



International Journal of **Soil Science**

ISSN 1816-4978



Academic
Journals Inc.

www.academicjournals.com

Fertility Status of Selected Soils in the Sudan Savanna Biome of Northern Nigeria

B.M. Shehu, J.M. Jibrin and A.M. Samndi

Department of Soil Science, Faculty of Agriculture, Bayero University, Kano, Nigeria

Corresponding Author: B.M. Shehu, Department of Soil Science, Faculty of Agriculture, Bayero University, Kano, 700001, Nigeria Tel: +2348032165559

ABSTRACT

Sustainable crop production in the Nigerian Sudan Savanna biome requires a good understanding of the fertility status of the soil in order to impose appropriate nutrient management strategies. Field surveys were conducted to assess the fertility status of selected soils from Shanono and Bunkure Local Government Areas (LGAs) of Kano State in the Northern Nigerian Sudan Savanna. All the surveyed fields had soil organic C, total N and ECEC within very low and low fertility classes. Very low and low available P was also found in the majority of fields with only 25.0 and 8.7% of the fields falling in the moderate P fertility range in Shanono and Bunkure LGA respectively. About 75.0% of fields in Shanono LGA and 39.1% in Bunkure LGA fell within the low exchangeable K class, with the rest of the fields having moderate level. Despite moderate to high content of exchangeable Ca and Mg in most of the fields, 4.3-8.7% of the fields had depleted status of the two basic cations. Micronutrients (Zn, Cu, Mn and Fe) levels in all the fields were in the moderate and high classes, except the subsurface soil of Shanono LGA where 4.2% of the fields had low Cu contents. Correlation analysis between northerly latitude and soil properties showed a northward increase in sand, pH and Zn levels and a decrease in silt and available Fe levels. The low status of Ca, Mg and Cu in some of the fields indicates the insufficiency of the current fertilizer recommendations which focus mainly on primary macronutrients (N, P and K). Therefore, apart from recommending all strategies that will enhance and stabilize organic matter, current fertilizer recommendations need to be reviewed and should contain other nutrients in addition to primary macronutrients.

Key words: Soil fertility status, sudan savanna, Nigeria

INTRODUCTION

Nigerian Sudan Savanna Zone is situated between latitudes 9°3' and 12°31' N and longitudes 4° and 14°3' E which covers about 22.8 million hectares representing about one quarter of Nigeria's geographical area (Manyong *et al.*, 1995). The region is characterized by high annual average temperature (28-32°C), short wet season and long dry season (6-9 months), abundant short grasses (<2 m) and a few scattered trees (Sowunmi and Akintola, 2010). Large expanse of arable land exists in the Sudan Savanna Zone of Nigeria with potential for the production of largely grain crops like maize, sorghum, millet, rice and wheat (FFD., 2012). However, the average yield of grain crops in the zone stood at 1.7 t ha⁻¹ compared to the world average of 4.0 t ha⁻¹ (FAOSTAT., 2012). This represents only 42.5% of the world attainable average yield which might be attributed to small holdings farmed by aging and resource poor farmers, whose yields are determined by the limiting

