



Assessment of Some Physico-Chemical Properties of the Soils of the Flood-Plain Soils of Sokoto Rima River

¹Dangaladima, W. , ²A. Ismaila, ³M.B. Sharu and ⁴A.R. Yahaya

Department of Agricultural Science,

Shehu Shagari College of Education Science Education, Sokoto, Nigeria.

ABSTRACT

The study assessed the micronutrient status of the flood-plain Soils of the Sokoto Rima River specifically the physico-chemical properties at the up-stream of the flood-plain soils of Sokoto Rima river, assess the physico-chemical properties at the mid-stream of the flood-plain soils of Sokoto Rima river and assess the physico-chemical properties at the down-stream of the flood-plain soils of Sokoto Rima river. The flood-plain was divided into three zones (up-stream, mid-stream and down-stream). Thirty (30) composite samples were collected each from the 3 zones and a total of ninety (90) samples were used for the study. The Soil samples were prepared and analysed for some micro-nutrients using standard laboratory procedures. Routine analysis for Soil texture, Soil pH, organic carbon, CEC, EC, total Nitrogen, available phosphorus, exchangeable potassium, Ca and Mg were carried out. Result of the study indicated that, the soils of the study area were slightly acidic (6.4, 6.2 and 6.1 for up, mid and down-stream respectively) mainly due to leaching, flooding and use of chemical fertilizers such as urea. Electrical conductivity (EC) was within the permissible limit (434.3, 654.3 and 742.8 μscm). Sodium was high (mean=1.7, 2.5 and 2.3 Cmolkg^{-1}) and so the likelihood of sodicity problem in the area. Except calcium which was low (mean=0.7, mean=0.7 and mean=1.2 Cmolkg^{-1}), Nitrogen (mean=0.5, mean=0.5 and mean=0.4 gkg^{-1}), potassium (mean=4.5, mean=3.7 and mean=4.1 Cmolkg^{-1}) and magnesium (mean=1.1, mean=1.2 and mean=0.8 Cmolkg^{-1}) were high and their deficiency is unlikely to occur under good agronomic practices. Higher contents of the micro-nutrients were also observed in the study area. Manganese was significantly higher in the mid-stream than in the up-stream and down-stream (mean=2.2, mean=2.9 and mean=2.2 mgkg^{-1}). Molybdenum was significantly higher in the up-stream but statistically similar in the mid and downstream (mean=1.9, mean=1.6 and mean=1.4 mgkg^{-1}). No significant differences were observed in the zinc and Fe content in all the 3 zones. Copper contents of the mid-stream and down-stream were statistically similar but significantly higher than the up-stream (mean=3.2, mean=4.3 and mean=4.3 mgkg^{-1}). Micro-nutrients were sufficiently supplied in the studied area and their deficiencies are unlikely to occur in the study area.

ARTICLE INFO

Article History

Received: April, 2019

Received in revised form: May, 2019

Accepted: June, 2019

Published online: November, 2019

KEYWORDS

Physico-Chemical, Flood-Plain, Soils, Sokoto, Rima River

INTRODUCTION

Sokoto State is an agrarian state with over 80 % of its population engaged in subsistence farming (SOSG, 2019). The state is endowed with vast area of land for crop production. The arable land is estimated at 839,569 hectares while the Fadama land occupies 142,075 hectares (SOSG, 2019). Fadama land has great potentials for all years round crop production than the adjacent upland. According to Singh (2011) the Sokoto State Fadama land can be grouped into three (3) based on their hydrological and geomorphological characteristics. The classes are

Fadama without stream channel; stream plain Fadama and flood plain Fadama. However, the state lifeline for growing crops is the floodplain of the Sokoto Rima River system which is covered with rich alluvial soil. During the rainy season, lowland rice is commonly grown but during the dry season, especially where irrigation facilities are used, varieties of crops like rice, onion, garlic, carrot, tomatoes, okra and many other vegetables are grown.

The quest to increase food production to meet the need of the increasing population and the zeal to diversify the export base of the State has led



to a more intensive use of the flood-plain soils (Mustapha, 2017). The consequence of this is that, soils become increasingly depleted of both macro and micro-nutrients. Micro nutrient elements play a significant role in crop production and have great influence on yield and quality of agricultural produce (John *et al.*, 2006). Deficiency of micro-nutrients causes serious decrease in crop yield just like the macro-nutrients and under extreme condition result to total crop failure (Chaudry *et al.*, 1983). In view of these the research work is conceived to assess the micro-nutrients fertility status of the floodplain soils of Sokoto Rima River.

