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Effect of Irrigation on Soil Properties in Jakara Kano, Nigeria

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ABSTRACT

Soil samples from the Jakara irrigation project site were evaluated with respect to possible degradation caused by irrigation. Most of the soils were neutral to alkaline with pH values ranging between 6.58 $\pm$ 0.04 and 10.45 $\pm$ 0.03. The electrical conductivity ranged from 0.3 $\pm$ 0.01 to 75.2 $\pm$ 0.06 dSm^{-1} which implies low to very high salinity. The concentrations of the exchangeable cations in the soils follow the order $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ with respective concentrations of 8.70 $\pm$ 0.4 to 187.8 $\pm$ 0.5 $cmol_cKg^{-1}$, 1.06 $\pm$ 0.05 to 5.49 $\pm$ 0.05 $cmol_cKg^{-1}$, 0 to 15 $\pm$ 0.05 $cmol_cKg^{-1}$ and 0.36 $\pm$ 0.02 to 2.73 $\pm$ 0.05 $cmol_cKg^{-1}$. It was noted that Na^+, a non-essential cation is dominant in the soil samples. The results showed ESP values much greater than 15% for all the soil samples studied which implies high soil degradation. The available P and C:N ratios ranged from 1.0 $\pm$ 0.01 to 4.9 $\pm$ 0.06μgg^{-1} and 0.2 to 11.0 respectively while the available K ranged from 8 $\pm$ 0.02 to 138 $\pm$ 6μgg^{-1} . It was observed that less than 17% of the total K was available for plant uptake. The soil was noted to be clayey in nature with CEC values ranging between 20 $\pm$ 2 and 86 $\pm$ 5 $cmol_cKg^{-1}$ with a ranking model indicating low fertility indices.

Keywords: Fertility ranking, Leaching, Saline-sodic, Soil properties

INTRODUCTION

Man is firmly dependent on soil for sustenance and interestingly, the quality of soil depends upon how man makes use of it. According to Rowell (1994), use of soils changes their properties, influencing both their interaction with the environment and their ability to produce crops. Perhaps chemical deterioration remains the greatest threat to irrigated agriculture in semi-arid world (Ogunwole *et al*, 2001).

Irrigation with water of poor quality results in chemical changes in the soil conditions (Briggs, 1993). The water safety criteria set by USEPA (1976) and FEPA (1990) gave less concern to the alkali and alkali earth metal ion concentrations because these elements are liable to biodegration (Essiet and Ajayi, 2000). However, for irrigation, the proportion of sodium is very important as it determines the suitability of the irrigation water. High concentration of sodium makes the water particularly objectionable and unsuitable for irrigation (Ayers and Westcot, 1985; Ibrahim and Dikko, 1999).

Among 22 dams in Kano State, in the north-western Nigeria, Jakara dam is the 5th largest having a total storage capacity, surface area of reservoir and height of 65190000m^3, 16590000m^2 and 14.33m respectively (Olofin, 1991). According to UNDP (1978) and Bichi (2000), the dry season flow of River Jakara is almost entirely made up of municipal sewage and industrial discharges which are drained into the Jakara dam. These industries include tanneries, where NaCl is used as pre-servative, and food processing industries (Ministry of Commerce and Industry, 1990). Hence, the environmental fate and state of the Jakara dam irrigation scheme needs be known. The study is aimed at investigating the status of the soil chemical properties and assessing its suitability for agricultural purposes.