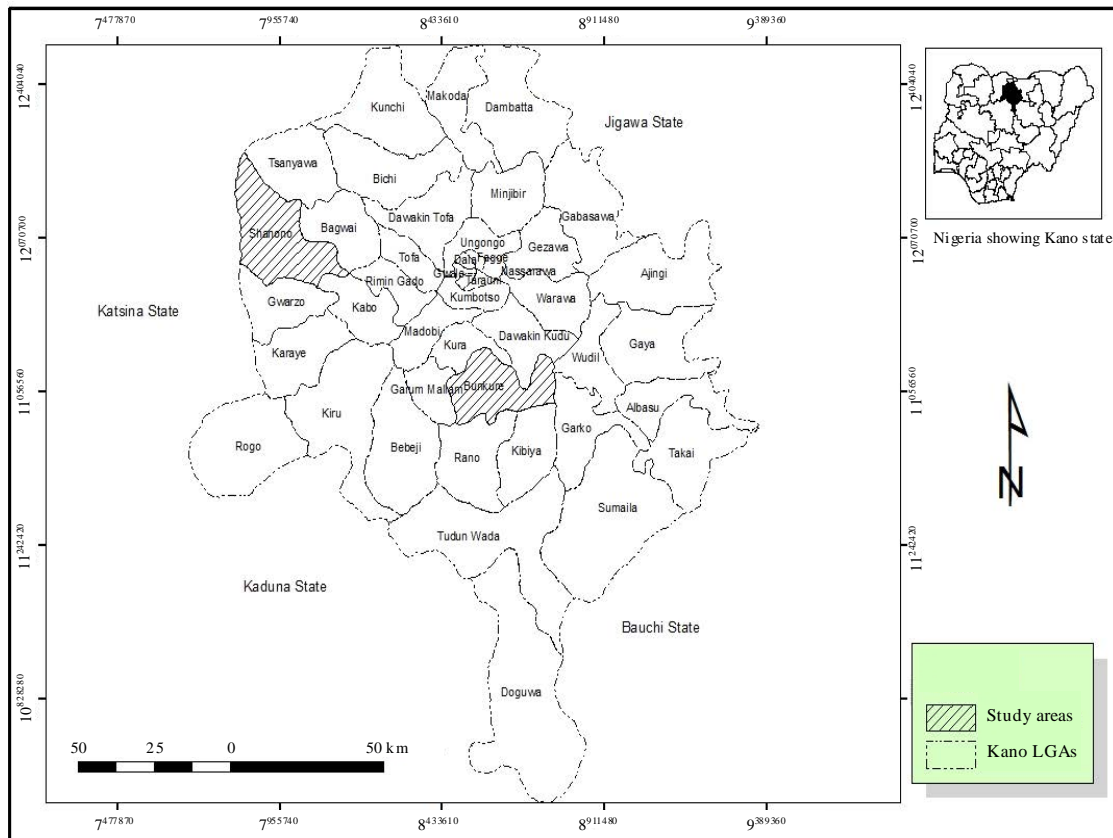
factors of bio-geophysical environment. Soil nutrient depletion and degradation have been reported to be one of the most bio-geophysical constraints to agricultural productivity in Sub-Saharan Africa (SSA) including Nigeria's Savanna Zone (Henao and Baanante, 2006).

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 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). Additionally, among the problems associated with poor mineral fertilizer use in Nigeria, is that of recommendations which are considered to be semi-site specific with mainly three essential macronutrients (N, P and K). This implies recommendations are based on the soil characteristics and properties of some fractions of larger areas. This type of recommendations leads to inappropriate fertilizer use, thus resulting in nutrient imbalance which affects the overall fertility and productivity of soils. To adapt better fertility management practices for increased and sustained productivity, periodic and site specific evaluation of soil fertility status is critical. Thus the need for site-specific soil fertility evaluation in the Northern Nigerian Sudan Savanna biome in order to recommend practices that will improve fertilizer use efficiency prompted this study.

MATERIALS AND METHODS

Study area: A survey to evaluate the fertility status of crop fields was conducted in Shanono and Bunkure LGAs of Kano State (Fig. 1). Kano State is located at latitude 11°30' N and longitude 8°30' E with land area of 20,760 km² (Adamu and Basse, 2010). Its vegetation falls mostly within the Sudan Savanna Zone (Shanono and Bunkure LGAs inclusive). The climate of Kano State is the tropical wet and dry type symbolized as AW by Koppen (Adamu and Aliyu, 2012). Annual average rainfall in the area range from 884-1200 mm (from north to south of the state) which is characterized by one peak period (mono-modal), usually attained in August (Buba, 2009; Tanko and Momale, 2013). The temperature is averagely warm to hot throughout the year at about 25±7°C (Olofin and Tanko, 2002). FAO/UNESCO genetic classification classified the soil of the extreme part of Northern Nigeria (Kano state inclusive) as leached tropical ferruginous soil developed on deeply weathered pre-Cambrian Basement Complex rock overlain by Aeolian drift of varying thickness (Adamu and Aliyu, 2012).

