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Evaluation of the Suitability of Water in Rivers for Irrigation in Northern Nasarawa State, Nigeria

[1]Samaila Kunden Ishaya, & [2]Kwarfwang Kevin Jack
[1]Department of Geography, Nasarawa State University Keffi.
[2]Department of Geography Plateau State University, Bokkos
Email: ikunden@yahoo.com

ABSTRACT
Water high in both the physical and chemical properties when used directly for irrigation is likely to result in the built-up of substances at levels to affect the productive capacity of the soil and lower crop yields. This study evaluates the suitability of water in rivers for irrigation in Northern Nasarawa State, Nigeria. Data for this study involved the collection of a total of 60 water samples from the three rivers (FarinRuwa, Mada and Antau) for rainy and dry seasons. Standard laboratory methods were used to determine pH, electrical conductivity, total dissolved solids, sodium, potassium, calcium, magnesium, chloride, phosphates, nitrates, carbonates and bicarbonates, boron, lead and iron. The results show the electrical conductivity of the rivers ranged from 44.5 for River Mada rainy season to 280.9uS/cm for River Antau dry season, pH was between 7.13 for River Antau dry season to 7.50 for river Antau rainy season. Sodium adsorption ratio was between 0.25 for River Mada dry season to 0.45 for River Antau dry season. Residual sodium carbonate was from -29.8 for River Antau dry season to -17.0 meq.l for river Mada dry season. Bicarbonate was highest 3.13 for River Antau dry season and lowest for River Mada rainy season. Boron was between 0.23 for River FarinRuwa rainy season to 0.52 for River Antau dry season. The results showed most variables of water from the rivers for the seasons were generally low and fall within the limits considered safe for irrigation by FAO, (1994) and Ayers and Westcots (1985). The suitability of the water was rated class 1 suitable 1 which indicates the water being excellent for irrigation without undesirable accumulation of dissolved salts, sodium and toxic metals at intensities to impact negatively on the soil and yields of crops. The study recommends that Farmers should utilize these rivers for dry season farming to boost food production and that both irrigation and rain-fed agriculture should be practiced on lands along the rivers as the water quality of the rivers is suitable for irrigation and have not impacted negatively on the soils..
Keywords: Irrigation, suitability, water quality, salinity and classification.

INTRODUCTION
The suitability of water expresses the fitness of water for a specific or a variety of uses including irrigation. The suitability of water for irrigation is therefore essential and determines the productive capacity of the soil and the quality and yields of crops grown. Water in surface reservoirs is easily accessible, cheap to exploit, and is replenished directly by rain drops from atmospheric precipitation. Studies have shown that irrigation uses greatest portion of water in both the developed and the developing countries using over 70% of the world's fresh waters (Miller and Gardiner, 2007). Enger and Smith (2006) and Cunningham, *et.al.,* (2007) observed irrigation as the major consumptive use of water in most parts of the world and accounts for about 80% of all water consumed in USA. Human activities however, have introduced into the natural drainage system wastes which by their volume, composition or both cannot readily be disposed through the natural recycling process resulting in water pollution problems. The utilization of water high in ionic substances may eventually lead to build up of the substances in the soil at a level likely to affect the soil productivity and reduce in yields of crops (Folorunso, *et.al.,* 2005). In most irrigation schemes in Nigeria the assessment of the quality of water used in irrigation has

not been given serious attention as such this poses serious threat to health of both farmers and the consumers of the crops (Samaila,*et.al.,* 2011). Though irrigation use of water has the advantage of potential treatment mechanisms in soils such as biological oxidation, ion exchange, chemical precipitation, adsorption and assimilation into growing plants however, the amount and kinds of impurities present in particular water should be determined for necessary guide if it is to be used without after effects for irrigation. It should be noted that the suitability of particular water for irrigation will depend on the adequacy of the drainage, the method of irrigation, salt tolerance of the crop and the management of irrigation and drainage. Therefore, before any water is used for irrigation its suitability must be ascertained and compared with existing water quality and or standards. Water when directly used for irrigation can increase the quantities of solutes there by raising the concentration of certain ions and eventually lowering the quality of the water for irrigation (Ayers and Westcots, 1994). Though irrigation is not new to most communities in Nasarawa state however, knowledge about the quality of water and the implication on crop development has not been given sufficient attention as a result farmers practice irrigation with water likely to pose threat to human health, soil productivity and low crop yields. Most studies on water quality in Nasarawa state evaluated surface water for domestic use (Gyar and Joseph 2009, Abiola, *et.al.* 2010 and Usman, *et.al.* 2010). It should be noted however that water quality for irrigation is as well important. Poor quality water when used directly for irrigation may contain pathogens and as well carcinogenic substances which are likely to bio-amplify within the food chain and cause ailments to human health. To overcome these problems evaluation of the suitability of water for irrigation is necessary.