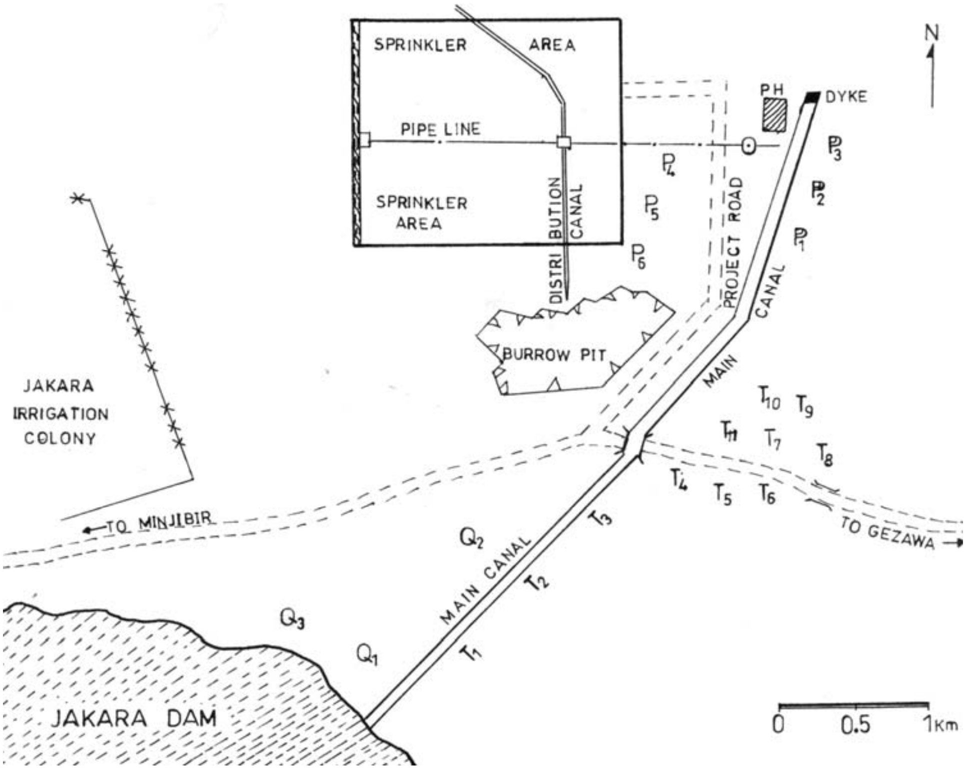

Fig 1. Map of the Sampling Area

MATERIALS AND METHODS

Twenty six surface soil (1 to 25cm) samples were taken from the government-allocated irrigation lands at the site and the pits were marked with metal shapes for easy identification. The samples were taken in labeled polythene bags and prepared for analysis according to the procedures described by Rowell (1994). The samples were marked P_1 to P_6, S_1 to S_6, Q_1 to Q_3 and T_1 to T_{11}.

The samples S_1 to S_6 were collected from the same place as P_1 to P_6 but during different seasons. These sampling areas together with that from which T_1 to T_{11} were taken are irrigated with the water from the canals running across the irrigated lands. The samples Q_1 to Q_3 are irrigated with well water located about 500m away from the dam (Fig 1).

Exchangeable cations were extracted by the neutral 1M CH_3COONH_4 method reported by Rowell (1994). The mixed-acid procedure of Agbenin (1995a) was chosen for the total elemental analysis of P. Soil total N was determined by Micro-Kjeldhal method using Labconco model #65000 rapid distillation apparatus. Soil pH was determined in 1:2.5 soil-water suspension using a calibrated Jenway model pH meter.

RESULTS

The soil pH ranged from 6.58 $\pm$ 0.04 to 10.45 $\pm$ 0.03 (Table 1) and the highest pH is well above the critical pH level recorded for most crops (Davies *et al.*, 1972). Landon (1991) reported 5.5 to 7.0 as the medium pH even though the lower range may be too acidic for some crops. The high alkalinity in the soils particularly T_1 to T_{11} is an indication of sodicity problem (Pitty, 1979).

Majority of the soils, P_1 to P_6, collected during the dry season registered increase in pH value over those obtained during rainy season, S_1 to S_6. This observation could be attributed to alkaline hydrolysis of accumulated sodium carbonate and bicarbonate present in the soil (Pitty, 1979; Rowell, 1994).

