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EFFECT OF IRRIGATION ON SOME CHEMICAL PROPERTIES OF FLUVISOLS IN SUDAN SAVANNA ZONE OF NIGERIA

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ABSTRACT
Soil studies were conducted to assess the effect of irrigation on exchangeable bases and cation exchange capacity in Sudan savanna zone of Nigeria. Accordingly, soil and irrigation water samples were collected from selected locations and analyzed for soil and irrigation water quality indicators using standard laboratory procedures while appropriate statistical analysis were carried out. The result of the study indicated that soils were non-saline (EC = 0.05 to 0.15 dS/m). The exchangeable Mg (1.28 to 2.23 cmol/kg) in the irrigated soils was high. No significant difference was observed between the irrigated and non-irrigated soils. The irrigation water was moderately acidic (pH 5.6 to 6.0) to slightly alkaline (pH 7.3 to 7.8) and non-saline and non-sodic with low EC (0.21 to 0.26 dS/m), Ca (10.47 to 29.77 mg/l), Mg (3.28 to 6.32 mg/l), K (1.27 to 10.55 mg/l) and Na (0.83 to 1.33 mg/l), total dissolved solids (88.1 to 92.70 mg/l) and SAR (0.28 to 0.39) were very low in the irrigation water. The irrigated soils were more alkaline than the non-irrigated soils. It is recommended that low soil fertility should be improved through incorporation of organic materials in the study area.

Key Words: Irrigation, Chemical Properties, Fluvisols, Sudan Savanna

INTRODUCTION

Fluvisols (IUSS, 2014) are soils developed on alluvial deposits; from L. fluvius, river. The etymology is misleading in that Fluvisols are not confined to river sediments but also develop on lacustrine and marine deposits. Many international soil names refer to this group, for example: 'Alluvial soils' (Russia, Australia), 'Fluvents' (USDA Soil Taxonomy) (FAO, 2001 and Ward, 2008). More so, these soils are also referred to as *Fadama* soils in Nigeria (Babaji, 2000). Fluvisols are young soils that have been directly exposed to hydrological variations and to intensive agricultural exploitation for centuries (Kercheva *et al.*, 2016). Their characteristics vary from coarse to fine textured, from acid to alkaline, from rich to poor in nutrients. However, the good natural fertility of most Fluvisols and the attraction of dwelling sites on river levees and on higher parts in marine landscapes were recognised in prehistoric times (FAO, 2007).

Although irrigation is useful for sustaining/increasing agricultural production, it is imperative that only good quality water is used. Poor quality water affects adversely the soil quality as well as crop production (Omar and Nzamouhe, 2017a & b). The high ground water table coupled with semi-arid conditions worsens the situation by making the fadama soils prone to salinization/sodification. Many researchers (e.g., Yidana *et al.*, 2011; Verwey and Vermeulen, 2011; Bouksila *et al.*, 2013) extensively reported that salinity and sodicity have been among the major problems of irrigated agriculture across world. Nonetheless, it is estimated that over 900 million hectares of agricultural land are impacted by salinity and sodicity, representing over 6% of all agricultural land and about 20% of the world's irrigated land (Munns, 2005; FAO, 2005; Wong *et al.,* 2010).

Neumann, (1995) observed that the physical properties of *Fluvisols* can be affected by soil water salinity, causing fine particles to bind together into peds. According to El-kharbotly *et al.,* (2003) salinity causes serious environment problems that affect grassland cover and animal feed availability in arid and semi-arid regions. The change in soil physical and chemical properties leads to increase in soil erosion, influencing dispersion, nutrient cycling as well as the activity of biotic organisms inhabiting the soil. Notably, there is a connection between the effect of land management practices on soil salinity and sodicity (Wong *et al.,* 2005). This can be concluded by the research conducted by Dollhopf, (2000) which observed that fine-textured soil containing excess sodium on their exchange site as a result of irrigation water present inside the soil are being attracted to small pores with a large amount of force, causing soil swelling, particle slaking from aggregates, and dispersion.

Soil affected by salinity are usually characterized by the presence of high soluble salts as a result of waterlogging of depressed topographic areas and increasing water tables. Under irrigated agriculture, salts are added continuously to the soils with each irrigation event (Qadir *et al.,* 2006a). Thus, soil salinity is a major threat to the sustainability of irrigated agriculture (Ghassemi *et al.,* 1995).

