Effects of Seasonal Flooding on the Quality of Irrigation Water in the Floodplains of Wukari, Taraba State of Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author ATG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AA and PIA managed the analyses of the study. Author AC managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This research was done in order to assess the effects of seasonal flooding on irrigation water quality of the floodplains of Wukari Area of Taraba state. Water samples were collected from five different flood plain locations (Nwuko, Tsokundi, Rafin-Kada, Gidan-Idi and Gindin-Dorowa) in 2016 and 2017. Completely randomized design (CRD) was employed replicated three times. The results obtained were subjected to analysis of variance and means separated using F-LSD test at P ≤ 0.05. The results of the water quality analysis showed that all the determined parameters were significantly different at the different sample locations, except water pH of the year 2016 which was not significantly different at the different sample locations. The results show that the flooded water could be used for irrigation since they were found to be relatively safe and hence required little or no treatment for soluble salts. Water from flooding within the Wukari Floodplains is recommended for supplementary irrigation.

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1. INTRODUCTION

A flood is an overflow of water that submerges land which is usually dry. Flooding is one of the major environmental crises of the century. Occurrence of flood is the most frequent among all natural disasters. Floods are caused by several factors. Rain continued without stopping and resulted in a flood. In low-lying areas, rain water will flow into the river. River filled with water will overflow, causing lowland covered with water. Besides that, urbanization is also affecting water flows especially in low-lying areas. In the past, creeks and valleys made the water flow; now the area has been covered with soil [1]. When it rains, water will flow from the hills to the low areas and became stagnant. The water will increase and flash floods will occur. Floods could influence water quantity by affecting quality in one of two ways. Floods either increase contaminants and sediments from urban and agricultural runoff during high rainfall causing a decrease in water quality. Or the high rainfall could increase a water body's volume thereby diluting contaminants and pollutants, this will either improve water quality or have no significant impact on water quality [2]. The disaster of flash flood causes serious losses in term of people lives and properties. Flood runoff also causes the deterioration of downstream water quality because of the sediments and waste from the ground [3]. Contamination of water, especially by organic loading, can cause characteristic changes in benthic community and water quality [4].

Although the development of irrigated agriculture can increase farm output, poor irrigation management may completely render agricultural soils unproductive through salt built-up in the soil. It is as a result of such accumulation that, extensive areas of land in the arid and semi-arid regions of India have gone out of cultivation [5]. Extensive irrigation and poor water management are the fundamental causes of water logging and salt build-up [5], as such development of salinity is a challenge to the permanence of irrigated agriculture and quality of water is an important consideration in any appraisal of salinity or alkalinity conditions in an irrigated area [5]. According to Foth [6] water in the form of rain and snow is quite pure, but by the time the water has reached the farm however, the water has picked up soluble mineral (salt) from soil and rock over and through which the water moved.

The most commonly dissolved elements in irrigated water are Ca, Mg, SO_4 Na, Cl, and CO_3 [7,5]. It is the concentration of these ions among other factors that determine the suitability of water for irrigation. The sources of water to be used for irrigation also affect profoundly the quality of irrigation, according to a study carried out on the suitability of some water sources for irrigation in Maiduguri Local Government Area of Borno State, Nigeria, [8] reported that out of' the 4 irrigation water sources sampled and analyzed for salinity/toxicity development, only that of Abbagana has the high tendency for salinity/toxicity development and it is related to household wastes. According to [5], to cope with effects of a poor water quality it is necessary to have detailed information concerning the quality of irrigation waters with reference to the criteria and standards and background of experience relating to the effects of irrigation water on soils and crops. For irrigation purposes, the usual criteria for determining water quality include electrical conductivity (EC), sodium absorption ratio (SAR), Total dissolved solids (TDS), pH, and residual sodium carbonate (RSC) [5]. Although there have been many studies on water quality analysis, there has not been any information on the irrigation water quality affected by the recent Nigerian flood disaster. The objective of this study therefore is to determine the irrigation water quality of the flood plains of Wukari LGA of Taraba State, Nigeria, in order to assess the impact of the flood on the irrigation water quality.