The EC of the soils ranged from 0.3±0.01 to 75.2±0.06 dSm^{-1} dSm^{-} (Table 1). Among 26

Table 1. pH, EC_e, Total carbon and Soil organic matter (%), Total Nitrogen (%), Carbon-Nitrogen Ratio, Total and Available Potassium (μgg^{-1}), Total and Available Phosphorus (μgg^{1})

S/No	Soil Sample	$pH_{1.5}$	EC_e dSm^{-1}	Total N %	Total C %	C:N Ratio	Total P μgg^{-1}	Avail P μgg^{-1}	Total K μgg^{-1}	Avail K μgg^{-1}
1	P_1	7.43±0.02	0.5±0.03	0.04±0.01	0.18±0.08	4.5:1	40.2±0.3	1.2±0.02	211±5	43±2
2	P_2	8.27±0.04	0.8± 0.02	0.20±0.02	0.05±0.04	0.2:1	35.3±0.4	1.0±0.01	256±3	58±5
3	P_3	8.31±0.02	1.0± 0.03	0.12±0.02	0.07±0.02	0.6:1	47.5±0.2	2.3±0.03	333±5	98±6
4	P_4	8.50	1.5± 0.02	0.08±0.01	0.39±0.03	4.9:1	84.0±0.8	3.1±0.05	422±6	40±5
5	P_5	6.89±0.06	2.2±0.04	0.04±0.02	0.18±0.02	4.5:1	24.4±0.3	1.4±0.02	156±3	29±2
6	P_6	9.52±0.03	1.3±0.03	0.20±0.01	0.23±0.01	1.2:1	28.0±0.4	3.9±0.04	278±7	33±4
7	S_1	9.63±0.04	1.2±0.01	0.12±0.01	0.08±0.03	0.7:1	47.5±0.5	3.4±0.03	489±5	119±6
8	S_2	7.29±0.06	0.2±0.01	0.04±0.02	0.38±0.02	9.5:1	58.5±0.7	1.9±0.02	189±8	37±3
9	S_3	8.59±0.05	0.6±0.02	0.04±0.01	0.44±0.01	11:1	34.1±0.3	2.3±0.02	189±2	44±6
10	S_4	8.63±0.05	1.2±0.03	0.16±0.02	0.04±0.01	0.2:1	30.5±0.5	3.7±0.04	411±9	77±3
11	S_5	8.27±0.04	0.8±0.02	0.08±0.03	0.49±0.04	6.1:1	28.0±0.6	2.1±0.05	300±7	87±2
12	S_6	8.30±0.02	0.3±0.01	0.16±0.01	0.04±0.01	0.3:1	37.8±0.7	1.9±0.02	222±5	39±5
13	Q_1	8.03±0.04	0.3±0.02	0.08±0.02	0.04±0.01	0.5:1	25.6±0.3	1.1±0.02	233±9	38±3
14	Q_2	6.58±0.03	1.3±0.04	0.08±0.01	0.72±0.02	9:1	29.2±0.2	1.1±0.03	200±8	18±1
15	Q_3	6.78±0.03	3.4±0.05	0.08±0.02	0.06±0.01	0.7:1	17.1±0.6	1.0±0.04	67±2	9±0.3
16	T_1	9.05±0.06	75.2±0.06	0.08±0.03	0.37±0.03	4.6:1	28.0±0.4	3.2±0.03	367±8	78±5
17	T_2	10.340.05	25.0±0.05	0.08±0.02	0.35±0.01	4.4:1	43.8±0.3	4.2±0.02	289±9	39±4
18	T_3	9.17±0.03	8.5±0.03	0.16±0.02	0.63±0.02	3.9:1	73.1±0.7	4.9±0.06	833±7	138±12
19	T_4	10.45±0.03	25.9±0.06	0.04±0.01	0.32±0.01	8:1	730.8±0.6	4.3±0.04	1323±22	138±6
20	T_5	9.82±0.04	28.8±0.04	0.08±0.02	0.12±0.01	1.5:1	23.1±0.3	2.0±0.02	89±8	11±2
21	T_6	9.28±0.05	7.2±0.02	0.04±0.01	0.37±0.02	9.3:1	21.9±0.7	1.5±0.01	444±12	111±12
22	T_7	9.91±0.04	8.8±0.05	0.04±0.02	0.13±0.01	3.3:1	23.1±0.3	1.6±0.03	800±23	138±8
23	T_8	8.85±0.02	4.5±0.06	0.12±0.01	0.20±0.02	1.7:1	75.5±0.7	3.0±0.04	411±12	63±5
24	T_9	10.43±0.03	39.4±0.08	0.08±0.03	0.13±0.01	1.6:1	60.9±0.3	3.0±0.03	678±13	138±6
25	T_{10}	10.29±0.05	8.8±0.04	0.08±0.02	0.07±0.02	0.9:1	19.5±0.4	1.7±0.04	167±9	33±6
26	T_{11}	10.43±004	16.4±0.05	0.12±0.01	0.02±0.01	0.1:1	21.9±0.3	2.3±0.02	467±6	8±0.02

