shehu *et al.,* 2015).

The need for productive and sustainable agriculture makes soil restoration and fertility management a priority and can be partly achieved in Nigeria through bush-fallow system and use of manures(Oyinlola and Chude, 2010). 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 use of mineral fertilizer in Nigeria has been often low with an average application of nutrient estimated at 5.7 $kgha^{-1}$ compared to the world average of 133.5 $kgha^{-1}$(Tanko, 2018).

Soil characterization provides the information for basic understanding of the soil physical, chemical, mineralogical and microbiological properties and helps to identify its potentials and the constraints as it affects crop production (Ibrahim *et al.,* 2016).Thus the systematic study of the physical and chemical properties of the soils could help in understanding the basic characteristics of the soils and the constraints associated with the management of the soils of the Guinea savannah. Therefore, the research work is aimed at obtaining credible information about the characteristics of soils in guinea savanna of Nigeria and the soil management practices that could best be suited to the area for sustainable agricultural production.

Material and Methods

Study Area

The study was conducted in Kaduna state which is located within the Guinea savanna of Nigeria. The state is characterized by a uni-modal rainfall distribution with the average annual temperature and rainfall of 27.3ºC and 1051.7mm respectively.The vegetation is an open savanna wood land type comprising mainly of tall grasses, shrubs and trees. Agricultural activities are a major activity in the zone.

Soil Sampling and Preparation

Soil was sampled from two regions in the state; Northern Guinea Savanna and Southern guinea Savanna. In each region, two locations were selected for sampling. Samaru kataf and Jama'a (Southern Guinea Savanna), Dakace and soba (Northern Guinea Savanna). Soil was sampled at an interval of 1Kilometer at 0 – 20cm depth in each location. Ten samples were collected from each location making a total of 40 samples. Each sample was air dried and prepared separately for analysis.

Laboratory Methods

Particle size distribution was determined using the principles of Bouyoucous-hydrometer method following dispersion of the soil with calgon solution (Bouyoucous, 1962). Cation exchange capacity (CEC) was determined by leaching the soil with 1M ammonium acetate (NH_4OAC) buffered at pH 7 as described by (Rhodes, 1982) while exchangeable bases was determined as described by Anderson and Ingram (1993). Soil pH was measured in both water and KCl_2 at a soil: water and soil KCl_2 ratio of 1:2.5 using a glass electrode pH meter. Organic carbon (OC) content of the soil was determined by dichromate oxidation method (Nelson and Sommers 1982). Total N was determined using the micro- Kjeldahl digestion method of Bremmer, (1996) while Available P was extracted using the Bray 1 method (Bray and Kurtz 1945).

Data Analysis

Descriptive statistics was used to summarize the data for soil properties using JMP Statistical package

Results

Particle Size Analysis

The range, mean, standard deviation and coefficient of variance of sand, silt and clay fraction of soils of Soba, Dakace, Samaru Kataf and Jama'a are presented in Table 1. Soba had a mean value of 59.30%, 30.28% and 10.42% for sand silt and clay with low sand variability (CV=11.63), whereas its silt fraction was moderately variable (CV=16.83) with the highest variability observed in its clay fraction (36.46).Generally the soil could be said to be sandy loam in texture.

An average value of 56.89%, 35.26% and 7.85% was recorded for sand silt and clay respectively for the soil of Dakace and dominantly sandy loam in texture with variability observed as low for

sand (CV= 13.83), moderate for silt (18.25)and high for clay(41.87). A mean of 64.96%, 18.18% and 16.86% of sand silt and clay respectively was recorded for Samaru Kataf with sandy loam texture as its dominant texture and variability observed to be lowfor sand (CV=11.66), moderate (CV16.62) and high(CV33.08). Jama'a had mean values of sand, silt and clay content as 58.79%, 20.25% and 20.96% with sand and clay having a moderate variability of CV=24.26 and 32.54 respectively while clay fraction was highly variable (CV=55.16).
The silt: clay ranges 0.61 – 1.49 with an average of 1.00 for Samaru kataf and Jama'a has silt/clay ratio range of 0.44 – 2.73 with an average of 1.22. Soba was observed to range from 1.50 – 4.87 with a mean of 3.23 while ranges 2.54 – 9.09 was observed in Dakace. Lower variability in the Silt: clay was observed in Soba and Samaru Kataf as compared to the ratio observed in Dakace and Jama'a

