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Suitability of Different Water Sources for Irrigation in Floodplain Areas of Jalingo, Taraba State, Nigeria for Sustainable Crop Production

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ABSTRACT

Floodplains known as 'Fadama' is encouraged in Nigeria by the world bank in order to boost agriculture and food security. This activity is being managed by the State ministries of agriculture through Agricultural Development Programmes (ADPs) nationwide. This is a case study of Jalingo area of Taraba State, Nigeria where farmers used any available water from rivers, streams and wells without any regulations. The water samples for quality analysis were collected in five (5) different floodplain locations from three (3) different sources. Fifteen (15) water samples were collected from river, borehole and well using plastic bottle container both in August (peak of raining season) and November (end of raining season) respectively. Data from water samples were subjected to analysis of variance (ANOVA) to test for significant effect of source and location water quality for irrigation purposes. The suitability of the source and location water quality after comparing with the water standard for irrigation have most of their chemical properties within safe limit for irrigation purposes both in August and November respectively. (pH =6.26 to 6.81, Total Dissolved Solid, TDS = 113 to 345 mg/L, Total Suspended Solid, TSS = 1.72 to 1.95 mg/L, Bicarbonates, HCO_3 = 5.76 to 10.88 mg/L, Carbonated, CO_3 = 0.07 to 0.77 mg/L, Sodium, Na = 0.003 to 0.031 mg/L, Magnesium Mg = 4.84 to 5.93 mg/L, Calcium, Ca = 9.62 to 11.97 mg/L). From the results of the study, it could be observed that the quality of water across the locations irrespective of period of observation and source are good and hereby recommended for irrigation purposes.

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Introduction

Irrigation is an artificial application of water to the land/soils to assist in the growing of food crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during period of inadequate rainfall. Irrigation is also used in improved crop production, protecting plant against frost, suppressing weed growth in grain field and preventing soil consolidation (Snyder and Melo-Abreu, 2005).

The increasing demand of water for irrigation and more recently, climate change, are main factors affecting the hydrological cycle (Gomez and Perez-Blanco, 2014). Irrigation water whether 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 salt, which has been a major problem for centuries, irritation water always carries substances derived from its natural environment or from the waste product of flooding and man's activities such as domestic and industrial effluents. (Hassan and Mahmud, 2017). The objectives of managing the quantity, quality and reliability of the nation's water resources are to achieve optimum, long term, environmentally sustainable, social and economic benefits for the society. People may have right on water but not ownership and Nigeria has established eight hydrological areas as the basic unit of water resources management (Federal Republic of Nigeria, 2004).

Water quality is an important factor when considering irrigation programme. Quality is determined by chemical composition of the water (Rashid et al., 1994). The common quality parameters are electrical conductivity (EC), sodium adsorption ratio (SAR), carbonates and bicarbonates, toxic chemicals such as chloride (Cl), boron (B) and sodium (Na) and trace elements. Soluble salts in irrigation water if present in sufficient quantities, may have very detrimental effects on crop yield and soil quality (Michael, 1999).

Poor quality irrigation water is generally more concerning as the climate change from humid to arid conditions. Salinity is not normally a threat where precipitation is a major source of salt-free water for crop production. Water that enters the soil and is not stored or consumed by evapotranspiration moves through the crop root zone, eventually reaching the water table. This percolating process flushes soluble salts. Less rainfall means smaller amount of precipitation available to leach salts (Barden et al., 1987). If the amount of water leaching through the soil is too low to remove salts, the soil's salt content increases and crop yield may decrease. In such situations, the soil is said to be salt-affected (Boman, 2000)

Studying the different sources of water within the flood plain areas is very imperative as this would enable evaluation of the water for effective agricultural production. As the human population is increasing at an alarming rate, there is pressing need to boost food production by using available water sources for irrigation purposes. Extending crop production through irrigation activities in Fadama (floodplain) areas is a promising venture aimed at increasing food production at a sustainable level (Oruonye, 2011). The data generated from this study will tend to equip floodplain users, the necessary information that would be essential for the management of the floodplains for sustainable agriculture and environment.

