© MAR 2022 | IRE Journals | Volume 5 Issue 9 | ISSN: 2456-8880

Evaluation of Physical and Chemical Properties of Soils at Bichi Local Government Area, Kano State, Nigeria

A. ABDULKADIR[1], Y. HALILU[2], S. SANI[3]
[1, 2, 3] *Department of Soil Science, Federal University Dutsin-ma, Katsina State*

Abstract- The research was aimed to evaluate the physical and chemical properties of soil at Bichi Local Government Kano State, Nigeria. A soil profile was dug at the Eastern and Western parts of the area under study, georeferenced using Global Positioning System (GPS). Site characteristics such as gradient, erosion, natural drainage, natural vegetation and land use were recorded. Soil profile morphological characteristics were studied including soil texture, structure, porosity and bulk density. From the soil profile, disturbed soil samples were taken from designated genetic horizons for physical and chemical analysis in the laboratory. Undisturbed cores samples were taken for the determination of bulk density. For soil fertility evaluation composite soil samples from the 0-30cm depth were collected from the sites. The results of the particle size distribution, bulk density and total porosity revealed that the textural class of the study area is dominantly sandy clay loam in the lower horizons whereas sandy loam in the upper horizons. The highest bulk density and total porosity values were recorded in horizon AP and the lowest values were recorded in horizon BC respectively. The maximum numerical values of Soil pH, electrical conductivity, cation exchange capacity, available phosphorous, total nitrogen, and organic carbon contents of the soil were obtained from horizon AP while the minimum numerical values were obtained from horizon BC. It, therefore, concluded that the soil of the study area has poor physical conditions and low levels of chemical fertility status. Organic amendment should be applied to the soils for improvement of the physical and chemical conditions of the soils.

Indexed Terms- Physical properties, Chemical properties; Bichi; Soil profile

I. INTRODUCTION

Considering the rapid growth of the population in Nigeria, improving crop productivity and resource use efficiency is highly required to ensure food security and environmental quality. The best way to reach this goal is to increase yield per unit area rather than by expansion of the cultivated area (Sultana *et. al*., 2016) In this respect, evaluating soil's Physico-chemical properties could greatly help in improving agricultural productivity. The fertility of the soil is determined by both its physical properties and its nutrient contents. The nutrients are required by living organisms for their growth and development (Evans *et al.,* 1987).

Some of the elements such as nitrogen (N), phosphorus (P) and potassium (K) are given more attention in Nigeria in evaluating soil fertility because of plants' urgent need for them and the common deficiency of these elements in most Nigerian soils. Similarly, soil organic carbon (OC), a key indicator of soil quality, is also considered an important and effective factor in soil productivity (Yadav *et al.,* 2000). The effect of available K and P on the performance of agricultural products has been reported by some researchers (Bohra and Doer, 1993). Soil OC, as well as soil physical properties, influences the supply of nutrients like N and P for growing plants, their availability or otherwise could increase or decrease the crop yields (Singh and Sherma, 2000). There is a need for improving the agricultural sector in Nigeria to increase food availability, reduce poverty, enable the country to increase markets for products and eventually become self-sufficient in basic food requirements. Food production has been failing to meet demand and the country has been importing food and receiving food aid to meet the demand due to its production shortfalls. Soil fertility improvement in a region plays an important role in the context of sustainable agricultural production. Physico-chemical properties of soils are complex, often non-linearly related, and spatially and temporally dynamic (Rowell, 1994). Several researches on soil Physico-chemical parameters have been conducted around the world but information on the physical and chemical properties of soils of Bichi Local Government is limited. This research is designed to bridge this gap of knowledge. Therefore, knowing the variability in soil properties becomes imperative in Agricultural development. Hence this study is designed to determine the Physico-chemical properties of soils of Bichi Local Government, Kano State Nigeria.

II. MATERIALS AND METHODS

- The Study Area

Bichi Local Government Area, Kano state Nigeria, has an area of 613km^2 with a population of about 277,099 people (census 2006). Bichi Local Government is located at latitude 12.14N and longitude 8.15E (Dada 2006). The vegetation is Sudan savannah type and it is characterized by sparsely populated trees, and mostly the trees are *Azadirachta Indica* species, with a little population of eucalyptus. The climate of Bichi is almost similar to other parts of the Kano state, the temperature ranges between a minimum of 15.8^{0}c and a maximum of 33^{0}c although sometimes during the harmattan it falls to as low as 10^{0}c. It has two seasonal periods which consist of wet and dry seasons. The period of the wet season lasts for about 4 months (from June to September), the average rainfall in August i.e the month is 133.4mm+59mm (Shehu et.al; 2018).

