

## EVALUATION OF SOIL AND WATER QUALITY OF LAKE GERIO IRRIGATION SCHEME, YOLA, ADAMAWA STATE, NIGERIA

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### **Abstract**

*Soil and water quality of Lake Gerio Irrigation Project were evaluated to ascertain their quality for irrigation purposes. Representative soil samples were randomly taken from phase 2B and phase 3B of the Irrigation Project at a depth of 0 – 10, 10 – 20 and 20 – 30 cm, respectively below the soil surface. Soil texture was determined and found to be predominately clay loam. Three water samples were also collected from the lake, main canal and River Benue. All the samples (soil and water) were analyzed for their chemical constituents. The result showed that the chemical compositions of the soil were within the standard acceptable limits (pH ranged from 6.36 to 6.46, EC ranged from 0.35-0.60 dS/m, TN ranged from 0.02-0.60%, Mg<sup>++</sup> ranged from 1.94-3.23 mg/l, Ca<sup>++</sup> ranged from 4.80-6.87 mg/l, Na<sup>+</sup> ranged from 0.58-0.90K<sup>+</sup> ranged from 0.63-1.20 mg/l, TEB ranged from 9.7-11.23 and TEA range 0.80-1.53. Chemical composition of Water indicated that (pH ranged from 6.95-7.13, EC ranged from 1.35-1.60 dS/m, TDS range 864-1024 ppm, Na<sup>+</sup> ranged from 1.70-1.96 mg/l, Mg<sup>++</sup> ranged from 1.00-2.00 mg/l, Ca<sup>++</sup> ranged from 2-6 mg/l and SAR ranged from 0.95-2.44. The results were subjected to analysis of variance (ANOVA) and the means were compared using the least significant difference (LSD). It was found that there was no significant difference among the parameters determined at 5% level of significance. The results of soil and water analysis were within the safe limits of EC, and SAR values of  $\leq 0.75$  dS/m,  $< 10$ , respectively. Thus the soil is far from being saline or alkaline and the water had no potential hazard to the soil as well as to the crop grown in the area.*

**Key Words:** Lake Geriyo, Evaluation, Soil, Water quality, Irrigation

### **1.0 Introduction**

The increasing need for crop production for the rising population is causing the rapid expansion of irrigation throughout the world [1]. Irrigation in Nigeria has become an issue of vital importance considering present population growth rate. According to [2], irrigation allows countries to bring order wise useless land into production, help increase yield by facilitating the introduction of more productive and high value crops and promote crop intensification by reducing the fallowing period and allowing farmers to grow several crops throughout the season. [3] defined irrigation as the artificial application of water to the soil for the purpose of supplying water essential for plant growth.

However, irrigated agriculture is dependent on an adequate water supply of useable quality. Thus, understanding knowledge of irrigation water quality is critical to the management of water for long-term productivity which is related to its effects on soils, crops and its management. High quality crops can be produced only by using high-quality irrigation water keeping other inputs optimal. Characteristics of irrigation water that defined its quality vary with

the source of the water [4]. The quality of water for irrigation is determined by its chemical composition and condition of use [5]. The suitability of water for irrigation depends on a variety of factors, most relevant and important are; salinity, element toxicity and sodicity. Therefore, irrigation with waters of poor quality may negatively alter soil physical and chemical properties and, consequently, may reduce soil quality for plant growth [6, 7, 8].

Soil quality is the capacity of a specific kind of soil to function within natural or manage eco-system boundaries to sustain plants, air quality and support human health and habitation [9]. According to [10], the function of soil is generally threatened by increasing and very often conflicting demands of a constantly growing human population and its activities such as irrigation, land use and climate change. These lead to a number of physical and chemical degradation processes that affected the sustainable functioning of soils. [11] stated that soil salinization has been identified as a major process of land degradation that has been the greatest cause of decreasing productivity in many irrigation projects, particularly in the Arid and Semi-Arid lands (ASALs). Effects of salinity are manifested in loss of land, reduced rates of plant growth, reduced yields, and in severe cases, total crop failure [12]. Also, [9, 13] reported that the concept of soil quality is useful to assess the condition and sustainability of soil and to guide research, planning and conservation policy. Soil quality evaluation is a tool to assess changes in soil caused by external factors and provides information about the functional status of that soil at the time of assessment [14]. Thus this research work attempts to find out the current quality of soil and water status under irrigation so as to provide the necessary management practices to be adopted as strategies to maintain and/or improve soil status and quality of water used for irrigation to enhance increase in crop production in Lake Gerio Irrigation Project.

