



An Assessment of Salinity Levels of Soils and Water in Irrigated Vegetable Farms around Lake-Alau Dam of Maiduguri, Borno State, Nigeria

***M.J. Magaji¹, A.M., Samndi¹; S.A. Pantami¹; B.L. Abdulrahman¹; I.B. Buji² and M.A.M. Abubakar³**

¹Department of Soil Science, Faculty of Agriculture, Bayero University, Kano, Nigeria.

²Department of Soil Science, Faculty of Agriculture, University of Maiduguri, Borno

³Department of Crop Science, Faculty of Agriculture, Nasarawa State University Keffi, Nasarawa, Nigeria.

ABSTRACT

The study was conducted in irrigated vegetable farms around Lake-Alau Dam of Maiduguri, Borno State, to assess the current salinity/sodicity level in both soil and water samples. Six surface (0-15cm) and six sub-surface (15 - 30cm) soil samples were obtained each from two wings (South and North) at the site. Three water samples were also obtained from the site (intake, in-field and field drain). Laboratory analyses were conducted to determine different physico-chemical properties of the soils and water samples. Results of the soil analyses showed that, the soils were slightly acidic to neutral (6.72-7.08) in reaction, low in organic carbon (2.82-3.00gkg⁻¹), ECEC (3.45-5.20 cmol (+) kg⁻¹), EC (0.36-0.52 dsm⁻¹) and SAR (0.11-0.15). These revealed that, there was no salinity problem in the soil at the time of the research in the area. Water samples analyzed from the In-take, In-field and Field-drains showed increased pH (7.42-7.91), SAR (0.66 - 1.44) and EC (0.71 - 0.78 dS/m) as water move from the In-takes to Field-drains. These also showed that, in the mean time crop production would be faced with minimal problems in the area. Organic and inorganic materials need to be in-cooperated in the soil so as to raise the fertility status of the soils.

Keywords: Sanility, Sodicity, Soil Physical and Chemical Properties.

INTRODUCTION

Soil salinity refers to the accumulation of salts (often dominated Chlorides, Sulphates and Carbonate) in soils and water to levels that can have negative impact on crop growth. Yield reductions occur when the salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in water stress for a significant period. Saline soils occurred where the supply of soluble salts exceed their removal from the soil. Salinity is characteristic of soils related to their contents of water-soluble salt (Charman and Murphy, 2000) which include both anion and cations of all salts, such as carbonate, sulphate, calcium, magnesium etc. Increasing soil salinity has a negative effect on soil stabilization, high level of salts and sodium ions destroys soil structure and makes some nutrients unavailable to plants. On the other hand, soil salinity has a great effect on some chemical properties like soil pH, electrical conductivity (EC), cation exchange capacity (CEC), sodium adsorption ratio etc. As a result of high concentrations of soluble salts in the soil, some nutrient elements may increase or decrease, depending on the concentration, may render the soil to be unproductive.

Soil salinity may affect the productivity of Agricultural lands directly as the consequences of the presence of a critical amount of soluble salts in the root zone which limit water nutrients uptake by plants. Loss of natural vegetation and subsequent increase in irrigation are the major contributing factors results in rising water tables, which ultimately cause salinity in agricultural soils (Munns *et al.*, 2002). As of the year 2000, the annual rate of land loss due to salinity is about 0.5 million hectare per year (Smedema, 2000). In another report by Metternicht and Zinck (2003), it was highlighted that around 955 million ha of land in the world is salinized due to primary salinization, and approximately 77 million ha is affected because of secondary salinization. According to Munns and Tester (2008), more than 45 million hectares of irrigated land have been damaged by salt worldwide, and 1.5 million hectares are taken out of production each year as a result of high salinity levels in the soil. Hence, Salinization was recognized as the main threats to environmental resources and human health in many countries, affecting about 1 billion ha of land worldwide/globally representing up to 7% of earth's continental extent, approximately 10 times the size of a country like Venezuela or 20 times the size of France (Yensen, 2008). It has been estimated that worldwide about 20% of the total cultivated land and 33% of irrigated agricultural lands are afflicted by high salinity, and many areas are continue to be affected, and the thread continues to increase each year due to introduction of irrigation in new areas (Patel *et al.*, 2011; Pooja and Rajesh, 2015). Furthermore, According to Pooja and Rajesh (2015) salinized areas are increasing at a rate of 10% annually for various reasons, including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. It has been estimated that more than 50% of the arable land would be salinized by the year 2050 (Jamil *et al.*, 2011). Therefore, Soil salinity is among the common soil characteristics that affect agricultural production, and it causes severe worldwide environmental problems particularly in arid and semi-arid areas (Gorji, *et al.*, 2019). Excess salt hinder crop growth and development not only by toxicity effect but by reducing water availability through osmotic effect and inducing imbalance in nutrients uptake by crop plants. Saline soil prevents water intake to plants from the root zone due to the diminishing osmotic potential of soil water (Bhatt *et al.*, 2008). Sodium chloride has been shown to reduce shoot water potential by increasing stomatal closure and transpiration (Asch *et al.*, 1995).