Field selection and soil sampling: A stratified random sampling was adopted where communities in each Local Government Area (LGA) were taken as strata and in each community (stratum), five farmers' fields were randomly selected. In Shanono LGA, the communities selected were Alajawa, Fariruwa, G-Dutse, Kundila and Kuraku, while in Bunkure LGA, communities



Source: Department of geography BUK (2013)

Fig. 1: Map of Nigeria and kano state showing the survey areas

selected includes Kulluwa, Kumurya, Satigal and Zanya. In each farmers' field, soil samples were taken at depths of 0-20 cm (surface) and 20-40 cm (subsurface), the coordinates of each sampling point were recorded in decimal degrees with a hand held Global Positioning System (GPS). A total of ninety soil samples were collected.

Soil analysis: Soils were air dried and passed through a 2 mm sieve before the analysis. Soil pH was evaluated with a glass electrode pH meter at 1:1 soil to water ratio. Organic carbon was determined by acid dichromate wet oxidation procedure as presented by Nelson and Sommers (1996). Total nitrogen contents of the soil were analyzed by micro-Kjedahl method (Bremner, 1996). Available phosphorus was determined in accordance with Mehlich-3 test developed by Mehlich (1984). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1 M NH₄OAC solution buffered at pH 7.0 as described by Anderson and Ingram (1998). Calcium and magnesium in the leachate were determined with an atomic absorption spectrophotometer, while K and Na were determined with flame photometer. Exchangeable acidity was analyzed by shaking the soil with 1 M KCl and titrated with 0.5 M NaOH (Juo, 1979). Effective Cation Exchange Capacity (ECEC) was obtained by the summation of exchangeable bases and exchangeable acidity. Micronutrients (Cu, Mn, Zn and Fe) were extracted in 0.1 M HCl and determined by atomic absorption spectrophotometry.

Statistical analysis: The data were subjected to descriptive statistics using crosstabs analysis; Pearson correlation analysis was used to determine the relationship between the studied soil fertility parameters and northerly latitude with the aid of IBM SPSS statistical software version 20.

RESULTS AND DISCUSSION

Soil fertility ratings of Esu (1991), Landon (1991) and NSPFS (2005) were used in interpreting the results obtained in this study.

Soil texture and organic carbon: The soils of the study sites varied from sandy loam to sandy clay loam (Table 1). Field survey of the farms in Shanono, showed that 95.8% of the fields had sandy loam surface soils, while in Bunkure LGA, 87% of the farms had sandy loam surface soils (Table 1). Similar trend was also found in the subsurface soils, even though with slightly higher clay contents. The sandy nature of the soils might be attributed to the parent material as the soils were developed predominantly on deeply pre-cambrian basement complex rocks such as granitic sandstone. Malgwi *et al.* (2000) and Voncir *et 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

Table 1: Percentage (%) distribution of soil texture, organic C, total N and available P in Shanono and Bunkure Local Government Areas (LGAs) of Kano State, Nigeria

Fertility indicators	Surface (0-20 cm)		Subsurface (20-40 cm)	
	Shanono	Bunkure	Shanono	Bunkure
Soil texture				
Sandy loam	95.8	87.0	91.7	73.9
Sandy clay loam	4.2	13.0	8.3	26.1
Organic C (%)				
Very low (<0.4)	91.7	73.9	95.8	100.0
Low (0.4-1.0)	8.3	26.1	4.2	0.0
Moderate (1.0-1.4)	0.0	0.0	0.0	0.0
High (1.4-2.0)	0.0	0.0	0.0	0.0
Very high (>2.0)	0.0	0.0	0.0	0.0
Total N (%)				
Very low (<0.05)	100.0	100.0	100.0	100.0
Low (0.06-0.1)	0.0	0.0	0.0	0.0
Moderate (0.11-0.15)	0.0	0.0	0.0	0.0
High (0.16-0.20)	0.0	0.0	0.0	0.0
Very high (>0.2)	0.0	0.0	0.0	0.0
Available P (mg kg⁻¹)				
Very low (<3.0)	58.3	60.9	95.8	100.0
Low (3.0-7.0)	16.7	30.4	4.2	0.0
Moderate (7.0-20.0)	25.0	8.7	0.0	0.0
High (>20.0)	0.0	0.0	0.0	0.0
ECEC (cmol (+) kg⁻¹)				
Low (<6.0)	100.0	100.0	100.0	100.0
Moderate (6.0-12.0)	0.0	0.0	0.0	0.0
High (>12.0)	0.0	0.0	0.0	0.0
pH (water)				
Strongly acid (5.0-5.5)	0.0	21.7	0.0	47.8
Moderately acid (5.6-6.0)	29.2	30.4	33.3	13.0
Slightly acid (6.1-6.5)	41.7	43.6	50.0	17.4
Neutral (6.6-7.2)	29.1	4.3	12.5	8.8
Slightly alkaline (7.3-7.8)	0.0	0.0	4.2	13.0