The chemical, physical and biological properties in water most not fall above the threshold value limit considered for irrigation water. Where there is high concentration of properties in irrigation water it will have negative effect on the growth and yield of crops and may result in the built up in the soils of harmful ionic elements thus affecting the productivity of the soils. Most studies on irrigation water quality have taken into consideration the presence of sodium ions in relation to calcium and magnesium, salinity caused by excess salts and toxic elements such as boron, lead, chloride, sulfate, nitrate and phosphate as being important in the assessment of water quality for irrigation. Though the presence of these substances in irrigation water may appear minute but their concentrations are likely to be lethal to the growth of many crops.

MATERIALS AND METHODS

Nasarawa state is well endowed with enormous water resources both surface and underground. The distribution of water seems to reflect the geology of the state with the northern basement complex rocks being source of surface water while the southern sedimentary formation is underlain by underground water. The study covered three rivers in the northern section of Nasarawa State comprised mostly of the basement complex formation. The rivers include Farin Ruwa, Mada and Antau whose water survive the dry season except for Antau which is fed with domestic effluents from Keffi town and provides water for irrigation in the dry season. The rivers being perennial have attracted human activities such as dry season farming and fishing thus providing a portion of the population

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gainful employment. Data for the study was obtained from laboratory analysis of 60 water samples twenty each along the three rivers for the two seasons (Rivers Antau, Mada and Farin Ruwa). The water samples were taken at thirty metres interval where irrigation is practiced. Parameters analysed for water included pH, electrical conductivity, total dissolved solids using Jenway portable meter, sodium, potassium by flame emission photometric method, calcium, magnesium by titrimetric method, chlorides using silver nitrates method, phosphates was by ascorbic acid method, nitrates by ultraviolet spectrophotometer screening, carbonates and bicarbonates AOAC method, boron, lead and iron by atomic adsorption spectrometric method The suitability of the water for irrigation was determined using the interim guidelines for irrigation water by Food Agricultural Organization (FAO, 1994) and standards for interpreting water quality for irrigation by Ayers and Wescots 1985. The classification of the water quality of the rivers for irrigation was done using The United State Salinity Laboratory Staff (USSLS) (1954) which has enjoyed widespread application for its consideration of both the factors of salinity and sodium hazards. Many scholars have used the proposal to classify water for irrigation for its consideration of sodicity and salinity which are major problems in irrigation water (James 1993, Ayers and Westcots 1994, Samaila 2005 and Maas 2010).

RESULTS AND DISCUSSIONS

Evaluation of the Suitability of Water for Irrigation

Evaluation of the water of the rivers was done to assess the potential of the quality of water for irrigation in the area. This involved the assessment of parameters such as salinity, caused by total dissolved salts, solidity caused by presence of sodium in water and toxicity from specific ion concentrations.

Salinity

The electrical conductivity and total dissolved solids in water for the rivers in the dry season as shown in table1 were low except for River Antau that recorded 280.9 uS/cm. The raining season mean concentrations were low for all the rivers ranging from 44.5 uS/cm for Mada River to 64.9 uS/cm for Farin Ruwa. Total solids for the rivers for both seasons was also low ranging from 26.2 mg/l for Mada raining season to 168mg/l recorded of dry season water of Farin Ruwa. The concentration of salts for the water for the rivers was less than 750 uS/cm considered for water without problem for use in irrigation by Ayers and Westcots, (1994). Since the water is low in salinity as indicated by the electrical conductivity this implies that the application of the water for irrigation will not affect the osmotic pressure of most plants to affect the uptake of water and nutrients from the soils. As shown in table 2 the level of electrical conductivity of water for the rivers was low and largely negligible to crops growth indicating that even sensitive crops may not be affected by the level of salinity of the rivers for all the seasons.