In arid and semi-arid regions of the world, soil salinization is one of the main drastic phenomena due to its adverse effects on land productivity and plant growth (Gorji, *et al.*, 2019). In these regions, precipitation is inadequate to keep natural percolation of water within the soil profile, and is also insufficient to neutralize the salts present in the soil and thus, it leads to accumulation of soluble salts in soil with negative effect on soil structure (Mulder *et al.*, 2011; Ülker *et al.*, 2018). In most areas of Northern Nigeria, salinity is mostly caused due to poor irrigation water quality, soil management, compaction and inadequate drainage facilities. The irrigation water usually contains calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^+). When the water evaporates from the soils, Ca^{2+} and Mg^{2+} often precipitate into carbonates, leaving only Na^+ as dominant ion in the soil (Serrano *et al.*, 1999). Increases in cations and their salts, particularly NaCl in the soil, generates external osmotic potential that can prevent or reduce the influx of water into the root. The resulting water deficit is similar to drought conditions and additionally compounded by the presence of Na^+ ions (Bohnert, 2007). Therefore, assessment of soil properties like soil salinity is crucial for land sustainability at a local and regional scale (Grunwald *et al.*, 2015). This study was aimed to assess salinity/sodicity level in irrigated vegetable farm of lake Alau-Dam, Borno State.

MATERIALS AND METHODS

The study was conducted in the vicinity of Lake-Alau Dam in Jere Local Government Area (LGA) of Borno State, and lies between latitude $11^{\circ}43'28.97''$ to $11^{\circ}43'33.63''$ N and longitude $13^{\circ}17'2.92''$ to $13^{\circ}17'6.88''$ E, with altitude of 354m above sea level. The area is characterized by two distinct seasons, dry season (October to June) and wet season (July to September) with an average annual rainfall of 470 mm (for 1981 to 2010 weather data) as reported by Dammo *et al.* (2015). Temperature is low in December and January and high around April and May, with minimum and maximum values of 22 and 40°C respectively. The soil of the area is predominantly sandy loam (Arku, *et al.*, 2011), and some clay-loam was found towards the riverside area, and the topography is generally flat with a slope of about 5%.