Soil salinization and sodification have been identified as major causes of land degradation (Cucci *et al.,* 2011). *Fluvisols* are prone to salinization probably due to the use of poor-quality irrigation water which affect soil properties (Singh, 2001). Even though irrigation is useful for sustaining agricultural production, it is imperative that only good quality water is used (Singh, 2001). Poor quality water can increase the osmotic potential in the soils which affect their physical and chemical properties. As a result of evapo-transpiration of water, soluble salts accumulate in soils. However, little or no data exist on the possible effect of the irrigation water on some selected soil chemical properties in Sudan savanna zone in Nigeria. Therefore, it is important to assess the irrigation water quality and its effects on some selected chemical properties of the *Fluvisols* in the study area.

MATERIALS AND METHODS

The study was conducted in Warwade town about 15 kilometers south of Dutse LGA (latitude 11^{o}40'30''N to 11^{o}46'30''N and longitude 9^{o}11'30''E to 9^{o}25'30''E) located in Jigawa State within the Sudan savanna of Nigeria (Figure 1). The study area experiences 3 to 4 months of rainfall (from June to September) with August being the peak (262 mm) and about 743 mm of precipitation falls annually. At an average temperature of 30^{o}C, April is the hottest month of the year. The lowest average temperatures in the year occur in January, when it is around 22.0^{o}C (Olofin, 1987). The underlying geology of the area is predominantly coastal plain sediments. Warwade is under the semi-arid region within the Sudan Savannah of the seven agro-ecological zones in Nigeria (Zangina, 2015). Total forest cover in the area and Jigawa state as a whole is very much below national average of 14.8% (Garba, 1998). This area is characterized by different size and kind of grasses and trees (e.g neem, mango, date palm, baobab, parkia, tamarine etc.) scattered within the environment. The nature of the soils occurring in this basement complex region is mainly from wind drift materials that have covered the regolith of the ancient rocks in some meters deep (Olofin, 1987).

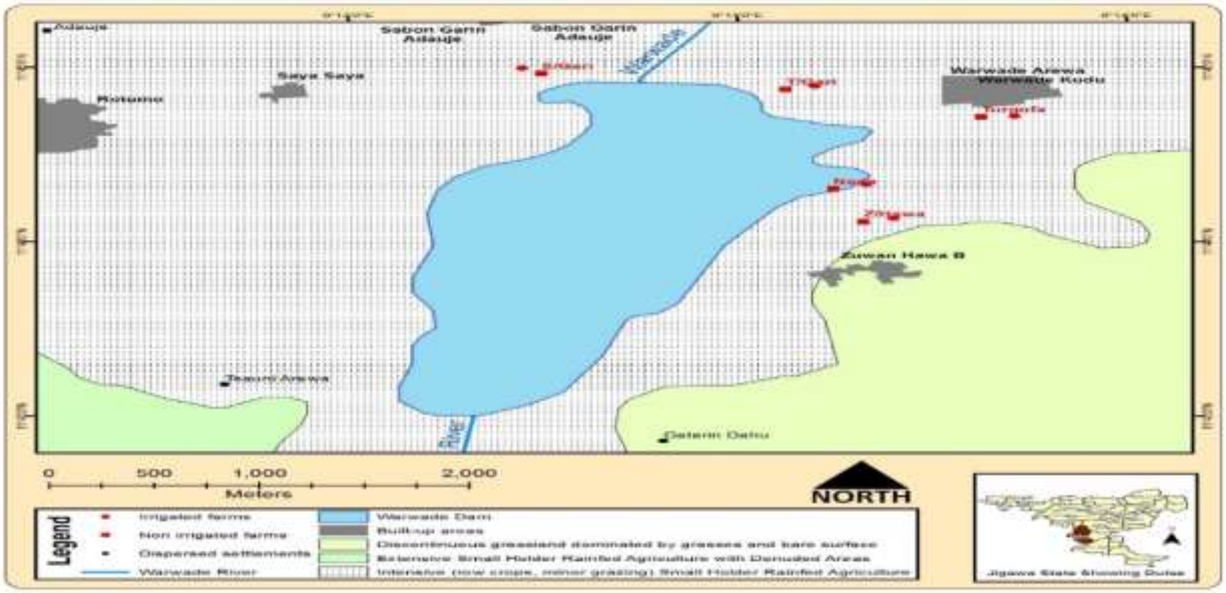

Figure 1: Map of the study area showing sampling sites.
Source: Cartography Laboratory, Department of Geography, Bayero University Kano (2017)