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Table 1: Electrical conductivity, total dissolved solids and pH for Rivers Antau, Mada and Farin Ruwa dry and wet season water

Parameter	Dry season			Raining season		
	Antau	Mada	Farin. Ruwa	Antau	Mada	Farin.Ruwa
ECw (uS/cm)	280.9	58.5	58.1	59.7	44.5	64.9
TDS (mg/l)	168.6	34.2	33.4	35.8	26.2	37.7
pH -	7.13	7.27	7.29	7.50	7.42	7.23

Table 2: Crop response to soil salinity

EC of soil extract uS/cm	Crop response
0 – 200	Largely negligible
200 – 400	Yields of sensitive crops may be restricted
400 – 800	Yields of many crops restricted
800 – 1600	Only salt tolerant crops
Above 1600	Very few tolerant crops

Source: Tivy, (1990).

The mean pH values for water for the rivers were slightly above neutral (alkaline). The dry season mean values were 7.13 for River Antau, 7.27 and 7.29 for River Mada and Farin Ruwa River respectively. The raining season values were slightly higher with River Antau recording 7.50, River Mada 7.42 and Farin Ruwa River 7.23. The slightly high pH observed for water of the rivers in the raining season may be attributed to agricultural return flow enriched with organic and chemical fertilizer during this period. The means for the rivers in the seasons fall within the range of 6.5 to 8.4 Ayers and Westcots (1994) considered safe for irrigation water. This implies that the solubility of most nutrients will not be interfered to a level to affect their availability for plants uptake.

Sodium hazards in water for Rivers Antau, Mada and Farin Ruwa

Carbonate, bicarbonate and cations concentrations for the water in the rivers for the study area are presented in table 3. The entire variables were traced for the rivers except for carbonate. Slight variations however were observed in the concentrations of the variables in the rivers for the seasons covered by this study.

Table 3: Carbonate, bicarbonate and cations for water in Rivers Antau, Mada and Farin Ruwa

Parameter	Unit	Rivers in dry season			Rivers in Rainy season		
		Antau	Mada	Farin Ruwa	Antau	Mada	Farin Ruwa
Sodium	me/l	1.83	1.32	1.02	0.99	1.83	0.95

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Calcium	me/l	22.6	11.4	18.3	20.3	22.6	14.3
Magnesium	me/l	10.2	6.5	8.7	8.1	10.2	7.5
Potasium	me/l	0.2	1.4	2.8	0.1	0.1	2.8
Carbonate	me/l	00	00	00	00	00	00
Bicarbonate	me/l	3.13	0.96	0.48	0.55	0.45	0.48
SAR	-	0.45	0.43	0.31	0.41	0.25	0.27
RSC	me/l	-29.8	-17.0	-23.5	-21.9	-22.5	-22.2

Water that does not have the proper proportion of calcium and magnesium significant problems with water infiltration and break down of soil structure develop. Sodium ion recorded for the rivers in the seasons was generally low when compared to divalent cations of calcium and magnesium as shown in table 3. The concentration of sodium for the rivers in the seasons ranged between 0.95 in Farin Ruwa rainy season to 1.85meq/l for river Antau dry season. All the mean values for the rivers of sodium are within the level of 120 mg/l considered for irrigation, (African Forum for Unity Regulations 2007). The mean concentrations of calcium ranged between 11.4 for Mada River dry season to 22.6meq/l for Antau dry season and Mada rainy season respectively. Magnesium was between 6.5 for River Mada dry season to 10.2meq/l for River Antau and Mada River dry season. High amounts of calcium and magnesium recorded for the rivers indicated that it counter the sodic effect of sodium and hence will not disperse soil particles therefore improve the internal drainage of the soil. The results of calcium and magnesium were also within the irrigation and reuse standard considered safe for irrigation (Ayers and Westcots, 1994). The impact of potassium in irrigation acts same as in sodium as such high potassium in the soil will interfere with the internal drainage and cause dispersal of soil aggregates. Potassium concentrations for the rivers in the seasons ranged from 0.1 for rainy water of Rivers in Antau and Mada to 2.8meq/l for River Farin Ruwa both rainy and dry seasons. The concentration of potassium in the water of the rivers for the seasons all were low and within the level of 50 mg/l considered for irrigation water.