- Soil Sampling

A reconnaissance field survey using transect walks, observations and descriptions; a site for a soil profile representative of the major soils of Bichi Local Government was identified. A soil profile pit was dug at the Eastern and Western parts of the area under study, georeferenced using Global Positioning System (GPS). Site characteristics such as gradient, erosion, natural drainage, natural vegetation and land use were also be recorded. Soil profile characteristics such as soil texture, structure, porosity and bulk density were observed. From the soil profile, soil samples were taken from designated genetic horizons for Physico-chemical analysis in the laboratory. Undisturbed cores samples were taken for the determination of bulk density. For soil fertility evaluation composite soil samples from the 0-30cm depth were collected from the sites. The soil samples were air-dried, ground and passed through a 2-mm sieve to obtain the fine earth fractions for determination of physical and chemical soil properties.

- Analysis of the Soil

Soil particle size distribution was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Bulk density was determined using the core sample method (Blake and Hartge, 1986.) Total porosity was calculated from the bulk density using the equation of (1-ρb/ρs) where ρb is the bulk density and ρs is the average particle density (2.65Mg/m3). The electrical conductivity (EC) of soils was determined using a soil: water ratio of 1:2.5 with the aid of an EC meter as described by Sahlemdhin and Taye (2000). The pH of the soils was measured in water and calcium chloride (0.01M CaCl2) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a glass electrode (Van Reeuwijk, 1992). The Walkley and Black (1934) wet digestion method was used to determine soil carbon content and percent soil OM was obtained by multiplying percent soil OC by a factor of 1.724. Total N was analyzed using the Kjeldahl distillation method as described by Black (1965). Bray 1 method was used for available P extraction (Landon, 1991) and read using a spectrophotometer at 860nm (Murphy and Riley, 1962) The exchangeable bases were extracted by saturating the soil with neutral 1M NH4OAc(Anderson and Ingram. 1993). Exchangeable Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by a flame photometer (Anderson and Ingram. 1993). Cation exchange capacity (CEC) was determined titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965).

- Data Analysis

The soil's physical and chemical properties were subjected to descriptive analysis using the statistical analysis system (SAS Institute, 1999).

III. RESULTS AND DISCUSSION

- Physical Properties of the Pedon

Particle Size Distribution (Soil texture)

The sand, silt and clay fractions of the soils differed within the horizons as presented in Table 1. The highest value of sand content was observed from horizon AP (76.80%) while the lowest was recorded from horizon BC (56.80%). The silt fraction with a high numerical value is EA_2 (14.65%) and the lower numerical value was recorded from horizon 2Bt (5.56%) respectively. The lower clay fractions content was observed from horizon AP (8.64%) while the higher value was horizon BC (28.64). The results of soil texture (particle size distribution) show that the textural class of the study area is dominantly sandy clay loam in the lower horizons whereas sandy loam in the upper horizons. The most probable reasons for these variations in the study area may be the difference in topography, slope gradient and parent material. Similarly, Thangasamy *et al.* (2005) reported that variation in soil texture may be caused by variation in parent material, topography, in situ weathering and translocation of clay. Soils of lower elevation sites had higher clay content than higher elevations (Sitanggang *et al*., 2006).

- Bulk Density

Significant variations were obtained among the bulk density values of the horizons within the pedon as presented in Table 1. The highest (1.66 g/cm^3) value was recorded in horizon AP and the lowest (1.39 g/cm^3) value was recorded in horizon BC respectively. The bulk density values decrease progressively from the upper horizon down to the lower horizons. This variation in bulk density could be attributed to variation in soil organic matter; soil texture, the intensity of cultivation (Sharma and Anil Kumar, 2003). Accordingly, the highest bulk density in horizon AP could be due to lower organic matter content and a higher degree of soil compaction due to intensive cultivation since this horizon (AP) has been cultivated for a long period. On contrary, the lower bulk density in horizon BC could be attributed to higher porosity and less disturbance of the land, and the contribution of trees in loosening the soil structure through their roots.