surface wind erosion. All the surveyed fields in the two LGAs had soil organic C level (Table 1) in the very low (<0.4%) and low (0.4-1.0%) fertility classes, with more than 73.0% falling into the very low class. The low level of organic C with a high proportion of sand particle will normally result in low aggregation, low water retention and poor physical stability of the soil (Salako, 2003) and therefore, low productivity of crops.

Total nitrogen, ECEC and available phosphorus: Very low total N (<0.06%) and low ECEC (<6.0 cmol (+) kg⁻¹) fertility levels were observed in all the surveyed fields across the two LGAs (Table 1). The low ECEC level implies that the soils were dominated by low activity clays and sesquioxides (Tan, 2000) and low organic colloidal fractions suggesting the soils would be susceptible to leaching. The contents of available P in the surface soils of Shanono LGA were 58.3, 16.7% and 25.0% very low (<3.0 mg kg⁻¹), low (3.0-7.0 mg kg⁻¹) and moderate (7.0-20.0 mg kg⁻¹), respectively. In Bunkure site, 60.9, 30.4 and 8.7% of the surveyed fields had very low (<3.0 mg kg⁻¹), low (3.0-7.0 mg kg⁻¹) and moderate (7.0-20.0 mg kg⁻¹) available P status in the surface soil, respectively. There was a major decrease in available phosphorus contents in the subsurface soils, where most of the surveyed fields indicated very low status compared to the values obtained in the surface soils. The low contents of organic C, total N, ECEC and available P obtained in the survey sites might be partly related to their inherent low status, such as the parent materials which are mainly of Aeolian origin, with low weatherable mineral reserve necessary for nutrient recharge (Manu *et al.*, 1991) and partly to the complete crop residue removal by the farmers in the survey area.

Soil reaction (pH): Percentage distribution of pH classes in the surface soils of Shanono LGA (Table 1) was in the following order: 29.2% moderately acid, 41.7% slightly acid and 29.1% neutral. While, subsurface soils pH distribution was in the order: 33.3% moderately acid, 50.0% slightly acid, 12.5% neutral and 4.2% slightly alkaline. Soil pH distribution in Bunkure study site were in the order: 21.7% strongly acid, 30.4% moderately acid, 43.6% slightly acid and 4.3% neutral for surface soils, while for the underlying subsurface soils pH distribution were in the order: 47.8% strongly acid, 13.0% moderately acid, 17.4% slightly acid, 8.8% neutral and 13.0% slightly alkaline. Therefore, apart from Bunkure LGA where 21.7% of the surface soils and 47.8% of the subsurface soils had strongly acid conditions (pH 5.0-5.5), the majority of the surveyed fields had pH values within the range of 5.5-7.0 considered ideal for most cultivated crops reported by Brady and Weil (2002). Additionally, exchange acidity (H⁺+Al³⁺) values were very low (<1.0 cmol (+) kg⁻¹) in most of the fields, suggesting that most of the soils have no potential acidity problems (data not shown).