1.1 Objectives of the Study

The objectives of the study are;

  i. To determine the irrigation water quality of the study area,
 ii. To assess the effects of seasonal flooding on the quality of water within the floodplains for irrigation.

2. METHODOLOGY

2.1 Study Area

The floodplains of Gidan Idi, Gindin Dorowa, Tsokundi, RafinKada and Nwuko are located in Wukari Local Government Area of Taraba State, Nigeria. Wukari Local Government Area lies on latitude 75°1'N and longitude 9°47'E. Wukari Local Government Area is located in the

Northern Guinea Savannah agro-ecological zone of Nigeria and has 2 distinct seasons; wet and dry. The wet season starts from April and ends in October, with mean Annual rainfall range of 1100-1250 mm and mean air temperature of 29°C and can reach 40°C in March. During the rainy season, the River Donga flows along the borders of Gindin – Dorowa, Tsokundi, Gidan Idi, Nwuko and Rafin-kada to a level of approximately 155 m above sea level. The "Ako" lake which acts as a natural reservoir discharges its annual flood into River Donga.The study area is subjected to intensive flooding especially during the rainy season usually between August and September. During this period, the "Ako" lake reaches their average maximum flooding level few weeks before River Donga attains its own level. At this stage, there would be no defined boundary between the lakes and the river and the whole area would be nundated (September - October) [9]. Consequently, most of the floodplain soil areas would be covered with flood for months.

Wukari Local Government Area has common boundaries with Ibi local government area to the North-West; Gassol Local Government Area to the North-East; Donga Local Government Area to the South-East; and Benue State to the South-West. The common tillage practices in the rice soils include animal tractions by use of ox-drawn plough and tractor mounted harrows. The common crop grown is rice. Secondary crops include sugar cane, vegetables (Onions, pepper, greens) and maize. Fishing activities (such as cat fish, lung fish) and brick making are common.

2.2 Sample Collection and Preparation

Three (3) flood water samples were collected each in 2016 and 2017 in each of the floodplain. A total of 15 water samples for year 2016 and 15 samples for year 2017 were collected. The samples were filtered using Whatman filter paper and taken to laboratory for analysis.

2.3 Laboratory and Field Analysis

pH and EC of flood were determined using pH meter and EC Meter respectively. Sodicity of water or soil is usually described in terms of the sodium adsorption ratio (SAR) of water (including soil solutions). CO_3 and HCO_3 contents were determined by titration with HCl using phenolphthalein and methyl orange indicators respectively [10,11]. Residual Sodium Carbonate

(RSC) was calculated from the values of calcium, magnesium, carbonates and bi-carbonates.

2.4 Statistical Analyses

The statistical analysis follows a five (5) treatment (location) affects with three (3) replications each in a randomized linear model procedure of statistic 8.0 version 2004 for ANOVA to test significant effect at 95% confidence limit using the procedure by [12]. If significant differences are observed, treatment means was separated using F-LSD.

3. RESULTS AND DISCUSSION

3.1 Effects of Seasonal Flooding on Water Quality within the Floodplains for Irrigation

The parameters considered under flood water quality analysis include pH, electrical conductivity (EC), exchangeable bases (Ca, Mg, Na and K), bicarbonate (HCO_3), carbonate (CO_3), chlorine (Cl_2), residual sodium carbonate (RSC) and sodium absorption ratio (SAR). Table 1 is the result of mean flood water qualities.

The results of water analysed from the water sources showed that the highest mean pH value of the flood water was 8.08 at Rafin Kada in the year 2016 and the lowest mean pH value of the flood water was 7.74 at Gindin Dorowa in 2016. The results show that these water sources have slightly alkaline to moderately alkaline properties with slight risk salinity/solidity development with time. The ANOVA showed that the pH value of the flood water indifferent locations investigated at P≤0.05 level of significance were not significantly different in 2016 but were significantly different in 2017.

The results of water analysed from the water sources show that the highest mean electrical conductivity value of the flood water was 2.15dS/m at Tsokundi in 2017 and the lowest mean electrical conductivity value of the flood water was 1.00dS/m at Gindin Dorowa in 2016.The electrical conductivity (EC) values were low which belongs to the C_1S_1 – low salinity medium water sodium water category.