Problem Statement

As a result of the growing need to increase food production in Nigeria, attention is being directed to a more intensive use of land on continuous basis (Mustapha, 2017). This is particularly so in Fadama land where the soil is utilized for all years round farming. The consequence of this is that, soils become increasingly depleted of both the macro and micro nutrients (Singh, 2011). Even when nutrients are applied to improve fertility, it is often the macro nutrients that are replenished. Other factors such as weathering, leaching, and decreased proportion of farm yard manure compared to chemical fertilizers and introduction of high yielding varieties continuously deplete the flood-plain soils of their micro nutrients reserve (Singh, 2011). These trends will continue unless appropriate steps are taken. It is on this basis that this work is conceived to assess the physico-chemical properties of the flood-plain soils of Sokoto Rima River with the view to proffer appropriate recommendations towards long term and sustainable increase in food production in the state.

Significance of the Study

Agricultural crop production practices demand fertilizer application to improve crop yield per unit area. In this regard, farmers need to know both the nutrient status of their soils and the nutrient requirements of their crops. As far as the micro nutrient elements are concerned, no comprehensive study on their contents and distribution in soils of Sokoto State is available (Singh, 2011; and SOSG, 2019). Such information as is available is only qualitative in nature and thus, not very useful or reliable in formulating fertilizer recommendation (Ojanuga, 2016). Result of this study will therefore be useful to provide basis for farmers fertilizer programme. The study will not only improve the soil

data bank of the state, but will also improve the agricultural planning development of the state and help to identify areas where micro nutrient fertilizers will be useful for high crop yield and economic returns. The study will also serve as a guide and reference point to the agronomist and policy makers.

Objectives of the Study

The main purpose of the study was to assess the physico-chemical properties at different locations of the flood-plain soils of Sokoto Rima River. This will go a long way in helping farmers and other stakeholders in agriculture to boost their farming activities in order to increase food production. Specifically, the study will:

- i. Assess the physico-chemical properties at the up-stream of the flood-plain soils of Sokoto Rima river
- ii. Assess the physico-chemical properties at the mid-stream of the flood-plain soils of Sokoto Rima river
- iii. Assess the physico-chemical properties at the down-stream of the flood-plain soils of Sokoto Rima river

Research Questions

- i. What are the physico-chemical properties at the up-stream of the flood-plain soils of Sokoto Rima River?
- ii. What are the physico-chemical properties at the mid-stream of the flood-plain soils of Sokoto Rima River?
- iii. What are the physico-chemical properties at the down-stream of the flood-plain soils of Sokoto Rima River?

MATERIALS AND METHODS

Study Area

Sokoto State has a total land area of 28,232.37 sqkm and is located between Latitude $11^{\circ}30' - 13^{\circ} 55'N$ and Longitude $4^{\circ} 07' - 6^{\circ} 56'E$ in the dry sub humid agro-ecological zone (Ojanuga, 2016). The state is situated in the North Western part of Nigeria and shares boundaries with Niger Republic to the North, Zamfara State to the East and South and Kebbi State to the South and Western parts respectively. The state enjoys the Sudan savanna type of vegetation with few scattered trees and numerous shrubs and herbs (Singh, 2011).

The agro-climate of Sokoto State consists of a long dry season (October-April) and a short rainy season (May-September). The average annual rainfall of the state is 565mm and occurs between May-October (Abubakar & Gaddafi, 2017). From late



October-February during the cold season, the climate is dominated by the Hammatan wind blowing Sahara dust over the entire land of the state. The dust dim the sun light thereby lowering the temperature significantly. The temperature varies between 15°C during the cold season (December-February) with an average of 27°C to 40°C during the hot season (March-May) (Singh, 2011).

The Sokoto Rima River runs through the state from Sabon Birni to Silame in the north-east to south-west direction (Figure 1). Within the available resources of this research work, it was not possible to sample all the soils of the flood plain. Hence, the floodplain in sokoto state which is roughly 212 km from Sabon Birni to Silame was divided into three zones (up-stream, mid-stream and down-stream) respectively. This division was based on land use system in the floodplain (Singh, 2011).

