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ASSESSMENT OF SOIL AND WATER PROPERTIES OF TSAMIYA IRRIGATION SCHEME, KACHAKO, KANO STATE, NORTHERN NIGERIA

*[1]Onokebhagbe, V. O., [1]Habib, D.W., [2]Nzamouhe, M., [1]Nkereuwem, M. E., [3]Adeleye, A. O. and [1]Auwalu, A.

[1]Department of Soil Science, Faculty of Agriculture, Federal University, Dutse, Jigawa State, Nigeria

[2]Department of Soil Science and Land Resource Management, Federal University, Wukari, Taraba State, Nigeria

[3]Department of Environmental Sciences, Faculty of Science, Federal University, Dutse, Jigawa State, Nigeria

*Corresponding author: victor.onokebhagbe@gmail.com

ABSTRACT

Studies were conducted to assess the quality of soil and water in Tsamiya irrigation scheme, Kachako, Kano State. Soil (0 – 20 cm depth) and water samples in 60 cl bottles were collected randomly from the farmlands and water body in Tsamiya irrigation scheme. Randomized completely block and completely randomized designs were employed in the soil and water sampling. Samples were collected in triplicates and subjected to routine analysis for quality indicators. The quality indicators determined for water and soil samples were pH, electrical conductivity (EC), total dissolved solids (TDS), boron, carbonates, exchangeable bases, available phosphorous, organic carbon and total nitrogen. The pH of water ranged from6.4 to 6.7, EC of water ranged from 0.16 to 0.17 dS m^{-1}. Total dissolved solids in water ranged from 121.67 to 126.67 mg l^{-1} while carbonates ranged from 1.00 to 2.99 mg l^{-1}.Values of boron obtained from the water samples ranged from 0.29 to 0.81 ppm while that of the sodium adsorption ratio (SAR) ranged from 1.20 to 1.52. The soils were moderately acidic with an average pH value of 6.0, EC values ranged from 0.21 to 0.24 dS m^{-1}while low ranges of exchangeable Na (0.002 to 0.004) were obtained. Salinity class of the soil was within the non-saline class. The results showed that the water possessed no significant threat to the soil. Results of the study also indicated that the soils were low infertility, non-saline and non-sodic. The study showed that both the water and the soil can be used for a wide range of irrigation activities under good management practices.

Keywords: Irrigation, qualitative, Tsamiya Irrigation Scheme, soil and water properties

INTRODUCTION

The success of an irrigation scheme is largely dependent on the soil-water quality and the efficiency of water use. Nearly all irrigation waters contain dissolved salts and trace elements, most of which result from the anthropogenic activities and weathering of rocks and minerals [1]. Drainage waters from irrigated lands, effluents from city sewages and industrial sludge also impact water quality [2]. The primary concern in most irrigation projects is the salinity levels in the soil and water because high salt content affects the structure of the soil and crop yield. However, a number of trace elements found in water can also limit its use for irrigation [3]. High level of exchangeable bases such as sodium and calcium contents in irrigation water affects the stability of soil structure by causing clay particles to disperse and block soil pores [4]. This reduces the rate of infiltration and soil permeability which leads to less leaching consequently accumulation of salts in the rhizosphere in levels that affect crop productivity and yield [5].

The region of Northern Ni geria is dotted with landscapes that are favourable for intensive irrigational schemes. Unfortunately, information on these potential irrigation landscapes is lacking mostly because of the lack of government or private sector interest and support for the farmers in these areas by way of assessing and documenting the characteristics of such identified landscapes that have the potential to support intensive irrigation activities. Tsamiya in Kachako Local Government Area of Kano state is one of such locations. It has the potential to support large scale of irrigation activities for the production of crops such as wheat, maize, sweet potatoes as well as vegetables. This potential is not fully utilised as the farmers on this landscape are mostly into subsistence farming without any support from the government and private sector. With adequate supply of water, this site has the potential to support irrigation activities throughout the dry season. But information on the quality of water and soil is lacking. Nevertheless, for maximum utilisation and efficient implementation of irrigation scheme in this location, there is the need to assess the soil and water quality. Therefore, the objective of this study was to appraise the quality of the soil and water resources of Tsamiya Irrigation scheme and make recommendations for developing and improving necessary management practices.