Soil Sampling
Five farms were selected within five villages namely Sabon Gari, Tsohon Gari, Turgupha, Nada and Zuwan-Hawa (Figure 1). Within each farm seven irrigated soil samples were collected randomly and were finally bulked to given a composite soil sample while seven non-irrigated soil samples (control) were collected from non-irrigated farm, bulked to give a composite soil sample as well. A total of five irrigated soil samples were collected within farms from five villages while five non-irrigated soil samples were collected to give a true representation of the non-irrigated farms. The soil samples were collected at a depth of 0 - 20 cm, using an Edelman clay auger. The soil samples collected were kept in black polythene bags after which they were properly labelled. The composite soil samples were air-dried and sieved through a 2 mm sieve. The soil parameters were analyzed using standard methods in the soil science laboratory at Bayero University Kano.

Analytical Procedure for Soil and Water Sample
The soil pH was determined in soil water ratio of 1:2.5 by using glass electrode pH meter (McNeal and Coleman, 1965) while the electrical conductivity (EC) was determined using saturated paste extract of 1:2.5 soil water ratio using electrical conductivity meter at 25^{o}C (Agbenin, 1995). Exchangeable bases (Ca, Mg, K and Na) were extracted using the method described by Anderson and Ingram (1993). Potassium and sodium were determined using flame photometer while calcium and magnesium were determined using atomic absorption spectrophotometer. Meanwhile, the water samples collected were analyzed for pH, EC, total dissolved solids (TDS), Na, K, Ca, Mg, Cl^-, SO^{-4}, NO_3^-, B, carbonates and bicarbonates using standard laboratory procedures while residual sodium carbonate (RSC) and sodium absorption ratio (SAR) were calculated using standard formulae.

Water Sampling
Five irrigation water samples were collected from 5 different villages (Sabon Gari, Tsohon Gari, Turgupha, Nada, and Zuwan-Hawa) which were stored inside a clean 60 cl bottle.

Experimental Design and Statistical Analysis
Nested design was used in soil sampling. Two treatments were considered and consisted of (i) Irrigated soils and (ii) Non-irrigated soils (control). Data collected was subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1967). Correlation coefficient (r-value) between some selected soil chemical properties and irrigation water properties was determined using R-

software (2017) to determine the effect of irrigation water on soil chemical properties.

RESULTS

Soil Chemical Properties

The pH ranged from moderately acidic to slightly alkaline cutting across the study area. The pH (H_2O) in the irrigated soil ranged from 6.88 (Nada) to 7.31 (Zuwan-Hawa) while the non-irrigated soil ranged from 6.47 (Turgupha) to 7.06 (Sabon Gari). The EC were observed to be very low throughout study area. The range of the EC from the irrigated soil was between 0.05 to 0.15 d/Sm while the non-irrigated soil ranged between 0.04 to 0.11 d/Sm. The soil exchangeable Ca and Na were both observed to be low (< 2 cmol/kg for Ca and 0.1 – 0.3 cmol/kg for Na) to medium (2 – 5 cmol/kg for Ca and > 0.3 cmol/kg for Na) throughout the study area (Esu, 1991). In the irrigated soils, the soil exchangeable Ca and Na ranged from 1.70 and 0.07 (Sabon Gari and Nada) to 4.64 and 0.14 cmol/kg (Zuwan-Hawa and Sabon Gari) while in the non-irrigated soils, it ranged from 1.58 and 0.6 (Tsohon Gari) to 3.14 and 0.09 cmol/kg (Nada and Sabon Gari). The soil exchangeable Mg was observed to be high (> 1 cmol/kg) throughout the study area (Esu, 1991). In the irrigated soils, the soil exchangeable Mg ranged from 1.28 (Sabon Gari) to 2.23 cmol/kg (Nada) while in the non-irrigated soils, it ranged from 1.77 (Sabon Gari) to 3.46 cmol/kg (Zuwan-Hawa). The soil exchangeable K was observed to be medium (0.15 – 0.3 cmol/kg) to high (> 0.3 cmol/kg) throughout the study area (Esu, 1991). In the irrigated soils, the soil exchangeable K ranged from 0.27 (Tsohon Gari) to 0.44 cmol/kg (Zuwan-Hawa) while in the non-irrigated soils, it ranged from 0.24 (Tsohon Gari and Turgupha) to 0.45 cmol/kg (Sabon Gari).