Table 1: the Particle size density and Clay: Silt of Soba, Dakace, Samaru Kataf and Jama'a

Location	Sand	Clay	Silt	Clay: Silt
Soba				
Range	50.40 - 71.12	5.60 -16.32	23.28 -39.28	1.50- 4.87
Mean	59.30	10.42	30.28	3.23
Standard deviation	6.90	3.80	1.06	1.06
Coefficient of variance	11.63	36.46	16.83	32.82
Dakace				
Range	44.40 -70.40	4.32 -14.32	25.28-43.28	2.54 -9.09
Mean	56.89	7.85	35.26	5.11
Standard deviation	7.81	3.29	6.44	2.07
Coefficient of variance	13.73	41.87	18.25	40.39
Samaru Kataf				
Range	52.40 -74.40	12.32 -28.32	13.28 -21.28	0.61 -1.49
Mean	64.96	18.18	16.86	1.00
Standard deviation	7.58	6.01	2.80	0.29
Coefficient of variance	11.66	33.08	16.62	29.42
Jama'a				
Range	33.12 -79.12	5.60 -46.32	12.56 -31.28	0.44 -2.73
Mean	58.79	20.96	20.25	1.22
Standard deviation	14.27	11.56	6.59	0.72
Coefficient of variance	24.26	55.16	32.54	59.06

Chemical Properties

pH and Electrical Conductivity

The result of soil pH (H_20 and 1M KCl) presented in Table 2 showed little variability across the soil orders. The pH (H_20) of Samaru Kataf is slightly acidic to neutral in nature with a pH range of 4.86 – 6.91 in all the locations and a mean value of 5.38, Jama'a of the same zone have pH (H_20) with a range of 5.27 – 6.48 and a mean value of 5.67. Soba of Northern Guinea Savanna ranges from 5.08 – 6.05 with an average of 5.60. Dakace have a pH (H_20) ranges 4.47 – 6.62 and average of 5.73. The results of the pH in 1M KCl shows dominance of strongly acidity of the soils. Variability level was low (CV < 15) across all the locations
The electrical conductivity of all the soil orders was relatively low (0.05 dSm^{-1}) except in Jama'a where the mean was 0.006. These were all within "very low category" (<4 dSm^{-1}) across all the

location which indicate non saline condition of all the soil orders according to Esu, 1991 of fertility ratings of Nigeria.

Table 2: pH and Electrical Conductivity of Soba, Dakace, Samaru Kataf and Jama'a

Location	pH(water)	pH(KCl)	EC
Soba			
Range	5.08 -6.05	3.93 5.31	0.01 0.06
Mean	5.60	4.66	0.02
SD	0.35	0.47	0.01
CV	6.21	10.00	66.98
Dakace			
Range	4.47 -6.62	4.40 -6.30	0.01 -0.03
Mean	5.73	5.50	0.01
SD	0.69	0.64	0.01
CV	12.13	11.59	47.03
Samaru Kataf			
Range	4.86 -6.91	3.84 -4.83	0.02 -0.06
Mean	5.38	4.35	0.03
SD	0.60	0.38	0.01
CV	11.21	8.73	43.46
Jama'a			
Range	5.27 -6.48	4.70 -5.45	0.02 -0.25
Mean	5.67	5.09	0.06
SD	0.34	0.30	0.07
CV	5.93	5.85	113.12

EC= electrical conductivity

Organic Carbon and Primary Nutrients

The result of organic carbon and primary soil nutrients are as presented in Table 3. Organic carbon recorded a range value of 0.10 – 0.74% with an average of 0.40% for Soba indicating low level of organic carbon. The range and average value of organic carbon for Dakace was between 0.16 – 1.24% and 0.46% respectively. The variability of organic carbon is also low (CV < 15) in both locations. Samaru Kataf recorded between 0.28 – 1.3% with an average of 0.77% which falls within "low" category according to Esu, 1991 of fertility ratings. Jama'a shows relatively higher Organic Carbon between 0.58 – 1.64% and mean value of 0.95% indicating moderate to low class (Esu, 1991).