MATERIALS AND METHODS

Study Area

The study area is within the Sudan savannah of the seven agro-ecological zones in Nigeria [6]. It falls within latitude 11°31'01.9"N and longitude 9°21'11.6"E.The wet season usually last for 3 to 4 months (i.e., from June to September) with August being the month with the highest average rainfall of 262 mm while about 743 mm of rainfall is recorded annually. At an average temperature of 30 °C, April is the hottest month of the year. The lowest average temperature in the year occurs in January, when it is around 20 °C. The underlying geology of the area is predominantly coastal plain sediments [7].

Figure 1: Aerial view of Tsamiya water body.

Soil and water sampling

Soil samples were collected randomly from the farmlands in Tsamiya irrigation scheme in triplicates. The soil samples were collected at a depth of 0-20 cm, using an Edelman clay auger. The soil samples collected from three locations within the study area were stored in a clean polythene bags which have been properly labelled. Three water samples were also collected from the upper middle and lower part of the dam inside a labelled clean 60 cl plastic bottle using dipping method.

Water Analysis

The water samples collected were analysed for pH, EC, total dissolved solids (TDS), Na, K, Ca, Mg, B, CO_3^{2-} and HCO^{3-}. Each water sample was analysed for the water quality indicators. The pH and EC were determined on pH meter and conductivity meter (at 25ºC), respectively. Total dissolved solids were determined by evaporation-drying method. Sodium adsorption ratio was calculated by the following formula:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} Mg^{2+}}{2}}} \text{--} (a)$$

Residual sodium carbonate was calculated using the following formula:

$$RSC = \left(CO_3{}^{2-} + HCO_3{}^{-}\right) \text{--} (b)$$

Where, the ionic concentrations were in mgl^{-1}. Boron was determined by the colorimetric method, while Ca and Mg were determined using an Atomic Absorption Spectrophotometer. Potassium and Na were determined by flame photometry. $CO_3^{2-}$and HCO^{3-}were determined by simple acidimetric titration in the presence of phenolphthalein for CO_3^{2-}at pH >8.5, and then in the presence of methyl orange for HCO^{3-}at pH <6.0 [8].

Soil analysis

The pH in H_2O was determined electrometrically using a glass electrode pH meter in a solid-liquid ratio of 1:2.5 while organic carbon (OC) was determined using Walkley-Black wet oxidation method as described by Nelson and Sommers [9]. Available P was extracted using Bray-1 method as outlined by Pansu and Gautheyrou [10]. Phosphorus in the extract was determined colometrically by the molybdate-phosphoric-blue method using ascorbic acids as a reducing agent [11]. Total N was determined by micro-Kjeldahl digestion technique method [12]. Exchangeable bases (Ca, Mg, K and Na) were extracted using the method described by Anderson and Ingram [13]. Potassium and Na in the extracts were determined using flame photometer (Jenway PFP7) while Ca and Mg was determined using atomic absorption spectrophotometry (Buck 211VGP, USA). Cation exchange capacity was determined using the electro-dialysis procedure as described by Anderson and Ingram [13].

Experimental Design and Data Analysis

Randomized completely block design (RCBD) was employed in soil sampling while water was sampled using completely randomized design (CRD) as the experimental layout. One-way analysis of variance (ANOVA) was carried out using SAS software package version 9.1

to evaluate the parameters of the irrigation water and soil. Mean separation for significant means was carried out using least significant difference.

RESULTS AND DISCUSSION

Chemical properties of water

The chemical properties of irrigation water are presented in Table 1. The pH of the irrigation water used within the study area were observed to be moderately acidic to neutral pH (6.43–6.70) with mean value of 6.55.