### **1.1 Effect of Water Quality on Soil Properties**

The normal pH range for irrigation water is from 6.5 to 8.4. Abnormally low pH may cause accelerated irrigation system corrosion where they occur. pH above 8.5 is often caused by high bicarbonate ( $\text{HCO}_3^-$ ) and carbonate ( $\text{CO}_3^{2-}$ ) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. According to [15], this alkaline water can intensify sodic soil conditions. While  $\text{EC}_w$  is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of sodium's specific detrimental effects on soil's physical properties. The SAR index quantifies the proportion of sodium ( $\text{Na}^+$ ) to calcium ( $\text{Ca}^{++}$ ) and magnesium ( $\text{Mg}^{++}$ ) ions in a sample. Calcium will flocculate (hold together), while sodium deflocculates soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems [15].

### **1.2 Effect of Water Quality on Crop Production**

Irrigation water whether of good quality or not, can have effect on plant growth, for example poor irrigation water quality with excess salt can damage plants in various ways, but the most common problems are caused by salts effecting osmotic relationship between the root and the soil moisture [16]. Water with high amount of salts can hinder the conversion of ammonium salts to nitrate by nitrifying micro-organisms in soil when used for irrigation. Furthermore, most tomato plants are more sensitive to salts during seed germination, seedling growth and when flowering or fruiting [17]. The author further stressed that the seed and seedling stages are vulnerable not only because the plant structures are immature and delicate, but also because tiny roots system draw moisture and nutrients from the soil surface where salts tend to concentrate. A

severe reduction in water infiltration rate due to water quality is usually related to either very low water salinity or to a high sodium adsorption ratio (SAR). In either case, the calcium content of the water may be at a relatively low concentration. If the calcium in the soil-water taken up by the crop is less than 2 me/l, there is a strong probability that the crop yield will be reduced due to calcium deficiency [18].

Salinity is a measure of the total amount of salt in water, when salt levels are too high, a salinity hazard may exist. Salts in soil and/or water can reduce water availability to the crop to such an extent that yield can be affected. Electrical conductivity or Total Dissolved Solids (TDS) tests are two means of measuring salinity. Electrical conductivity is a useful and reliable index for the measurement of water salinity or TDS in water. Electrical conductivity in water is due to ionization of dissolved inorganic solids (minerals, salts, elements of both cations and anions). The total amount of TDS should be used together with SAR. TDS levels below 700 mg/l and SAR below 4 are considered safe; TDS levels between 700 and 1,750 mg/l and SAR levels between 4 and 9 are considered slightly safe, while levels above these are considered hazardous to any crop. Properties of soil, ground water and landscape interact with the salinity of the irrigation water to either increase or decrease the salinity hazard [19].

Lake Gerio Irrigation Scheme is an irrigation scheme established by the Federal Government of Nigeria aimed at increasing crop production and livelihood of the ever increasing population. Irrigation activities have been going on in the area for over 30 years. It is imperative that good quality water should be used to sustain the soils in the area. However, continues irrigation of soil may pose adverse effect on both the soil and water quality, thereby reducing the crop yield. This can be as a result of poor water quality and soil infertility in the area. In irrigation, poor water quality with excess salts affect plants in many ways, but the most common problems are caused by salts which influence the osmotic relationship between roots and soil moisture [16]. Thus, knowledge of the soil and water quality status within a potential irrigation area is essential for economic and technical reasons. Hence this study was carried out to evaluate some physico-chemical properties of soil and water to ascertain the quality of water used for irrigation and soil properties to provide the necessary management practices to be adopted as strategies to maintain and/or improve the salinity status of the soil to enhance crop production at Lake Gerio Irrigation Project.