Soba of Northern Guinea Savanna zone had ranges of 0.11 – 0.53% of Total Nitrogen with a mean value of 0.20%, and falls within moderate to high category class according to Esu, 1991 while Dakace found to have very low to moderately low level of total Nitrogen with a range of 0.04 – .21% and a mean value of 0.12% according to Esu, 1991 of fertility ratings and fertility maps of Nigeria.

Results on Total nitrogen as presented in Table 3 shows that Samaru Kataf zone have a total N ranges from 0.07 – 0.21%and a mean value of 0.14%, rated low to moderately low in almost all the locations except in two locations that have moderately high total N as according soil fertility maps of Nigeria (2005). Jama'a ranges 0.07 – 0.49% and a mean Value of 0.15% of total N which was rated moderately low to high content according to Esu, 1991 of fertility ratings.

The results of available and total P (as shown on Table 3) of Soba range for available and total Soil P were 0.28 – 5.26mgKg^{-1} and 53.3 – 525.0mgKg^{-1} with a mean of 2.27 mgKg^{-1} and 285.83mgKg^{-1} respectively which fall between very low to low available P and moderate to high total P based on Esu 1991 fertility ratings, while Dakace had ranges of 2.08 – 27.00mgKg^{-1} and 28.33 – 570.00mgKg^{-1} and a mean value of 6.57mgKg^{-1} and 235.17mgKg^{-1} respectively for available and total P and were rated low to high based on Esu, 1991 of fertility ratings.
Samaru Kataf of the SGS was in the range of 3.25 – 5.88 mgKg^{-1} and 130.00 – 496.67 mgKg^{-1} with a mean of 4.46mgKg^{-1} and 321.00 mgKg^{-1} respectively, these values are rated "low" and "High" respectively for available and total Phosphorus based on fertility maps of Nigeria. Jama'a of the same zone had ranges of 0.14 – 11.63 mgKg^{-1} and 68.33 – 238.33 mgKg^{-1} and a mean of 4.22 mgKg^{-1} and 158.50 mgKg^{-1} respectively and was rated very low to moderate content of available and total P according to fertility maps of Nigeria and Esu, 1991 fertility rating scale.
The result on exchangeable Potassium (K) was shown in Table 3. The result reveals that Samaru kataf have Exchangeable K range from 0.14 – 0.30 Cmol(+)Kg^{-1} with an average of 0.17 Cmol(+)Kg^{-1} and was rated low to moderate class based of Esu, 1991 of fertility ratings. Jama'a of the same zone have a range of exchangeable K from 0.12 – 0.53 Cmol(+)Kg^{-1} and an average of 0.23 Cmol(+)Kg^{-1} rated low to high content of exchangeable K as according to Esu, 1991 fertility ratings of Nigeria.
Soba of NGS have Exchangeable K range of 0.12 – 0.65 Cmol(+)Kg^{-1} and a mean of 0.25 Cmol(+)Kg^{-1} and was rated low to high category as according to Esu, 1991 of fertility ratings, and Inceptisols of the same zone have exchangeable K in a range of Cmol(+)Kg^{-1} and a mean value of 0.30 Cmol(+)Kg^{-1} also fall within moderate to high exchangeable K across all the locations. But on average, all the soil orders in the Guinea Savanna are rated "medium" according to Esu, 1991 fertility ratings of savanna soils of Nigeria.

Table 3: organic carbon, total nitrogen, available P and Total P of Soba, Dakace, Samaru Kataf and Jama'a

Location	O.C	NITTROGEN	AVAILABE P	TOTAL P	K
Soba					
Range	1.01 -1.21	0.11 -0.53	0.24 -4.58	53.33 -525.00	0.12 -0.65
Mean	1.12	0.20	2.27	285.83	0.25
SD	0.07	0.12	1.30	210.18	0.17
CV	6.21	61.36	57.32	73.53	67.07
Dakace					
Range	0.89 -1.32	0.04- 0.21	1.81 -23.51	28.33 -570.00	0.14 -0.57
Mean	1.14	0.12	5.72	235.17	0.30
SD	0.14	0.06	6.44	218.38	0.14
CV	12.13	46.40	112.51	92.86	47.58
Samaru Kataf					
Range	0.97 -1.38	0.07 -0.21	2.83 -5.12	130.00 -496.67	0.14 -0.30
Mean	1.07	0.14	3.88	321.00	0.17
SD	0.12	0.05	0.74	172.89	0.05
CV	11.21	33.33	18.98	53.86	30.05
Jama'a					
Range	1.05 -1.29	0.07 -0.49	0.12 -10.13	68.33 -238.33	0.12 -0.53