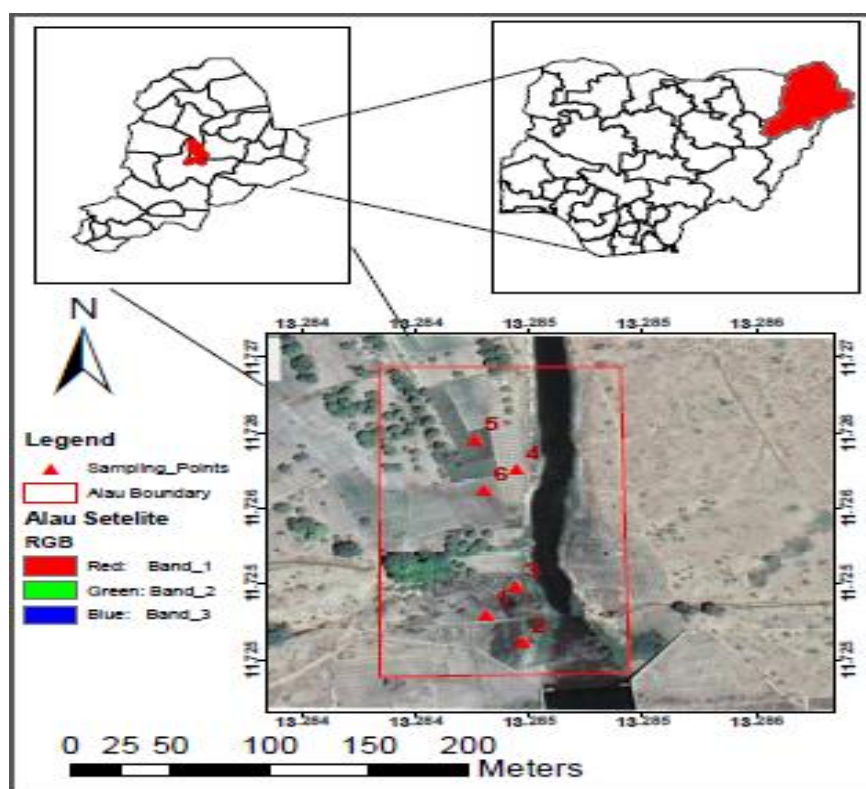


Figure 1: Map of Study Area showing; Borno State, Jere LGA and Sampling Points.

Twelve soil samples were collected from the site. Six soil samples each were obtained from two wings of the study site (wing A=North, wing B=South) at depths of 0 – 15 cm (surface) and 15 – 30 cm (sub-surface) respectively. The soil samples were air-dried, and passed through 2 mm sieve, the fine separates were used for physical and chemical analyses. Three water samples were also collected from three locations namely; Intake, In-field and Field drain sites. Bouyoucos hydrometer method was used for particle size analysis, pH was determined in a 1:2.5 soil: water ratio using glass electrode pH meter (IITA, 1979) and Electrical Conductivity (EC) was determined using the same extract using an EC meter (Bower and Wilcox, 1965). Organic carbon was determined using the Walkley and Black (1934) oxidation method. Exchangeable bases (Calcium, Magnesium, and sodium) were determined by the Ammonium saturation method (Anderson and Ingram, 1998). Available phosphorus was extracted using the Bray No. 1 method (Bray and Kurtz, 1945). Phosphorus in the extract was determined calorimetrically by the molybdo - phosphoric – blue method

using ascorbic acid as a reducing agent (Murphy and Riley, 1962). Analysis of variance was used to compare the soil properties of different points within the two wings and depths, their means was separated using Fisher's Least Significant Difference (LSD), and the result was compared with the critical limits for interpretation (Esu, 1990; and Landon, 1991).

RESULTS AND DISCUSSION

The results of the Particle size analysis for the soil samples from the study area (Table 1) indicated that the surface soils were loamy sand, while the sub-surface soils were sandy loam texture. The average values of sand contents were 81.9 %(surface) and 78.8 %(sub-surface) at North wing and 82.7 %(surface) and 77.9 %(sub-surface) for South wing, these indicated that the surface soil had more sand than sub-surface at both wings. This could be attributed to the fact that particle size decreases with soil depth as a result of eluvial process.

Table 1: Some Physico-chemical properties of soils at Lake Alau Dam Area of Borno State.