## **2.0 Materials and Methods**

### **2.1 Study Area**

The study area is Lake Gerio irrigation project located at the north western part of Jimeta, Yola North Local Government Area of Adamawa State. It is bounded between latitude 19° 16' to 91° 9'N and longitudes 12° 21' to 22°18'E (Fig. 1). It covers an area of 850 ha with 320 ha currently under cultivation. The area has two major seasons, the rainy and the dry season. The rainy season lasts from the beginning of May to the end of October, while the dry season last from November to the end of April. The driest months are January and February where the average minimum relative humidity is 13%. The wettest months are August and September [20] where depth of rainfall reaches up to 25% of the total annual rainfall. The hottest month is April with monthly average temperature of 39.7°C. While the coldest months are December and January with minimum average temperature of 16°C [21].

## 2.2 Soil Samples Collection

Soil samples were taken from the experimental sites (phase 2B and 3B) designated as part A and B respectively. Randomized complete block (RCB) designs were used in sampling the sites. In each part, three blocks of 0.24 ha were designed (i.e. designated as plot A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub> and B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub>) and from each plot, three composite soil samples were randomly taken at different depths (0-10) cm, (10-20) cm and (20-30) cm, using an auger and assigned as:

Plot A: A<sub>1,1</sub>, A<sub>1,2</sub>, A<sub>1,3</sub>, A<sub>2,1</sub>, A<sub>2,2</sub>, A<sub>2,3</sub>, A<sub>3,1</sub>, A<sub>3,2</sub>, and A<sub>3,3</sub>, Plot B: B<sub>1,1</sub>, B<sub>1,2</sub>, B<sub>1,3</sub>, B<sub>2,1</sub>, B<sub>2,2</sub>, B<sub>2,3</sub>, B<sub>3,1</sub>, B<sub>3,2</sub>, and B<sub>3,3</sub>. A total of 18 soil samples were collected as shown in Table 1. The soil samples collected were kept in polythene bags and then transported to the Department of Soil Science laboratory, Modibbo Adama University of Technology Yola for analysis.

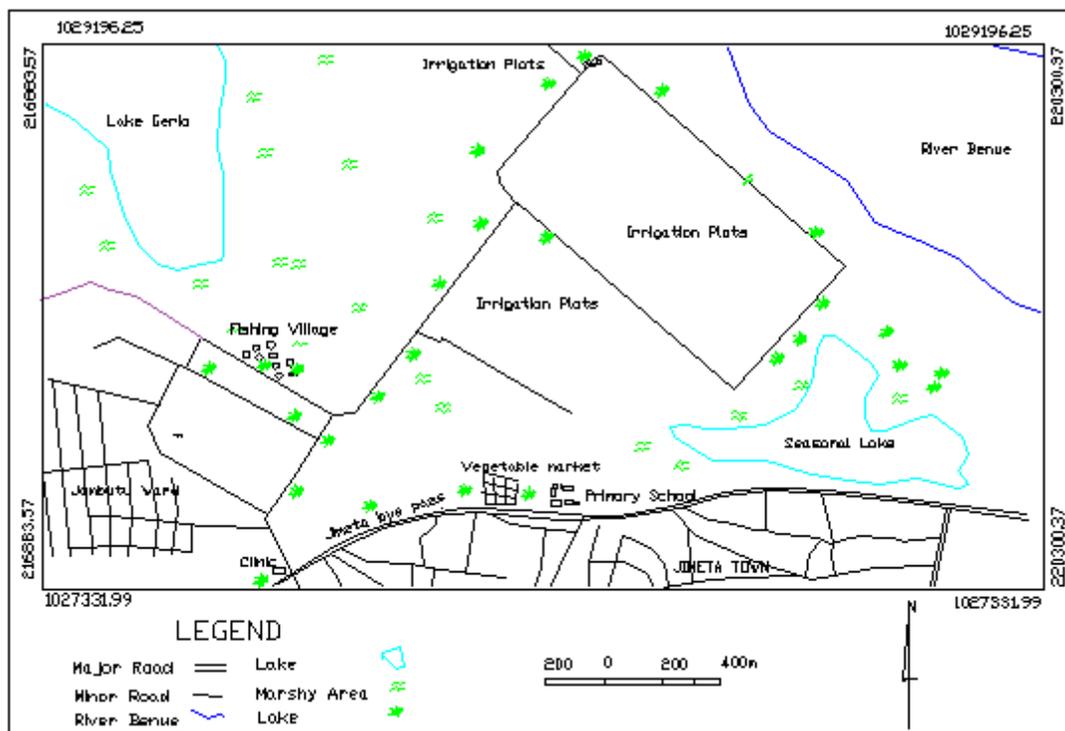


Fig. 1: Location Map showing the Sampling area of the Irrigation Project.