Exchangeable cations: Results for exchangeable cations (Ca, Mg, Na and K) are shown in Table 2. Calcium contents in all the surveyed fields in both surface and subsurface soils were in moderate (2.0-5.0 cmol (+) kg⁻¹) fertility status, except only 8.7% of the subsurface soils of Bunkure LGA that were in low (<2.0 cmol (+) kg⁻¹) condition. The Mg values across the two LGAs fell within moderate (0.3-1.0 cmol (+) kg⁻¹) to high condition (>1.0 cmol (+) kg⁻¹) except low status in 4.3% of the fields being observed in the subsurface soils of Bunkure LGA. Most of the fields had moderate Na contents (0.1-0.3 cmol (+) kg⁻¹), with less than 5.0% of the fields had values considered as being low (<0.1 cmol (+) kg⁻¹). In Shanono and Bunkure LGAs 75.0 and 39.1% of the fields at the surface had a low K status (<0.15 cmol (+) kg⁻¹), with 25.0 and 60.9% of the fields having moderate contents (0.15-0.30 cmol (+) kg⁻¹). Similar patterns of K distribution in the subsurface soils were noticed but with a relative decrease from moderate to low status compared to the surface soils. The moderate

Table 2: Percentage (%) distribution of exchangeable cations (Ca, Mg, K and Na), Ca: Mg ratio and available micronutrients (Zn, Cu, Mn and Fe) in Shanono and Bunkure Local Government Areas (LGAs) of Kano State Nigeria

Soil properties	Surface (0-20 cm)		Subsurface (20-40 cm)	
	Shanono	Bunkure	Shanono	Bunkure
Exchangeable Ca (cmol (+) kg⁻¹)				
Low (<2.0)	0.0	0.0	0.0	8.7
Moderate (2.0-5.0)	100.0	100.0	100.0	91.3
High (>5.0)	0.0	0.0	0.0	0.0
Exchangeable Mg (cmol (+) kg⁻¹)				
Low (<0.3)	0.0	0.0	0.0	4.3
Moderate (0.3-1.0)	83.3	87.0	70.8	91.3
High (>1.0)	16.7	13.0	29.2	4.4
Exchangeable K (cmol (+) kg⁻¹)				
Low (<0.15)	75.0	39.1	79.2	60.9
Moderate (0.15-0.30)	25.0	60.9	20.8	39.1
High (>0.3)	0.0	0.0	0.0	0.0
Exchangeable Na (cmol (+) kg⁻¹)				
Low (<0.1)	4.2	4.3	0.0	4.3
Moderate (0.1-0.3)	95.8	95.7	100.0	95.7
High (>0.3)	0.0			
Ca:Mg Ratio				
Low (<3:1)	41.7	52.2	50.0	39.1
Normal (3:1-5:1)	58.3	43.5	45.8	47.8
High (>5:1)	0.0	4.3	4.2	13.0
Available Zn (mg kg⁻¹)				
Low (<0.8)	0.0	0.0	0.0	0.0
Moderate (0.81-2.0)	8.3	69.6	16.7	69.6
High (>2.0)	91.7	30.4	83.3	30.4
Available Cu (mg kg⁻¹)				
Low (<0.2)	0.0	0.0	4.2	0.0
Moderate (0.21-2.0)	100.0	100.0	95.8	100.0
High (>2.0)	0.0	0.0	0.0	0.0
Available Mn (mg kg⁻¹)				
Low (<1.0)	0.0	0.0	0.0	0.0
Moderate (1.1-5.0)	0.0	0.0	0.0	0.0
High (>5.0)	100.0	100.0	100.0	100.0
Available Fe (mg kg⁻¹)				
Low (<2.5)	0.0	0.0	0.0	0.0
Moderate (2.51-5.0)	0.0	0.0	0.0	0.0
High (>5.0)	100.0	100.0	100.0	100.0

to high content in exchangeable Ca, Mg and Na in the fields could be the consequence of their inherent rich contents and the soils have not significantly lost these cations through leaching and other weathering processes. Across the two LGAs and soil depths, between 39.1 and 52.2% of the surveyed fields had low Ca: Mg ratio (<3:1), meaning that uptake of P in those fields may be inhibited (Landon, 1991). In addition, low Ca: Mg ratio showed the possibility of deterioration of the structural stability with consequent surface sealing, decreased infiltration, increased runoff and erosion during rainfall events (Dontsova and Norton, 2001). This is because hydration energy and radius of Mg are greater than Ca (Bohn *et al.*, 1985). This causes a large separation distance between clay layers and less attraction between them which then causes flocculation and low structural stability of the soil. However, about 43.5 and 58.3% of all the fields across the two studied soil depths had normal Ca: Mg ratio (3:1-5:1), this considered an optimum range for the availability of most nutrients. Between 4.2 and 13.0% subsurface soils of all the surveyed fields and about 4.3% surface soils of the studied fields in Bunkure LGA had high Ca: Mg ratio (>5:1), this implies Mg increasingly become unavailable with increasing Ca contents and P availability may be also reduced.