Sampling	Depth	Sand	Silt	Clay	Textural	pH	EC	OC	AP	Ca	Mg	Na	K	CEC	ESP
		Particle Size Distribution													
Location	(cm)	----- %	-----		Class		dSm ⁻¹	%	mgkg ⁻¹	-----	Exchangeable Bases			-----	%
											cmol(+) kg ⁻¹				
North Wing															
1	0 – 15	80.5	8.7	11	Loamy sand	7.3	0.48	0.29	3.84	2.75	1.71	0.21	0.14	4.81	4.37
2	0 – 15	82.1	0.82	9.7	Loamy sand	6.8	0.41	0.297	3.1	2.51	1.25	0.17	0.19	4.12	4.13
3	0 – 15	83.1	6.4	10.5	Loamy sand	6.5	0.48	0.287	2.89	2.94	1.57	0.18	0.12	4.81	3.74
Average	0 – 15	81.9	7.8	10.4		6.9	0.46	0.291	3.18	2.73	1.51	0.19	0.15	4.6	4.15
1	15 – 30	77.2	10.5	12.3	Sandy loam	7.0	0.51	0.284	3.97	2.89	1.82	0.24	0.17	5.12	4.69
2	15 – 30	79.1	10.4	10.5	Loamy sand	7.0	0.47	0.281	3	2.48	1.27	0.23	0.13	4.71	4.88
3	15 – 30	80.2	8.5	11.3	Loamy sand	6.1	0.41	0.283	2.82	2.63	1.15	0.16	0.18	4.12	3.88
Average	15 – 30	78.8	9.9	11.4		6.7	0.47	0.283	3.26	2.67	1.61	0.21	0.16	4.7	4.52
South Wing															
1	0 – 15	79.4	9.4	11.2	Loamy sand	5.9	0.4	0.3	0.08	2.38	1.25	0.15	0.18	4.96	3.02
2	0 – 15	86.4	8.6	5	Sandy loam	6.2	0.46	0.289	3.45	2.71	1.45	0.16	0.17	4.58	3.49
3	0 – 15	80.8	8	11.5	Sandy loam	6.5	0.41	0.297	4.34	2.39	1.35	0.21	0.16	4.09	5.13
Average	0 – 15	82.7	8.67	9.2		6.2	0.42	0.295	3.62	2.49	1.38	0.17	0.16	4.2	4.05
1	15 – 30	75.8	11.5	12.7	Sandy loam	6.2	0.49	0.294	3.99	2.84	1.8	0.17	0.13	4.94	3.44
2	15 – 30	80.1	11.5	8.4	Sandy loam	7.7	0.49	0.282	2.99	2.52	1.99	0.24	0.19	4.94	4.86
3	15 – 30	76.9	10.3	14.9	Sandy loam	6.1	0.45	0.284	3.98	2.98	1.17	0.16	0.16	4.47	3.58
Average	15 – 30	77.9	11.2	12		6.5	0.48	0.285	3.65	2.79	1.65	0.19	0.16	4.8	3.97
LSD (p≤0.05) (Location)		NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (p≤0.05) (Depth)		3.37	2.88	NS		NS	NS	0.0067	NS	NS	NS	NS	NS	NS	NS

Note: LSD = least Significance differences, NS = Not Significant, EC = Electrical Conductivity, OC = Organic Carbon, AP = Available Phosphorus, Ca = Calcium, Mg Magnesium, Na = Sodium, K = Potassium, CEC = Cation Exchange Capacity, ESP = Exchangeable Sodium Percentage.

The clay contents were 9.7% (surface) and 11.9% (subsurface). These results corroborate with that of Abdul Hady (2005) which showed that the values of sands in Maiduguri decreases with depth while fine particles (silt and clay) of soil increases with depth. The soil reaction (pH) ranged from 6.5 at the surface to 6.7 in the underlying soil of North wing; and 6.2 (surface) to 6.5 (sub-surface) in South wing with averages of 6.5 and 6.6 surface and sub-surface respectively. This indicates that, the soil in the area was slightly acidic. The results were within the ranges reported by Abdul Hady in 2005 and Bashir, *et al.*, 2017 in the same environment. Electrical conductivity of the soils ranged from 0.41-0.51 dSm⁻¹ with means of 0.45 dSm⁻¹ (surface) and 0.48 dSm⁻¹ in both wings. This result was similar to that of Landon (1991), who stated that an EC value of 0.02-0.59 dSm⁻¹ indicates low salt contents. The average values of ESP were 3.58% (surface) and 3.97% (sub-surface) at both wings. There was no significant difference (P=0.05) for pH, EC and ESP in both wings and depths. In determining the salinity/sodicity of soils, the U.S Salinity Laboratory Staff (1954) provides the critical limits for EC (dSm⁻¹), ESP(%) and pH respectively as >4, <15 and <8.5 for saline, >4, >15 and <8.5 for saline sodic, and <4, >15 and >8.5 for sodic soils. As the EC, ESP and pH values for the studied area were less than critical values (Table 1), the soils could be said to be normal, by implication, salinity/sodicity problems are not expected and would not cause any problem in the farm for now. Average values of organic carbon were low, with 2.93 gkg⁻¹ and 2.84 gkg⁻¹ for both surface and sub-surface, which shows a decrease in organic carbon content with depths, and were not significantly (varied) between the wings with less uniform distribution among depth. Omeje (1991) stated that organic carbon content of Chad Basin ranged from 0.069-1.46% with a C:N ratio of 3.05-3.64 which is similar to the results obtained in the study area. Available Phosphorus contents were 3.40 mgkg⁻¹ (surface) to 3.46 mgkg⁻¹ (subsurface) with the average of 3.98 mgkg⁻¹ (surface) and 3.65 mgkg⁻¹ (subsurface) in both wings. Higher values recorded for available phosphorus at the surface than the subsurface might be attributed to higher organic materials in that layer. The average value of potassium in the study area was 0.16 cmol(+)kg⁻¹ in both surface and subsurface of both wings which indicate no significant differences (P=0.05) at all levels. This indicates that potassium content was moderate in the site and the results tallied with that of Abdul Hady (2005), who reported that potassium was moderate in soils of Maiduguri. Mean calcium content were 2.61 cmol(+)kg⁻¹ (surface) and 2.73 cmol(+)kg⁻¹ (sub-surface) in the studied area. Magnesium varied from 1.45 cmol(+)kg⁻¹ (surface) to 1.63 cmol(+)kg⁻¹ (sub-surface) which showed that there was more magnesium at sub-surface than surface. Both Ca and Mg values did not vary significantly (P=0.05) between wings and between depths. Sodium content also ranged from 0.18 cmol(+)kg⁻¹ (surface) to 0.20 cmol(+)kg⁻¹ (subsurface) in the site. The slightly higher values of exchangeable cations in the study area was also reported by Kargo and Adnan (1985) who observed that calcium dominated the exchange complex followed by magnesium and potassium with values of Sodium as the lowest. Low cation exchange capacity (CEC) of 4.39 cmol(+)kg⁻¹ (surface) and 4.72 cmol(+)kg⁻¹ (subsurface) were recorded in Lake-Alau. The low values of CEC could be possibly attributed to the dominance of sand fractions in the area. This finding was in agreement of the result obtained by Nwaka (1995), who obtained low values of CEC of 6.0 cmol(+)kg⁻¹ for sandy soil and 20 cmol(+)kg⁻¹ for clay in dispersion of soil in Borno State.