Materials and Methods

Study Area

Jalingo is located between latitude 8°47' to 9°01'N and longitudes 11°o9' to 11°30'E. It is bounded to the North by Lau Local Government Area, to the East by Yorro Local Government Area, to the South and West by Ardokola Local Government Area. It has a total land area of about 198km^2. Jalingo LGA has a population of 139,845 people according to the 2006 population census, with a projected growth rate of 3%. The relief consists of undulating plain interspersed with mountain ranges. Between Kwaji-mika to the East and Kona to the West, stretching to Kassa-Gongon to the South exist this compact massif of rock outcrops. The mountain ranges run from Kona area through the border Jalingo and Lau LGAs down to Yorro and Ardo-kola LGAs in a circular form to Gongon area, this gives a periscopic semi-circle shape that is almost like a shield to Jalingo town (TSMEUD, 2012).

Water sample collection /Experimental design

In each of the floodplains, three (3) water samples were taken each in a river in August and November. Water samples were also taken in boreholes and wells in each floodplain in August and November for analysis. Three (3) samples of water were collected each from river, Borehole and well from the five floodplain areas. A total of thirty (30) water samples were collected in plastic bottles and were taken to the laboratory for analysis. The experimental design used was Complete Randomized Design (CRD) with location, source and period of observation as factors.

Laboratory Analysis

pH of water was determined on-site using a pre-calibrated pH meter with glass electrode. Conductivity meter was used to measure electrical conductivity. Argentoimetric titration technique was used to determine chloride while major cations (Na^+, Mg^{2+}, Ca^{2+}, K^+) as well as heavy metals, zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), were analysed by the atomic absorption spectrophotometer. Boron, carbonated, bicarbonates and nitrates were determined using spectrophotometer. In addition, appropriate reagent blanks were prepared for each analysis using instrumentation technique in order to ensure quality control and quality assurance. Information generated from the water analysis were matched with the water quality standards (Table 1) to assess the degree of restriction of the water (whether the water will have non, slight or severe restriction).

Results and Discussions

The suitability rating of the various water sources and their location effects for August and November, 2016 on quality of irrigation water are presented in Tables 2, 3, 4 and 5 respectively.

pH

pH influences nutrients availability and is a major indicator of other water quality parameters. Highly acidic or alkaline irrigation water may damage irrigation equipment and lead to other soil and water management problems. Highly alkaline water could intensify sodic soil conditions (USDA, 2012).

The results showed that pH did not show any significant difference ($P<0.05$) across location and source of water. Also, the interactions did not show any significant difference among the water sources. pH across the locations ranged from 6.30 (SG) to 6.81 (AK), while across three sources, pH ranged from 6.38 (WL) to 6.77 (RV). These values fall within the acceptable safe limits for irrigation water (6.5 – 8.4) as provided by USEPA (1994) and NCRS (2013). The results showed that Angwan-karofi had highest pH (6.81) even though it was within safe limits. The river water had higher value of pH (6.77) than the other water sources (Tables 2, 4).

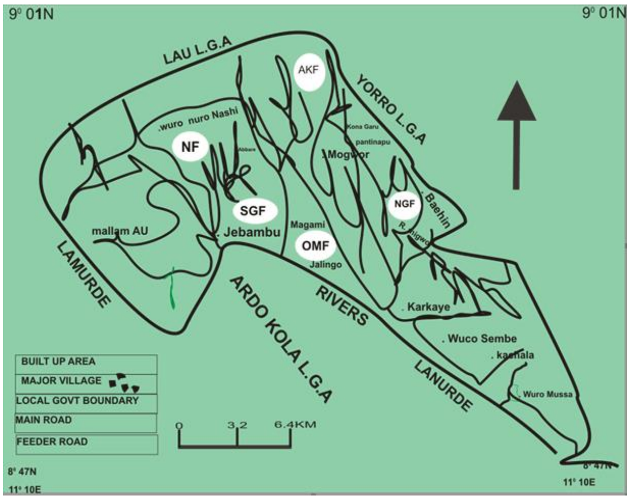

Figure 1. Map of Jalingo Local Government Area showing FloodplainAreas
Source: (TSMEUD, 2012).
KEY: MGF = Magwoi Floodplain, OMF = Old Magami Floodplain, SGF = Sabon-gari Floodplain, NF = Nukkai Floodplain, AKF = Angwan Karofi Floodplain

Table 1. Guidelines for Interpretation of Water Quality for Irrigation (FAO, 1985)