The sodium adsorption ratio a most popular measure for predicting the potential problems for soil productivity and crop yields showed low concentration for the rivers in all the seasons. The sodium adsorption ratio of water was generally low due to the high concentration of calcium and magnesium ions over that of sodium. The sodium adsorption ratio of between 0.25 and 0.45 for the seasons recorded for the rivers were low and within the 0-3 considered suitable with no problem when used for irrigation. This implies that the use of the water in the rivers for irrigation will not have mark influence with penetration of water into the soil and hence will not be accompanied with permeability problem. Carbonate was not detected for all the rivers due to the low pH recorded for the area (pH< 8.5). Bicarbonate was however detected for all the rivers and with slight variation. The bicarbonate concentration was between 0.45 for river Mada rainy season to 3.13meq/l River Antau dry season, Ayers and Westcot (1994) observed that bicarbonate concentration of 1.5me/l is without problem in irrigation water while 1.5me/l to 8.5me/l has increasing problem. This

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showed that the rivers in all seasons except for River Antau dry season had concentrations that will not pose problem in the use of water for irrigation. River Antau dry season water however will be accompanied by increased bicarbonate problem in the soil if used for irrigation. The implication of high bicarbonate in water is that it will result in the precipitation of calcium and magnesium ions from the soil thus raising sodium adsorption ratio. The impact of carbonate and bicarbonate in irrigation water is best measured on their proportion to calcium and magnesium ions. Residual sodium carbonate therefore shows the degree of bicarbonate in irrigation water. Residual Sodium carbonate was between -29.8 for River Antau dry season to -17.0meq/l for River Mada dry season. The high concentrations of calcium and magnesium in water above those of carbonate and bicarbonate resulted in the negative values recorded for the rivers in all seasons. The values of RSC were very low indicating that carbonate and bicarbonate concentration in the rivers have not reach cronic levels to impact on the soil to precipitate calcium and magnesium ions thus to interfere with internal the drainage of the soil.

Specific ions toxicity of water in Rivers Antau, Mada and Farin Ruwa

The trace elements in water of the rivers for the seasons were highest for iron as shown on table 4 The high mean concentrations of 2.68 mg/l and 2.51 mg/l for dry and raining season water in River Antau indicates that there is the need to be cautious in the application of the water as it may result in the built up of iron in the soil and bio applify in plants to cause harm when the water is used continuously for irrigation. Other rivers in the seasons show lower values of iron. The United Forum for Unity Regulations (2007) recommended 5.0 mg/l as allowable in irrigation water, the use of water for irrigation from these rivers will not pose problem of iron accumulation in the soil.

Table 4: Specific ion toxicity in water for Rivers Antau, Mada and Farin Ruwa.

Parameter	Unit	Dry season			Raining season		
		Antau	Mada	Farin Ruwa	Antau	Mada	Farin Ruwa
Iron	mg/l	2.68	1.25	1.00	2.51	1.98	1.22
Lead	mg/l	0.03	0.04	0.03	0.03	0.02	0.04
Boron	mg/l	0.52	0.49	0.32	0.43	0.33	0.23
Phosphates	mg/l	1.72	0.05	0.52	1.04	1.72	0.26
Nitrates	mg/l	0.70	0.07	0.42	0.09	1.72	0.23
Chloride	mg/l	25.9	16.00	25.6	20.9	18.1	16.4