Table 2 showed the distribution of some chemical properties of water in Lake Alau. pH values of in-take, in-field and field-drain were recorded as 7.8, 6.9 and 7.5 respectively.

Table 2. Some Chemical properties of water in Lake-Alau Dam

	pH	EC	TDS	P	K	Ca	Mg	Na	SAR
			←	mg ^l ⁻¹	→		←	meq ^l ⁻¹	→
In-take	7.8	0.61	390.4	2.94	0.85	2.81	1.26	2.40	1.72
In-field	6.9	0.72	460.8	3.01	1.07	4.37	1.55	2.50	1.43
Field-drain	7.5	0.81	518.5	4.18	1.28	5.42	2.63	3.20	1.32
Mean	7.4	0.71	456.3	3.38	1.07	4.20	1.81	2.70	1.49

Note: EC = Electrical Conductivity, TSD = Total Dissolved Salt, P = Phosphorus, K = Potassium, Ca = Calcium, Na = Sodium, SAR = Sodium Absorption ratio

These values are within the acceptable of pH range (6.3 to 8.1) required for irrigation as reported by Salifu *et al.* (2017) in western Ghana. The results indicated that there was an increase in pH of water from In-field to Field-drain probably due to the addition of certain materials (dissolve salts) in the water because high concentration of such salts in the solution might raises the pH of the water. Electrical Conductivity was low at all the three points (0.61, 0.72 and 0.81) dSm⁻¹ showing an increasing trend from the source to field-drain and is not saline, with Total Dissolve salt (TDS) of 390.4, 460.8 and 518.5 mg^l⁻¹ for in-take, in-field and field-drain respectively. Tahir (1991) reported that when saline-sodic water with EC of 2.5-5.8 dSm⁻¹ and SAR of 13-26 was used for irrigation, it reduces sodium to the exchange complex of soil and reduces infiltration rate and permeability of soils. However, Jurinak *et al.* (1984) reported that any water with an EC >2 dSm⁻¹ and SAR value >6 is not recommended for irrigation. Recently, such EC value is far below the lower limit (<4 dSm⁻¹) considered as not suitable for irrigation, and similar result was obtained by Bashir *et al.* (2017) which considered the water as excellent for irrigation. Based on Ayers and Westcott (1985) degree of restriction on use of water classification, water with TDS values less than 450 mg/l are described as “None” and considered suitable or good for irrigation (Bashir *et al.*, 2017). Phosphorus content in water ranged from 2.94 mg^l⁻¹ (in-take), to 4.8 mg^l⁻¹ (Field-drain) with mean value of 3.38 mg^l⁻¹. The values of potassium content varied from 0.85 - 1.28 mg^l⁻¹ with mean value of 1.07 mg^l⁻¹. All the values of potassium under the three stages are within the acceptable limit of <21.07 mg^l⁻¹ as reported by Reddy (2013). Mean values of calcium, magnesium and sodium were recorded as, 4.20, 1.81 and 2.70 meq^l⁻¹ respectively. There was an increase of macro-element concentration as water moved from In-take to Field drain. The concentration of soluble salts especially phosphorous and Potassium were generally higher at field drains which may be due to chemicals from either fertilizer or organic materials dissolved in the field and lowest concentration was normally found at the intake stage. The values of SAR in water were 1.72 (in-take), 1.43 (in-field) and 1.32 (field-drain), the values decreased as water moved from in-take to field-drain. The values recorded are less than the SAR value of 10 which is classified as excellent for irrigation use (Sadashivaiah *et al.*, 2008). Lower ranges of 0.3 – 3.5 were considered normal for irrigation purposes (Al-Ahmadi, 2013 and Bashir, 2017).