The upstream and down-streams were exclusively cultivated by the peasant farmers in the area while the mid-stream was cultivated by the peasant farmers with some input assistance from the government (because of the government project "Goronyo - Wurno irrigation scheme"). From each zone, areas of high agricultural activities were identified and selected for soil sampling. These areas thus served as sampling units.

From each sampling unit, five (5) transects were formed. On each transect there were six (6) sampling points. The sampling spots on each transect were 10m apart. In each sampling location, ten (10) soil samples were taken randomly between the depths of 0-20cm with the aid of soil augur and made into a composite sample. Thirty (30) composite samples were therefore collected from each zone and a total of ninety (90) composite samples were collected from the three zones.

Each composite sample was labeled and put into a clean polythene bag for easy conveyance and avoidance of contamination. The samples were then air dried, ground using ceramic pestle and mottle and then sieved through 2 mm sieve and stored for laboratory analysis. Basic determinations were carried out using standard laboratory procedures.

The soil samples were analysed for total and available micro nutrients particularly Zn, Cu, Fe, Mn, and Mo. Routine analysis for soil pH, soil texture, organic matter, CEC, EC, total nitrogen, available phosphorus, exchangeable potassium, Ca and Mg were also carried out.

The perchloric-nitric-sulphuric acid digestion method as described by Sparks (1999) was

employed to dissolve the total micro-nutrients for analysis. While the available micro-nutrients (Zn, Cu, Fe, Mn and Mo) were extracted using dilute hydrochloric acid extraction (0.1N HCl method) developed by Nelson *et al* (1959). The micro-nutrients in the digest and extract were read using Atomic Absorption Spectrophotometer (AAS) as recommended by Cowley in 1980. Soil pH was determined using soil pH meter in a 1:2 soil-water suspension (McLean, 1982). The particle size distribution analysis was carried out by the Bouyoucos (1951) hydrometer method as modified by Day (1965). The textural classes were determined using USDA textural triangle. Organic carbon was determined by Walkley (1934) wetoxidation method (CF = 1.33) and Cation Exchange Capacity (CEC) by Ammonium Acetate method. Nitrogen was determined by macro-Kjeldahl method. Phosphorus was determined by Bray and Kurtz (1945) method. Potassium and sodium were determined with a flame photometer while calcium and magnesium were determined by EDTA titration method. Descriptive statistics (mean, median, and standard deviation) were used to achieve the objectives.

RESULTS AND DISCUSSION

Physico-chemical Properties

Soil pH

Table 1 shows the mean values of some selected physical and chemical properties of the studied soil. The mean pH values for the up-stream, mid-stream and down-stream soils were 6.4, 6.2 and 6.1 respectively. Similarly, the pH ranges from 5.4-7.5 for up-stream soils, 5.3-7.1 for mid-stream soils and 4.7-7.7 for down-stream soils. This result compares relatively with the mean pH value of 6.6 at the lower end of River Rima in Sokoto as obtained by (Mohammed, 1991). Yacouba (1996) also reported a range of 5.1-6.3 for soils in the Sokoto Rima River Basin. In 1987 the Soil Science Society of America rated soils with pH < 4.5 as extremely acidic, 4.6- 5.0 as very strongly acidic, 5.1-6.0 as strongly acidic and 6.1-6.5 as slightly acidic (Mohammed 1991). Based on this rating, the soils of the study area were within the slightly acidic range which is appropriate for most crops (Singh, 2011). The slightly acidic conditions of the soils might be attributed to the flooding which washes away some of the basic nutrients. Also, periodic leaching of some basic nutrients and the addition of some acid forming fertilizers like urea might have contributed to the slightly acidic condition of the soils.

Table 1: Physico- Chemical Properties of the Flood-plain soils of the Sokoto Rima River.

Sampling site	pH (H ₂ O)	EC µscm	OC		Sand	Silt %	Clay	Textural class
			gkg ⁻¹					
Up-Stream	6.4 ⁺	434.3 ⁺	22.8	39.2	89.6	6.7	3.7	Sand
Mid-Stream	6.2 ⁺	654.3 ⁺	13.2	22.7	33.9	38.1	28.0	Silt loam
Down- Stream	6.1 ⁺	742.8 ⁺	17.8	29.6	32.5	13.2	54.3	Clay loam

Electrical Conductivity

Electrical conductivity of the soils of the study area ranges from 76.8 to 691.2 µscm⁻¹ (mean=434.3) for the up-stream soils, 121.6 to 1843.2 µscm⁻¹ (X=654.3) mid-stream soils and 326.4 to 1811.6 µscm⁻¹ (mean=742.8) for the downstream soils respectively. A mean value of 506µscm⁻¹ was reported by (Mohammad, 1991). Mustapha (2017) gave 2000 µscm⁻¹ as the critical safe limit of Electrical conductivity for most soils of Savanna zones. High electrical conductivity value of 1843.2 µscm⁻¹ was observed in the mid-stream and the lowest in the up-stream. However, all the soils of the study area were within the permissible limit of electrical conductivity as suggested by Mustapha (2017).