P. Irrigation Problems	Degree of Restriction			
	Units	None	Slight – moderate	Severe
Salinity				
EC_w	dSm^{-1}	>0.7	0.7 – 3.0	>3.0
TDS	mgL-1	>1.2	1.2 – 0.3	>0.3
Infiltration				
SAR2 = 0 – 3 and EC_w		>0.7	0.7 – 0.2	>2
3 -6		>1.2	1.2 – 0.3	>0.3
6 – 2		>1.9	1.9 – 0.5	>0.5
12 – 20		>2.9	2.9 – 1.3	>1.3
20 – 40		>5.0	5.0 – 2.9	>2.9
Specific ion Toxicity				
Sodium (Na)	SAR	<3	3 – 9	>9
Chloride (Cl)	me L^{-1}	<4	4 – 10	>10
Boron (B)	mg L^{-1}	<0.7	0.7 – 3.0	>3.0
Miscellaneous effect				
Nitrogen (NO_3 – N)[3]	mg L^{-1}	<5	5 – 30	>30
Bicarbonates (HBO_3)	me L^{-1}	<1.5	1.5 – 8.5	>8.5
pH	Normal range = 6.5 – 8.4			

EC_w means Electrical conductivity of irrigation water at 25°C. 2: SAR means sodium adsorption ratio. 3: NO_3-N means nitrate nitrogen reported in terms of elemental nitrogen. P: Potential

Table 2. Suitability of Water Quality for Irrigation in Jalingo Floodplains (August 2016)

Floodplain/ Sources	Water Properties						
	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)	SAR	HCo_3 (mg/L)	$N0_3$ (mg/L)
Location							
AK	6.81±0.05	508.00±14.80	335.00±10.3	1.84±0.07	0.009±0.00	7.74±1.81	0.170±0.05
MG	6.71±0.08	265.00±12.00	196.00±7.40	1.88±0.04	0.006±0.00	10.84±0.94	0.231±0.01
NK	6.50±0.17	73.83±5.76	113.70±2.36	1.73±0.04	0.012±0.01	7.47±1.58	0.160±0.01
OM	6.73±0.04	394.17±8.60	209.00±4.09	1.75±0.03	0.008±0.01	5.76±0.29	0.140±0.00
SG	6.30±0.26	329.70±6.54	224.20±4.67	1.74±0.04	0.005±0.01	8.12±2.20	0.211±0.06
CV	12.52	14.50	14.92	13.14	17.19	11.25	12.56
LSD	0.02	3.78	3.77	0.04	0.008^{ns}	0.09	0.006
Sources							
BH	6.67±0.04	429.70±6.37	288.00±3.83	1.81±0.01	0.004±0.00	6.90±1.58	0.120±0.02
RV	6.77±0.04	147.90±407	104.70±2.99	1.87±0.04	0.013±0.00	9.59±0.91	0.220±0.03
WL	6.38±0.19	365.00±1.00	254.00±6.34	1.69±0.03	0.001±0.00	7.46±0.99	0.211±0.02
CV	17.15	16.25	14.21	13.12	14.21	13.14	16.10
LSD	0.03	4.89	4.87	0.06	0.006	0.11	0.008
Interactions							
AK X BH	6.84	555.00	342.50	1.84	0.000	2.44	0.020
AK X RV	6.66	80.50	50.00	2.05	0.003	12.25	0.218
AK X WL	6.93	888.50	612.50	1.65	0.000	8.52	0.295
MG X BH	6.44	645.00	425.00	1.85	0.000	12.44	0.217
MG X RV	6.92	79.00	40.50	2.00	0.018	12.25	0.210
MG X WL	6.76	72.00	122.50	1.79	0.000	7.85	0.285
NK X BH	6.69	91.00	52.50	1.75	0.024	12.25	0.219
NK X RV	6.86	60.00	70.50	1.85	0.008	6.30	0.145
NK X WL	5.94	70.50	188.00	1.61	0.003	3.85	0.124
OM X BH	5.58	375.00	265.00	1.80	0.000	6.15	0.146
OM X RV	6.82	387.50	282.00	1.65	0.021	6.30	0.149
OM X WL	6.79	420.00	80.00	1.82	0.004	4.85	0.133
SG X BH	6.80	482.50	325.00	1.83	0.000	1.21	0.018
SG X RV	6.62	132.50	80.50	1.80	0.016	10.89	0.395
SG X WL	5.48	374.00	267.00	1.61	0.000	12.25	0.217
LSD	0.05	8.47	8.44	0.10	0.015	0.20	0.014

Means on the same column with different superscript are statistically significant ($P<0.05$), ns=not significant. AK= Angwan, BH= Borehole, MG= Mayo-Gwoi, RV= River, NK= Nukka WL= Well, OM= Old-Magami, SG= Sabon-Gari, EC = Electrical Conductivity, TDS = Total Dissolve Salts, TSS = Total Suspended Solid, SAR = Sodium Adsorption Ratio, HCO_3 = Bicarbonates, NO_3 = Nitrates