Table 1: Chemical properties of irrigation water at Tsamiya Irrigation Scheme

Water Quality Parameters	Sample 1	Sample 2	Sample 3	SE
pH	6.7	6.5	6.4	NS
EC (dSm^{-1})	0.16	0.17	0.16	NS
TDS ($mg\ l^{-1}$)	126.67^{a}	125.33^{a}	121.67^{b}	±0.92
Boron (ppm)	0.81^{a}	0.29^{c}	0.47^{b}	±0.08
Carbonates ($mg\ l^{-1}$)				
CO_3^{2-}	1.21^{b}	1.00^{c}	1.72^{a}	±0.220
HCO_3^{-}	2.50^{b}	1.50^{c}	2.99^{a}	±0.210
Exchangeable bases ($mg\ l^{-1}$)				
Ca	5.81^{a}	4.11^{b}	3.94^{b}	±0.330
Mg	3.97^{a}	2.13^{b}	2.02^{b}	±0.340
K	1.87	1.07	2.20	NS
Na	3.36^{a}	2.20^{c}	2.95^{b}	±0.170
SAR	1.52^{a}	1.25^{b}	1.20^{b}	±0.060

Means with the same letters are not significantly different at $p < 0.05$, where letters in superscript represent the mean rankings of the water quality parameters of the three samples. SAR denotes sodium adsorption ration; TDS denotes total dissolved solids; EC denotes electrical conductivity

The electrical conductivity of the irrigation water ranged from 0.16–0.17 dSm^{-1} which was observed to be very low and therefore not susceptible to salinity. The total dissolved solids (TDS) ranged from 121.67–126.67 $mg\ l^{-1}$. However, the TDS was observed to be very low indicating that the irrigation water does not contain high level of soluble salts, which might invariably affect the soil's ability to supply water and nutrients.

The mean values of the pH fell within the range of 5.65–7.39 reported by Omar and Nzamouhe [14] for irrigation water in Warwade Irrigation Scheme, Jigawa State. However, for pH outside this range, appropriate steps should be taken to avoid the negative influence in the soil and plant. This however, lead to the classification of the irrigation water in the non-saline class (C1) as described by Schoeneberger *et al.* [15]. The mean value (0.12 dSm^{-1}) was lower than the mean value of 0.23 dSm^{-1} reported by Omar and Nzamouhe [14] in a similar study area. This is also higher lower than the mean value of 0.19 dSm^{-1} as reported by Aliyu *et al.* [16] in water used for irrigation in Galma irrigation project.

The mean TDS value of 124.56 mg l^{-1} was higher than the mean value of 69.26 and 104.50 mg l^{-1} in Oba and Ora river, Ogbomoso, Southwest Nigeria as reported by Abegunrin *et al.* [17]. However, this was lower than that of Aliyu *et al.* [16] who reported a mean value of 134.4 mg l^{-1} in Galma floodplain, Kaduna State. However, Omar [18] reported that the increase in TDS may be in connection with the increase in pH value of irrigation water.

The boron concentration ranged from 0.29–0.81 ppm with a mean value of 0.52 ppm which is considered to be non-toxic to plant as described by FAO [19]. This was however lower than that of JARDA [20] with a mean value of 0.014 ppm while Omar and Nzamouhe [14] reported a higher boron concentration in Warwade Irrigation Scheme with a mean value of 4.91 ppm which was attributed to the naturally occurring boron present in the groundwater primarily as a result of leaching from rocks and soils containing borates and borosilicates [21].

Carbonate and bicarbonate concentrations in all the irrigation water considered ranged from 1.00 to 1.72 mgl^{-1} (mean value = 1.31 mgl^{-1}) and 1.50–2.99 mgl^{-1} (mean value = 2.33 mgl^{-1}) respectively and are found to be safe for irrigation activities as rated by FAO [22]. In this regards, it is safe to say that the water has no degree of restriction in use and therefore, a permeability problem is not expected to occur. More so, there will be little or no precipitation of calcium carbonate and magnesium carbonates from the soil solution as described by Aghazadeh and Mogaddam [23]. This is in also in conformity with the findings of JARDA [20] and Omar and Nzamouhe [14] in a similar study area.

The concentration of sodium (Na) in the irrigation water was generally very low. The values ranged from 2.20–3.36 mgl^{-1} (mean value = 2.84 mgl^{-1}). The values were below 50 mgl^{-1} which means that sodicity problem is not expected.