Organic Carbon

Organic carbon content varied from 3.0-24.9 gkg⁻¹(X=22.8) for up-stream, 6.8-20.5 gkg⁻¹(X=13.2) for mid-stream and 7.2-21.9 gkg⁻¹(X=17.8) for down-stream respectively (Table 1). Up-stream and down-stream soils are rated high in organic carbon as their values are greater than 15 gkg⁻¹ as suggested by Esu, (1991). The mid-stream soils are rated medium in organic carbon since their value falls within the range of 10-15 gkg⁻¹ as specified by Esu (1991). The high to medium organic carbon content of the study area is a clear indication that farmers in the area apply appreciable amount of organic matter to their farms.

Total Nitrogen

Nitrogen has been reported to be the most limiting plant nutrient in tropical soils (Brady and

Weil, 2003). Similar low Nitrogen ratings were also obtained from Fadama soils in Bauchi State (Mustapha, 2017) and in soils elsewhere in Nigeria (Kparmwang, 1996; Singh, 2011). The total nitrogen content of the study area ranges from 0.18-0.84 gkg⁻¹ (X=0.47) for up-stream soils, 0.28-0.70 gkg⁻¹ (X=0.51) mid-stream and 0.18-0.91 gkg⁻¹ (x=0.44) for down-stream soils respectively (Table 2). This result indicated that the soils were rated high in total nitrogen (>0.2 gkg⁻¹) as indicated in Table 2.

The high nitrogen content might be attributed to the use of organic manure in addition to the inorganic nitrogenous fertilizers, planting of cover crops especially legume crops and non-removal of plant residues after harvest. The recent flooding experienced in the studied area might also contribute to the high nitrogen content of the soils since most of the fertilizers and organic manure applied elsewhere were transported by the flood and deposited in the flood-plain. The higher mean recorded in the mid-stream section may also be due to application of nitrogenous fertilizers as government assistance is more in this section.

Phosphorus (P)

Available phosphorus content of the up-stream, mid-stream and down-stream soils varied from 0.46-0.89 mgkg⁻¹ (X=0.6), 0.46-0.75 mgkg⁻¹ (X=0.6) and 0.33-0.64 mg kg⁻¹ (X=0.5). From Table 2, these values were generally less than 10 mgkg⁻¹ and so rated low in available phosphorus.

Table 2. Some chemical properties of the Flood-plain Soils of the Sokoto Rima River

Sampling location	N gkg ⁻¹	P mgkg ⁻¹	Cmolkg ⁻¹					CEC	ESP	SAR
			Ca	Mg	K	Na				
Up-stream	0.5	6.0	0.7	1.1	4.5	1.7	9.3			
Mid-stream	0.5	6.0	0.7	1.2	3.7	2.5	9.6			
Down- stream	0.4	5.0	1.2	0.8	4.1	2.3	12.7			



This result conform to the earlier findings of Saddiq et al (2018), that phosphorus is one of the limiting nutrient to crops in West African soils and about 80 % of the African soils have inadequate supply of phosphorus.

The progressive decline in the available phosphorus from up-stream to down-stream may be related to the parent materials from which the soils were formed. Also, crop removal and periodic flooding of the area may have a contributory hand in the problem. Similar study by Noma *et al.* (2004) also confirmed the consistent low phosphorus content for soils of the Sokoto Rima River Basin.

Potassium (K)

The exchangeable Potassium content varied from 1.03-1.26 cmolkg^{-1} for up-stream soils, 0.77-2.26 cmolkg^{-1} mid-stream and 0.72-1.74 cmolkg^{-1} for down-stream soils (Table 2). By the rating of Esu (1991), the soils of the study area were generally high in potassium content. In a similar study, Mustapha (2017) obtained a range of 0.23-0.54 which was equally rated high in potassium. The high potassium content of the soils of the study area may be attributed to the incorporation of plant residues after harvest. Burning of the plant residues as practiced by some farmers and addition of chemical fertilizers (especially those containing potassium) also increases the levels of potassium in the soils of the study area. Increase in silt content as pointed by Bationo *et al* (1991) might also contribute to the increased level of potassium in the study area.