Mean	1.13	0.15	3.67	158.50	0.23
SD	0.07	0.12	2.66	71.91	0.12
CV	5.93	80.60	72.38	45.37	53.72

O.C = organic carbon; P = phosphorous; K = potassium

Exchangeable Acid and Cation Exchange Capacity (ECEC)

The results on exchangeable acid (Al^{3+} + H^{+}) are as shown in Table 4. A range of 0.33 - 0.83 Cmol(+)Kg^{-1} and 0.50 – 0.83 Cmol(+)Kg^{-1} and a mean of 0.70 and 0.77Cmol(+)Kg^{-1} were observed for Soba and Samaru kataf respectively. Jama'a ranged from 0.50 – 0.83Cmol(+)Kg^{-1} with a mean of 0.63Cmol(+)Kg^{-1} and Dakace ranges from 0.33 – 0.83 Cmol(+)Kg^{-1} with a mean value of 0.67 Cmol(+)Kg^{-1}.

All the results for Exchangeable Acidity (H^{+} +Al^{3+}) across all the soil orders was less than 1 Cmol(+)Kg^{-1} and this values were rated as generally low (<1.0 Cmol(+)Kg^{-1})

Table 4: Cation exchange Capacity and Exchangeable acid of Soba, Dakace, Samaru Kataf and Jama'a

Location	CEC	EA
Soba		
Range	3.05 -7.05	0.33 - 0.83
Mean	5.11	0.70
SD	1.15	0.17
C V	22.48	24.59
Dakace		
Range	1.60 -15.63	0.33 - 0.83
Mean	5.46	0.67
SD	4.12	0.18
C V	75.48	26.35
Samaru Kataf		
Range	2.01 -7.44	0.50- 0.83
Mean	4.17	0.77
SD	1.75	0.12
C V	41.84	15.20
Jama'a		
Range	2.72 -8.62	0.50 -0.83
Mean	5.96	0.63
SD	2.08	0.13
C V	34.86	20.76

CEC= Cation exchange Capacity; EA = Exchangeable acid

Discussion

Particle Size Analysis

Generally all the soil were identified as been dominantly sandy loam with observed Variations in the content of silt and clay. However, soils Samaru kataf were observed to be lower silt than the clay content, when compared to the Alfisols of Northern Guinea Savanna. Akpa et al. (2014) explained the influence of Harmattan dust as a contributor of silt in surface soils. The results obtained is similar with the findings of (Ibrahim *et al.,* 2016; Sharu *et al.,* 2013).

High sand content as been reported by Wilson. (2010) and Akpa et al. (2014)to be a common phenomenon for Savanna soils has it reflects the granitic origin of the parent materials of the soils and may be attributed to the removal of the fraction by surface run-off as well as by alluviation. Odunze (2003) opined that the soils in the Northern Guinea Savanna have dominantly Kaolinite clays and are sandy to sandy-loam in texture. They have low available soil moisture retention capacity and encourage nutrient loss away from the rooting depth, this may be due to high rate of mineralization due high temperature and low rainfall of the area and also due to crop removal.

It has been reported that "old" parent materials usually have a silt: clay ratio below 0.15 while silt : clay above 0.15 are indicative of "young" parent materials or that silt : clay of < 1.00 could mean that these soils had undergone ferralitic pedogenesis, or the low silt/clay probably implied that these soils still have weatherable minerals in them (Ibrahim *et al.,* 2016; Lawal, 2013). Similar results was reported by Ibrahim *et al.*(2016) and Sharu *et al.*(2013).

pH and Electrical conductivity

The low pH across the locations from each soil order may be attributed to the use of chemical fertilizer and other amendments (most especially of Ammonium Nitrate origin) by most of the farmers across the region to supply nutrients for field crops(Tanko, 2018). Similarly, Mustapha*et al.*(2017) and Tanko (2018) obtained similar results on their work on the soils of Savanna soils, thus, implying salinization is not a significant pedogenic process in the soils this region and the soils does not contain a concentration of soluble salt that may hamper the growth of plant.