CONCLUSION AND RECOMMENDATIONS

The results of the study indicated that, soils were loamy sand and slightly acidic to neutral in reaction, low in exchangeable bases and nutrient elements, pH, SAR and EC values were also low (7.42, 1.49, 0.17), implying the soil is non-saline, and could be use for vegetable production. The water used for irrigation was non-saline, and the results showed increasing

pH, TDS exchangeable Bases, EC, and decreasing SAR values as water moved from the source to field drain. The general salinity level for water was low and may not likely contribute to soil salinity problems in the soils of the study area. Organic and inorganic materials need to be in-cooperated into the soil to raise the fertility status of the soils.

REFERENCES

- Abdul-Hady, M. (2005). Relations between Soil Properties and Soil moisture contents using path analysis, *Appl. Sci.* J20:358-370.
- Al-Ahmadi, M.E. (2013). Hydro chemical characterization of groundwater in wadi Sayyah, Western Saudi Arabia. *Appl. Water Sci.* 3:721-732.
- Anderson, J. S. and Ingram, J. I. S. (1998). *Tropical soil biology and fertility*. A Hand Book of Methods (second edition), information press, U.K. 221pp.
- Arku, A. Y., Musa, S. M., Mofoke, A. E. and Dibal, J. M. (2011). Re-examining raweffluents from Nigerian Bottling Company Maiduguri for crop irrigation. *J. Appl. Phytotechnol. Environ. Sanit.* 1(1):43-49.
- Asch, F., Doflin, K. and Biswa, T. (1995). Respose of Rice variety to salinity and air humidity. A possible involvements of root-bone ABA; 177:11-19.
- Ayers, R.S. and Westcott, D.W. (1985). Water quality for agriculture (No.29): Food and Agriculture Organization of the United Nations, Rome, Italy.
- Bhatt, M.J., Patel, A.D., Bhatti, P.M. and Pandey, A.N. (2008). Effect of soil salinity on growth, water status and nutrient accumulation in seedlings of *Ziziphus mauritiana* (RHAMNACEAE). *Journal of Fruit and Ornamental Plant Research*, 16, 383–401.
- Bohnert, H. J. (2007). *Abiotic Stress*: John Wiley & Sons, Ltd.
- Bower, C. A. and Wilcox, L. V. (1965). Soluble salts. In C.A. Black (ed) *Methods of Soil Analysis* part 1. Agron No. 9 Madison Wisconsin U.S.A 768pp.
- Bray, R. H. and Kurtz, L. T. (1945). Determination of total Organic and Available Form of P in Soils. *Soil Science Journal*, 59, 39-45.
- Charman, P.V.E. and Murphy, B.w. Eds. (2000). *Saline Soil their properties and managements*. Oxford University, South Melbourne.
- Dammo, M. N., Ibn Abubakar, B. S. U. and Sangodoyin, A. Y. (2015). Quantitative analysis of rainfall variations in northeastern region of Nigeria. *Journal of Agricultural and Crop Research*, Vol. 3(5), pp. 67-72.
- Esu, I. E. (1991). Detailed soil survey of NIHORT Farm at Bunkure, Kano State, Nigeria. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. 72 pp.
- Gorji, T., Yıldırım, A., Sertel, E. and Tanık, A. (2019). Remote sensing approaches and mapping methods for monitoring soil salinity under different climate regimes. *International Journal of Environment and Geoinformatics* 6(1): 33-49.