Calcium (Ca)

Calcium content of the soil of the study area varied from 0.5-0.8 cmolkg^{-1} ($x=0.7$) for the up-stream soils, 0.5-1.0 cmolkg^{-1} ($x=0.7$) mid-stream soils and 0.6-2.2 cmolkg^{-1} ($x=1.2$) down-stream soils. Saddiq *et al* (2018) obtained a range of 2.74-3.20 cmolkg^{-1} while Mohammed (1999) reported a mean value of 0.80 cmolkg^{-1} . Also Esu (1991) gave the critical levels of calcium in soils as <2 cmolkg^{-1} low, 2-5 cmolkg^{-1} as medium and >5 cmolkg^{-1} as high. Based on this rating, the soils of the study area were generally low in calcium contents except the downstream which was medium. Although the soils were low in calcium content, the result obtained suggested that the soils of the study area were generally within the allowable safe range of calcium as earlier pointed by Yebo (2015). The low calcium contents of the up-stream and mid- stream soils may be attributed to crop removal particularly due to intensive cultivation of

the soils. Flooding also might contribute to the low calcium as most of it was washed away to the downstream. Although, the soils were slightly acidic, no significant liming practices have been undertaken to increase the pH of the soils and so no significant amount of calcium is applied in the area. Under low pH, Ca^{+2} concentration decreases (Samuel *et al.*, 2006). This might also be a contributory factor to the low amount of calcium in the study area.

The downstream soil was medium in calcium contents. This might be attributed to the high cation exchange capacity (CEC) recorded compared to the upstream and downstream soils. Total calcium in high CEC acid soils can be high to provide sufficient plant available Ca^{+2} (Samuel *et al.*, 2006). Also, flooding which carried most of the calcium and other organic debris from up-stream through mid-stream and finally deposited them at the downstream might be a factor in the up-rise in the calcium content of the downstream soils. Application of inorganic fertilizer in the area might also have contributed to the increased in calcium content of the area.

Magnesium (Mg)

Magnesium content of the study area varied from 0.9-1.4 cmolkg^{-1} ($x=1.13$) for up-stream soils, 0.8-1.6 cmolkg^{-1} ($x=1.2$) mid-stream and 0.5-1.3 cmolkg^{-1} ($x=0.79$) down-stream soils respectively. These ranges closely agreed with the result obtained by Singh (2011), who reported a range of 0.32-0.99 cmolkg^{-1} for soils of the Sokoto Rima River Basin. Similar study by Musa (2004) indicated a range of 0.12-0.51 cmolkg^{-1} ($x=0.25$ cmolkg^{-1}). According to Esu (1991), magnesium was rated low at <0.3 cmolkg^{-1} , medium at 0.3-1.0 cmolkg^{-1} and high at >1.0 cmolkg^{-1} . Based on this rating, the soils of the study area were generally high in magnesium content. Parent materials from which the soils were formed may be a contributory factor to the high magnesium content in the soils of study area. Use of irrigation water laden with magnesium as pointed by Brady and Weil (1999) might have also contributed to the high level of magnesium in the study area.

Sodium (Na)

The concentration of sodium varied from 1.4-1.9 cmolkg^{-1} ($x=1.7$), 1.9-2.9 cmolkg^{-1} ($x=2.5$) and 1.5-3.3 cmolkg^{-1} ($x=2.3$) for up-stream, mid-stream and down-stream soils respectively. According to Esu (1991), values less than 0.1 cmolkg^{-1} are classified low in sodium; 0.1-0.3 cmolkg^{-1} medium and greater than 0.30 cmolkg^{-1} is considered high in sodium. This



indicates that, the soils of the study area were generally high in sodium and by implication could cause salinity hazard particularly that caused by sodium. The high sodium content of the soils may be attributed to the high evaporation rate associated with the soils of the arid zones (Brady and Well 2003). Water from the underground water table is brought up to the surface by capillarity and this result in the accumulation of the sodium and other soluble salts after the evaporation. Use of salt laden irrigation water, excessive irrigation and poor drainage of the soils might also contribute to the high sodium content of the soils.

