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Assessment of Irrigation Water Quality and Some Selected Physical/Hydraulic Properties of Soil at Dala Irrigation Site Maiduguri

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Abstract: *Irrigation water quality and Soil salinity were major factors limiting agricultural productivity in irrigation schemes located in semi-arid areas. A study was conducted to assess the quality of irrigation water and some selected soil physical and hydraulic properties used in Dala Irrigation site located in Maiduguri, Borno state to understand how irrigation water quality is related to quality of soils in the area. Surface water and groundwater samples from the selected study areas were collected and analyzed for Physio-chemical parameters. Several soil samples were also collected and analyzed for infiltration capacity, bulk density and textural classification. The physicochemical properties of the sampled water were determined; includes pH, electrical conductivity, temperature, total dissolved solids, major ions (Ca, Mg, K, Na, Fe, NO_3, SO_4^{2+}) were analyzed at the National Agency for Food Drugs Administration and Control (NAFDAC) zonal office Maiduguri laboratory and sodium adsorption ratio (SAR), were calculated from the significant cations studied for the criteria of irrigation water quality and suitability for irrigation. The results indicated that the groundwater had high concentrations of Ca, Mg, Mn, Fe and PH compared to the surface irrigation water source. All the Physio-chemical parameters monitored in both surface and ground water samples fell within FAO specifications for irrigation purposes. The sodium adsorption ratio index for both samples fall under Excellent and Good classification. However, the result of the soil analysis of the study area revealed that the soil were mostly sandy to sandy loam soil. While the infiltration rate and bulk density of the soil in the study area were moderate in nature.*

Key words: *Salinity, Electrical conductivity, cations, adsorption, hydraulics.*

1.0 Introduction

Water scarcity is seen as a major constraint to intensify agriculture in a sustainable manner as an attempt to meet the food requirements of a rapidly growing human population. The ever increasing human population, climate change due to increased emissions of greenhouse gases (GHGs), and intensification of agriculture, are putting severe pressure on the world's two major non-renewable resources of soil and water, and thus pose a big challenge to produce sufficient food to meet the current food demand. The present world population of 7.3 billion people is predicted to grow to over 9 billion by 2050, with the majority of this population increase occurring in developing countries, most of which already face food shortages. The injudicious use of saline/brackish water is all too often associated with the development of soil salinity, sodicity, ion toxicity, and groundwater pollution. Because of these negative effects, it is important to have a better understanding of exactly how the quality of water influences the management of irrigated agriculture, especially in arid and semi-arid regions.

Assessment of irrigation water quality is becoming an important issue considering the rapid growth of population, together with the extension of irrigation activities. Irrigation depends not only on sufficient amounts of water, but also on its good quality which is essential for the quantity of crops, maintenance of soil productivity, and protection of the environment. The quality of the irrigation water may affect both crop yields and soil physical conditions, even if all other conditions and cultural practices are optimal (FAO, 1985). Irrigation waters whether derived from springs, diverted from streams, or pumped from wells, contain appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility. In addition to the dissolved salts, which has been the major problem for centuries, irrigation water always carries substances derived from its natural environment or from the waste products of man's activities (domestic and industrial effluents). The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients (Ayers and Westcot, 1985; Rowe et al., 1995). The quality and quantities of the water used are as variable as the environmental and geological characteristics, between different seasons as affect by different factors [Ayers et al. 2007]. The variation in water quantity is directly related to productivity in irrigation in the short term while water quality affects productivity in the long term (Rauff and Bello, 2015). The main cause of salinization and sodification is the use of poor-quality irrigation water and continued use of this water leads to increasing salinization and sodification problems and ultimately results in increased cost of production and crop failures (Rauff and Bello, 2015). Salinization is especially serious where groundwater is used for irrigation with the problem being coupled by conversion from natural deep-rooted trees and shrubs to commercial shallow-rooted crops that cause the water table to rise and bring more salts with it to the upper layers (wong, et al, 2010 and mapanda, et al. 2011). In addition to effects on crop production, salinity and sodicity have been linked to environmental degradation including loss of below and above ground carbon stocks as vegetation health deteriorate and making soils more susceptible to erosion (Setia, 2012, Rahimi, 2010 and Bresler, 1981). The most common criteria considered in evaluating the quality of irrigation water are: Salinity hazard, Sodium hazard, Salt index, Alkalinity hazard, Permeability hazard, Specific ion toxicity hazards. Salinity conditions in agricultural soils have been found to vary over space and seasons (Az-Gnadji, et al, 2013). Salinity in soils develops through a rising water table and the subsequent evaporation of the soil water. There are many causes of the rising water table, e.g. restricted drainage due to an impermeable layer, and when deep-rooted trees are replaced with shallow-rooted annual crops. Under such conditions, the groundwater dissolves salts embedded in rocks in the soil, with the salty water eventually reaching the soil surface, and evaporating to cause salinity.