Table 1: Soil Sample Collection Distribution

Depth of sampling (cm)	Plot A		
	Plot A1	Plot A2	Plot A3
0-10	A11	A21	A31
10-20	A12	A22	A32
20-30	A13	A23	A33
Depth of sampling (cm)	Plot B		
	Plot B1	Plot B2	Plot B3
0-10	B11	B21	B31
10-20	B12	B22	B32
20-30	B13	B23	B33

### 2.3 Water Sampling Collection

The water samples were collected from the main storage reservoir (lake) at three different stations, main canal (at two stations upstream and downstream) and were thoroughly mixed to make a representative sample (designated as L, M) and from River Benue (R). The samples collected were kept in containers that were thoroughly washed to avoid any contamination and they were immediately taken to the Department of Soil Science laboratory, Modibbo Adama University of Technology, Yola for analysis

### 2.4. Determination of Soil Textual Classification

The soil samples were dried under room condition for three days; the samples were then crushed and sieved through a 2 mm square grid for analysis. The textural classification of the soil was determined as detailed by [22] and showed that the soil was predominately Clay loam in texture as shown in Table 2.

**Table 2: Soil Textural Classification of Geriyo Irrigation Project**

Location	Depth (cm)	%Sand	%Clay	%Silt	Textural Classification <sup>a</sup>
Phase 2B	0 – 10	39.30	31.00	28.80	Clay loam
	10 – 20	32.70	37.20	30.10	Clay loam
	20 – 30	36.00	34.50	29.50	Clay loam
Phase 3B	0 – 10	38.70	36.50	24.80	Clay loam
	10 – 20	35.30	34.50	30.10	Clay loam
	20 – 30	36.70	35.20	27.50	Clay loam

a = Based on USDA Soil Textural Classification

### 2.5 Determination of Soil Chemical Properties

The chemical Properties analyzed include pH, EC, total nitrogen, exchangeable bases (K, Ca, Na and Mg), TEB, TEA, ECEC, ESP and SAR. Cation exchange capacity (CEC) was determined using 1 M ammonium acetate (NH<sub>4</sub>OAc) at pH 7 (neutral NH<sub>4</sub>OAc) method [23]. Exchangeable bases (K, Na, Ca, and Mg) were extracted using ammonium acetate extraction technique. In the extract, K and Na was determined by flame photometry [24] while Ca and Mg were determined by titration method of determining CEC. Total nitrogen was determined by Macro-Kjeldahl-distillation method. Soil pH measurement was made in 1:1 soil-water ratio on a pH meter. Electrical conductivity (EC) was determined in a 1:5 soil-water extract at 25°C on a Cole Parmer model conductivity meter, the values were multiplied by a factor of 6.4 to obtain EC of saturation extract, Al<sup>3+</sup> and H<sup>+</sup> was determined by titration method of determining effective CEC. From the chemical data obtained, sodium adsorbed ratio (SAR) and exchangeable sodium percentage (ESP %) was calculated using expressions developed by [25, 26].

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}[(Ca^{2+})+(Mg^{2+})]}} \quad (1)$$

where ; Na<sup>+</sup>, Ca<sup>2+</sup> and Mg<sup>2+</sup> are expressed in meq/l

$$ESP = \frac{\text{exchangeable } Na^+, \text{ cmol ckg}^{-1}}{\text{cation exchange capacity, cmol ckg}^{-1}} \times 100\% \quad (2)$$

## **2.6 Water Samples Analysis**

The water samples collected were analyzed for pH, EC, TDS, Na, Ca, Mg, SAR and ESP using standard methods [27]. The pH and EC of the water samples were measured directly using pH and EC meters respectively.  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  were determined by titration method of determining CEC. With the determination of  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$ , CEC,  $\text{Na}^+$  and  $\text{K}^+$ , SAR and ESP were calculated as defined by [25,26] in equations 1 and 2.