Table 3: Pearson correlation (r) between soil fertility parameters and northerly latitude

	Northerly latitude	
	0-20 (cm)	20-40 (cm)
Clay	-0.20	-0.10
Silt	-0.40**	-0.47**
Sand	0.33*	0.34*
OC	-0.01	0.36*
N	-0.05	0.26
P	0.15	0.17
ECEC	-0.14	0.09
pH	0.51**	0.30*
Ca	0.04	0.06
Mg	-0.17	0.20
K	0.22	-0.29
Na	-0.08	0.26
Ca:Mg	0.16	-0.19
Zn	0.63**	0.46**
Cu	0.25	0.13
Mn	0.14	-0.11
Fe	-0.75**	-0.81

***Significance at 5% level of probability, **Significance at 1% level of probability

Available micronutrients: Zinc levels in the two LGAs fell within moderate (0.81-2.0 mg kg⁻¹) to high (>2.0 mg kg⁻¹) status (Table 2). The Zn levels were similar to the levels obtained by Kparmwang and Malgwi (1997) for the soils in the Northern Guinea Savanna of Nigeria; but contrary with the thematic maps produced by NSPFS (2005) where the whole of Kano State fell within a low Zn fertility class. Moderate Cu content (0.21-2.0 mg kg⁻¹) was observed in all the soil layers of the surveyed fields, except in Bunkure LGA fields, where 4.2% of the subsurface soils had low Cu contents (<0.2 mg kg⁻¹) as showed in Table 2. High Mn (>5.0 mg kg⁻¹) and Fe (>5.0 mg kg⁻¹) contents were found in all the surveyed fields (Table 2). The high levels of Mn and Fe are not amazing due to slightly acidic to neutral pH reactions of the soils. Manganese and Fe deficiencies are unlikely to occur in acid soils. At only pH above 7.5 (alkaline) as reported by Sillanpaa (1982) Mn availability will become very low owing to the formation of hydroxides and carbonates. Furthermore, Fe knew to be soluble under relatively acid and reducing condition (Chesworth, 1991). The low level of Cu observed in some fields in Bunkure LGA indicates that the current fertilizer recommendations which focused only on N, P and K might be insufficient; other nutrients apart from N, P and K may also determine the yield. Nziguheba *et al.* (2009) stated that application of only NPK fertilizers, especially in cereals, increases yields but also accelerates the depletion of other nutrients not supplied and thus lead to nutrient deficiencies or imbalances.

Correlation between soil fertility parameters and northerly latitude: The result of correlation analysis in the study indicated that Sand, pH and Zn positively correlated with northerly latitude as opposed to silt and Fe (Table 3). This implies that a decrease in pH, resulted in an increase in Fe contents in the more northerly latitudes. This could be attributed to the rainfall pattern of the study sites, as it decreases from south to north. High rainfall cause leaching of basic cations and poor soil aeration, that results in decrease soil pH and reduce Fe³⁺ (ferric) to Fe²⁺ (ferrous). A ferrous form of iron (Fe²⁺) is very soluble and where it is the predominant increases iron availability in soil (Chesworth, 1991). Positive correlation of sand and a negative correlation of silt with northerly latitude imply aggradation of sand particles with proportionate removal of silt particles toward a northward direction, this might be ascribed to the dominance of northeast trade wind that contributed to surface erosion and sorting of soil materials in the survey sites.

CONCLUSION

The study disclosed that most of the surveyed farmers' fields were sandy loam, with low organic C, total N, available P and ECEC. The pH values were within the optimal ranges required for crop production, except in Bunkure LGA where 21.7% of the fields were strongly acidic. Despite that, most of the fields had moderate to high base contents, 4.3-8.7% of the fields had depleted Ca and Mg. The status of the micronutrients in the surface layer of the fields were above the critical levels with no potential deficiency indication.