Chemical Properties of Irrigation Water

The pH of the irrigation water used within the study area was observed to be moderately acidic (5.6 – 6.0) to slightly alkaline (7.3 – 7.8) in nature. The irrigation water was found to be normal for irrigation activities in the area based on the report of FAO (1985). The pH ranged from 5.65 (Zuwan-Hawa) to 7.39 (Sabon Gari). The mean value of pH of the irrigation water indicated that the irrigation water was safe for irrigation purposes.

The EC ranged from 0.21 (Sabon Gari and Zuwan-Hawa) to 0.26 dS/m (Nada). However, the EC of the irrigation water was observed to be very low and therefore not susceptible to either salinity within the study area (Ayers and Westcott, 1985).

The TDS ranged from 88.1 (Nada) to 92.7 mg/L (Turgupha). However, the TDS was observed to be very low (Ayers and Westcott, 1985) within the study area. The result of total dissolved solid shows that the water does not contain high level of soluble salts which could affect the soils' ability to supply water and nutrients (Karanth, 1994).

The Boron concentration in the irrigation water was observed to fall within the range of 4.47 (Turgupha) to 5.58 mg/l (Zuwan-Hawa). The boron concentration was found to be very high with an average value of 4.91 mg/l, which is considered to be toxic to plant and however not safe for irrigation activities based on McCarthy and Ellery, (1994) proposed limits for boron concentration in irrigation and this is in support with the findings of Adamu, (2013). There was no trace of carbonates in the irrigation water. However, in terms of bicarbonate concentration in the irrigation water, it ranged from 122 (Sabon Gari and Nada) to 152.5 mg/l (Tsohon Gari, Turgupha and Zuwan-Hawa). This was rated as slight to moderate (Ayers and Westcott, 1985) and therefore, considered suitable for irrigation activities.

The Cl^- of the irrigation water ranged from 53.25 (Sabon Gari, Turgupha and Nada) to 71 mg/l (Tsohon Gari and Zuwan-Hawa). It has also been observed that the irrigation water contained high chloride level (Landon, 1991) indicating that the water will cause chloride toxicity to crops under irrigation. The SO_4^{-2} ranged from 1.33 (Turgupha) to 13.88 mg/l (Zuwan-Hawa). Nonetheless, the level of SO_4^{-2} was found to below. The NO_3^- ranged from 3.50 (Nada) to 17.51 mg/l (Zuwan-Hawa). However, the concentration of NO_3^- was found to be slight to moderate as described by (Ayers and Westcot, 1985) and therefore considered non-toxic.

However, within the irrigation water exchangeable bases, Mg ranged from 3.28 (Zuwan-Hawa) to 6.32 mg/l (Turgupha), Ca ranged from 10.47 (Zuwan-Hawa) to 19.77 mg/l (Turgupha), K ranged from

1.27 (Zuwan-Hawa) to 10.55 mg/l (Sabon Gari) while Na ranged from 0.83 (Zuwan-Hawa) to 1.33 mg/l (Nada). Nonetheless, the concentration of Ca and Na were found to be low since they were below the recommended maximum concentration (Na is 40 mg/l and Ca is 20 mg/l) (Landon, 1991) while Mg, Ca, K and Na were all found to be low since they were below the recommended maximum concentration (Landon, 1991).

The SAR mg/l was observed to be very low (Ayers and Westcott, 1985) in the study area and was considered non-sodic and therefore safe for irrigation activities (Richards, 1954) which sodicity hazard might not occur and crops may grow without any deleterious effect on the soil and crop yield (Rhoades, 1982). Nonetheless, SAR value ranges from 0.28 (Turgupha) to 0.39 mg/l (Nada).

While the concentration of RSC mg/l was found to be higher than the suitable limit as described by (Landon, 1991). Residual sodium carbonate mg/l was also observed to be within the range of 144.8 (Nada) to 178.6 mg/l (Turgupha). The irrigation water was considered not safe as indicated by the mean value (162.7 mg/l) of the RSC.

Comparative Studies

The comparative analysis between the chemical properties of irrigated and non-irrigated *Fluvisols* at the Sudan savanna zone of Nigeria are presented in Table 2. However, soil reaction in water, Ca, K and Na were found to be higher in irrigated soils than the non-irrigated soils with mean values of 7.03 and 6.78, 3.06 and 2.39, 0.35 and 0.30 and 0.09 and 0.07 respectively (Table 2**)**. The non-irrigated soils where however, found to be higher in concentration of exchangeable Mg with the mean values of 2.70 and 1.90 respectively. This technically implies that the irrigated soils are more alkaline than the non-irrigated soils.