Potassium (K) concentration in water ranged from 1.07–2.20 mgl^{-1} (mean value = 1.71 mgl^{-1}). The high value could be in connection to the application of inorganic fertilizers like NPK fertilizer in large quantity which invariably leads to the leaching of these minerals into the water and thereby causing the build-up of K in water. The FAO safe range is 0–2 mgl^{-1} [22]. Notably, the mean value of K was found to be within the standard range in the water and could be sued for irrigation activities but, however, the build-up of K should be closely monitored as it could lead to K toxicity over time.

The concentrations of Ca and Mg in the water were found to be low with mean values of 4.62 and 2.71 mgl^{-1}. They were within the threshold class of low salinity described by FAO [22]. The ratio of Ca:Mg was greater than one. Generally, the result showed low concentration of magnesium in the water. However, it is safe to say that salinity problem should not be expected. The low values obtained for Ca and Mg resulted from the slightly acidic pH, because according to Oiganji *et al.*, [24] soils with pH values ranging from neutral to slightly alkaline are associated with high values.

The Ca:Mg ratio of the irrigation water was found to have a mean value of 1.86 which implied that the effect of Na in the irrigation water was reduced since Ca:Mg ratio was greater than one and this irrigation water is dominated by Ca. This is also in agreement with the findings of Rahman and Rowell [25], Singh [26], and Omar and Nzamouhe [14]. Even so, since the ratio of Ca and Mg in the irrigation water in all the locations was >1, the effect of Na may be reduced and Ca was found to be the dominant cation in the irrigation water. This indicates that the water is safe for irrigation activities. More so, the higher the ratio, the less damaging is the SAR or Na concentration and this is in conformity with the findings of Rahman and Rowell [25], Omar [27], and Omar and Nzamouhe [14].

The computed values of the sodium adsorption ratio (SAR) ranged from 1.20–1.52 mgl^{-1} with mean value of 1.32 mgl^{-1} and were rated low against FAO [22] scale and was considered non-sodic and therefore safe for irrigation activities. More so, it is safe to say that the irrigation water falls in S1 or low Na class as shown in Table 2 below.

Table 2: Classification of water based on USSL sodium hazard for irrigation

Sodium hazard class	Range	Water Class
S1	<10	Excellent
S2	10-18	Good
S3	18-26	Doubtful
S4	>26	Unsuitable

FAO [22]

The mean value (1.32 mgl^{-1}) was lower than the mean value of 6.32 reported by Aliyu *et al.*, [16] in Galma floodplain of Zaria. This was also lower than the mean value of 3.58 as reported by Tsuzom and Olaniyan [28] in the irrigation water of Nasarawa – Kakuri area of Kaduna State. However, the lower concentration of SAR in the irrigation water might be in connection to the high ratio of Ca and Mg in the irrigation water as reported by Omar and Nzamouhe [14].

Chemical properties of soil

The soil pH readings across the study area were moderately acidic to slightly acidic and ranged from 6.0–6.1 with a mean value of 6.03. The reports of JARDA [20] and Oiganji *et al.*, [24] indicated that similar soils in Jigawa and Niger states were found to be moderately acidic (5.60–5.84) and slightly acidic (5.5–6.3). The low pH may be associated with the silica rich parent materials of the soils [29]. The moderate acidity of the soils may also be connected with the leaching of exchangeable bases as a result of constant ponding of the soils through irrigation activities and seasonal flooding in the area [14]. Therefore, it is important to note that some plant nutrients may not be readily available in the soils of the study area.

Table 3: Chemical properties of irrigated soil in Tsamiya Irrigation Scheme

Soil parameters	Site 1	Site 2	Site 3	SE (±)
pH	6.1	6	6	NS
EC (dSm^{-1})	0.22	0.21	0.24	NS
Av. P ($mgkg^{-1}$)	0.3^a	0.2^b	0.3^a	0.02
Mg ($cmol\ kg^{-1}$)	0.52^a	0.056^b	0.062^b	9.37
K ($cmol\ kg^{-1}$)	0.035	0.028	0.049	NS
Ca ($cmol\ kg^{-1}$)	0.022	0.012	0.013	NS
SEB ($cmol\ kg^{-1}$)	0.598^a	0.108^c	0.227^b	1.72
TN (gkg^{-1})	0.056^a	0.034^b	0.030^b	0.004

Means with the same letters are not significantly different at $p< 0.05$where letters in superscript represent the mean rankings of the soil quality parameters in the samples. SEB denotes sum of exchangeable bases; OC denotes organic carbon; TN denotes Total Nitrogen.