- Total Porosity

The results presented in Table 1 show that there is a strong variation in total porosity among the horizons. The highest (47.63%) and lowest (37.32%) values were recorded in horizon BC and AP respectively. Total porosity is an index of the relative pore space in the soil. Its value generally ranges from 30 (in compacted subsoil) to more than 60% in well-aggregated, high-OM surface soils (Brady and Weil, 2002). According to FAO (2006b) rating of total porosity, the percent total porosity of the sub-surface horizons was high (> 40%) while that of the surface horizons were ranged from low to moderate ranges. The high total porosity observed in the subsurface horizons of the study area implies a better aggregation and indicates better conditions of root penetration and movement of water and air and that of the surface horizon limit root penetration and restrict movement of water and air to some extent, which indicates poor conditions of the soils for crop production. This result confirms the finding of (Sani et.al 2019) who reported that coarse-textured soils tend to be less porous than fine-textured soils. The total porosity of the studied soils showed an inverse pattern with the values of bulk density.

- Chemical Properties of the Soil Pedon

Soil pH (Soil Reaction)

The pH of the soil varied across the horizons as presented in Table 2. The maximum numerical value was obtained from horizon AP (6.8) while the minimum numerical value was obtained from horizon BC (4.2) respectively and the average pH value of the horizons was 5.8. By rating the pH values of the horizons using Foth and Ellis, (1997) standard, the pH at horizons $EA_{2,}$ 2Bt and B3 were slightly acidic while horizon BC was very strongly acidic respectively; and AP horizons were rated as neutral. The degree and nature of soil reaction are influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials**,** application of commercial fertilizers and other farming practices (Rowell, 1994; Miller and Donahue, 1995; Tisdale *et al.*, 1995; Brady and Weil, 2002). This is the reason why the pH of upper horizons tends to fall within the range of slightly acidic to neutral due to agricultural or farming practices. The result indicates that the pH mean values of the horizons, especially horizons (EA_2, 2Bt and B3) fall within the normal range of 5.5 - 6.5 reported being optimum for the release of plant nutrients (Odunze *et al.*, 2006).

- Electrical Conductivity (EC)

The electrical conductivity (EC) value across the horizons varies as shown in Table 2. The maximum numerical value was obtained from horizon AP (0.120 ds/m) while the minimum numerical value was obtained from horizon BC (0.06 ds/m) respectively and the average value of the horizons was 0.086 ds/m. The result revealed that the electrical conductivity of the horizons increased downward, this may be due to the differences in geology and agricultural management. By rating the values with the critical limit for salinization (4 ds/m), all the horizons are not prone to salinity threats and the soils will support many crops.

- Organic Carbon (OC)

The organic carbon values across the horizons vary as presented in Table 2. The maximum numerical value was obtained from horizon AP (0.75%) while the minimum numerical value was obtained from horizon BC (0.38%) respectively and the average value of the horizons was 0.55%. The organic carbon contents decreased downward due to the low level of organic materials within the horizons. By rating with Emerson (1991); the organic carbon content of the horizons was extremely low to low range, which indicates very poor structural condition, very low structural stability and severely eroded degraded surface. The result was in agreement with the finding of Mathew and Nair (1997) who reported organic carbon increased with enrichment of upper layer soil with organic manure, this is the reason why the organic carbon content at surface horizons is higher than that of the lower horizon.

- Total Nitrogen

Total nitrogen values across the horizons vary as presented in Table 2. The maximum numerical value was obtained from horizon AP (0.07%) while the minimum numerical value was obtained from horizon BC (0.04%) respectively and the average value of the horizons was 0.056%. According to the ratings given for total nitrogen by Bruce and Rayment (1982), all the horizons were qualified for a very low to low range. This indicates that the variations in total nitrogen within the horizons are related to the nature of the organic materials and leaching activities in the soil. The result confirmed the finding of Jones and Wild, (1978) who reported that the nature and the origin of the soils as well as inadequate application of nitrogen-based chemical fertilizers influence the nitrogen content of the soil.

- Available Phosphorous

Clear differences were observed among the horizons as shown in Table 2 in available phosphorous. The minimum available phosphorous was observed in horizon BC (3.85 mg/kg) while the maximum value was recorded from horizon AP (6.22 mg/kg) with a mean value of 5.39 mg/kg. Based on the rating set by Holford and Cullis (1985), the available P content in the horizons Bt and B3 were classified as a very low range while the remaining horizons were classified as a low range. This variability in the soil available phosphorous contents between the horizons might be a result of different soil management practices, specifically, the type and rate of organic fertilizers and the rate of inorganic fertilizer used in the study. The sandy nature of this soil combined with the inherent characteristics of the parent material and relatively lower pH could also be the other cause of lower available P content. These results conform with the findings of Sanchez *et al.* (1997), that P is a limiting nutrient in many sandy soils of the semi-arid tropics.