Relationship between Soil and Irrigation Water Chemical Properties

The relationship between irrigation water chemical properties with the chemical properties of irrigated soils at the study area are presented in Table 4**.** The pH of the soil and that of the irrigation water was found to be negatively and non-significantly correlated (r=-0.89). The negative correlation observed between the pH of the irrigated soil and that of irrigation water indicate that there was no relationship between the two variables. The correlation between pH of the irrigated soils and Na and SAR were negatively correlated with r values of -0.9 and -0.42 respectively. The concentrations of Ca, Mg and K in the irrigated soils and the irrigation water were found to be negatively correlated with r values of -0.78, -0.21 and -0.38 respectively. However, Na concentration in the irrigated soils and the irrigation water was found to be positively correlated with r value of 0.11. All the soil and irrigation water properties were found to be significantly ($P<0.05$) correlated (Table 4) with the exception of correlation between soil pH and irrigation water pH, EC, Mg and Na. Similarly, soil Ca was observed to be non-significantly correlated with Ca in the irrigation water. Soil Mg and irrigation water Mg and K were also non-significantly correlated. Also soil K was non-significantly correlated with EC and K of the irrigation water while soil Na was also observed to be non-significantly correlated with the concentration of K and Na in the irrigation water.

Table 1 Selected Chemical properties of irrigated and non-irrigated Fluvisols in Sudan savanna zone of Nigeria.

Village	Farm	pH	EC	Exchangeable Bases			
				Ca	Mg	K	Na
		(H2O)	d/Sm	(cmol/kg)			
	Irrigated	6.92	0.06	1.70	1.28	0.33	0.14
Sabon Gari	Non irrigated	7.06	0.11	2.87	1.77	0.45	0.09
Tsohon Gari	Irrigated	7.04	0.05	2.13	1.89	0.27	0.08
	Non irrigated	6.66	0.04	1.58	1.98	0.24	0.06
Turgupha	Irrigated	7.02	0.08	2.42	2.09	0.35	0.08
	Non irrigated	6.47	0.06	2.18	3.41	0.24	0.09
Nada	Irrigated	6.88	0.06	4.41	2.23	0.37	0.07
	Non irrigated	6.84	0.11	3.14	2.90	0.29	0.07
Zuwan-Hawa	Irrigated	7.31	0.15	4.64	2.01	0.44	0.08
	Non irrigated	6.87	0.08	2.18	3.46	0.27	0.06

Key: EC= Electrical conductivity; Ca = Calcium; Mg = Magnesium; K = Potassium; Na = Sodium

Table 2 Comparative analysis between some selected chemical properties of irrigated and non-irrigated *Fluvisols* in Sudan savanna zone of Nigeria.

Village	pH	EC	Exchangeable Bases			
			Ca	Mg	K	Na
	(H_2O)	d/Sm	cmol/kg			
			Irrigated			
Sabon Gari	6.92	0.06	1.70	1.28	0.32	0.14
Tsohon Gari	7.04	0.05	2.13	1.89	0.27	0.08
Turgupha	7.02	0.08	2.42	2.09	0.35	0.08
Nada	6.88	0.06	4.41	2.23	0.37	0.07
Zuwan-Hawa	7.31	0.15	4.64	2.01	0.44	0.08
			Non-irrigated			
Sabon Gari	7.06	0.11	2.87	1.77	0.45	0.09
Tsohon Gari	6.66	0.04	1.58	1.98	0.24	0.06
Turgupha	6.47	0.06	2.18	3.41	0.24	0.09
Nada	6.84	0.11	3.14	2.90	0.29	0.07
Zuwan-Hawa	6.87	0.08	2.18	3.46	0.27	0.06
MIR	7.03	0.08	3.06	1.90	0.35	0.09
SDIR	0.22	0.03	1.01	0.69	0.07	0.02
MNIR	6.78	0.08	2.39	2.70	0.30	0.07
SDNIR	0.22	0.03	0.62	0.79	0.09	0.01
t-value	0.08^{ns}	0.89^{ns}	0.35^{ns}	0.07^{ns}	0.32^{ns}	0.32^{ns}

ns= not significant at t=5% and t=1% respectively, MIR= mean of irrigated soils, MNIR= mean of non-irrigated soils, SDIR= standard deviation of irrigated soils, SDNIR= standard deviation of non-irrigated soils

Table 3 Chemical properties of irrigation water in Sudan savanna zone of Nigeria.