Lead was generally low for the water of the rivers in the seasons. The values of lead were from 0.02 to 0.4mg/l for the rivers in all the seasons. None of the values of lead was above 0.05 mg/l. Reed, 2004 recommended 5.0 mg/l of lead as permissible in irrigation water, this therefore indicated that lead poisoning in the soils will not result from the use of water for irrigation on the irrigated fields in the study area. Boron is an essential element required by many plants at small concentration for their growth. Boron concentration ranged from 0.23

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in water of River Farin Ruwa rainy season to 0.52mg/l for River Antau dry season. Food and Agricultural Organisation (1985) recommended 0.7 mg/l as having no degree of restriction on use for irrigation. This implies that boron toxicity will not result from the use of water in the area and that even sensitive plants are not threatened by the concentration of boron in the water as shown in table 4. Phosphate and nitrate are important nutrients required for plants, their presence in excessive amounts will result in over stimulation of growth and delayed maturity in plants. Phosphates observed for the Rivers was between 0.05mg/l for Farin Ruwa River in dry season and 1.72mg/l for Rivers Antau dry season and Mada rainy season. Ayers and Westcots (1994) observed nitrate of 5.0 mg/l has no degree of problem for irrigation water. Nitrate just like phosphate was also for the water of the rivers. The lowest of 0.07mg/l was recorded for River Mada dry season while the highest of 1.72mg/l was observed for River Mada rainy season. African Forum Unity Regulations (2007) observed 3.5 mg/l of phosphate as being suitable for irrigation. The values of phosphates and nitrates for the rivers as shown in table 4 were below these recommended levels and therefore will not impact negatively in the soil to affect plants growth.

Chloride was low for the rivers ranging from 16 mg/l for River Mada dry season to 25.9 mg/l for dry season water of River Antau. According to Ayers and Westcots (1994) chloride of 4me/l in water has no limiting problem for application in irrigation water. The values of chloride in the rivers were generally lower than the 4 me/l as such chloride toxicity will not result in accumulation in the soil to impact negatively on the plants developmental processes. The present quality of water in the rivers covered by this study showed the water was suitable for irrigation and without limitation to use. The low values of electrical conductivity observed for the rivers indicates that the application of water for irrigation will not result in salinity built up in the soil to reduce the uptake of water and nutrients by plants. The high concentrations of divalent cations of calcium and magnesium result in the low sodium adsorption ratio and residual sodium carbonate observed for the rivers in the seasons and where this condition exists it is likely to counteract the possible effect of sodium ion in the soil colloids. Low sodium adsorption ratio of less than 1 recorded for the rivers showed that sodium accumulation will not pose problem for the soil from the use of water in the rivers for irrigation. This therefore implies that internal drainage, poor soil structure and permeability will not be impeded to affect the normal developmental processes in plants. Residual sodium carbonate was low for the rivers in the seasons due to high concentrations of calcium and magnesium ions in the water. The low residual sodium carbonate recorded for the rivers means that calcium and magnesium ions will not precipitate to further complicate the presence of sodium in the soils.

Trace metals for the rivers were generally low below the toxic levels considered for irrigation water. Phosphate, nitrate and chloride were within the range considered with no problem and limitation to use. The general levels of the concentration of specific ion toxicity in the soils were as well low as shown in table 4. The water of the rivers covered by this study is

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Volume 4, Number 2, June 2019
http://www.casirmediapublishing.com

of excellent quality and its application for irrigation will not pose problems in the soils from sodicity by excess sodium or salinity due to excessive accumulation of dissolved salts.
Boron is present in water as boric acid and in this form may be toxic to plants even at very low concentrations. As observed by Rainwater and Thatcher (1960) boron content in natural water hardly exceeds 2mg\l. According to Musa, et.al (1993) highly sensitive crops are affected by boron concentration at as little as 0.5 mg/l. Boron is however an important substance required in small amount by the plants. Table 5 shows the sensitivity of plants to boron. Results of boron in this study 0.23-0.52mg/l shows boron was low and comparing this to table 5 implies that even sensitive crops will not be affected by the presence of boron in the water of the rivers.