Table 3. Suitability of Water Quality for irrigation in Jalingo Floodplains (August 2016)

Floodplain/ Sources	Water Properties							
	$S0_4$ (mg/L)	$C0_3$ (mg/L)	Cl (mg/L)	Na (ppm)	Mg (ppm)	Ca (ppm)	K (ppm)	B (ppm)
Location								
AK	0.005±0.00	0.56±0.15	35.40±1.12	0.003±0.01	5.27±0.74	11.97±1.56	6.55±0.84	0.18±0.12
MG	0.015±0.00	0.45±0.16	24.40±1.07	0.018±0.01	5.09±0.45	9.62±1.19	5.19±0.38	0.08±0.02
NK	0.007±0.00	0.38±0.14	45.43±7.78	0.021±0.01	5.93±0.64	10.33±1.26	4.21±0.22	0.10±0.01
OM	0.008±0.01	0.38±0.11	16.26±4.97	0.027±0.01	4.84±0.69	10.22±1.37	4.76±0.47	0.11±0.00
SG	0.011±0.00	0.77±0.03	24.10±7.92	0.017±0.00	5.50±0.55	11.15±1.01	5.06±0.34	0.09±0.01
CV	10.25	13.21	10.26	13.14	15.21	14.71	012.23	12.34
LSD	0.001	0.15^{ns}	0.19	0.003	0.04	0.06	0.08	0.12^{ns}
Sources								
BH	0.011±0.01	0.40±0.11	30.82±6.31	0.003±0.00	3.60±0.12	7.46±0.22	4.99±0.33	0.10±0.04
RV	0.010±0.00	0.56±0.11	48.92±4.52	0.045±0.01	6.82±0.17	14.23±0.45	6.39±0.42	0.14±0.04
WL	0.008±0.00	0.56±0.09	7.60±2.87	0.005±0.00	5.57±0.26	10.27±0.71	4.08±0.13	0.09±0.19
CV	14.21	12.32	12.41	11.04	16.21	15.24	12.30	10.14
LSD	0.002	0.20^{ns}	0.25	0.004	0.05	0.07	0.10	0.16^{ns}
Interactions								
AK X BH	0.001	0.06	49.11	0.000	3.66	7.57	6.75	0.08
AK X RV	0.014	0.86	56.76	0.010	7.55	16.21	8.75	0.43
AK X WL	0.001	0.75	0.32	0.000	4.61	12.03	4.15	0.03
MG X BH	0.013	0.46	14.39	0.000	3.67	6.74	4.40	0.15
MG X RV	0.015	0.45	57.43	0.055	5.96	13.16	6.36	0.02
MG X WL	0.018	0.44	1.28	0.000	5.66	8.96	4.82	0.07
NK X BH	0.016	0.45	56.58	0.015	3.91	6.65	4.00	0.06
NK X RV	0.002	0.36	58.84	0.035	7.03	13.47	4.90	0.14
NK X WL	0.003	0.34	20.85	0.015	6.86	10.86	3.75	0.10
OM X BH	0.018	0.35	25.45	0.000	2.90	8.30	4.35	0.11
OM X RV	0.004	0.37	22.68	0.072	6.69	15.52	6.22	0.08
OM X WL	0.003	0.42	0.64	0.010	4.94	6.83	3.70	0.13
SG X BH	0.003	0.67	8.55	0.000	3.85	7.95	5.45	0.11
SG X RV	0.015	0.78	48.86	0.053	6.86	12.81	5.75	0.04
SG X WL	0.015	0.87	14.89	0.000	5.79	16.96	4.00	0.13
LSD	0.004	0.34^{ns}	0.44	0.008	0.08	0.13	0.18	0.28^{ns}

Means on the same column with different superscript are statistically significant ($P<0.05$), ns=not significant. AK= Angwan, BH= Borehole, MG= Mayo-gwoi, RV= River, NK= Nukka WL= Well, OM= Old-magami, SG= Sabon-gari, EC = Electrical Conductivity, TDS = Total Dissolve Solid, TSS = Total Suspended Solid, SAR = Sodium Adsorption Ratio, HCO_3 = Bicarbonates, NO_3 = Nitrates

EC (µS/cm)

Electrical conductivity (EC) is a measure of salinity from all the ions dissolved in a sample which includes negatively charged ions (e.g Cl^- and NO_3^-) as well as positively charged ions (e.g Ca^{++} and Na^+). EC of the water according to locations ranged from 73.83 (NK) to 508,00 (AK) µS/cm while in terms of water sources, the EC values ranged from 147 (RV) to 429 (BH) µS/cm. There was no significant difference ($P>0.05$) between the values across the locations and sources as well as interactions (Tables 2, 4).