Village	pH	EC dS/m	TDS	Boron	CO_3^-	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}	Exchangeable Bases Mg	Ca	K	Na	RSC	SAR
			mg/l												
Sabon Gari	7.39	0.21	92.5	4.80	0	122	53.25	10.51	3.27	6.26	19.35	10.55	1.16	147.6	0.32
Tsohon Gari	7.13	0.22	92.7	4.60	0	152.5	71.00	7.01	1.94	6.05	17.64	2.95	1.16	176.2	0.34
Turgupha	7.05	0.23	55.1	4.47	0	152.5	53.25	7.01	1.33	6.32	19.77	2.95	1.00	178.6	0.28
Nada	6.97	0.26	88.1	5.12	0	122	53.25	3.50	7.65	5.99	16.82	2.53	1.33	144.8	0.39
Zuwan-Hawa	5.65	0.21	91.1	5.58	0	152.5	71.00	17.51	13.88	3.28	10.47	1.27	0.83	166.2	0.32
Mean value	6.84	0.23	83.9	4.91	0	140.3	60.35	9.11	5.61	5.58	16.81	4.05	1.09	162.7	0.33

Table 4 Correlation matrix between irrigation water parameters with selected chemical properties of irrigated Fluvisols in Sudan savanna zone of Nigeria.

Soil properties	pH	EC (dS/m)	TDS	Boron	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}	Mg	Ca	K	Na	SAR	RSC
			(mg/l) Irrigation water parameters											
pH(H_2O)	-0.89^{NS}	0.88 ^{NS}	0.07*	0.56*	0.72*	0.76*	0.85*	0.64*	-0.89 ^{NS}	-0.82*	-0.50*	-0.9 ^{NS}	-0.42*	0.50*
EC(dS/m)	-0.95^{NS}	1.00 ^{NS}	-0.03*	0.75*	0.44*	0.43*	0.81*	0.82*	-0.93 ^{NS}	-0.85*	-0.47*	-0.84*	-0.31*	0.19*
Ca(cmol/kg)	-0.76*	0.66*	0.17*	0.84*	0.003*	0.21*	0.24*	0.87 ^{NS}	-0.69*	1.00 ^{NS}	-0.67*	-0.18*	0.42*	-0.24*
Mg(cmol/kg)	-0.39*	0.29*	-0.36*	0.20*	0.35*	0.12*	-0.27*	0.29*	1.00 ^{NS}	-0.31*	-0.92 ^{NS}	-0.04*	0.19*	0.28*
K(cmol/kg)	-0.84*	0.89 ^{NS}	-0.01*	0.84*	0.05*	0.09*	0.61*	0.88 ^{NS}	-0.80*	-0.77*	1.00 ^{NS}	-0.56*	-0.03*	-0.18*
Na(cmol/kg)	0.42*	-0.28*	0.27*	-0.16*	-0.52*	-0.35*	0.20*	-0.26*	0.26*	0.36*	0.97 ^{NS}	0.11 ^{NS}	-0.15*	-0.45*

NS signifies not significant at p= 5%

*** signifies significant at p=5%**

DISCUSSION

Soil Chemical Properties

The soil reaction ranged from moderately acidic to slightly alkaline. Jigawa State Rural Development Authority reported similar moderate acidity (5.60 – 5.84) of the irrigated soils (JARDA, 2008) in the same study area. Similar result was reported by Omar (2011) for fadama soils in south western Bauchi state which ranged from 5.77 – 6.36. Ojanuga (2006) associated the moderate acidity of most fadama soils in Nigeria to their silica-rich parent material. The reports of Oiganji *et al.,* (2015) also indicated that similar soils in Niger state were found to be moderately and slightly acidic with pH values of and 5.5 – 6.3. However, Chemura *et al.,* (2014) reported moderately alkaline soil reaction (8.0 to 8.2) for irrigated soils and 7.2 (slightly alkaline) for non-irrigated soils. The moderate acidity of the soils may not be unconnected with leaching of exchangeable bases as a result of constant ponding of the soils through irrigation activities and seasonal flooding in the area.

