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Assessment of Salinity and Sodicity Status of Sokoto-Rima Flood Plains of Sokoto State, Nigeria and Its Implications for Agricultural Activities

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Abstract: *Salinity and sodicity are major problems in irrigated lands, rendering them unsuitable for crop production. This study was conducted to assess the status of salinity and sodicity in the Sokoto-Rima Flood Plains of Sokoto State, Nigeria, and its implications for agricultural activities in the area. Two locations were selected for the study (Kolkolawa and Nasarawa floodplain). Soil samples were collected from surface soils at a depth of 0 – 30 cm from the two locations. The soil samples obtained were analyzed for physical and chemical properties using standard procedures. The results showed that the soils were imperfectly to poorly drained. Soil texture was loam-sand in Kolkolawa and silt clay-loam in Nasarawa. Mean soil pH values were rated slightly alkaline to strongly alkaline in Kolkolawa and moderately acidic to strongly alkaline in Nasarawa (7.2 – 7.9); organic carbon was low to medium (5.3 – 9.7 g/kg), while cation exchange capacity was medium to high (8.7 – 19.7 cmol/kg), and base saturation (70 - 71 %) was high in both locations. Electrical conductivity (0.35 – 0.79 dS/m) and sodium absorption ratio (0.13 – 0.64) were low, while exchangeable sodium percentage (ESP) (6.7 – 8.9 %) was moderate in both Kolkolawa and Nasarawa. Among the two locations, soils in Nasarawa were observed to be tending toward sodicity due to high pH (> 8.5), high sodium (1.60 cmol/kg), and ESP (8.9 %) content, which could be attributed to poor drainage, parent material, and the use of low-quality water for irrigation. Soils with high pH reduce the availability of essential nutrients like iron, zinc, manganese, and phosphorus, which are essential for plant growth. The study therefore recommends the construction of drainage systems, leaching of soil with quality water, planting* of tolerant crops, and the use of farmyard manure to increase soil quality and fertility.

Key words: agriculture, flood plain, salinity, savanna, sodicity.

INTRODUCTION

Soil salinity is the second-largest land degradation after soil erosion and has been linked to the downfall of agricultural communities for the past 10,000 years (Shahid et al., 2018). Available cultivable lands for agricultural production have been grossly affected by salinization. Salinization, the process of salt accumulation, most often occurs where the soil or parent material contains high levels of soluble minerals, has a poor drainage system, or where shallow water tables allow salty groundwater to move upward and deposit salts due to evaporation (Varvel et al., 2008). Salinization can also occur when irrigation water containing high levels of soluble salts is applied to the land over a prolonged period, as well as through certain fertilizers, amendments, and manure that can contribute to salt accumulation in localized areas (Ann and Clain, 2005). Furthermore, salt accumulates in agricultural soils as a result of environmental factors such as climate change, excessive use of groundwater, poor drainage associated with massive irrigation and intensive farming, and the use of low-quality water in irrigation (Machado and Serralheiro, 2017).

Salt-affected soils generally occur more frequently in arid and semi-arid climates where precipitation is inadequate to leach salts, causing them to remain in the soil profile (Sileshi and Kibebew, 2016). The salts build up over time when they cannot be leached out of the soil profile. About 1 to 20% of irrigated land is lost annually due to salt-related problems, and most salt-related land degradation problems are, to a large extent, human-induced (Zaman et al., 2018). Salt-affected soils are classified as either saline, sodic, or saline-sodic. Saline soils are soils with an electrical conductivity (EC) above 4 dS/m, a Sodium Absorption Ratio (SAR) below 13, and an exchangeable sodium percentage (ESP) below 15. Sodic soils are soils with an EC below 4 dS/m, a SAR above 13, and an ESP above 15, while saline-sodic soils are soils with an EC above 4 dS/m, a SAR above 13, and an ESP above 15 (Leticia et al., 2015; Jimoh et al., 2020). Approximately 0.8 million km^2 suffer from secondary salinization caused by land mismanagement, with 58% of these areas being irrigated, and nearly 20-25% of all irrigated land is salt-affected globally, limiting agricultural production (FAO, 2006).