The SEB observed ranged from 0.108–0.598 $cmolkg^{-1}$ and as much considered to be very low when compared against the rating scale given by Esu [30]. The SEB value was reported to be much lower than 6.07 $cmolkg^{-1}$ reported by Omar and Nzamouhe [14] for soils at Warwade irrigation scheme. More so, soils with CEC values less than 16 $cmolkg^{-1}$ are considered to be non-fertile while fertile soils have CEC values higher than 24 $cmolkg^{-1}$[31]. This however, describes the soils to be non-fertile and will therefore respond to fertilization. Thus, the low values of exchangeable bases (Na, Mg, K and Ca) may be attributed to the low clay and organic carbon content of the soils of the study area.

The organic carbon (OC) in the soils were very low [30] ranging from 3.8–6.3 gkg^{-1}. This could be in connection to overgrazing, bush burning and the use of crop residues for animal feed and other domestic which invariably influences the depletion of organic matter in the soils [32, 33]. The % OC value was reported to be much higher than 5.17 gkg^{-1} reported by Omar and Nzamouhe [14] for soils at Warwade irrigation scheme, Jigawa State.

The available P in the soils ranged from 0.23–0.3 mgkg^{-1} and are, according to the rating by Esu [30] to be low which is characteristic of a typical savannah soil of Northern Nigeria [22]. The low level of available P may be in connection to the low level of OC influenced by rapid mineralization or due to the parent material having low weather able reserve Omar and Nzamouhe [14].

The Total N in the soils was generally low ranging from 0.030–0.056 gkg^{-1}[30]. This is not in conformity with the findings of Omar and Nzamouhe [14] and Mustapha [34]in a similar study area. However, the low N content may be in connection to the impeded N mineralization under anaerobic condition, which does not pass the ammonia stage and thus, is subsequently lost as a gas to the atmosphere [35].

The electrical conductivity (EC) of the soils were observed to be very low (0.21–0.24 dSm^{-1}) when compared to the soil salinity rating as shown in the FAO [22]. The EC values of 0–2 dSm^{-1} indicated non-saline soils. Electrical conductivity above2 dSm^{-1} indicates salinity at various levels [37]. On this note, the soils in the study area were found to be non-saline and therefore considered to be safe for irrigation activities. More so, the low EC observed in the study area may be due to the moderate acidity of the soils as earlier observed Omar and Nzamouhe [14].

Table 4: Soil salinity rating based on electrical conductivity

Soil salinity class	EC (dSm^{-1})
Non saline	0-2
Slightly saline	2-4
Moderately saline	4-8
Strongly saline	8-16
Very strongly saline	>16

Source: FAO Soil Bull. 39 (1988).

The mean values of exchangeable Na (0.003 cmolkg^{-1}), Mg (0.21 cmolkg^{-1}), K (0.034 cmolkg^{-1}) and Ca (0.016 cmolkg^{-1}) were found to be very low. Sodium and Mg did not vary across the treatments as shown in (Table 3). The Na, Mg, K and Ca values were observed to have slightly deviated from the fairly moderate to high values generally found in soils under irrigation as observed by Carroll and Klinkenberg [37]; Dikko *et al.* [38]; Omar [18]; Omar and Nzamouhe, [14]. The low values recorded here are as result of the slightly acidic pH. This is because soils with pH values within the range of neutral to slightly alkaline are associated with high values of exchangeable bases [38]. Furthermore, the sandy textured nature of the soils and the need for frequent irrigation encourages its leaching, which explains its deviation from the assertion of its accumulation in arid and semi-arid environments [39].

RECOMMENDATION AND CONCLUSION

From the study conducted, it can be concluded that the soils of Tsamiya Irrigation Scheme in Kachako are predominantly not fertile, non-saline and non-sodic. The water from the irrigation scheme was also observed to be non-saline and non-sodic and regarded to be safe for irrigation activities. However, the hazard of using this water might be low at this time, nevertheless, regular monitoring of the water should be carried out in order to prevent the buildup of salts to a certain toxicity that may affect the quality of water and soil as well as crop growth.