Organic Carbon and Primary Nutrients

Low organic matter content of the region has been attributed to factors such as continuous cultivation, frequent burning of farm residues commonly carried out by farmers which tends to destroy much of the organic materials that could have been added to the soil(Sharu *et al.,* 2013).Lawal (2013) pointed out that low organic carbon content of the soils is characteristics of the savanna due to partly to rapid decomposition and mineralization of organic matter and to poor management sometimes by burning of crop residues by farmers.Moderate levels of organic carbon are usually expected at the top layers as explained by Fagwalawa *et al.* (2014) due to accumulation and decomposition of organic debris accumulates at the top of the soil.

There is variation in the level of total Nitrogen within all the soil in the Guinea Savanna. These variations in the content of total soil N in the Guinea Savanna region may be due to inconsistency from the use of Nitrogenous fertilizer by most of the farmers of the area.Noma et al (2011) suggested that the irregularly variations in the total Nitrogen in the Guinea Savanna zone could be attributed to the influence of continuous cultivation, crop residue removal as well as different level of fertilizer use among the farmers.Differentcropping system and management practices may also influence mineralization rate in addition to nutrient mining.This is in line with the findings of(Ibrahim *et al.,* 2016; Sharu *et al.,* 2013 and Shehu*et al.,*2015).

The low contents of available P obtained on average across most of thelocations might be related to parent materials made up of low weatherable mineral reserve necessary for nutrient recharge and partly to the complete crop residue removal by the farmers in the Guinea Savanna region.(Ibrahim *et al.,* 2016; Tanko, 2018). Voncir *et al*. (2006) further proposed that the reason for the observed low phosphorus in the Savanna region could be due to the prevalent soil management practices which encourage the export of nutrients in harvested crops without adequate replacement.The high content of total P observed may be due to P fixation.

Dakace have higher content of exchangeable K when compared with Ultisols and Alfisols of SGS and NGS zone, this is due to its appreciable low clay content over other soil orders as a clay particle is a strong magnet in comparison to sand, silt and humus. Clay soils hold potassium very tightly and resist leaching. This characteristic makes it more difficult to recover potassium from clay soils(Nnaemeka, 2013).The results obtained is similar to the findings of Ibrahim *et al*.(2016) Sharu *et al*. (2013) Shehu *et al.* (2015) and Tanko (2018).

Exchangeable Acid and Cation Exchange Capacity

Low exchange acidity is an indication of little or no acidity problems and therefore Al^{3+} is not part of the dominance cation in the soil of this region(Ibrahim et al., 2016) with similar results obtained by Raji and Mohammed (2000). It was proposed that the contribution of exchange acidity to potential acidity is very low in soils of Nigerian savannas.

Variation in the Cation Exchange Capacity across all the soil orders of the Guinea Savanna region were observed ranging from very low to very high and Jimoh *et al.* (2016) proposed that high value

of CEC indicates good nutrient retention, release and buffering capacity of the soil.The low CEC recorded on some of the soil was expected since the percentage organic matter is generally below the critical value and CEC has direct relationship with SOM.
The CEC results obtained is in line with the findings of Ibrahim et al. (2016) and Oyinlola and Chude (2010)in Northern Nigeria Savanna.Lawal (2013) also reported high level of CEC in the surface soils of Southern Guinea Savanna zone of Nigeria, whichcould be attributed to the nature of clay minerals (kaolinite) dominant in the savanna zone of Nigeria. It may also be a reflection of the intensity of weathering that produced the soils or as a result of continuous mining through cultivation(Odunze, 2003; Shehu *et al*., 2015).

Conclusion

The evaluation of the properties of the soils of the Guinea savanna revealed that the soils were majorly sandy loam, acidicand low organic carbon content. Total nitrogen was rated moderate to low while cation exchange capacity was rated from very low to high. Availablephosphorus was rated low with exchange potassium rated high. To enhance and maintain soil productivity; guided fertilizer/inorganic use and management practices is a must for sustainable continuous cropping. Relevant information that can affect decisions on use and management of these soils has been highlighted by this study.

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