Excess salts in the root zone hinder plant roots from withdrawing water from the surrounding soil. This, in turn, lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone (Ezekiel et al., 2016). Salinity causes soil fine particles to bind together into aggregates (flocculation), which is beneficial in terms of soil aeration, root penetration, and growth. However, excess salinity is detrimental to plant growth, as it reduces infiltration, hydraulic conductivity, and increases surface crusting (dispersion) (Pearson, 2004). Salinization negatively impacts plant health, soil properties, water quality, and other land resource uses (Brady and Weil, 2002; Singh and Singh, 2013). Soils in the Northern savanna regions have been experiencing an increase in salt buildup, resulting in salinity problems in irrigated fields, exacerbated by climate change (Jibrin et al., 2008; Jimoh et al., 2020; Uke and Haliru, 2021). Limited research exists on salinity management for wetland soils in Sokoto, highlighting the need for this study. This information is crucial for efficient and holistic use of soil and water resources for sustainable crop production (Anita et al., 2020). Moreover, this information about Nigeria's land base is required for land use and land management decisions at various levels of natural resource development. This paper aims to assess the salinity and sodicity status of the Sokoto-Rima Flood Plains of Sokoto State, Nigeria and discuss its implications on agricultural activities in the area.

MATERIALS AND METHODS

Study Area

The study area has a typical Sudan Savanna vegetation type. The area is intensively cultivated to array of crops such as onion, tomato, cowpea and millet. The length of growing period is 90-150 days (Ojanuga, 2006).

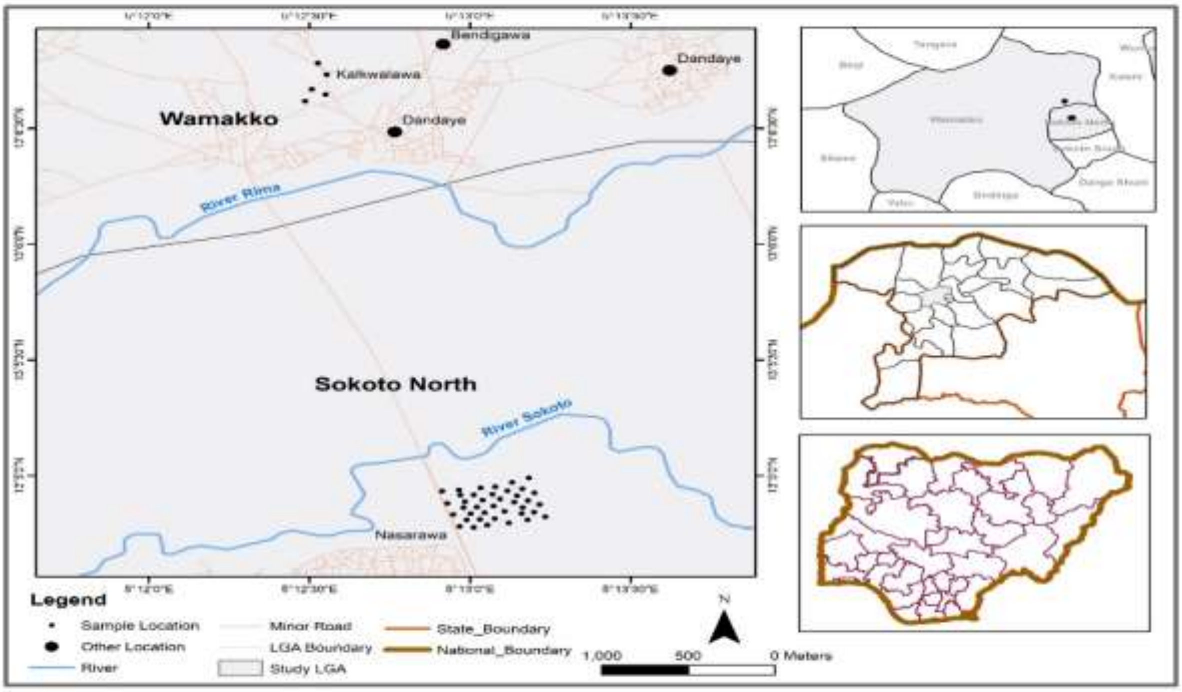

Figure 1: The Study Area
Source: Adapted from the Administrative map of Sokoto State, GIS Lab. ABU, Zaria.