Table 5: Sensitivity of plants to boron in irrigation water

Plants	Boron in irrigation water (mg/l)
Highly sensitive	0.1
Sensitive	0.1 – 1.25
Semi tolerant	0.7 – 2.5
Tolerant	1.6 - 4.0

Source: Urroz, (1976)

Classification of water in the rivers for irrigation.
The classification of the suitability for irrigation for the rivers under this study considered the USSL staff (1954), Israelson and Hansen 1962 and the modified version of Thorne and Peterson (1971) for the classification of water quality for the rivers. The classification took into consideration those parameters that have mark influence on irrigation water such as SAR, RSC, EC and Boron. Similar works by Aliyu et al (2016) and Talabi et al (2017) also considered these variables in the assessment of suitability of water for irrigation in Gulma Flood Plains, Zaria and River Owan respectively.

Table 6: Classification of suitability for irrigation of water in Rivers Antau, Mada and Farin Ruwa in the dry and raining seasons

Rivers	SAR	RSB	EC	Boron	Class	Remark
Dry season						
Antau	0.45	-29.8	280.9	0.52	Class 1 suitable 1	Excellent
Mada	0.43	-17.0	58.5	0.49	Class 1 suitable 1	Excellent
Farin Ruwa	0.31	-23.5	58.1	0.32	Class 1 suitable 1	Excellent
Raining season						
Antau	0.41	-21.9	59.7	0.43	Class 1 suitable 1	Excellent
Mada	0.25	-22.5	44.5	0.33	Class 1 suitable 1	Excellent
Farin Ruwa	0.27	-22.2	64.9	0.23	Class 1 suitable 1	Excellent

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Table 6 shows the classification of water in the rivers covered by this study. The classes of the water in the rivers in the seasons fall on class 1 suitable 1 due to the low content of salts as indicated by EC, SAR, RSC and boron in the water. The class 1 suitable 1 water observed for the rivers for the seasons covered by this study indicate the water to be excellent for irrigation use and without fear of undesirable accumulation of dissolved salts, sodium or toxic metals to impact negatively on the soils and yields of crops. The growth of plants from the use of water and the soil will be enhanced and will not result in obnoxious bio-amplification in plants to affect the consumers of the products. This then implies that since the water for the study area is of excellent quality for irrigation, plants grown on the soils using the water will not pose health problems from magnification of the substances in plant cells. Since the quality of water recorded for this study is excellent for irrigation, this implies that health problems likely to be encountered from the consumption of crops produced from the water will not impact negatively on the health of people in the study area.

CONCLUSION

The suitability of water for irrigation is essential to the growth of crops and maintenance of soil productivity. Water with high concentration of ionic substances is likely to be accompanied with built up of the substances at intensities and levels likely to affect the productivity of the soils and the yields of crops. The result of water from the rivers covered by this study showed that most of the variables considered were generally low for the rivers in all seasons. The low concentration of the variables of water in the rivers for both dry and rainy seasons implies that the use of the water for irrigation will not be accompanied by serious after effects on the soils and crops grown. The classification of the suitability of water in the rivers by considering electrical conductivity, sodium adsorption ratio, residual sodium carbonate and boron showed these variables were low. The low concentration observed of the variables placed the water on excellent for irrigation use and without fear of undesirable accumulation of dissolved salts, sodium or toxic metals to impact negatively on the soils. The use of the water for irrigation will enhance soil productivity and yields of crops. Since the quality of water recorded for this study is excellent for irrigation, this implies that health problems likely to encounter from the consumption of crops produced from the water will not have mark influence on the people in the study area.

RECOMMENDATIONS

Since the study observed the water from the rivers for both dry and rainy seasons was excellent for irrigation without fear of accumulation of substances at levels to impair the soil or the yields of crops. The study therefore recommends that: Farmers in the area should utilize these rivers for dry season farming to boost food production in the area. Both irrigation and rain-fed agriculture should be practiced on lands along the rivers as the water quality used during irrigation is suitable. This therefore indicates that the soil quality could have not been affected by accumulation of ionic substances at level to impact negatively on the growth of crops. More lands should be open up along these rivers to provide more employment to restless unemployed youth in the area and as well as to keep the farmers busy

throughout the year. Farmers in the area should ensure sound irrigation practices are employed so as to ensure the maintenance of the present quality of water observed for the rivers.

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