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flood water was 7.74 at Gindin-Dorowa in 2016. The result show that these water sources have slightly alkaline to moderately alkaline properties with slight risk salinity/solidity development with time. The ANOVA showed that the pH value of the flood water indifferent locations investigated at P≤0.05 level of significance were not significantly different in 2016 but were significantly different in 2017.

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at 0.05 probability levels showed the differences among some of the mean electrical conductivity values of the flood water of the flood plain locations are statistically significant.

The results of water analysed from the water sources show that the highest mean sodium, potassium, calcium and magnesium values of the flood water were 16.82, 14.51, 26.77 and 8.40 cmol(+)/kg respectively and the lowest mean sodium, potassium, calcium and magnesium values of the flood waterwere7.81, 6.87, 11.71 and 4.50 cmol(+)/kg respectively. The ANOVA performed showed that all the sodium, potassium, calcium and magnesium values of the flood water were significantly different for the different locations investigated at P≤0.05 level of significance for both the periods studied. The means separation using F-LSD at 0.05 probability levels showed the differences among most of the flood plain locations are statistically significant for the sodium, potassium, calcium and magnesium values of the flood water.

Table 1. Results of mean flood water qualities

| Year | Quality parameters | Location (Water source) | | | | | F-LSD $_{0.05}$ |
		NWRS	TSRS	RKRS	GIRS	GDRS	
2016	pH	8.01	7.90	8.08	7.98	7.74	-
	EC (dS/m)	2.00	1.43	1.00	1.34	2.13	0.115
	Na	16.82	11.74	8.79	7.81	14.62	1.243
	K	14.51	11.11	6.87	11.94	11.01	0.041
	Ca	26.77	17.09	11.94	15.17	16.10	0.207
	Mg	7.20	6.80	4.50	7.34	7.20	0.288
	HCO$_3$	3.57	3.21	2.56	2.62	2.53	0.018
	CO$_3$	0.64	0.78	0.79	0.91	0.82	0.018
	Cl	13.31	12.71	12.40	9.81	8.80	0.018
	RSC	-29.53	-19.90	-13.76	-18.98	-19.87	0.855
	SAR	4.08	3.31	2.83	2.33	4.28	0.368
2017	pH	7.81	7.89	7.92	7.92	7.96	0.018
	EC (dS/m)	2.14	2.15	1.91	1.46	2.01	0.045
	Na	16.42	12.15	10.61	9.21	9.01	1.013
	K	11.01	11.26	8.22	7.05	11.41	0.018
	Ca	18.37	16.64	18.29	11.71	16.42	1.687
	Mg	7.48	7.55	7.35	7.56	8.40	0.872
	HCO$_3$	3.45	3.05	3.00	2.86	2.63	0.223
	CO$_3$	0.63	0.69	0.71	0.86	0.91	0.036
	Cl	13.53	11.42	12.31	11.56	11.95	1.062
	RSC	-21.79	-20.36	-21.60	-15.57	-18.86	3.257
	SAR	4.57	3.54	3.14	3.03	2.56	0.442

Key: NWRS-Nwoko Floodplains; TSRS-Tsokundi Floodplais;
RKRS-Rafinkada Floodplains; GIRS-Gidan Idi Flood plains;
GDRS-Gindin Dorowa Floodplains

The results of water analysed from the water sources show that the highest mean HCO_3, CO_3 and Cl_2 values of the flood water were 3.57, 0.91 and 13.53 cmol(+)/kg respectively and the lowest mean HCO_3, CO_3 and Cl_2 values of the flood water were 2.53, 0.63 and 8.80 cmol(+)/kg respectively. The mean values of HCO_3 content of the flood water were rated low to moderate; the concentrations of carbonate (CO_3) contents of the flood water were rated very low and the chloride contents of the flood water were rated medium to high. The low to moderate concentrations of bicarbonate, very low concentration of carbonate and the moderate to high concentration of chorine further supports acidity in the water because most dissolved carbon dioxide and carbonates must have been reduced to either carbonic acid (H_2CO_3) or are in the transitional state of bicarbonate [1].This indicates that free CO_3 is very low or absent and they are all rated low [13,14,1]. It implies that all the pedons are non-calcareous. The low amount of CO_3 in the study area may be attributed to the presence of calcium silicate which according to [14] is more soluble than $CaCO_3$.