TDS (mg/L)

The results for total dissolved solids as presented on Table 2 showed that there was no significant difference ($P>0.05$) across locations, sources and interaction, however, the values recorded ranged from 113.70 (NK) to 335.00 (AK) mg/L across the five locations, 104.70 (RV) to 288.00 (BH) mg/L across the three sources. In terms of interactions also there was no significant difference ($P>0.05$), but Angwan karofi gave higher value of 612.50mg/L (Tables 2, 4).

TSS (mg/L)

The results of total suspended solids in the water as presented on Table 2 was low and within acceptable limits of 2 – 5.5 mg/L. It showed that there was no significant difference ($P>0.05$) in TSS between locations, sources and interaction. However, values across locations ranged from 1.73 (NK) to 1.88 (MG) mg/L, in terms of sources of water, the values were 1.69 (WL) to 1.87 (RV) mg/L in terms of interactions, Angwan Karofi River had highest TSS (2.05 mg/L) followed by Mayo-Gwoi River (2.00 mg/L). These values were all within acceptable limits (FAO, 1985).

SAR

The results for sodium absorption ratio (SAR) showed that there was no significant difference (Tables 2, 4) ($P>0.05$) across the locations and water sources as well as interactions. The values ranged from 0.005 (SG) to 0.012 (NK). For the water sources, the values ranged from 0.001 (WL) to 0.013 (RV). SAR assesses the Na status and permeability hazard of irrigation water. It measures the relationship between soluble Na, Ca and Mg, which is used to predict the exchangeable Na fraction equilibrated with a given solution (Leinaur and Dwitt, 2013). The critical values for irrigation water are 0.009 mg/L hence, water from Nukkai and River Sabon Gari posed some danger of high SAR. High SAR values in irrigation water applied to soils can caused dispersion of soil colloids hence destroying soil aggregation and structure.

Table 4. Suitability of Water Quality for Irrigation in Jalingo Floodplains (November 2016)

F/ Sources	Water Properties						
	pH	EC (µS/cm)	TDS (mg/L)	TSS (mg/L)	SAR	HCo_3 (mg/L)	$N0_3$ (mg/L)
Location							
AK	6.77±0.06	510.00±14.80	345.00±1.04	1.93±0.07	0.001±0.01	7.80±1.86	0.13±0.03
MG	6.72±0.09	256.00±12.00	203.00±7.37	1.77±0.01	0.007±0.00	10.88±0.93	0.52±0.33
NK	6.50±0.17	67.33±7.41	114.80±2.28	1.72±0.05	0.004±0.01	7.60±1.63	0.17±0.01
OM	6.72±0.04	384.67±8.91	218.00±4.20	1.75±0.05	0.009±0.00	6.06±0.42	0.18±0.02
SG	6.26±0.26	323.30±6.74	221.00±4.48	1.95±0.09	0.006±0.01	8.11±2.19	0.18±0.05
CV	11.25	12.31	11.21	13.21	10.26	12.41	16.24
LSD	0.01	3.63	2.05	0.03	0.001	0.08	0.34
Sources							
BH	6.65±0.04	427.20±6.36	292.20±3.82	1.92±0.05	0.000±0.00	7.05±1.60	0.32±0.20
RV	6.75±0.04	140.20±4.03	108.80±3.07	1.81±0.06	0.016±0.00	9.77±0.87	0.22±0.01
WL	6.38±0.19	357.00±1.01	259.90±6.43	1.74±0.02	0.001±0.00	7.45±1.00	0.17±0.02
CV	15.23	14.12	16.23	14.21	12.35	14.21	13.54
LSD	0.02	4.69	2.64	0.04	0.001	0.11	0.44
Interactions							
AK XBH	6.81	561.00	351.00	1.85	0.000	2.44	0.02
AK X RV	6.59	80.00	55.50	2.15	0.002	12.55	0.22
AK X WL	6.92	888.00	627.50	1.80	0.000	8.40	0.16
MG X BH	6.44	635.00	429.50	1.79	0.000	12.48	1.20
MG X RV	6.90	70.00	42.00	1.80	0.022	12.25	0.23
MG X WL	6.81	62.50	137.50	1.74	0.000	7.93	0.14
NK X BH	6.69	90.00	85.50	1.88	0.000	12.55	0.21
NK X RV	6.86	51.00	72.50	1.70	0.012	6.40	0.16
NK X WL	5.96	61.00	186.50	1.59	0.000	3.85	0.13
OM X BH	6.58	365.00	277.50	1.87	0.000	6.55	0.15
OM X RV	6.80	377.50	291.00	1.60	0.023	6.90	0.25
OM X WL	6.78	411.50	85.50	1.78	0.004	4.75	0.14
SG X BH	6.76	485.00	317.50	2.25	0.000	1.24	0.01
SG X RV	6.60	122.50	83.00	1.80	0.018	10.77	0.24
SG X WL	5.42	362.50	262.50	1.82	0.000	12.30	0.30
LSD	0.04	8.13	4.58	0.07	0.001	0.20	0.76