## **3.0 Results and Discussion**

### **3.1 Chemical Analysis of Soil**

Table 3 shows the chemical parameters investigated (pH, EC, TN,  $\text{Mg}^{++}$ ,  $\text{Ca}^{++}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ , TEB, TEA, ECEC, ESP and SAR) at the depth of 0 – 10, 10 – 20 and 20 – 30cm, respectively below the soil surface in the experimental area. Table 3.1 indicates that the soil pH in phase 2B ranged from 6.37-6.50 and in phase 3B, the pH values ranged from 6.08-6.50 for the entire depth of sampling. However, lowest pH value of 6.08 was obtained in phase 3B at the depth of 0-10 cm below the soil surface. These pH values of 6.08-6.50 obtained is within the medium range class preferred by most crops including vegetables and are in the range of 5.20 -7.66 recorded in earlier studies by [28].

Table 3 shows the EC values for the entire depths of sampling of the experimental area. The EC values varied from 0.35 to 0.55 and 0.48 to 0.60dS/m for Phase 2B and 3B with an average EC value of 0.50dS/m for the entire area. The soil EC values obtained implied that Geriyo Irrigation Project soils has not reached critical stage and is safe in terms of salinity effects. Table 3 indicated that TN values ranged from 0.02 – 0.04% with an average value of 0.03% for the experimental area, which is in line with [29] who observed that in extreme cases, total nitrogen values could be 0.02% or 0.03% .

Table 3 indicated that the Calcium ion concentration values ranged for the areas between 5.33 – 6.87mg/l and 4.80 – 6.23mg/l for the depth of sampling in plot 2B and 3B, respectively with a mean value of 5.89mg/l for the area. The result is in the range of 0.90 – 11.50mg/l obtained in earlier studies by [28] for soils in Geriyo Irrigation Project, which is rated high in calcium fertility.

Table 3 shows the  $\text{Mg}^{++}$  mean values of the experimental farm which revealed that  $\text{Mg}^{++}$  values ranged from 1.94 – 6.87mg/l with an average value of 2.58mg/l for the whole experimental area. These values of  $\text{Mg}^{++}$  are within the medium range reported by [28] which are rated as high in  $\text{Mg}^{++}$  fertility.

**Table 3: Chemical Properties of Soils in Lake Gerio Irrigation Project**

Location	Depth (cm)	pH	EC (dS/m)	TN (%)	→ (mg/l)					TEB	TEA	ECEC	ESP (%)	SAR
					Mg <sup>++</sup>	Ca <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>						
Phase 2B	0 – 10	6.50	0.51	0.04	1.94	5.90	0.83	1.02	9.68	0.80	11.69	7.19	0.50	
	10 – 20	6.37	0.35	0.02	2.59	6.87	0.85	0.92	11.23	0.80	10.82	6.82	3.80	
	20 – 30	6.50	0.55	0.04	2.78	5.33	0.58	1.01	9.70	1.00	10.70	5.62	0.31	
Phase 3B	0 – 10	6.08	0.52	0.04	1.94	6.23	0.90	0.94	10.02	1.53	11.73	13.14	0.43	
	10 – 20	6.49	0.48	0.03	2.97	6.23	0.90	0.63	10.73	1.13	11.46	5.69	0.33	
	20 – 30	6.50	0.60	0.04	3.23	4.80	0.59	1.20	9.82	1.33	11.38	7.97	0.48	
MEAN		<b>6.41</b>	<b>0.50</b>	<b>0.04</b>	<b>2.58</b>	<b>5.89</b>	<b>0.78</b>	<b>0.95</b>	<b>10.20</b>	<b>1.10</b>	<b>11.30</b>	<b>7.74</b>	<b>0.98</b>	
LSD	at 5%	<b>0.37<sup>ns</sup></b>	<b>0.05<sup>ns</sup></b>	<b>0.01<sup>ns</sup></b>	<b>-5.70<sup>ns</sup></b>	<b>0.83<sup>ns</sup></b>	<b>6.07<sup>ns</sup></b>	<b>0.19<sup>ns</sup></b>			<b>-2.61<sup>ns</sup></b>	<b>2.25<sup>ns</sup></b>	<b>0.89</b>	