The ANOVA performed showed that all the bicarbonate (HCO_3), carbonate (CO_3) and chlorine (Cl_2) values of the flood water were significantly different for the different locations investigated at P≤0.05 level of significance for both the periods studied. The means separation using F-LSD at 0.05 probability levels showed the differences among most of the flood plain locations are statistically significant for the bicarbonate (HCO_3), carbonate (CO_3) and chlorine (Cl_2) values of the flood water.

The results of water analysed from the water sources show that the highest mean residual sodium carbonate value of the flood water was -13.76 and the lowest mean residual sodium carbonate value of the flood water was -29.53.The ranges of values of residual sodium carbonate were rated low.The Residual Sodium Carbonate (RSC) mean values for irrigation water are below critical values (less than zero). The values obtained are similar to the -1.46 earlier reported by Ishaku and Matazu (1988) for River Benue. [15] and [14] considered 2.5 as the critical value for residual sodium carbonate. The residual sodium carbonate of the water exhibited a negative value in all the locations. This negative value of the residual sodium carbonate of the water may dissolve some carbonate. This may in part explain the lower or absence of free carbonate in the water [14]. This will result in

decreasing SAR of the water solution. The Analysis of Variance (ANOVA) test confirm the observed variations, in that, the differences amongst the different flood water locations are statistically significant at 0.05 probability level for both the periods studied. The analysis of means using F-LSD at P≤0.05 shows that only most of the location means are statistically different.

The results of water analysed from the water sources show that the highest mean sodium absorption ratio value of the flood water was 4.57 and the lowest mean sodium absorption ratio value of the flood water was 2.33. SAR values were low which belongs to the C_1S_1 – low salinity medium water sodium water category. The SAR of 10 – 18 is the critical limit for S_2 sodium water category. Thus the water appear free from salinity and sodicity hazards since their sodium and SAR values are low, in fact sodium made up about 34.37 per cent of total cation in water. According [16], when sodium reaches 50 – 70% of the cations in dissolved salts, exchangeable sodium begins to accumulate in the irrigated soil. To some extent, this explains Exchangeable Sodium Percentage (ESP) for soils.

The ANOVA showed that sodium absorption ratios of the flood water were significantly different for the different locations investigated at P≤0.05 level of significance for both the periods studied. The means separation using F-LSD at 0.05 probability levels showed that the differences among some of the mean sodium absorption ratios of the flood water locations are statistically significant.

4. CONCLUSION

From the study conducted it can be concluded that the flooded water could be used for irrigation since they were found to be relatively safe and hence required little or no treatment for soluble salts. Water from flooding within the Wukari Floodplains is recommended for supplementary irrigation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix 1. Water quality analysis