The climate of Sokoto State is wet and dry, generally hot semi-arid tropics in Koppen classification of AW type. It is characterized by long dry season from October through May/June and a short but intensive wet season from May/June through September with a mean annual rainfall slightly below 750 mm. The rainfall pattern shows a marked seasonal variation with a single peak reaching maximum in August (Kowal and Knabe, 1972). The mean annual rainfall decreases gradually from the south to northern parts of the state. The rainy season is then followed by a short dry spell which could last for two to three months known as Harmattan. A period of cold, dry and dusty weather normally precedes the fairly long dry season. The temperature fluctuates within a range of 16 ^{0}C during cold nights to over 40 ^{0}C during the hot days. The relative humidity during dry season is about 15-20% and reaches up to 70-75% during the rainy season.

Soil Sampling

The study involved a detailed soil survey using rigid-grid method (100 m × 100 m) super imposed on the two floodplains (Kalkolawa and Nasarawa floodplains). Surface soil was collected at a depth of 30cm from the intersections of the grinds in the two locations using soil auger. Eighteen soil samples were collected from Kalkwala floodplain while thirty-nine samples were collected from Nasarawa floodplains. The difference in samples size was due to the size of the floodplains. The bulked samples were collected for laboratory analysis.

Laboratory Methods

The samples were air-dried, gently crushed using a wooden mortar and pestle and then sieved through a 2mm mesh. The sieved samples were stored for chemical and physical analyses. Particle size distribution was determined by the hydrometer method (Agbenin, 1995). Soil pH (1:1) in H_20 was determined using glass electrode pH meter (Agbenin, 1995). Organic carbon content of the soils was determined by the modified Walkley-Black method as described by Agbenin, (1995). Exchangeable sodium in the soil was determined using the ammonium acetate extract from the CEC determination. Sodium was determined using flame photometer. Electrical conductivity was determined by Wheatstone bridge method (Agbenin, 1995). Exchangeable Sodium Percentage (ESP) and Sodium Absorption Ratio (SAR) (Agbenin, 1995).

1. $$\text{PBS} = \frac{\text{Total Exchangeable Bases}}{\text{CEC}} \times 100$$
2. $$\text{ESP} = \frac{\text{Exchangeable Sodium}}{\text{CEC }(NH_4OAc)} \times 100$$
3. $$\text{SAR} = \frac{\text{Na}}{\frac{\sqrt{\text{Ca+Mg}}}{2}}$$

Data Analysis

The data collected from soil analysis was subjected to t-test analysis to assess variation in soil properties between the two floodplains at 0.05 level of significant in statistical package for social science (SPSS) software, version 23.

RESULT AND DISCUSSION

The results of soil physical and chemical analysis are presented in Table 1. Sand content varies from 8.0 to 90.0 (mean 70.8 %) in Kolkolawa floodplains and 2.0 to 62.0 (18.6 %) in Nasarawa floodplains. Sand content was significantly ($p < 0.001$) higher in Kolkolawa than in Nasarawa floodplains.

Soil texture under Kolkolawa was classified as loam sand while Nasarawa soils were classified as Silt clay loam.

Similarly, Silt content varies from 6.0 to 40.0 (mean 15.2 %) in Kolkolawa and 28.0 to 78.0 (51.7 %) in Nasarawa floodplains. Silt content was significantly ($p < 0.001$) higher in Nasarawa than in Kolkolawa floodplains. While Clay content varies from 4.0 to 68.0 (mean 13.9 %) in Kolkolawa and 10.0 to 64.0 (29.7 %) in Nasarawa floodplains. Clay content was significantly ($p < 0.001$) higher in Nasarawa than in Kolkolawa floodplains. Soil in Nasarawa was significantly higher in clay and silt while soil in Kolkolawa was significantly higher in sand content. Soil pH varies from 7.5 to 8.6 (7.9) in Kolkolawa and 5.5 to 8.7 (7.2). Soil pH was significantly ($p < 0.001$) higher in Kolkolawa than in Nasarawa floodplains. Soils in Kolkolawa floodplains was rated slightly alkaline to strongly alkaline while soils in Nasarawa floodplains was rated moderately acidic to strongly alkaline.