LSD = list significant difference, ns = not significant

Table 3 also shows the mean values of sodium ion concentration, potassium, TEB, TEA, EC, ESP and SAR for the depth of soil sampling in the experimental farm. Table 3 showed that mean values of sodium ion concentration, potassium, ECEC, ESP and SAR were 0.78, 0.95, 10.20, 1.10, 11.30 mg/l, 7.74 and 0.98, respectively. The result implies that sodium ion concentration is suitable for plant growth and when in excess will increase the soil osmotic pressure, thereby reducing the crop growth and subsequently low yield. Also, potassium ranged between 0.08 – 3.03 mg/l and can be rated as high in potassium fertility which is in line with [28] for Gerio Irrigation Project. In addition, the result revealed that the CEC could be categorized as high and ESP non-alkali as observed in earlier report by [30, 31]. Thus the low ESP value could be attributed to the high calcium concentrations in the soils which is safe for crop production. Table 3 also shows the SAR values recorded for the soil in the experimental farm which indicates that SAR values ranged between 0.31-3.80 percent for the entire soils and had a mean value of 0.98% which is within the safe limit for soils and crop in the area.

### 3.2 Chemical Analysis of Water

Lake Geriyo, Main canal and River Benue were assessed based on EC, pH, TDS, Na<sup>+</sup>, Mg<sup>++</sup>, Ca<sup>++</sup> and SAR. Table 4 showed the values of EC, pH, TDS, Na<sup>+</sup>, Mg<sup>++</sup>, Ca<sup>++</sup> and SAR for the study area. Table 4 revealed that EC values ranged from 1.35 to 1.60 dS/l with a mean value of 1.50 dS/l. The EC values in the range of 1.35 -1.60 dS/l are in the range of 0.07 to 3 dS/l recorded in earlier studies [32]. Thus, the water in Geriyo Irrigation Project could be categorized as salinity free.

Table 4 shows the pH values of the experimental area of the Geriyo Irrigation Project which indicated that pH values ranged from 6.95 to 7.10 with a mean value of 7.04. The result is slightly greater than the mean value of 6.78 earlier reported [28] for Gerio Irrigation Project. The slight increase in pH values could be due to yearly use of chemicals on the farm which is washed into the lake and the water from river Benue. In addition Table 4 shows the TDS values of the three locations ranged from 864 – 1024 ppm with a mean value of 962 ppm. The result is higher than the mean value of 192 mg/l earlier obtained by [28] for Gerio Irrigation Project. Irrigation water with total dissolved solids (TDS) less than 450 ppm is considered good, and that with greater than 2000 ppm is not suitable for irrigation purpose [33]. Therefore, the water samples analyzed could be considered safe for irrigation in line with [34, 35].

**Table 4: Chemical Properties of Water in Geriyo Irrigation Project**

Sample	EC (dS/m)	Ph	TDS (ppm)	Na <sup>+</sup> (mg/l)	Mg <sup>++</sup> (mg/l)	Ca <sup>++</sup> (mg/l)	SAR
L	1.60	7.03	1024	1.78	1.00	6.00	0.95
M	1.35	6.95	864	1.70	1.50	2.00	1.28
R	1.56	7.13	998	1.96	2.00	3.00	2.44