Cation Exchange Capacity (C.E.C)

The mean values of cation exchange capacity (CEC) for the up-stream, mid-stream and down-stream soils are presented in Table 2. However, the CEC of the soils varied from 8.5-9.7 cmolkg^{-1} , 9.4-9.9 cmolkg^{-1} and 11.8-12.9 cmolkg^{-1} for up-stream, mid-stream and downstream soils respectively. Studies in Kebbi State by Singh (2011) revealed a range of 0.6-8.4 cmolkg^{-1} . Esu (1991) and Afu, Isong, and Awaogu (2019) classified soils with $\text{CEC} < 6.0 \text{ cmolkg}^{-1}$ as low, 6-12 cmolkg^{-1} as medium and $>12.0 \text{ cmolkg}^{-1}$ as high. According to this classification, soils of the study area were generally medium in CEC. Similar result was obtained by Musa (2004) while working on irrigated soils in Sokoto State. The values obtained ranged from 6.3-8.7 cmolkg^{-1} ($X=6.16$) and was rated medium based on the rating by Esu (1991).

Addition of organic matter by the farmers coupled with the use of inorganic fertilizers might have contributed to the medium CEC of the study area. Deposition of organic substances as a result of flooding might have also contributed to the medium CEC of the soils of the study area.

CONCLUSION

The results presented and discussed so far confirmed that the soils of the study area are slightly acidic. This soil condition is appropriate for most of the crops grown in the area. Sodium was high in the soils of the study area and that was an indication of possible salinity problem. Phosphorus was generally low in the soils of the study area and may have a negative effect on the overall fertility of the soil. Calcium was low particularly in the up and mid-stream soils and may contribute to the decline in the fertility of the soils. The results have also shown that, micro-nutrient elements studied were sufficiently

supplied and so deficiencies of such elements are unlikely to occur in the study area.

RECOMMENDATIONS

The following recommendations were made based on the findings of the study

1. Annual checkup of the soil condition is required to ascertain the pH and to apply necessary management strategy for sustainable agriculture in the area.
2. Effective management strategies such as drainage, mulching and application of gypsum should be adapted to reduce excess salt accumulation and to minimize subsequent build-up.
3. The deficiency of phosphorus in the area can be prevented by increased organic matter usage in addition to the application of phosphatic fertilizers. This will be in consonance with the current advocacy of integrated soil fertility management (ISFM), which combines the use of inorganic and organic fertilizers for the maintenance of fertility on fragile soils for sustainable and maximum productivity.
4. Particular attention should be given to improve the calcium contents of the soils of the study area (especially in the up-stream and mid-stream sections) mainly due to its low contents compared to the other elements.
5. Although, the micro-nutrients of the area studied were relatively sufficient, application of organic matter by the farmers will help to maintain the levels of these elements for a long term sustainable agriculture in the area.

REFERENCES

- Abubakar, S. D. & Gaddafi, B. (2017). Soils and Water Interplay in Sokoto-Rima Flood Plain. *Saudi Journal of Humanities and Social Sciences*. 10(1); 856-863.
- Afu, S. M., Isong, I. A. and Awaogu, C. E. (2019). Agricultural Potentials of Floodplain Soils with Contrasting Parent Material in Cross River State Nigeria. *Global Journal of Pure and Applied Sciences*. 25(19), 13-22.
- Bouyoucos, C. H. (1951). A recalibration of the hydrometer for making mechanical analysis of soils. *Agronomy Journal*, 43: 434-438.
- Brady, N.C and R.R. Well (2003). *The Nature and Properties of Soils*. 13th ed. Prentice Hall. Upper Saddle River, New Jersey, USA.



- Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Science*. 59:39-45
- Chaudry, M.S., M.O. Orode, I.J. Gana, and A. Abdullahi (1983) *Crop Calendar for Bakolori Project*. Sokoto Rima River Basin Development Authority, Sokoto.
- Day, F. R. (1965). Particle fractionation and particle size analysis. In: C.A. Black (ed). *Methods of Soil Analyses*. American Society of Agronomy. Madison, Wisconsin, USA, Pp545-566.
- Esu, I. E. (1991). Detail soil survey of Nigeria Institute for Agricultural Research (NIHRT) Farm at Bunkure, Kano State. Ahmadu Bello University Zaria.
- John, L.H., D.B. James, L.T Samuel and L.N. Werner (2006). *Soil Fertility and Fertilizers- An Introduction to Nutrients Management 7th ed.* P.244-289.
- Kparmwang, T. (1996). Inherent fertility status of upland and fadama soils in Bauchi State, Nigeria. *Noma*. 12:1-7.
- Malaku, S., R.Dams and L. Moens (2005). Determination of trace elements in agricultural soil samples by inductively coupled plasma spectrometry micro waves and digestion versus aqua regia extraction. 544: 117-125
- McLean, E. O. (1982). Soil pH and lime requirements. In: A.L. Page (ed). *Methods of Soil Analysis*. Part 2. Chemical and Microbiological Properties. American society of Agronomy. Madison Wisconsin. USA. 199-224.
- Mohammed, S. (1996). Soil Salinity, oodicity and water logging. In: Rashid A. and K.S. Memon Islamabad Pakistan P 472-506.
- Musa, A. A. (2004). Assessment of the quality of Tube well water and the irrigated fadama soils in Sokoto State, Nigeria. Soil testing and Plant analysis, 3rd ed. *Soil Science Society of America*, Madison Wisconsin. USA.
- Mustapha, A.B. (2017). Effects of supplemental irrigation on the growth and yield of Pearl millet (*Pennisetum glaucum*) in the dry sub-humid region Maiduguri, Borno State, Nigeria. An Msc dissertation submitted to the postgraduate school, Usmanu Danfodiyyi University, Sokoto. 2011.
- Nelson, J. L., L. C. Boawn and F.G. Viets (1959). A method of assessing zinc status of soils using acid "extractable zinc and titrable alkalinity" values. *Soil Science America*, 88:275-283.
- Noma, S. S., A. G. Ojanuga, and M.A Aliyu (2004). Detailed soil survey of the Sokoto Rima Floodplain at Sokoto Nigeria. In Salako F.A., M.T. Adetunji, A.G. Ojanuga, T.A. Arowolowo and S.O Ojeniyi (eds). *Managing Soil Resources for Food Security and Sustainable Environment*. Proceedings of the 29th Annual conference of the Soil Science Society of Nigeria held in Dec. at University of Agriculture Abeokuta, Nigeria 319p
- Ojanuga, A. G. (2016). *Agro-Ecological Zones of Nigeria*; National Special Programme for Food Security. P124.
- Saddiq, A. M., D. T. Gungula, S. Mustapha and A.M. Chiroma (2018). Micronutrient status in some selected Local Government Areas of Adamawa State, Nigeria. Proceedings of the 32nd annual conference of Soil Science Society of Nigeria held at MAUTECH Yola. pp 196-214.
- Samuel, L. T., L. N. Werner, D. B. James and L. H. John (2003). *Soil Fertility and Fertilizers 5th ed.* Published by Asoke K. Ghosh, Prentice – Hall of India private limited. 66-77.
- Sharma, D. B. S, Mukhopadihyau and S. Anora (2005). Total DTPA extractable micro-nutrients in relation to pedogenesis in some Alfisols of Punjab, *India Soil Science*. 170: 559-572.
- Singh, B. R. (2011). Characteristics of the Fadama soils in Sokoto-Rima River Basin in Dundaye District. In: B. R. Singh (Ed), *Management of Marginal Lands in Nigeria*. *Soil Science Society of Nigeria*, Usmanu Danfodiyyo University, Sokoto. 147-152.
- Sokoto State Government Diary (2019). Ministry of Information, Sport and Culture, Sokoto.
- Sparks, D. L. (1999). *Methods of soil analysis part 3 Chemical Methods*. *Soil Science society of America*. Madison, Wisconsin USA. pp120-126
- Walkley, A. (1947). A critical examination of a rapid method for determining organic carbon in soils. Effects of variation in digestion conditions and organic soil constituents. *Soil Science*, 63: 251-263
- White, J. G. and R. J., Zasoski (1999). Mapping soil micronutrients. *Field Crops Research* 60:11-26
- Yacoouba, M. (1996). Physico-chemical Properties of the Fadama soils in Sokoto Rima River Basin Sokoto State, Nigeria. Msc. (Soil Science)



Dissertation Submitted to the Department of
Soil Science and Agricultural Engineering,
Usmanu Danfodiyo University, Sokoto,
Nigeria.

Yebo, B. (2015). Integrated soil fertility management
for better crop production in Ethiopia.
International Journal of Soil Science. 10, 1-
16.