Appendix 1.1. Flood water qualities in 2016

Source	Replications	pH	EC (dS/m)	Na	K	Ca	Mg	HCO$_3$	CO$_3$	Cl	RSC	SAR
RKRS	1	8.02	2.00	18.15	14.51	26.60	7.20	3.58	0.63	13.30	-29.59	4.42
	2	8.10	2.00	16.20	14.50	27.00	7.20	3.56	0.64	13.31	-30.00	3.92
	3	7.90	2.01	16.10	14.52	26.70	7.20	3.57	0.64	13.32	-29.00	3.91
Mean		8.01	2.00	16.82	14.51	26.77	7.20	3.57	0.64	13.31	-29.53	4.08
TSRS	1	7.90	1.42	11.80	11.12	17.20	6.80	3.21	0.78	12.72	-20.01	3.41
	2	7.89	1.43	12.41	11.10	17.00	6.80	3.21	0.78	12.70	-19.81	3.31
	3	7.91	1.44	11.60	11.12	17.08	6.81	3.22	0.78	12.70	-19.89	3.22
Mean		7.90	1.43	11.74	11.11	17.09	6.80	3.21	0.78	12.71	-19.90	3.31
RKRS	1	7.62	0.86	7.82	6.82	11.90	4.98	2.56	0.78	12.40	-13.54	2.69
	2	8.41	1.06	8.92	6.90	11.90	4.50	2.56	0.80	12.40	-13.04	3.12
	3	7.96	1.09	9.62	6.90	12.01	4.52	2.56	0.80	12.40	-14.77	3.35
Mean		8.08	1.00	8.79	6.87	11.94	4.50	2.56	0.79	12.40	-13.76	2.83
GIRS	1	8.01	1.34	7.80	11.94	15.20	7.34	2.62	0.91	9.82	-19.01	2.32
	2	7.90	1.34	7.80	11.93	15.20	7.74	2.62	0.90	9.80	-19.01	2.32
	3	8.02	1.34	7.83	11.95	15.10	7.34	2.61	0.92	9.81	-18.91	2.34
Mean		7.98	1.34	7.81	11.94	15.17	7.34	2.62	0.91	9.81	-18.98	2.33
GDRS	1	7.92	2.20	14.62	11.02	16.21	7.20	2.53	0.82	8.79	-20.04	4.27
	2	7.28	2.09	14.62	11.00	16.10	7.20	2.54	0.82	8.80	-19.64	4.29
	3	8.01	2.11	14.62	11.00	16.21	7.21	2.52	0.82	8.80	-19.97	4.27
Mean		7.74	2.13	14.62	11.01	16.10	7.20	2.53	0.82	8.80	-19.87	4.28
Grand mean		7.94	1.58	11.96	11.09	17.41	6.61	2.90	0.79	11.41	-20.39	3.37

Appendix 1.2. Flood water qualities in 2017

Source	Replications	pH	EC (dS/m)	Na	K	Ca	Mg	HCO₃	CO₃	Cl	RSC	SAR
NWRS	1	7.81	2.14	16.42	11.01	19.48	7.48	3.52	0.63	13.29	-22.81	4.47
	2	7.81	2.14	16.42	11.01	19.42	7.50	3.42	0.62	12.29	-22.88	4.47
	3	7.80	2.15	16.43	11.02	16.26	7.50	3.42	0.63	14.01	-19.69	4.76
Mean		7.81	2.14	16.42	11.01	18.37	7.48	3.45	0.63	13.53	-21.79	4.57
TSRS	1	7.90	2.16	12.14	11.26	15.60	7.62	3.01	0.69	13.02	-19.52	3.56
	2	7.89	2.14	12.16	11.25	17.01	7.51	3.10	0.69	12.96	-20.74	3.47
	3	7.87	2.15	12.15	11.26	17.01	7.52	3.03	0.68	13.03	-20.83	3.60
Mean		7.89	2.15	12.15	11.26	16.64	7.55	3.05	0.69	11.42	-20.36	3.54
RKRS	1	7.92	1.91	9.21	8.20	18.46	6.92	3.00	0.72	11.42	-20.66	2.59
	2	7.92	1.92	11.01	8.24	18.21	7.62	3.00	0.70	12.49	-22.13	3.59
	3	7.92	1.91	11.60	8.22	18.21	7.51	3.00	0.71	13.01	-22.01	3.23
Mean		7.92	1.91	10.61	8.22	18.29	7.35	3.00	0.71	12.31	-21.60	3.14
GIRS	1	7.92	1.41	9.20	7.04	11.42	7.91	2.56	0.89	11.26	-15.88	2.96
	2	7.91	1.52	9.22	7.06	12.26	7.56	3.00	0.81	11.34	-16.01	2.93
	3	7.93	1.46	9.21	7.06	11.46	7.20	3.02	0.82	12.09	-14.82	3.02
Mean		7.92	1.46	9.21	7.05	11.71	7.56	2.86	0.86	11.56	-15.57	3.03
GDRS	1	7.96	2.01	9.02	11.42	16.42	9.42	2.68	0.92	12.01	-15.06	2.51
	2	7.96	2.01	9.00	11.40	16.42	8.20	2.60	0.90	12.21	-21.12	2.56
	3	7.95	2.00	9.01	11.41	16.41	7.58	2.61	0.90	11.62	-20.48	2.60
Mean		7.96	2.01	9.01	11.41	16.42	8.40	2.63	0.91	11.95	-18.86	2.56
Grand mean		7.89	1.93	11.48	9.75	16.39	7.67	3.00	0.75	12.48	-19.622	3.42