The EC was observed to be low throughout the study area and there were no significant differences between the irrigated and non-irrigated soils. This agrees with the findings of Chemura *et al.,* (2015) that no significant differences were observed between irrigated and non-irrigated soils in similar environment. However, Hailu *et al.,* (2016) reported higher EC values in the irrigated soils than the non-irrigated soils with EC values ranging from 1.3 to 1.6 dS/m. According to Landon (1991) EC values of 0 to 2 dS/m indicate non-saline soils, while EC above 2 dS/m indicate salinity at various levels. Based on this, both the irrigated and non-irrigated soils were found to be non-saline and therefore considered to be safe for irrigation purposes. The low EC observed in the study area may be due to the moderate and slight acidity of the soils (Table 1) as earlier observed.

The concentrations of exchangeable Ca and Na were found to range from low to medium and were higher in the irrigated than the non-irrigated soils with mean values of 3.06 and 2.39 cmol/kg and 0.09 and 0.07 cmol/kg respectively. This may not be unconnected with low concentrations of Ca and Na in the irrigation water (Table 3). Omar (2011) reported similar observation in fadama area of south western Bauchi state that Ca concentration (2.02 to 3.89 cmol/kg) were moderate. On the contrary Kparmwang (1996) reported higher values of Ca (5.84 cmol/kg) for fadama soils in the same area. Moderate concentration of exchangeable Na was also reported by Omar (2011) for similar soils in Bauchi state. It is important to note that if proper soil management practices are not taking, the soil may develop a weak structure which can impair crop production in all the location studied. This is because the present moderate status of the exchangeable Na in the soils can easily become high with improper soil management. Therefore, soil management practices such as incorporation of organic material e.g crop residues and or farmyard manure should be practiced to address this likely problem.

Concentration of exchangeable Mg was high throughout the study area but higher in the nonirrigated soils. However, Omar (2011) reported moderate concentrations in fadama areas in south western Bauchi state. It was however higher in the non-irrigated soils presumably due to litter accumulation over time.

The moderate to high concentration of exchangeable K in the irrigated soils is in agreement with report of Carroll and Klinkenberg (1972) in which fadama soils in North- East Nigeria were observed to have moderate content of exchangeable K. Omar (2011) also reported high K content in similar soils. This may not be unconnected with the presence of muscovite which is common in fadama areas. Singer and Munns (1996) reported that muscovite is an important source of K in wet soils. They also reported that muscovite glitters in wet soils. However, all the soil chemical properties analyzed are within the Table 1.

Chemical Properties of Irrigation Water

The mean value of pH of the irrigation water indicated that the irrigation water was safe for irrigation purposes. Malgwi (2001) observed that irrigation water with pH range from 6.5 to 8.4 is regarded as safe for irrigation purposes. The mean values of the pH fell within the range of 7.89 to 8.13 reported by Omar (2011) for irrigation water in south western Bauchi State.

The irrigation water was considered safe as indicated by the mean value (0.23 dS/m) of the EC. This facilitated the classification of the irrigation water in C_1 or non-saline class as described by Schoeneberger *et al*., (2002). The mean value (0.23 dS/m) was higher than the mean value of 0.075 dS/m reported by Omar (2011) in similar irrigation water. This is also higher than the mean value of 0.19 dS/m as reported by Aliyu *et al.,* (2016) in water used for irrigation in Galma irrigation project.

The mean value of TDS (83.9 mg/l) of the irrigation water was found to be safe for irrigation purposes. The mean value of 83.9 mg/l was higher than the mean value of 31.00 mg/l reported by Adamu (2013) for irrigation water in Watari irrigation project. However, this was lower than that of Aliyu *et al.,* (2016) and Omar (2011) who reported a mean value of 134.4 mg/l and 115.39 mg/l respectively for irrigation at similar study area. Nonetheless Omar (2011) reported that the increase in TDS may be associated with the increase in pH value of the irrigation water.

The mean value of Boron in the irrigation water was found to be 4.91 mg/l and was however considered not safe for irrigation activities as described by FAO (1985). This was however higher than that of Aliyu *et al.,* (2016) who reported a mean value of 0.72 mg/l in a similar study area. Adamu (2013) reported a value of 5.34 mg/l for irrigation at Watari irrigation project. Notably, the presence of high boron concentration in the irrigation water may be as a result of naturally occurring boron present in groundwater primarily as a result of leaching from rocks and soils containing borates and borosilicates (WHO, 2003).

There was no trace of carbonates in the irrigation water indicating that it is safe for irrigation purposes as described by FAO (1985). This is also in line with the research conducted by Omar (2011) who detected no concentration of boron in the irrigation water. Nonetheless, this agrees with the observation of Du Preez, (1961) that Nigerian basement complex ground water contains no CO_3 ions.