REFERENCES

[1] Subba, R.N. (2006). Seasonal variation of groundwater quality in part of Guntur district, Andhra Pradesh, India. *Environmental Geology*, 44(5), 579-586.

[2] Adriano, D.C., Bolan, N.S., Vangronsveld, J. & Wenzel, W.W. (2005). Heavy metals. In: Hillel, D. (Ed). *Encyclopedia of Soils in the Environment*, Academic Press, New York.

[3] Jain, C.K., Bandyopadhyay, A. & Bhadra, A. (2010). Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. *Environ. Monit. Assess*, 166(1-4), 663-676.

[4] Rengasamy, P., North, S. & Smith, A. (2010). *Managing sodic soils and groundwater irrigation in the Murray Irrigation regions*. Final report to Murray Irrigation Limited. Project No. EN 1/04). University of Adelaide, Australia.

[5] North, S.H. (2005). Making the most of available water supplies. In 'GRDC Research Update: Irrigation. "*Maximising the enterprise*". Tocumwal, NSW. (Ed. Lamb, J), GRDC: St Peters, SA.

[6] Yakubu, M., Bello, S., Noma, S.S. & Danmowa, N.M. (2006). Quality of irrigation water and soil characteristics of Fadama lands in Sokoto metropolis. In: *Proceedings of the 30th Annual Conference of the Soil Science Society of Nigeria*, Umuahia.

[7] Olofin, E.A., (1987). *Some Aspect of the Physical Geography of Kano Region and Related Human Response.* Debis Standard Printers, Kano.

[8] Baruah, T.C. & Barthakur, H.P. (1998). *A textbook of soil analysis*. Pashupati printers, Delhi.

[9] Nelson, D.W. & Sommers, L.E. (1986). Total carbon, organic carbon and organic matter. In SD(ed): *In methods of soil analysis, Part 2*.America Society of Agronomy, Madison.

[10] Pansu, M. & Gautheyrou, J. (2006). *Handbook of soil analysis, mineralogical, organic and inorganic methods*. Springer, France.

[11] Reeuwijk, V. (1993). *Procedures for Soil Analysis; Technical paper No. 9. Fourth Edition.* International soil reference and information centre (ISRIC).Wageningen.

[12] Bremmer, J.M. (1996). Nitrogen – total. In: D. L., Sparks. *Methods of soil analysis part 3. Chemical methods*, SSSA, Madison,

[13] Anderson, J.M. & Ingram, J.S. (1993). Tropical soil biology and fertility. In *A Handbook of methods (2nd ed)*. Information Press, U.K.

[14] Omar, G. & Nzamouhe, M. (2017). Comparative studies on physico-chemical properties of *Fluvisols* in Warwade Irrigation Scheme, Jigawa State, Nigeria.*Biological and Environmental Sciences Journal for the Tropics*, 14(3), 59 – 68.

[15] Schoeneberger, P.J., Wysocki, D.A., Benham, E.C. & Broderson, W.D. (eds.) (2002). *Field book for describing and sampling soils, Version 2.0***.** National Resources Conservation Service, USDA, Lincoln, N.E.

[16] Aliyu, J., Malgwi, W.B., Jimoh, I.A., Shobayo, A.B. & Ibrahim, M.M. (2016). Suitability assessment of surface water for irrigation in Galma Floodplain, Zaria, Kaduna State North Western, Nigeria. *Journal of Scientific Research & Reports*, 10(7), 1-9.

[17] Abegunrin, T.P., Awe, G.O. & Adejumobi, M.A. (2016). Water quality status of three different rivers for Fadama-oriented irrigated agriculture in Ogbomosho, South –West Nigeria. *Archives of Current Research International,* 3(3), 1-16.

[18] Omar, G. (2011). Assessment of the fertility status of some irrigated Fluvisols in Northern Guinea Savannah of Nigeria. *Savannah Journal of Agriculture*, 6(1), 19–31.

[19] Food & Agriculture Organization (FAO), (1985). Guidelines: Land evaluation for Irrigated Agriculture**.**Soil Bull. No 55, FAO Room Italy.

[20] Jigawa State Agricultural and Rural Development (JARDA), (2008). Soil and water analysis of some selected irrigation sites in Jigawa State, Nigeria. JARDA, Dutse.