Key: NWRS= Nwukwo floodplains; TSRS= Tsokundi floodplains; RKRS= Rafin-kada floodplains;
GIRS= Gidan-Idi floodplains; GDRS= Gindin-dorowa flood plains

Appendix 2. Statistical analysis for flood water quality parameters

Source 2016	Df	SS	MS	F-cal	F-tab	Source 2017	Df	SS	MS	F-cal	F-tab
pH	4	0.152	0.038	0.574	3.48	pH	4	0.039	0.010	120.750	3.48
Error	10	0.660	0.066			Error	10	0.001	0.0001		
Total	14	0.812				Total	14	0.039			
EC	4	2.694	0.674	175.393	3.48	EC	4	0.953	0.238	368.469	3.48
Error	10	0.038	0.004			Error	10	0.006	0.0006		
Total	14	2.732				Total	14	0.960			
Na	4	173.850	43.463	92.968	3.48	Na	4	110.706	27.676	89.258	3.48
Error	10	4.675	0.467			Error	10	3.101	0.310		
Total	14	178.525				Total	14	113.807			
K	4	90.620	22.655	43567.295	3.48	K	4	48.679	12.170	86926.59	3.48
Error	10	0.005	0.001			Error	10	0.001	0.0001		
Total	14	90.625				Total	14	48.680			
Ca	4	372.496	93.124	7178.104	3.48	Ca	4	88.295	22.074	25.661	3.48
Error	10	0.130	0.013			Error	10	8.602	0.860		
Total	14	372.625				Total	14	96.897			
Mg	4	15.725	3.931	154.615	3.48	Mg	4	2.081	0.520	2.266	3.48
Error	10	0.254	0.025			Error	10	2.296	0.230		
Total	14	15.980				Total	14	4.377			
HCO_3	4	2.640	0.660	12372.687	3.48	HCO_3	4	1.093	0.273	18.192	3.48
Error	10	0.001	0.0001			Error	10	0.150	0.015		
Total	14	2.640				Total	14	1.243			
CO_3	4	0.117	0.029	547.062	3.48	CO_3	4	0.160	0.040	91.000	3.48
Error	10	0.001	0.0001			Error	10	0.004	0.0004		
Total	14	0.117				Total	14	0.165			
Cl	4	46.982	11.746	160167.409	3.48	Cl	4	5.739	1.435	4.209	3.48
Error	10	0.001	0.0001			Error	10	3.409	0.341		
Total	14	46.983				Total	14	9.148			
RSC	4	389.027	97.257	440.301	3.48	RSC	4	78.402	19.601	6.113	3.48
Error	10	2.209	0.221			Error	10	32.064	3.206		
Total	14	391.235				Total	14	110.466			
SAR	4	7.544	1.886	45.651	3.48	SAR	4	7.011	1.753	29.895	3.48
Error	10	0.413	0.041			Error	10	0.586	0.059		

Source 2016	Df	SS	MS	F-cal	F-tab	Source 2017	Df	SS	MS	F-cal	F-tab
pH	4	0.152	0.038	0.574	3.48	pH	4	0.039	0.010	120.750	3.48
Error	10	0.660	0.066			Error	10	0.001	0.0001		
Total	14	0.812				Total	14	0.039			
EC	4	2.694	0.674	175.393	3.48	EC	4	0.953	0.238	368.469	3.48
Error	10	0.038	0.004			Error	10	0.006	0.0006		
Total	14	2.732				Total	14	0.960			
Na	4	173.850	43.463	92.968	3.48	Na	4	110.706	27.676	89.258	3.48
Error	10	4.675	0.467			Error	10	3.101	0.310		
Total	14	178.525				Total	14	113.807			
K	4	90.620	22.655	43567.295	3.48	K	4	48.679	12.170	86926.59	3.48
Error	10	0.005	0.001			Error	10	0.001	0.0001		
Total	14	90.625				Total	14	48.680			
Total	14	7.957				Total	14	7.597			