The mean value of HCO_{3-} (140.3 mg/l) of the irrigation water was found to be slight to moderate for irrigation purposes. This is in support with the findings of JARDA (2008) who discovered a mean value of 176 mg/l for irrigation in a similar study area. However, this was not in conformity with the research conducted by Aliyu *et al.,* (2016) who found a mean value of 2.35 mg/l in Galma floodplain. Adamu (2013) reported that bicarbonates become an increasing concern as the water increases from a pH of 7.4 to 9.3. However, bicarbonates can be found in water of lower pH.

The concentration of Cl^- was found at a mean value of 60.35 mg/l which is not safe for irrigation activities as reported by Landon (1991). This is not in agreement with the report of Omar (2011) who reported a mean value of 0.18 mg/L in similar study area. The high concentration of Cl^- in irrigation may be as a result of the application of inorganic fertilizer, landfill leachate and irrigation drainage and this is in conformity with the report of Department of National Health and Welfare (1978).

The mean value of SO_4^{-2} (5.61 mg/l) of the irrigation water was found to be safe for irrigation activities as described by Landon (1991). This was considerably higher when compared to the mean value (2.89 mg/l) reported by Aliyu *et al.,* (2016) at Galma floodplain. The mean value of NO_{3-} (9.11 mg/l) of the irrigation water was found to be safe for irrigation purposes as described by FAO (1985). The mean value of NO_3^- was lower than that of Adamu (2013) who reported a value of 9.87 mg/l for irrigation activities in Watari irrigation project.

The Ca : Mg ratio of the irrigation was found to be 3.01 which implies that the effect of Na in the irrigation water is reduced since the Ca : Mg ratio is greater than one and this irrigation water is dominated by Ca. This is also in conformity with the report made by Omar (2011). However, since the ratio of Ca and Mg in the irrigation water in all the locations is greater than one (Table 3)**,** the effect of Na may be reduced and Ca was the dominant cation in the irrigation water. This implies that the water is safe for use. The higher the ratio, the less damaging is the SAR or Na concentration and this is in conformity with the research conducted by Omar (2011).

The irrigation water was considered safe as indicated by the mean value (0.33) of the SAR. This makes it easier to classify the irrigation water in S_1 or low Na class as described by Soil Salinity Laboratory Staff (1954). The mean value (0.33) was lower than the mean value of 0.71 as reported by Omar (2011) in the irrigation water of Northern Guinea Savannah of Nigeria. However, the low concentration of SAR in the irrigation water can be attributed to the higher ratio of Ca and Mg in the irrigation water.

The irrigation water was considered not safe as indicated by the mean value (162.7 mg/l) of the RSC. The mean value (162.7 mg/l) was higher than the mean value of –13.36 mg/l reported by Aliyu *et al.*, (2016) in Galma floodplain of Kaduna state. The high concentration of RSC may be as a result of the weathering of basalt which is an igneous rock present in the study area. This is in conformity with the report of Stevens (1962) (Table 3).

Comparative Studies

There were differences between the chemical properties of the irrigated and non-irrigated soils as indicated by their mean values (Table 2). However, the differences were not significant. This result is in conformity with the report of Tekwa *et al.*, (2013) that there were no significant differences between pH mean values of irrigated and non-irrigated soils in Numan fadama soils. Chemura *et al.*, (2014) reported non-significant differences between the mean values of exchangeable K in irrigated and non-irrigated soils.

Relationship between Soil and Irrigation Water Chemical Properties

Nonetheless, these negative correlations indicate that there was no correlation between the parameters mentioned, therefore, indicative of the fact that the irrigation water did not influence the soil pH, exchangeable Ca, Mg, K, Na and SAR. This finding further confirms the non-salinity and non-sodicity of the irrigated soils as earlier observed. This may be due to the good quality of the irrigation water used for irrigation in the study area and also due to the fact that irrigation activities in the study area started only recently.

CONCLUSION

This result, by implication, showed that the irrigated and the non-irrigated soils were not fertile, non-saline and non-sodic. The irrigation water was also found to be non-saline and non-sodic therefore regarded as safe for irrigation purposes in the study area. Therefore, the irrigation water did not influence soil salinity and sodicity indicators.

Recommendations

In corporation of organic materials such as crop residue and or farmyard manure should be applied to the soils to improve the soil fertility. Application of inorganic fertilizer can also improve the fertility of the soil in the study area. Use of good soil management practices that can reduce Na concentration such as incorporation of organic material should be practiced.

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