To improve and sustain the fertility status of these soils, current fertilizer recommendations need to be reviewed and improved to include other nutrients in addition to the primary macronutrients (N, P and K). Manure and crop residue incorporation will enhance organic matter and ECEC thereby improving soil condition and retention/release of nutrients and water. Liming and any management practice to improve the pH condition is required specifically to the fields with strongly acidic reactions.

REFERENCES

- Adamu, A.U. and S.E. Bassey, 2010. Incidence of *Strongyloides stercoralis* infection in Ungogo, Nassarwa, dala and fagge local government areas of Kano State, Nigeria. *Bayero J. Pure Applied Sci.*, 3: 76-80.
- Adamu, G.K. and A.K. Aliyu, 2012. Determination of the influence of texture and organic matter on soil water holding capacity in and around Tomas irrigation scheme, dambatta local government Kano State. *Res. J. Environ. Earth Sci.*, 4: 1038-1044.
- Anderson, J.M. and J.S.I. Ingram, 1998. *Tropical Soil Biology and Fertility: A Handbook of Methods*. 2nd Edn., CAB International, Wallingford, UK., Pages: 221.
- Bohn, B.L., B.L. McNeal and A.G. O'Connor, 1985. *Soil Chemistry*. 2nd Edn., Wiley-Inter Science Publications, New York, USA.
- Brady, N.C. and R.R. Weil, 2002. *The Nature and Properties of Soils*. 13th Edn., Pearson Education, Singapore, ISBN-13: 9780130167637, Pages: 960.
- Bremner, J.M., 1996. Nitrogen-Total. In: *Methods of Soils Analysis: Chemical Methods*, Sparks, D.L. (Ed.). American Society of Agronomy (ASA) and Soil Science Society of America (SSSA), Madison, WI., USA., pp: 1085-1121.
- Buba, L.F., 2009. Temperature variation as indicator of global warming over northern Nigeria. *Proceedings of the Annual Conference of Nigeria Environmental Society, (ACNES'09), Abuja*.
- Chesworth, W., 1991. Geochemistry of Nutrients. In: *Micronutrients in Agriculture*, 2nd Edn., Mortredt, J.J., L.M. Shuman and R.M. Welch (Eds.). Soil Science Society of America Inc., Madison, Wisconsin, USA., pp: 427-476.
- Dontsova, K. and L.D. Norton, 2001. Effects of Exchangeable Ca: Mg Ratio on Soil Clay Flocculation, Infiltration and Erosion. In: *Sustaining the Global Farm*, Scott, D.E., R.H. Mohtar and G.C. Steinhardt (Eds.). National Soil Erosion Research Laboratory, USDA-ARS, West Lafayette, Indiana, pp: 580-585.
- Esu, I.E., 1991. Detailed soil survey of NIHORT farm at Bunkure Kano state, Nigeria. Institute for Agricultural Research Samaru, Zaria, Nigeria.
- FAOSTAT., 2012. Crop production data archives. <http://faostat.fao.org/site/339/default.aspx>.
- FDALR., 1999. Assessment of soil degradation in Nigeria. Project Report, Federal Department of Agricultural Land Resources, Abuja, pp: 259.
- FFD., 2012. Fertilizer use and management practices for Nigeria. Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria, pp: 1-215.