Table 1: Soil physical and chemical properties of Kalkalawa and Nasarawa.

	Location	N	Mean	Std. Error	Minimum	Maximum	Sig. Level
Sand	Kolkolawa	18	70.89	5.07	8.00	90.00	0.000
	Nasarawa	39	18.62	2.41	2.00	62.00	
Silt	Kolkolawa	18	15.22	1.91	6.00	40.00	0.000
	Nasarawa	39	51.74	1.87	28.00	78.00	
Clay	Kolkolawa	18	13.89	3.70	4.00	68.00	0.000
	Nasarawa	39	29.74	2.31	10.00	64.00	
Soil pH H_2O	Kolkolawa	18	7.99	0.08	7.50	8.60	0.000
	Nasarawa	39	7.28	0.10	5.50	8.70	
O.C	Kolkolawa	18	5.27	0.91	0.600	14.760	0.000
	Nasarawa	39	9.72	0.47	3.885	18.555	
Na	Kolkolawa	18	0.26	0.03	0.11	0.66	0.000
	Nasarawa	39	1.60	0.10	0.54	3.32	
Ex. Acidity	Kolkolawa	18	0.08	0.02	0.05	0.20	0.000
	Nasarawa	39	0.27	0.03	0.05	1.00	
EC	Kolkolawa	18	0.35	0.07	0.01	1.10	0.003
	Nasarawa	39	0.79	0.09	0.10	2.25	
SAR	Kolkolawa	18	0.13	0.02	0.03	0.34	0.000
	Nasarawa	39	0.64	0.04	0.25	1.21	
ESP	Kolkolawa	18	6.65	1.16	0.56	16.85	0.055
	Nasarawa	39	8.89	0.56	3.47	17.23	

Source: Authors' Computation

Soil organic carbon (O.C) varies from 0.6 to 14.7 (5.3 g/kg) in Kolkolawa and 3.8 to 18.5 (9.7 g/kg) in Nasarawa floodplains. Soil O.C was significantly ($p < 0.001$) higher in Nasarawa than in Kolkolawa floodplains. Soils in Kolkolawa floodplains was rated very low to medium while soils in Nasarawa floodplains was rated low to high. This corroborates previous study in savanna region (Jibrin et al., 2008; Eleke et al., 2018; Jimoh et al., 2020). The low OC implies high degradation of organic matter which could be attributed to paucity in vegetation, continuous cultivation and high mineralization rate in the Northern Guinea savanna ecologies (Hassan et al., 2015). Adaikwu and Ali (2013) also attributed low OC to high temperatures which rapidly breakdown organic matter and inhibiting nitrogen fixation by rhizo-bacteria in savanna environs.

Soil exchangeable sodium (Na) varies from 0.11 to 0.66 (0.26 cmol/kg) in Kolkolawa and 0.54 to 3.32 (1.60 cmol/kg) in Nasarawa floodplains. Soil exchangeable Na was significantly ($p < 0.001$) higher in Nasarawa than in Kolkolawa. Soils in Kolkolawa floodplains was rated medium to high while soils in Nasarawa floodplains was rated high to very high. Higher value of Na could destroy soil structure and lead to poor water infiltration and air exchange, which can impair plant growth. This finding corroborates Jibrin et al. (2008); Babalola et al. (2011), Ibrahim et al. (2018) and Jimoh et al., (2020) who also reported higher Na content in soils and attributed it to nature of parent material in the location and use of low-quality water for irrigation.

Soil exchangeable acidity (EA) varies from 0.05 to 0.20 (0.08 cmol/kg) in Kolkolawa and 0.05 to 1.00 (0.27 cmol/kg) in Nasarawa floodplains. Soil exchangeable EA was significantly ($p < 0.01$) higher in Nasarawa than in Kolkolawa floodplains. Soils in Kolkolawa was rated low while soils in Nasarawa floodplains was rated low to medium in acidity. This implies that the soils have little or no acidity problems. Raji and Mohammed (2000) and Jimoh et al., (2016) reported similar results and submitted that the contribution of exchange acidity to potential acidity is very low in soils of Nigerian savannas.