Means on the same column with different superscript are statistically significant ($P<0.05$), ns=not significant. AK= Angwan, BH= Borehole, MG= Mayo-gwoi, RV= River, NK= Nukka WL= Well, OM= Old-magami, SG= Sabon-gari, EC = Electrical Conductivity, TDS = Total Dissolve Solid, TSS = Total Suspended Solid, SAR = Sodium Adsorption Ratio, HCO_3 = Bicarbonates, NO_3 = Nitrates, F: Floodplain

The higher values of SAR in the river water (Tables 3, 4) may be as a result of dissolved Na in the water relative to other sources. Being an open source where community washes clothes and other domestic utensils that may introduce salts into the water. The critical values for irrigation water are 0.009 mg/L hence, water from Nukkai and river posed some danger of high SAR.

HCO_3

The results of bicarbonates (Tables 2, 4) also, did not show any significant difference ($P>0.05$). The range of values across location was from 5.76 (OM) to 10.84 (MG) mg/L while across sources, the values ranged from 6.90 (BH) to 9.59 (RV) mg/L. In the locations, Mayo-Gwoi gave higher value of 10.84 mg/L which was slightly above the safe limit for irrigation water of 10 mg/L (Landon, 1991). In terms of interactions, Angwan Karofi-river, Mayogwoi-borehole, Mayogwoi-river, Nukkai-borehole, Sagongari-river and Sabongari-well where all above the critical levels. Bicarbonates (HCO_3) is produced by dissolving CO_2 in water. High levels of HCO_3 in irrigation water can cause unsightly foliar deposits on leaf tissues, precipitate salts, clod drip emitters and soil pores, form complexes with Mg and Ca^- reducing plant uptake of Ca, Mg and colloidal dispersion (Leinauer and Dewitt, 2013). It also increases soil pH if the buffering capacity of the soil is low (Barnabas et al., 2017). In the location, Mayogwoi gave the higher value of 10.84 mg/L which was slightly above the safe limit for irrigation water of 10 mg/L (Landon, 1991). In terms of interaction, AK × RV, MG × BH, MG × RV, NK × BH, SG × RV and SG × WL were all above the critical levels (Tables 2, 4). This implies that the irrigation water in the area could be at risk with regard to bicarbonates. High CO_3 and HCO_3 in water essentially increase the Na hazard of the water to a greater level than that indicated by SAR (Adamu, 2013). These imply that the irrigation water within these areas could be at risk with regards to bicarbonates.

$N0_3^-$

The critical value for nitrate in irrigation water is 1.0 mg/L (Landon, 1991). By this standard, all the locations and water sources could be described as being within safe limits. There was no significant difference ($P>0.05$) between locations, sources and interactions. The $N0_3^-$ level across locations ranged from 0.14 (OM) to 0.23 (MG) mg/L, while across the sources sampled, $N0_3$ ranged from 0.12 (BH) to 0.22 (RV) mg/L. All the values were very low, although it may seem nitrogen in whatever form may be desirable for plants growth. The risk associated with excess nitrogen, especially the nitrate form which is not adsorbed at exchange sites is the tendency for it to be leached into underground water or being washed away via drainage water to sundry water sources where it can cause eutrophication (Adamu, 2013).