[21] World Health Organization (WHO), (2003). Boron in drinking-water (Guidelines for drinking-water quality).2nd ed. Addendum to Vol. 2. *Health criteria and other supporting information*. World Health Organization, Geneva.

[22] Food & Agriculture Organization (FAO), (1994). Irrigation subsector review**.** Investment Centre Report No. 89/91 CJP-NIR 45 SR, Rome.

[23] Aghazadeh, N. & Mogaddam, A.A. (2010). Assessment of groundwater quality and its suitability for drinking and agricultural uses in the Oshnavieh area, North West of Iran. *Journal of Environmental Protection*, 1, 30-40.

[24] Oiganji, E., Igbadun, H.E, Ahmed, A. & Oliver, U.E. (2015). Implication of Bakolori dam irrigation activities on its physical resources. *African Journal of Agricultural Research*, 10(7), 690–696.

[25] Rahman, W.A. & Rowell, D.L. (1979). The influence of magnesium in saline and sodic soils: A specific effect or a problem of cation exchange? *J. Soil Science* 30, 535–546.

[26] Singh, B.R. (2001). Water and soil quality in the Fadama land of semi-arid north-East, Sokoto State, Nigeria.in: B.R. Singh (ed.) *Management of Western Nigeria*. 1. Quality of irrigation water. *Journal of Agriculture and Environment*, 2(2), 297-310.

[27] Omar, G. (2020). Fertility Status of Soils in Eastern Jigawa State of Nigeria. *SLU Journal of Science and Technology*, 1(1), 32-38.

[28] Tsuzom, J.N. & Olaniyan, I.O. (2015). Stream water quality assessment for irrigation at Nasarawa - Kakuri Area of Kaduna, Nigeria. *Current Journal of Applied Science and Technology*, 8(6), 608-615.

[29] Ojanuga A.G. (2006). Management of fadama of soils for food security and poverty alleviation. In: *Management of fadama soils for environmental quality, food security and poverty alleviation in Nigeria*. Proceedings of the 30th annual conference of the SSSN, Makurdi.

[30] Esu, I.E. (1991). Detailed soil survey of NIHORT farm at Bunkure, Kano State Nigeria. Institute of Agricultural Research, Ahmad Bello University, Zaria, Nigeria.

[31] Gachene, C.K.K. & Gathiru, K. (2003). Soil fertility and land productivity**.** Technical Handbook, no. 30. Nairobi, Kenya.

[32] Ogban, P.I. & Ekerette, I.O. (2001). Physical and chemical properties of coastal plain sandy soils of South-Eastern Nigeria. *Nig. J. Res.* 2, 6–14.

[33] Voncir, N., Mustapha, S., Amba, A.A. & Kparmwang, T. (2006). Inherent fertility status of Alfisols, Inceptisols and Entisols in Gubi Series, Bauchi, Bauchi State, Nigeria. *Journal of Applied Sciences*, 6(13), 2825-2828.

[34] Mustapha, S. (2007). Physico-chemical properties and fertility status of some haplicplinthaquults in Bauchi Local Government Area of Bauchi State, Nigeria. *International Journal of Soil Science,* 2, 314-319.

[35] Brady, N.C. & Weil, R.R. (2010). *The nature and properties of soils*. Prentice Hall Inc. New Jersey, U.S.A.

[36] Landon, J.R. (1991). *Booker tropical soil manual*. Longman Scientific and Technical Essex, UK.

[37] Carroll, D.M. & Klinkenberg, K. (1972). Soils. In: Tuley, P. (eds) *The land resources of Northeast Nigeria*. Volume 1. The environment. Land resource study No. 9 and map 3. Surbition.

[38] Dikko, A.U., Abdullahi, A.A. & Ousseini, M.S. (2010). Soil fertility assessment of the Lugumain canal of Wurno Irrigation Project, Sokoto State, Nigeria, five years after rehabilitation. *Nigerian Journal of Basic and Applied Sciences.* 18(2), 243-248.

[39] Adamu, G.K. (2013). Quality of irrigation water and soil characteristics of Watari irrigation project. *American Journal of Engineering Research,* 2(3), 59-68.