Irrigation water quality and quantity have direct and indirect impact on soil characteristics (physical and chemical) especially in semi-arid regions that unfortunately depend on irrigation (Rahimi, et al, 2000). The amount and kind of salts present will determine the suitability of water for irrigation. With poor water quality, various soil and cropping problems can be expected to develop there may also be significant differences in the quality of water available on a local level depending on whether the source is from surface water bodies (rivers and ponds) or groundwater aquifers with varying geology, and whether the water has been chemically treated. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients (Ayers R.S. et al., 1994). Water has unique chemical properties due to its polarity and hydrogen bonds. It is able to dissolve, absorb or suspend many different compounds. Thus in nature water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as biological activities (Aiyesanmi, A.F. 2006). Supplies of good quality water for crop irrigation, is highly necessary for irrigation monitoring for maximum crop production to ensure food security in semi- arid region. Thus, there is a high dependency on untreated water for irrigation purposes (Olubanjo, 2016). Huge amounts of low-quality water use in irrigation may result in various problems such as toxicity for crops, damage to soil quality, diffusion of parasites, and drawbacks in irrigation systems. Also, poor quality irrigation water will result in low crop production (Bortolini, 2018, Dhirendra, 2009 and Masoudi et al. 2006). Irrigation water with good quality is determined based on the characteristics necessary for plant development and growth at acceptable levels of concentrations. The objectives of the study were to (1) assess the Physio- chemical properties of the irrigation water used at Dala Alamderi irrigation project Maiduguri, Borno state and (2) determine some selected Physical and hydraulic properties of soils at the study area. (3) Compare the result of objective (1) with FAO irrigation water quality standard. It is hoped that knowledge generated from this study would guide farmers on the use of quality irrigation water to maximize the yield of crops, agricultural and environmental conditions for sustainable irrigation schemes in semi-arid regions.

2.0 Materials and Methods

2.1 Study Area

The research was conducted at Dala Alamderi Irrigation site located in Maiduguri, Borno state. It lies between latitudes 11° 45`N and 11° 51`N, Longitudes 13° 2`E and 13° 9`E and 345m above mean sea level with a mean annual rainfall of about 625mm and annual temperature of 28-40 .2°C (Adeniji et al, 2013). The climate of Maiduguri is generally semi-arid with moderate variation in temperatures; the mean monthly maximum temperature is highest (40.2°C) prior to and during the onset of the rains in April and the lowest (31.3°C) during the peak of cold in the month of January. The soils in Maiduguri is predominantly sand to sandy loam having low moisture retention and high permeability, and few places with clay to clay-loam. The crops that is mostly grown in area includes tomatoes, onion, pepper, okro, water melon etc.

2.2 Soil Sampling

The irrigation site was divided into two parts for the purpose of sample collection, which is separated by the river passing through the site. The total soil samples collected was six (6) at different points within the study area. A soil auger was used to collect the soil samples up to 30 cm depth and all sampling and sample handling as described by Okalebo *et al.* The soil samples collected were taken to laboratory for particle size analysis and bulk density test at the civil Engineering Laboratory, Ramat Polytechnic Maiduguri. While infiltration was carried out at the irrigation site using double ring infiltrometer.