Soil electrical conductivity (EC) varies from 0.01 to 1.10 (0.35 dSm^{-1}) in Kolkolawa and 0.54 to 3.32 (0.79 dSm^{-1}) in Nasarawa floodplains. Soil EC was significantly ($p < 0.01$) higher in Nasarawa than in Kolkolawa. Soils in Kolkolawa was rated low (< 2 dS/m) while those in Nasarawa was rated low to medium (< 2 to 4 dS/m) (Leticia et al., 2015). This confirms reports by Jibrin et al. (2008) in Sudan Savanna, Ibrahim (2012) in soils of Sahel savanna, Ibrahim et al. (2018) and Jimoh et al. (2020) in soils of Guinea Savanna. Generally, the mean values were low indicating non-saline status of the soils according to the limits set by Schoeneberger et al. (2002). These imply that salinization is not a significant pedogenic process in the soil and may not hamper growth of most plants. This may be attributed to the non-saline nature of irrigation water used for cropping in the floodplains and adequate rainfall amount annually received in the area to maintain leaching of excess salts. Although there is appreciable amount in Nasarawa and the need to monitor it accumulation to avoid reaching critical level.

Sodium absorption ratio (SAR) varies from 0.03 to 0.34 (0.31) in Kolkolawa and 0.25 to 1.21 (0.64) in Nasarawa floodplains. Soil SAR was significantly ($p < 0.001$) higher in Nasarawa than in Kolkolawa floodplains. Soils in Kolkolawa and Nasarawa floodplains were both rated low in SAR been less 13 to classified it as sodic soils (Sanda et al., 2007, Leticia et al., 2015). Soil exchangeable sodium percentage (ESP) varies from 0.56 to 16.85 (6.65 %) in Kolkolawa and 3.47 to 17.23 (8.89 %) in Nasarawa floodplains. Soil ESP was not significantly different between the two locations similar to

BS. Mean value of ESP in Kolkolawa and Nasarawa floodplains were both rated low to medium being below and slightly above 15%; the critical limit for sodicity (Brady and Weil, 2002, Leticia et al., 2015). Soil in Kolkolawa is thus classified as non-sodic while some part of Nasarawa is classified as sodic soils due to ESP of > 15%. These imply that sodification is a significant pedogenic process in soils Nasarawa. Sodic soils are usually more dispersed, less permeable to water and are of poor tilth, usually plastic and sticky when wet and are more prone to form clods and crust on drying (Babalola et al., 2011). High Na^+ content of the soils may be as a result of low-lying topography of the flood plain which contributed salts and fertilizer materials in the soils. This corroborates the findings of Jibrin et al. (2008) in soils of Kano River Irrigation Project, Babalola et al. (2011) on some wetland soils in southern Nigeria and Ibrahim et al. (2018) in soils of Chanchaga Irrigation Scheme, Minna.

Agricultural Implications of Sodicity

The soil characteristics in the study area indicate a tendency towards sodicity, which can have several agricultural implications:

1. **Soil Structure Degradation**
   High sodium levels can lead to soil dispersion, reducing soil porosity and permeability. This affects water infiltration and aeration, which are critical for root growth and microbial activity.

2. **Reduced Water Availability**
   Sodic soils can become compacted and have poor water-holding capacity, making it difficult for plants to access water. This can lead to drought stress even when the soil is wet.

3. **Nutrient Imbalances**
   High pH levels can affect the availability of essential nutrients for plants. For instance, micronutrients like iron, manganese, and zinc become less available in alkaline conditions, potentially leading to deficiencies.

4. **Toxicity and Reduced Crop Yields**
   Sodium toxicity can directly impact plant growth, particularly in sensitive crops. High pH can also lead to an accumulation of certain elements to toxic levels.

5. **Impact on Microbial Activity**
   High pH and sodicity can negatively affect soil microbial activity, which is crucial for organic matter decomposition, nutrient cycling, and soil health.

Causes and Management

i. Poor Drainage: Leads to waterlogging and accumulation of salts, including sodium.
ii. Parent Material: Some soils naturally have high sodium content based on their geological origin.

iii. Use of Low-Quality Water: Irrigation water with high sodium content can exacerbate sodicity.