- Grunwald, S., Vasquesy, G.M. & Rivero, R.G. (2015). Fusion of soil and remote sensing data to model soil properties. *Advances in Agronomy*, 131, 1-109.
- IITA, (1979). International Institute of Tropical Agriculture. Selected Method of Soil Analysis. Manual Series No.1 Revised Edition. IITA Ibadan, Nigeria. 70pp. Istanbul+5: Reviewing and Appraising Progress Five Years After Habitat II.
- Jamil, A., Riaz, S., Ashraf, M. and Foolad, M.R. (2011). Gene expression profiling of plants under salt stress. *Crit. Rev. Plant Sci.* 30(5):435–458.
- Jurinak, J.J., Amerhein, C., and Wagenet, R.J (1984). Sodic hazard: the effect of SAR and salinity in soils and overburden materials. *Soil Science* 137:152-158.
- Kargo, H. and Adnan, M.Y. (1985). United concept of salts stress in plants, Genetic Engineering Regulations. *Journal of Chemical Engineering* 20:235.
- Landon, J.R. (Ed.), (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.
- Metternicht, G.I. and Zinck, J.A. (2003). Remote sensing of soil salinity: potentials and constraints. *Remote Sens. Environ.*, 85, 1–20.
- Mulder, V.L., Bruin, S. De, Schaepman, M.E. and Mayr, T.R. (2011). The use of remote sensing in soil and terrain mapping, A Review. *Geoderma*, 162, 1–19.
- Munns, R. (2002). Comparative physiology of salt and water stress. *Plant, Cell & Environment*, 25(2), 239-250.
- Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59, 651-681.
- Murphy, J. and Riley J. P. (1962). A modified single solution method for the determination of phosphate in natural water. *Anal. Chem. Act*, 27:31-36.
- Nwaka, G.I.C. 1995. The Dune soil of Borno, *Animal of Borno* 10:262-285.
- Omeje, M.U. (1991). The Fertility status and constraints of Chad Basin Soils. In Gadzama, N.M. et al (eds.). *Arid Zone Hydrology and Water Resources*. University of Maiduguri Press. pp.277-290.
- Patel, B.B., Patel Bharat, B. and Dave, R.S. (2011). Studies on infiltration of saline–alkali soils of several parts of Mehsana and Patan districts of north Gujarat. *J. Appl. Technol. Environ. Sanitation*. 1(1):87–92.
- Pooja, S. and Rajesh, K. (2015). Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation *Saudi Journal of Biological Science*. 22(2): 123–131.
- Reddy, K. S. (2013). Assessment of groundwater quality for irrigation of Bhaskar Rao Kunta watershed, Nalgonda District, India. *Int. J. Water Resour. Environ. Eng.* 5(7):418-425.

- Sadashivaiah, C., Ramakrishnaiah, C. R. and Ranganna, G. (2008). Hydro chemical analysis and evaluation of groundwater quality in Tumkur Taluk, Karnataka State, *India. Int. J. Environ. Res. Public Health* 5(3):158-164.
- Salifu, M., Aidoo F., Hayford M. S., Adomako, D. and Asare, E. (2017). Evaluating the suitability of groundwater for irrigational purposes in some selected districts of the Upper West region of Ghana. *Appl. Water Sci.* 7(2):653.
- Serrano, R., Culianz-Macia, F. and Moreno, V. (1999). Genetic engineering of salt and drought tolerance with yeast regulatory genes. *Scientia Horticulturae*, 78, 261-269.
- Smadema, L.K. (2000). Global drainage need and challenges. The role of drainage in today's world. 8th Edition New Delhi.
- Tahir, H., Shahid, M. S., Abbas, M., Jilani, G. and Javaid M. A. (1991). Brackish Ground water use technology in salt affected soils through soil fertility management. *Journal of Drainage Irrigation* 3, 20-24.
- Ülker, D., Ergüven, O. and Gazioğlu, c. (2018). Socio-economic impacts in a Changing Climate: Case Study Syria. *International Journal of Environment and Geoinformatics (IJEgeo)*, 5(1), 84-93.
- Walkley, A. and I.A. Black. (1934). An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and inorganic soil constituents. *Soil Sci.* 63:251-263.
- Yensen, N. P. (2008). Halophyte uses for the twenty-first century. In: Khan M.A., Weber D.J., editors. *Ecophysiology of High Salinity Tolerant Plants*. Springer; Dordrecht. pp. 367–396.