L = lake; M = main canal; R = River Benue

Table 4 shows the values of Sodium (Na<sup>+</sup>) observed in the area, Table 3.2 revealed that Na<sup>+</sup> values ranged from 1.78 to 1.96 mg/l with an average value of 1.81 mg/l. These Na<sup>+</sup> values obtained indicate that soils in Geriyo Irrigation Project are free from risks of sodium toxicity. Also, Table 4 shows the Magnesium and calcium ion concentration in the lake, main canal and River Benue, respectively. Table 4 indicates that magnesium and calcium ion

ranged between 1.00-2.00 and 2.00-6.00 mg/l for lake, main canal and river Benue, respectively. Table 4 shows the SAR values of water obtained for the study area. Table 4 indicates that SAR values recorded varied from 0.95 – 2.44 for lake, main canal and river Benue with a mean value of 1.56 for the entire water in the study area. The result is below the mean value of 2.38 earlier reported by [28] for Lake Gerio Irrigation Project. [29] classifies SAR values below 10 as low. Thus, as SAR is a factor of sodium against calcium and magnesium, the low values recorded may not be a surprise as the sodium values are also relatively low. These further elaborate the zero risk factor associated with these irrigation waters.

#### **4.0 Conclusion**

The soil textural classification of the experimental area is predominantly clay loam. This means that there will be drainage and permeability problems because of the higher percentage of clay recorded. The parameters measured in relation to salinity (pH, EC, Na and SAR) indicated that the soil is far from being saline or alkaline. The results obtained for water analysis indicated that irrigation water at Geriyo irrigation project is good for irrigation and has no potential hazard to the soil as well as to the crops grown in the area. Thus soil and irrigation water at Geriyo irrigation project is safe for irrigation purposes.

#### **References**

1. Farnji, K.K. and Mahajam I.K (1996). Irrigation and Drainage in Nigeria. Food and Agricultural Organization, Year book 1968, Vol. 22 International Commission on Irrigation and Drainage, New Delhi.
2. Moigne, G.L (1991). Water Resources in the 1990s. In Garbus, L., Pritchard, A. and Knudsen, D. (ed). Agricultural Issues in the 1990s. Proceedings of the 11th Agricultural Sector Symposium. World Bank, pp. 123-128.
3. Carran, A. J (1988) Measuring and Improving Irrigation System Performance at the field level, in irrigation Australia 1998 conference: water essential for life. Melbourne (Ed. Connellan G. J) pp 190-199.
4. APHA., (2005). Standard methods for examination of water and wastewater. 21st ed. American Public Health Association, Washington DC, USA.
5. Faruq, I.M., M. Jahangir and A.S. Al-Shareef (1996). Chemical characteristics of Saudi ground water, Al-Qassim. Bio. Sci. J. Biol. Soc. 4: 123-140.
6. Oster, J.D., (1994). Irrigation with poor quality water. J. Agric. Water Management. 25, 271– 297.
7. Oster, J.D., Shainberg, I. (2001). Soil responses to sodicity and salinity: challenges and opportunities. Aust. J. Soil. Res. 39, 1219–1224.
8. Buckland, G.D., Bennett, D.R., Mikalson, D.E., de Jong, E. and Chang, C., (2002). Soil salinization and sodication from alternate irrigations with saline- sodic water and simulated rain. Can. J. Soil Sci. 82, 297– 309.
9. Karlen, D. L., Mausbach, M. J., Doran, J. W., Cline, R. G., Harris, R. F., and Schuman, G. E. (1997). Soil quality: A concept, definition and framework for evaluation. Journal of Soil Science Society of America Journal, 61, 4–10.
10. European Environment Agency/United Nation Environment Programme (2000). Down to Earth: Soil degradation and Sustainable Development in Europe – a Challenge for