2.3 water sampling

The water samples were collected the same way as the soil samples in terms of collection point. Seven (7) water samples were collected for analyzing the irrigation water to determine its quality; four (4) from the bore-hole water and three (3) from the adjacent River Ngadda which is a surface source of irrigation water. The samples were collected in clean PVC bottles washed and rinsed with distilled water. The water samples was sent for analysis at the National Agency for Food Drugs Administration and Control (NAFDAC) zonal office Maiduguri. The water samples were analyzes for pH, EC, temperature, TDS, Ca2+, Mg2+, Na+, Cl−. Potassium, Nitrate, carbonate, sulphates, iron, manganese.

2.4 Water Analysis

The Parameters such as electrical conductivity (EC), temperature and pH were determined on the site (in situ test) with standard calibrated portable pH/EC/TDS/temperature meter made by Hanna instrument, HI 93703. The analysis for Physio-chemical properties such as Ca2+, Mg2+, Na+, K+, NO3, SO42+, and Cl- with other parameters were the major ions in ground and surface water of the study area were determined using atomic absorption spectrophotometer (AAS) (Mclean, 1965). The concentration were analyzed and calculated the irrigation index based on the standard method used by Reddy in the determination of sodium absorption ratio (SAR). **2.4.**

Sodium Adsorption Ratio (SAR)
This was calculated by employing equation stated by Raghunath as:

$$SAR = \frac{Na^{+}}{\sqrt{Ca^{2+} + Mg^{2+}/2}}$$

2.4 Data Analysis

The data collected for both Physio- chemical properties of soil and water were analyzed using simple descriptive statistical analysis.

3.0 Result and Discussion

3.1 Physio-Chemical Characteristics of the River and Well Water

Physio-chemical parameters are the most important factors used in assessing the suitability of irrigation water (Rhoades, 1977, Rogers, *et al*, 2003). The mean values of the various chemical constituents when compared with the FAO, (1994) water standards for irrigation were seen to fall within the ranges recommended as suitable for irrigation (Table 3.1).

Table 3.1 Physio-chemical properties of irrigation water quality with FAO standard limit.

Parameter	A1	A2	A3	B1	B2	B3	B4	FAO
PH	5.73	5.71	7.20	6.07	6.16	6.59	7.82	6.0 – 8.5
EC	966.0	999.0	168.3	244.0	217.0	325.0	240.0	**0-** 3000mmhos/cm
Temp	27.7	26.8	21.4	27.4	27.3	27.2	25.1	25 – 30^{0}C
TDS	380.0	340.0	140.0	80.0	80.0	60.0	360.0	0 -2000mg/l
Na	30.10	41.4	42.3	18.40	24.80	36.8	76.70	0 -40me/l
Ca	1.14	1.10	1.42	2.00	1.60	2.00	1.67	0 -20me/l
Mg	0.38	0.17	0.47	0.70	0.55	0.70	0.53	0 -5me/l
Cl	108.0	133.0	140.0	27.0	27.0	40.0	100.0	0 -30me/l
Mn	0.18	0.20	0.16	0.35	0.38	0.41	0.37	0 -2mg/l
Fe	0.28	0.24	0.26	0.70	0.64	0.67	0.63	0 -1.5mg/l
SO_4	20.00	18.0	19.0	16.2	17.4	18.0	17.0	0 -20me/l
NO_3	2.30	2.50	1.92	1.80	1.70	1.90	3.14	0 -10mg//
HCO_3	16.30	15.6	14.2	9.86	11.2	10.64	10.01	0 -10me/l
K	7.30	4.40	7.30	3.90	5.00	5.40	5.10	0 -20mg/l
TH	46.0	47.0	48.0	72.0	76.0	73.0	77.0	<80mg/l

Where A1, A2 and A3 represent surface water samples, while B1, B2, B3 and B4 represent ground water samples.

The pH value ranges from 5.71 to 7.20 for surface water sources with the mean value of 6.21 which indicating the samples were neutral in nature and slightly acidic for the surface water which was comparatively lower than that of the groundwater (6.1 to 7.9) with a mean value of 6.6 which were slightly acidic unless for the sample B4 which is 7.84. The slightly acidic nature of the pH value for the surface water might be as a result of the effect of waste disposal and agro-chemicals from the upstream (Islam, et al, 2004). The range of the PH values for both surface and ground water were within the recommended FAO limit as presented in Table 3.1.