To manage these issues, strategies such as improving drainage, using gypsum to reduce sodium levels, and selecting salt-tolerant crops can be employed. Additionally, careful water management and monitoring of soil health are essential.

Management Strategies

1. Gypsum Application: Adding gypsum can help replace sodium with calcium, improving soil structure and reducing sodicity.
2. Improved Drainage: Installing drainage systems can help leach out excess salts and sodium.
3. Use of Organic Matter: Adding organic amendments can improve soil structure and microbial activity.
4. Crop Selection: Choosing crops that are tolerant to sodic conditions can help maintain productivity.
5. Water Management: Using good quality irrigation water and managing irrigation practices to minimize salt buildup.

CONCLUSION AND RECOMMENDATION

The parameters used in assessing level of salinity and sodicity are soil pH, electrical conductivity, sodium absorption ratio and exchangeable sodium percentage. The soil pH was tending toward alkalinity, EC and SAR of the floodplains was low, while exchangeable sodium percentage was moderate in Kolkolawa and Nasarawa respectively. Among the two locations, Soils in Nasarawa was observed to be tending toward sodicity due to high pH (> 8.5) high sodium and ESP content; which could be attributed to poor drainage, parent material and use of low-quality water for irrigation. Sodicity poses significant challenges to agricultural productivity. Understanding the causes and implementing appropriate management strategies are crucial for maintaining soil health and ensuring sustainable agricultural practices. Construction of drainages, leaching of soil with quality water, planting of tolerant crop and use of farm yard manure to increase soil quality/fertility was recommended.

REFERENCES

Adaikwu, A. O & Ali, A. (2013). Assessment of some soil quality indicators in Benue State. *Nigeria Journal of Soil Science*; 23(2):66-75.

Agbenin, J. O. (1995). *Laboratory Manual for Soil and Plant Analysis*. Department of Soil Science, Ahmadu Bello University Zaria, Kaduna State.

Ann, M. & Clain, J. (2005). Salinity and Sodicity Management. Montana State University and the Montana State University Extension Service. *Soil and water Management*. Module 2,16.

Babalola, T. S., Oso, T., Fasina, A. S. & Godonu, K. (2011). Land Evaluation Studies of two Wetland Soils in Nigeria. *International Research Journal of Agricultural Science and Soil Science* (ISSN: 2251-0044) Vol. 1(6) pp. 193-204. Available online http://www.interesjournals.org/IRJAS

Brady, N. C. & Weil, R. R. (2002). *The Nature and Properties of Soils*.13th edition. Pearson Education. India.

Eleke, P. N., Ezeaku, P. I. & Okenmuo, F. C. (2018). Properties and Conservation Needs of Wetland Soils along Kaduna River, Northern Guinea Nigeria. *Journal of Scientific Research and Reports.* 20(4): 1-10; Article no. JSRR.42888. ISSN: 2320-0227

Ezekiel, I., Toyin, J., & Samuel, A. (2016). Modeling cation exchange capacity and soil water holding capacity from basic soil properties. 5(4), 266–274. https://doi.org/10.18393/ejss.2016.4.266-274

Food and Agriculture Organisation (FAO) (2006). *Water in agriculture: opportunity untapped*. Rome: Food and Agriculture Organization of the United Nations

Food and Agriculture Organisation (FAO) (2020). Mapping of Salt-Affected Soils: Technical Manual, FAO, Rome, Italy

Hassan, M., Raji, B. A., Malgwi, W. B. & Agbenin, J. O. (2015). The basaltic soils of Plateau State, Nigeria: Properties, classification and management practices. *Journal of Soil Science and Environmental Management.* 6(1):1-8, doi 10.5897/JSSEM12.026 ISSN 1996-0816.

Ibrahim, A. K., Bolaji A. A., John J. M., Peter A. A., Murtala I. A., Hillary A. & Michael E. A. (2018). Assessment of Soil Salinity and Irrigation Water Quality of Chanchaga Irrigation Scheme I, Minna, Niger State. FUOYE *Journal of Engineering and Technology*. 3 (1):57 – 60. http://dx.doi.org/10.46792/fuoyejet.v3i1.151 engineering.