Table 5. Suitability of Water Quality for Irrigation in Jalingo Floodplains (November 2016)

Floodplain/ Sources	Water Properties							
	$S0_4$ (mg/L)	$C0_3$ (mg/L)	Cl (mg/L)	Na (ppm)	Mg (ppm)	Ca (ppm)	K (ppm)	B (ppm)
Location								
AK	0.006±0.00	0.07±0.01	35.50±1.12	0.003±0.00	5.28±0.74	11.97±1.56	6.54±0.88	0.05±0.01
MG	0.008±0.01	0.21±0.13	24.30±1.07	0.024±0.01	5.07±0.46	9.64±1.18	5.23±0.37	0.05±0.01
NK	0.020±0.00	0.20±0.12	54.40±1.19	0.015±0.00	5.89±0.63	10.34±1.26	4.27±0.18	0.08±0.01
OM	0.016±0.01	0.20±0.12	16.26±4.95	0.031±0.01	4.85±0.70	10.23±1.71	4.74±0.45	0.10±0.00
SG	0.008±0.00	0.40±0.14	24.08±7.91	0.020±0.01	5.49±0.53	11.14±1.03	5.09±0.37	0.09±0.01
CV	8.21	9.14	10.62	10.12	11.14	8.95	11.20	10.32
LSD	0.002	0.26^{ns}	0.07	0.002	0.04	0.06	0.06	0.01
Sources								
BH	0.011±0.00	0.35±0.11	30.87±6.36	0.000±0.00	3.59±0.12	7.46±0.20	4.99±0.34	0.09±0.01
RV	0.019±0.00	0.23±0.10	54.31±6.73	0.054±0.00	6.81±0.17	14.25±0.45	6.40±0.43	0.05±0.01
WL	0.005±0.00	0.07±0.00	7.61±2.87	0.002±0.01	5.56±0.24	10.27±0.71	4.14±0.14	0.09±0.01
CV	13.24	12.31	12.36	12.24	13.27	12.24	10.12	13.24
LSD	0.003	0.34^{ns}	0.09	0.003	0.05	0.08	0.08	0.02
Interactions								
AK XBH	0.002	0.07	49.56	0.000	3.66	7.66	6.80	0.08
AK X RV	0.016	0.08	56.76	0.010	7.55	16.20	8.82	0.05
AK X WL	0.002	0.07	0.31	0.000	4.64	12.04	4.00	0.02
MG X BH	0.013	0.48	14.19	0.000	3.61	6.83	4.35	0.08
MG X RV	0.006	0.06	57.44	0.072	5.95	13.16	6.36	0.02
MG X WL	0.004	0.08	1.29	0.000	5.67	8.94	5.00	0.06
NK X BH	0.015	0.45	56.61	0.000	3.90	6.67	4.05	0.05
NK X RV	0.036	0.08	85.85	0.045	7.04	13.49	4.85	0.09
NK X WL	0.010	0.08	20.88	0.000	6.74	10.85	3.92	0.12
OM X BH	0.018	0.06	24.41	0.000	2.87	8.27	4.25	0.11
OM X RV	0.025	0.45	22.69	0.084	6.74	15.58	6.15	0.08
OM X WL	0.006	0.08	0.67	0.010	4.95	6.83	3.83	0.13
SG X BH	0.005	0.66	8.55	0.000	3.90	7.88	5.50	0.11
SG X RV	0.014	0.46	48.81	0.062	6.80	12.82	5.85	0.04
SG X WL	0.004	0.07	14.87	0.000	5.79	12.70	3.94	0.13
LSD	0.006	0.59^{ns}	0.16	0.005	0.10	0.15	0.15	0.04

Means on the same column with different superscript are statistically significant ($P<0.05$), ns=not significant. AK= Angwan, BH= Borehole, MG= Mayo-gwoi, RV= River, NK= Nukka WL= Well, OM= Old-magami, SG= Sabon-gari, EC = Electrical Conductivity, TDS = Total Dissolve Solid, TSS = Total Suspended Solid, SAR = Sodium Adsorption Ratio, HCO_3 = Bicarbonates, NO_3 = Nitrates

SO_4

Sulphates in the water across locations ranged from 0.005 (AK) to 0.015 (MG) mg/L. for the sources however, the values ranged from 0.008 (WL) to 0.011 (BH) mg/L. The values did not show any significant difference ($P>0.05$) across locations and water sources as well as the interactions between locations and water sources. Sulphates of Ca and Mg are known to form hard scales on water pipes and blocks drip emitters. Large concentrations of sulphate have a laxative effect on some people and in combination with other ions, give water a bitter taste (Brady and Weil, 2002).