- Henao, J. and C. Baanante, 2006. Agricultural production and soil nutrient mining in Africa: Implication for resource conservation and policy development. Technical Bulletin No. IFDC T-72, International Fertilizer Development Center, Muscle Shoals, USA.
- Jones, M.I. and A. Wild, 1975. Soils of West African savanna. The maintenance and improvement of their fertility. Technical Communication No 55 of the Commonwealth Bureau of Soils, Harpenden, UK. Commonwealth Agricultural Bureau (CAB), Farnham Royal, UK., pp: 246.
- Juo, A.S.R., 1979. Selected methods for soil and plant analysis. Manual Series No 1, International Institute of Tropical Agriculture, Ibadan, pp: 70.
- Kparmwang, T. and W.B. Malgwi, 1997. Some available micronutrients in profiles of ultisols and entisols developed from sandstone in North-Western Nigeria. Proceedings of the 23rd Annual Conference on Soil Science Society of Nigeria, March 2-5, 1997, Sokoto, Nigeria, pp: 43-50.
- Lal, R., 1997. Deforestation, tillage and cropping systems effects on seepage and runoff water quality from a Nigerian Alfisol. *Soil Tillage Res.*, 41: 261-284.
- Landon, J.R., 1991. Booker Tropical Soil Manual. Longman Publishers, Harlow, UK., Pages: 134.
- Lombin, G., 1987. Soil and climate constraints to crop production in the Nigerian savanna region. Proceedings of the 15th Annual Conference of Soil Science Society of Nigeria, September 20-24, 1987, Kaduna.
- Malgwi, W.B., A.G. Ojanuga, V.O. Chude, T. Kparmwang and B.A. Raji, 2000. Morphological and physical properties of some soils at Samaru, Zaria, Nigeria. *Niger. J. Soil Res.*, 1: 58-64.
- Manu, A., A. Bationo and S.C. Geiger, 1991. Fertility status of selected millet producing soils of West Africa with emphasis on phosphorus. *Soil Sci.*, 152: 315-320.
- Manyong, V.M., G.K. Smith, S.S. Weber, S.S. Jagtab and B. Oyewole, 1995. Macro characterization of agricultural system in West Africa: An overview. Resource and Crop Management Research Monograph No. 21, International Institute of Tropical Agriculture (IITA), Ibadan, pp: 66.
- Mehlich, A., 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Commun. Soil Sci. Plant Anal.*, 15: 1409-1416.
- NSPFS., 2005. Nigerian soil fertility rating and thematic fertility maps. National Special Programme for Food Security (NSPFS), Abuja, Nigeria.
- Nelson, D.W. and L.E. Sommers, 1996. Total Carbon, Organic Carbon and Organic Matter. In: *Methods of Soil Analysis: Part 3 Chemical and Microbiological Properties*, Bigham, J.M. (Ed.). ASA, CSSA, SAAJ, Madison, WI., pp: 961-1010.
- Nziguheba, G., B.K. Tossah, J. Diels, A.C. Franke and K. Aihou *et al.*, 2009. Assessment of nutrient deficiencies in maize in nutrient omission trials and long-term field experiments in the West African Savanna. *Plant Soil*, 314: 143-157.
- Odunze, A.E., 2006. Soil properties and management strategies for some sub-humid of savanna zone Alfisols in Kaduna State, Nigeria. *Samaru J. Agric. Res.*, 22: 3-14.
- Olofin, E.A. and A.I. Tanko, 2002. Laboratory of areal differentiation: Metropolitan Kano geographical perspective. Department of Geography, Bayero University, Kano.
- Oyinlola, E.Y. and V.O. Chude, 2010. Status of available micronutrients of the basement complex rock-derived alfisols in Northern Nigeria savanna. *Trop. Subtrop. Agroecosyst.*, 12: 229-237.
- Salako, F.K., 2003. Soil physical conditions in Nigerian savannas and biomass production. Lecture Given at College on Soil Physics Trieste, March 2003, Abeokuta, Nigeria, pp: 364-377.
- Sillanpaa, M., 1982. Micronutrients and the nutrient status of soils. Bulletin, No. 48, A Global Study FAO Soils, FAO, Rome, Italy.

- Sowunmi, F.A. and J.O. Akintola, 2010. Effect of climatic variability on maize production in Nigeria. *Res. J. Environ. Earth Sci.*, 2: 19-30.
- Tan, K.H., 2000. *Environmental Soil Science*. 2nd Edn., CRC Press, Boca Raton, FL., Pages: 452.
- Tanko, A.I. and S.B. Momale, 2013. *Geography of Kano Region*. Adonis and Abbey Publishers Ltd., New York, USA., Pages: 33.
- Voncir, N., S. Mustapha, V.A. Tenebe, A.L. Kumo and S. Kushwaha, 2008. Content and profile distribution of extractable zinc (Zn) and some physicochemical properties of soil along a toposequence at Bauchi, Northern Guinea Savanna of Nigeria. *Int. J. Soil Sci.*, 3: 62-68.
- World Bank, 2010. Fertilizer consumption (kilograms per hectare of arable land). <http://data.worldbank.org/indicator/AG.CON.FERT.ZS>.