Ibrahim, A. K. (2012) *Assessment of Soil Quality for Irrigation in Some Fadama Lands in Yamaltu, Gombe State*. LAP Lambert Academic Publishing, pp. 70. ISBN: 978-3-8454-7396-3.

Isirimah, N. O., Dickson, A. A. and Igwe, G. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology*. Osia, Int'l publishers Ltd. Nigeria, pp. 31.

Jibrin, J. M., Abubakar, S. Z. & Suleiman, A. (2008). Soil Fertility Status of the Kano River Irrigation Project Area in the Sudan Savanna of Nigeria. *Journal of Applied Science*. 9 (4): 692-696.

Jimoh, A. I., W. B. Malgwi, J. Aliyu and A. B. Shobayo (2016). Characterization, Classification and Agricultural Potentials of Soils of Gabari District, Zaria, Northern Guinea Savanna Zone Nigeria. *Biological and Environmental Sciences Journal for the Tropics* (BEST JOURNAL) 13(2); 102-113. ISSN 0794 – 9057.

Jimoh A. I., Yusuf, Y. O., Odunze, A. C. & Malgwi W. B. (2020). Assessment of Salt Build-Up: In Kubanni Flood Plain Soils Of Zaria, Kaduna State Nigeria. Nigerian Geographical Journal, 14 (1): 43 - 55. ISSN:1358 – 4319.

Kowal, D. & Knabe, D. J. (1972). *An Agro climatological Atlas of the Northern State of Nigeria.* Ahmadu Bello University press, Zaria, Nigeria.

Leticia, S. S., Uttam, S. & Davis, E. K. (2015). Soil salinity: testing, data interpretation and recommendations. *University of Georgia Agricultural Extension circular* (pp. 1019)

Machado, R. M. A., Serralheiro, (2017). Soil Salinity: Effect on Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization. Horticulture, 3(30):1 – 13Ojanuga, A.G. (2006). Agro ecological zones of Nigeria Manual. National Special programme for food security and FAO. Pp 124.

Pearson K. E. (2004). *The basic effects of salinity and sodicity effects on soil physical properties. Information highlight for the general public*. http:// water quality. Montana.edu/docs/methane/basics highlight.shtml.

Raji, B.A. and Mohammed, K. (2000). "The Nature of Acidity in Nigerian Savanna Soils", Samaru Journal of Agricultural Research, Vol. 16, pp. 15-24

Sanda, A. R., Ogunwale, J. O., Oluwasemire, K. O. & Raji, B.A. (2007). Effects of Drainage Water Recycles and Irrigation Scheduling on Soil Properties and yield of tomato under a high-water table in Northern Nigeria. In Uyovbisere, E.O., Raji, B.A., Yusuf, A.A, Ogunwale, J.O, Aliyu, L. and Ojeniyi, S.O (Eds). *Soil and water management for poverty alleviation and sustainable environment.* Proceeding of the 31st annual conference of SSSN/ABU, Zaria, Nigeria. Nov. 11th to 17th, 2006

Schoeneberger, P. J., Wysocki, D. A., Benham, E. C. & Broderson, W. D. (Eds) (2002). *Field Book for Describing and Sampling Soils*, version 2.0 Nat. Soil survey center. NRCS, USDA, Lincolns, NE.

Shahid, S. A., Zaman, M. & Heng, L. (2018) Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques, Springer International Publishing, New York, NY, USA.

Sileshi, A. A. and Kibebew, K. (2016). Status of salt affected soils, irrigation water quality and land suitability of dubti/tendaho area, Haramaya University, Harar, Ethiopia.

Singh, A.P. & Singh, A.R. (2013) - Seasonal changes in the physic-chemical attributes of salt affected habitat. *India Journal of Science Research*. 4(1): 105-115.

Varvel, G. E., Koenig, R. T. & Ulery, A. (2008). *Saline and iron sodic water and soils*. Montana State University. Water quality and irrigation management. http://www.watrquality.montana.edu/does/methane/salinesodic-faq.shtml.

Zaman, M., Shahid, S. A., & Heng, L. (2018). Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques. In Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques (Issue January). https://doi.org/10.1007/978-3-319-96190-3