- Cation Exchange Capacity

The cation exchange capacity value across the horizons varies as shown in Table 2. The maximum numerical value was obtained from horizon AP (5.84 cmol/kg soil) while the minimum numerical value was obtained from horizon BC (3.16 cmol/kg soil) respectively and the average value of the horizons was 4.61 cmol/kg soil. Based on the rating suggested by Hazelton and Murphy (2007) soils of the horizons were qualified for the very low to low range. The variation in CEC values of the studied soils maybe because of variation in nature and type of clay minerals. This result agreed with the finding of Oades *et al.*, (1989) reported that OM is responsible for about 25-90 % of the total CEC of surface mineral soils. Therefore, soil CEC is expected to increase through the improvement of the soil OM content and clay contents in the soil. Although there is variability in CEC values of the studied soils, the high to very high CEC values indicate that the soils can retain a high amount of cations such as K^+, Ca^{2+} and Mg^{2+} to support plant growth. According to Mohammed *et al.* (2005), the high values of CEC offer high buffering capacity to the soil.

Table 1: Physical Properties of Soil Pedon at Bichi Local Government Area.

Horizon Description	Bulk density (g/cm^3)	Total Porosity (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class
AP (0-30cm)	1.66	37.32	76.8	14.56	8.64	Sandy loam
EA_2 (30-57cm)	1.60	39.81	70.8	14.65	14.64	Sandy loam
2Bt (57-89cm)	1.50	45.22	68.8	5.56	25.64	Sandy Clay Loam
B3 (89-137cm)	1.41	46.92	64.8	8.56	26.64	Sandy Clay Loam
BC(137-200cm	1.39	47.63	56.8	14.56	28.64	Sandy Clay Loam
Mean	1.50	43.38	67.6	11.58	20.84	Sandy Clay Loam
Minimum	1.39	37.32	56.8	5.56	8.64	Sandy loam
Maximum	1.66	47.63	76.8	14.65	28.64	Sandy Clay Loam
SE ±	0.0541	2.043	3.323	1.905	3.904	

Table 2: Chemical Properties of Soil Pedon at Bichi Local Government Area.

Horizon Description	pH	EC (ds/m)	CEC (cmol/kg)	Available P (mg/kg)	Total N (%)	Organic C (%)
AP (0-30cm)	6.8	0.060	5.84	6.22	0.07	0.75
EA_2 (30-57cm)	6.3	0.080	5.21	5.80	0.06	0.63
2Bt (57-89cm)	6.4	0.070	4.75	6.11	0.06	0.58
B3 (89-137cm)	5.3	0.100	4.11	4.99	0.05	0.42
BC(137 -200cm)	4.2	0.120	3.16	3.85	0.04	0.38
Mean	5.8	0.086	4.61	5.39	0.056	0.55
Minimum	4.2	0.060	3.16	3.85	0.04	0.38
Maximum	6.8	0.120	5.84	6.22	0.07	0.75
SE ±	0.464	0.011	0.461	0.442	0.0051	0.068

SE (Standard Error of Mean).

CONCLUSION

The results of the particle size distribution, bulk density and total porosity revealed that the textural class of the study area is dominantly sandy clay loam in the lower horizons whereas sandy loam in the upper horizons. The highest bulk density and total porosity values were recorded in horizon AP and the lowest values were recorded in horizon BC respectively. The maximum numerical values of Soil pH, electrical conductivity, cation exchange capacity, available phosphorous, total nitrogen and organic carbon contents of the soil were obtained from horizon AP while the minimum numerical values were obtained from horizon BC. It therefore concluded that the soil of the study area has poor physical conditions and low levels in chemical fertility status.

REFERENCES

[1] Black, C.A, 1965. Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA. 1572p.

[2] Bohn, H.L, B.L. McNeal and G.A. O'Connor, 2001.Soil chemistry, 3rd Ed. John Wiley andSons, Inc., New York. 307p.

[3] Bohra JS, Doerfling K. 1993. Potassium nutrition of rice (Oryza sativa L.) varieties under NaCl salinity. Plant soil 152: 299-303.

[4] Bouyoucos, G.J., 1962. Hydrometer method improvement for making particle size analysis of soils. *Agron. J*. 54: 179-186.

[5] Brady, N.C. and R.R. Weil, 2002.The nature and properties of soils, 13th Ed. Prentice- Hall Inc., New Jersey, USA. 960p.

[6] Chapman, H.D., 1965. Cation exchange capacity. *In*: C.A. Black, L.E. Ensminger and F.E. Clark (Eds). Methods of soil analysis. Agronomy. 9: 891-901. Am. Soc. Agro., Inc., Madison, Wisconsin.