The electrical conductivities for the surface water sample sources range from 168.3 to 999.0 mmhos/cm with the mean value of 711.1 mmhos/cm in which the value is below the critical water conductivity of 5000 mmhos/cm which is within the permissible limit. While the EC values for ground water samples range between 217.0 to 325.0mmhos/cm with the mean value of 256.6mmhos/cm. An indication of this values shows that the water sources were free from salinity problems as the electrical conductivity gives a good indication of the extent of the dissolved salts.

The temperature is the most important physical variable and therefore one of the important water qualities attributes to irrigation system. In Table 3.1, the temperature value for surface water ranges from 21.4 to 27.7ºC with the mean value of 25.3ºC, while the ground water samples range from 25.1 to 27.4ºc with mean value of 26.8ºc which fell within the optimal water temperature. According to FAO the target guidelines is 25-30ºC, within which maximal growth rate of plant, efficient food conversion, best condition for aquatic lives, resistance to disease and tolerance of toxins are enhanced (Islam, et. al., 2004 and Sulchdev, 2012).

The total dissolved solids (TDS) in water is one of the essential parameters to be determined in relation to irrigation water quality level because many toxic solid materials may be imbedded in the water which may cause harm to the plants (Masoudi, et, al., 2006). TDS for the surface water samples range from 140 to 380 mg/L and ground water samples has the TDS values range from 60 to 360mg/l. The values do not exceed the critical level of 2000 mg/L recommended by FAO standard.

The sodium value for the surface water sources ranges from 30.10 to 42.3mg/l with the mean value of 37.9 mg/l and ground water samples range from 18.4 to 76.7mg/l with a mean value of 39.2mg/l. The mean values for the both samples were much closed to the critical limit of 40me/l recommended by FAO. Sodium content is an important factor in irrigation water quality evaluation. Plant roots absorb sodium and transport it to leaves where it can accumulate and cause injury. Irrigation water with high level of sodium salt can be particularly toxic if applied to plant leaves [Chang, et. al., 2001 and Masoudi, et, al., 2006].

The content of Ca in the surface water samples varies from 1.10 to 1.42 me/l with mean value of 1.22 me/l, while the groundwater water samples has values range between 1.6 to 2.0me/l with mean value of 1.82me/l. The result from the both surface and ground water samples in the study area were within the FAO standard as given in Table 3.2.

Magnesium is a significant parameter for determination of suitability of irrigation water. It is also the constituents in natural water and its salts contribute to water hardness. The concentration of magnesium ion in the surface water range from 0.17 to 0.38 me/l while ground samples contain value range between 0.53 to 0.70 me/l in the study area. All the values recorded from the both samples were within the FAO standard limit.

The chloride analyzed in the surface water samples ranges between 40 to 133 mg/L (Table 3.1) with the mean value of 93.7mg/L. The ground water samples has the range from 27 to 100mg/l with average value of 48mg/l. The water sources can be used since the values were below critical value of 355 mg/l that can result into toxic absorbed by roots and also damage sensitive ornamental plants.

Potassium is one of the natural occurring in the groundwater and surface water (Alfred, et. al., 2011(. Potassium value of the surface water ranges from 4.4 to 7.3mg/l with the mean value of 6.3mg/l. The ground water samples values range between 3.9 to 5.4mg/l with mean value of 4.8mg/l. These values were accepted limit for irrigation and agricultural use according to FAO permissible limit of the value of 20 mg/L.

Manganese (Mn) ranged from 0.16 to 0.20 mg/l and 0.35 to 0.41 mg/l for surface and ground water samples respectively. The values obtained for the both samples were within the acceptable FAO limit of 0 to 2 mg/l. The concentration of iron in surface water sample range between 0.24 to 0.28mg/l and ground water sample contain the values range between 0.63 to 0.70mg/l. All the values obtained from the samples in the study area fall below the FAO permissible limit of 1.5 mg/L. Sulphates values in the surface water sample ranged from 18.0 to 20.0 mg/l. While in the ground water, the values ranged from 16.2 to 19.0mg/l. The concentration of sulphates in both surface and ground water samples fall within the range of FAO permissible limit of 0 to 1.5me/l. The bicarbonate in the surface water ranged from 14.2 to 16.3 meq/l, while in the well water ranged from 9.86 to 11.2me/l. The mean values for the both samples were 15.4 and 10.4 meq/l respectively. The values recorded were slightly above FAO permissible limit.