- the 21st Century. Environmental Issue Report 16. Copenhagen: EEA and United Nations Environment Programme Regional Office for Europe.
11. FAO (2000). Global Network on Integrated Soil Management for Sustainable use of Salt affected Soils. Pp 13.
  12. Rhodes and Loveday (1990). Salinity in Irrigation Agriculture. **In:** Stewart B.A. and D.R. Nielson's Irrigation of Agricultural Crops. Agronomy no 30. pp 1089-1139.
  13. Doran, J. W., and Jones, A. J. (1996). Methods for assessing soil quality. *SSSA Special Publication* 49. Madison, WI: Soil Science Society of America.
  14. United States Department of Agriculture (2001). Soil Quality-Introduction. Soil Quality Information Sheet. United States Department of Agriculture, Natural Resources Conservation Service-Quality Institute. Web page (reference: soils.usda.gov/sqi/files/sq\_one\_1.pdf). Pp. 12.
  15. Mass., (1990).Crop salt tolerance. In: Agricultural Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp. 262-304.
  16. Malash, N., T.J Flowers and Ragab. R (2005). The Effect of irrigation systems and water management practices using saline and non-saline water on tomato production. *J. Agric. Water. Management*, 78:25-38.
  17. Breckle, S.W., (1995). The significance of salinity in water, desertification and development, dry land Ecology in social perspective, Academic press, London, and New York, pp: 277-292.
  18. Rhoades, J.D. (1982). Cation exchange capacity. *In:* A.L. Page (ed.) Methods of soil analysis. Part 2: Chemical and microbiological properties (2nd ed.) Agronomy 9:149-157.
  19. Peterson, H.G., (1999). Water Quality and Micro-irrigation for Horticulture [http://www.safewater.org/PDFS/resources/water\\_quality/info/Resource\\_Water\\_Qual\\_Facts.pdf](http://www.safewater.org/PDFS/resources/water_quality/info/Resource_Water_Qual_Facts.pdf).
  20. Adebayo, A.A (1997). The Agroclimatology of rice production in Adamawa State PhD Thesis Dept of Geography F.U.T. Minna Nigeria. Pp 78.
  21. Adebayo, A.A., Tukur A.E (1999). Adamawa State in map (Editor).Dept., Geography, F. U. T. Yola 1st Ed Paraclete Publishers Yola, Nigeria, 33: 112.
  22. Love day, J. (1974) Method for Analysis of Irrigation Soils. Tech. communication, No. 45 of Common Wealth Bureau of Soils Australia. 208p.
  23. Sumner, M.E. and W.P. Miller. (1996). Cation exchange capacity and exchange coefficients. In D.L. Sparks (ed.) Methods of soil analysis, Part 3. Chemical methods. Soil Science Society of America, Book series no. 5. Pp.11.
  24. Adepetu, J. A., Nabhan, H. and Osinubu A. (2000). Simple soil, water and plant testing techniques for soil resources management: proceedings of a training course held in Ibadan, IITA, 168pp.
  25. Donahue, R.L, Miller, R.W. and Chickluna, J.C. (1990).Introduction to soils and plant growth 5th Ed. New Delhi: Prentice- Hall. Pp.56.
  26. Brandy, N.C and Weil, R.R. (1999). The nature and properties of soil. 12<sup>th</sup> edition. Prentice hall inc New jersey. 118-169pp.

27. FAO (1980). *Physical and Chemical Methods of Soil and Water Analysis*. Rome, pp 30 – 208.
28. Hong A.H. (2006), *Evaluation of Soil and Water Quality under Small Scale Irrigation in Selected Vegetable Farms of Lake Gerio*. M. Eng. Thesis Department of Agricultural Engineering Federal University of Technology Yola-Nigeria. Pp.33 – 59.
29. Landon, J. R. (ed) (1991). *Booker Tropical Soil Manual*, John Wiley and Sons Inc.; New York. Pp. 113 – 115.
30. Withers, B. and Vipond, S. (1983). *Irrigation: Design and Practice*. Batsford Academic and Educational Ltd, London, Pp. 110-128. Gupta and I.C. Gupta (1997). *Management of saline soils and waters*, Scientific Publications, Jodhpur. Pp.88.
31. Shoeneberger, P. J., D. A Wysocki, E. C. Benham., W.D. Broderson (Eds) . (2002). *Field Book for Describing and Sampling soils Version 2.0* National soil Survey Center , National Resources Conservation Services, U. S. Department of Agriculture, Lincoln. Pp. 22.
32. FAO, (1985). *Guidelines. Land evaluation for Irrigated Agriculture*. Soil Bull. No 55, FAO. Rome Italy. Pp 20 – 22.
33. Bauder, T.A., R.M. Waskom, P.L. Sutherland and Davis, J.G. (2011) *Irrigation Water Quality*. Colorado State University, Extension, Crop series/Irrigation. Fact sheet No. 0.506 Pp.4.
34. Miller and Gardiner (2007). *Water Quality for Agriculture, Irrigation*. Irrigation and Drainage paper 29, rev. 1. Food and Agriculture Organization of the United Nation, Rome.