[7] Cook, R.L. and B.G. Ellis, 1987. Soil management: A world view of conservation and production. John Wiley & Sons, Inc., U.S.A. Malabar, Florida. 413p.

[8] Evans, L.J., Kay, B.D. and Thomas, R.L. (1987). Soil Science, 1987 – 2000: A Study Guide and Laboratory Exercise Manual. Department of Land Resource Sciences. University of Guelph, Ontario, Canada.

[9] FAO (Food and Agriculture Organization).2006b. Guidelines for soil description.4th edition FAO of the United Nations, Rome.

[10] Foth, H.D. and B.G. Ellis., 1997.Soil fertility, 2nd Ed. Lewis CRC Press LLC., USA. 290p.54

[11] Foth, H.D., 1990. Fundamentals of soil science, 8th Ed. John Wiley and Sons, Inc., New York,USA. 360p.

[12] Gao, G. and Chang, C. 1996. Changes in cation exchange capacity and particle size distribution of soils associated with long-term annual applications of cattle feed lot manure. *Soil Science*, 161: 115-120.

[13] Gregorich, E.G., B.H. Ellert and C.M. Monreal, 1995. Turnover of soil organic matter and storage of corn residue carbon estimated from natural 13C abundance. *Can. J. Soil Sci.* 75:161-164.

[14] Landon, J.R. 1991. *Booker tropical soil manual*: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.

[15] Miller, R.W. and R.L. Donahue, 1995.Soils in our environment, 7th Ed. Prentice Hall Inc. Englewood Cliffs, New Jersey. 649p.

[16] Rowell, D.L. 1994. *Soil science: Methods and applications*. Longman group UK Limited. Sanchez, P.A., Sheperd, K.D., Soul, M.J., Place, F.M., Buresh, R.J., Izac, A.M.N., Mokwunye, A.U, Kwesiga, F.R., Ndirtu, C.G. and Woomer, P.L. 1997. *Soil fertility replenishment in Africa*. An investment in natural resource capital. pp. 1-46. *In*: Buresh, R.J. Sanchez, P.A. and Calnoun, F. (eds.). SSSA special publication No.51.*SSSA. Am. Soc. Argon. Madison, Wisconsin, USA. pp: 1-46*

[17] Rowell, D.L., 1994. Soil science: Methods & Applications. Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, UK. 350p.

[18] Sanchez, P.A., 1976. Properties and management of soils in the tropics.*John Wiley and Sons, Inc.*, New York, USA. 618p.

[19] Sani, S., Pantami, S. A. and Sani M. (2019). Evaluation of Soil Physical Properties at Jibia Irrigation Project, Katsina State, Nigeria. FUDMA journal of Agriculture and Agricultural Technology 5(1) pp 231-243

[20] SAS (Statistical Analysis System) Institute, 1999. The SAS system for windows, version 8.1, Vol.1. SAS Institute Inc. Cary NC., USA.

[21] Singh M, Sherma SN. 2000. Effect of wheat residue management practices and nitrogen rate on productivity and nutrient uptake of rice

(Oryza sativa) & wheat (Triticum aestivum) cropping system. *Indian J Agric Sci 70: 835-839*

[22] Sitanggang, M., Rao, Y. S., Nayan Ahmed and Mahapatra, S. K. 2006, Characterization and classification of soils in watershed area of Shikohpur, Gurgaon district, Haryana. *Journal of Indian Society Soil Science*, 54: 106–110.

[23] Sultana M.S., Rahman M.H., Rahman M.S., Sultana T. and Paul A.K. (2016). Postharvest soil fertility status of rice (Hybrid Dhan Hira 2) as influenced by vermicompost, pressmud and urea. *International Journal of Scientific and Research Publications*, Volume 6, Issue 1, ISSN 2250-3153

[24] Thangasamy, A., Naidu, M. V. S., Ramavatharam, N. and Raghava Reddy, C. 2005, Characterization, classification and evaluation of soil resources in Sivagirimi crowatershed of Chittoor district in Andhra Pradesh for sustainable land use planning. *Journal of Indian Society Soil Science*, 53:11–21.

[25] Walkley, A. and I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*. 37: 29-38.

[26] Yadav R, Dwivedi B, Prasad K, Tomar O, Shurpali N, Pandey P. 2000. Yield trends and changes in soil organic-C and available NPK in a long-term rice–wheat system under integrated use of manures and fertilizers. Field Crop Res 68(3): 219-246