$C0_3^-$

Carbonates in the water falls within the safe limits for irrigation water (4.0 mg/L) as stipulated by Landon, (1991). There was no significant difference ($P>0.05$) in the $C0_3$ values (Tables 3, 5) across sources of water and the interactions between location and sources. The result showed that $C0_3^-$ ranged from 0.38 (NK) to 0.77 (SG) mg/L across location. In terms of sources, the values were 0.40 (BH) and 0.56 (RV) mg/L. For the interaction also, $C0_3^-$ ranged from 0.06 (AK+BH) to 0.87 (SG+WL) mg/L.

Cl^-

The chloride content of the water across the five locations and three sources did not show statistically significant difference ($P>0.05$) (Tables 3, 5). Most of the values recorded were within the safe limits for irrigation water (250 mg/L) based on Landon (1991), Cl^- ranged from 16.26 (OM) to35.40 (AK) mg/L. In terms of interactions, Cl^- in water did not show any significant difference ($P>0.05$) and values ranged from 0.32 (AK+WL) to 56.76 (AK+RV) mg/L.

Exchangeable Cations (Na, Mg, Ca and K)

Na in the water did not show any significant difference ($P>0.05$) across locations sources and in the interactions between location and sources. The values for Na across location ranged from 0.003 (AK) to 0.027 (OM) (mg/L). Among the sources, the values ranged from 0.003 (BH) to 0.017 (SG) ppm. All these values fall within safe limit for irrigation water (1.0 ppm) (Tables 3 and 5).

Mg in the water did not show any significant difference ($P>0.05$) across location, sources and in their interactions. Mg values ranged from 4.84 (OM) to 5.93 (NK) ppm across locations. In terms of sources, Mg values ranged from 3.60 (BH) to 6.82 (RV) ppm. The values for interactions ranged from 2.90 to 7.55 ppm indicating no potential risk (Tables 3, 5).

Ca ranged from 9.62 (MG) to 11.97 (AK) ppm across the five locations. In the sources, Ca ranged from 7.46 (BH) to 14.23 (RV) ppm while in terms of interactions, Ca ranged from 6.65 (NK+BH) to 16.96 (SG+WL) ppm. The result did not show any significant difference (P>0.05) across the locations, sources and interactions. The critical value for calcium is 15.0 ppm. K values among sources ranged from 4.08 (WL) to 6.39 (RV) ppm. The values were within acceptable limits of 5 – 10 ppm. Ca and Mg in the water did not show any significant difference (P>0.05) across location /source and their interactions. The values for Mg indicated no potential risk and the critical value for Ca is 15.0 ppm (Landon, 1991). The relatively lower amount of Mg compared to Ca (Tables 3, 5) may be good because Mg deteriorates soil structure particularly where water is high in sodium or highly saline. The reason for the structural degradation is that high level of Mg usually promotes a higher development of exchangeable Na in irrigated soils. The Mg content of water is also considered as important qualitative criteria in determining water quality for irrigation because more Mg in water will adversely affect crop yields, as the soil become more alkaline. Generally, Ca and Mg maintain a state of stable equilibrium in most waters (Christenson et al., 1977) (Tables, 3, 5).

Boron (B)

Boron in the water ranged from 0.08 ppm (MG) to 0.18 ppm (AK) across locations. Across the different water sources, the values ranged from 0.09 (WL) to 0.14 ppm (RV). In terms of interactions, B ranged from 0.03 to 0.43 ppm. The results indicated that there was no significance difference (P>0.05) in the B concentration of the water across the locations, sources and interactions.

Conclusion

Different physico-chemical properties of irrigation water in the different floodplain areas of Jalingo were compared with the water quality standards set for irrigation. Most of the floodplain locations examined in the study area exhibit common features and are being exploited. Inspite of the efforts of the Agricultural Development Programmes attached to the State ministries of Agriculture to supervise farmers in their respective locations, their efforts are insufficient. Most of the floodplain farmers in the study areas are semi-illiterate with scanty level of knowledge. Some of the irrigation water sources used by them are effluents which contain some toxic hazardous chemicals and pathogenic agents. The irrigation water sources in all the different locations of the floodplains are of good quality. However, SAR, Cl, CO_3, HCO_3 levels in the water sampled were of concern which require immediate attention and appropriate solution. All areas where agriculture is being practiced require routine irrigation examination as a recommended factor. The National Environmental Standard, and Regulation Enforcement Agency, NESREA as one of the regulatory bodies should educate the water users and bring quality standards in order to prevent use of contaminated water for irrigation purposes.

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