3.2 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio which relates the sodium content with the dications of calcium and magnesium ranged from 5.40 to 13.8mg/l in the surface water, while the values range from 1.94 to 9.18mg/l in ground water samples of the study area as presented in Table 3.2. It was a significant parameter for determination of suitability of irrigation water. High sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability. In the study area, the SAR values obtained fall within the excellent and good classifications for ground and surface water samples respectively as indicated in Table 3.3 and also fall within the FAO permissible limit for irrigation in Table 3.1.

Table 3.2: Results for sodium adsorption ratio parameters indexes for irrigation quality of the study area

Location	Na^+	Ca^{2*}	Mg^{2+}	SAR
A1	30.1	11.4	38	6.0
A2	41.4	11.0	17	13.8
A2	42.3	14.2	47	5.4
B1	18.4	20.0	70	1.94
B2	24.8	16.0	55	2.94
B3	36.8	20.0	70	3.88
B4	76.7	16.7	53	9.18

Table 3.3: Classification of water based on SAR values

SAR Values	classification
>10	Excellent
10 to 18	Good
18 to 26	Fair
>26	poor

3.3 Physio-hydraulic properties of soil

The physical and hydraulic properties of the soil in the study area is presented in Table 3.4. The physical property of the soil analyzed was the soil textural analysis. The result of the soil randomly collected from the three locations indicated that the soil of the study area were mostly sandy to sandy loam soils. At location A and C, with 0 to 15cm and 15 to 30cm depth, the result show that the soil were sandy loam and sandy soils. While at location C, the soil at both 0 to 15cm and 15 to 30cm depth were sandy loam soils as presented in Table 3.4. The result of bulk density analysis presented in Table 3.4 indicate that location A has 1.54g/cm^3 at a depth of 0-15cm while 1.78g/cm^3 at 15-30cm with the average density of 1.66g/cm^3. The result at location B Shows the bulk density at 0-15cm is 1.54g/cm^3 and that of 15-30cm is 1.65g/cm^3 with an average value of 1.60g/cm^3. The bulk density of 1.34g/cm^3 and 1.58g/cm^3 was determined at 0-15cm and 15-30cm depth respectively at location C. All the result at the three locations indicates that bulk density at 0-15cm were less dense than that at 15-30cm depth. The infiltration rate at the three locations shows that location A has the highest infiltration rate value of 37.8cm/hr, then followed by the values at location C and B with values of 35.30 and 32.5cm/hr respectively. There was sharp initial drop in all the three location but gradually reached stable flow. This might be as result of different in the initial moisture content the area. The variation in the steady infiltration values obtained from the location would be attributed to the result of bulk density and particle size stated above.

Table 3.4. The Physical and hydraulic properties of the soil in the study area

location	Depth cm	Sand %	Silt %	Clay %	Textural class	Bulk density g/cm^3	Infiltration Rate (cm/hr)
A	0 -15	68.2	10.0	10.6	Sandy loam	1.54	37.80
	15 -30	87.5	20.4	2.0	Sandy	1.78	
B	0 -15	57.1	41.5	6.6	Sandy loam	1.54	32.50
	15 -30	62.2	28.7	8.8	Sandy loam	1.65	
C	0 -15	63.2	31.2	1.2	Sandy loam	1.34	35.30
	15 -30	86.4	6.8	0.2	Sandy	1.58	

4.0 Conclusion

An evaluation of the irrigation water quality and some selected soil physical and hydraulic properties at Dala Irrigation site Maiduguri, Borno State was carried out to determine the suitability of the water for irrigation purposes. The result of the water quality reveal that the PH value of the water was slightly acidic and slightly alkaline in nature. The temperature, EC and total dissolve solid of both surface and ground water samples fall within the FAO standard limit. The sodium adsorption ratio index for both samples fall under Excellent and Good classification. The concentration of all the parameters of the water samples fall within the tolerable limit as recommended by the FAO (1994).Hence, hazards associated with the use of both surface water and ground water for irrigation are presently very low at the study area. The soil texture in the study area range between sandy to sandy loam soils. The infiltration rate and bulk density of the study area were moderate

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