soil samples investigated 15 namely, P_1 to P_6, S_1 to S_6 and Q_1 to Q_3 were either non-saline (with EC_e < 2.0 dSm^{-1}) or slightly saline (with EC_e between 2.0 and 4.0 dSm^{-1}). Eleven of the soils, T_1 to T_{11}, were saline (with EC_e > 4.0 dSm^{-1}).

The values of the exchangeable cations were shown in Table 2. The Na^+ concentrations were very high ranging from 8.70 ± 0.4 to 187.8 ± 0.5 $cmol_cKg^{-1}$. All the soils studied have exchangeable Na^+ percent (ESP) values above 15% (Table 2) and are consequently not within tolerable limits. According to Pitty (1979), an ESP of 15% is widely accepted as the lowest limit, above which soils are adversely affected by sodicity problem.

The soils could therefore be classified into the less polluted non-saline sodic ones which include P_1 to P_6, S_1 to S_6 and Q_1 to Q_3, and the highly polluted saline sodic ones, that is T_1 to T_{11}. This classification has been justified both by experiment and by observation. Regular consultations of the farmers in the irrigation site indicated that there is loss of yield even with tolerant crops in the highly polluted saline sodic locations and some lands have even been abandoned. The level of pollution is so high that the area where samples T_3 and

Table 2. Exchangeable cation concentrations and CEC ($cmol_cKg^{-1}$), Exchangeable sodium percent (ESP) and Percent base saturation (PBS) status.

S/No	Soil Sample	Exch K^+ ($cmol_cKg^{-1}$)	Exch Na^+ ($cmol_cKg^{-1}$)	Exch Ca^{++} ($cmol_cKg^{-1}$)	Exch Mg^{++} ($cmol_cKg^{-1}$)	CEC ($cmol_cKg^{-1}$)	Mean ESP (%)	Mean PBS (%)
1	P_1	1.42±0.03	20.8±0.3	0.83±0.02	1.48±0.05	79±3	26	31
2	P_2	0.97±0.04	20.8±0.7	1.66±0.04	1.76±0.07	74±2	28	34
3	P_3	1.67±0.05	20.8±0.5	0.83±0.03	3.29±0.05	48±6	43	55
4	P_4	1.67±0.04	20.8±0.6	4.16±0.08	4.11±0.08	86±5	24	36
5	P_5	1.67±0.06	20.8±0.3	3.33±0.04	4.40±0.07	38±3	55	79
6	P_6	0.97±0.03	20.8±0.8	3.33±0.03	4.26±0.07	33±3	63	89
7	S_1	0.36±0.02	9.6±0.5	ND*	1.35±0.03	25±2	38	45
8	S_2	0.83±0.03	17.4±0.6	ND*	1.54±0.08	23±1	76	86
9	S_3	0.83±0.04	16.5±0.7	ND*	2.61±0.07	20±3	83	100
10	S_4	1.07±0.08	14.8±0.3	1.66±0.04	3.26±0.08	53±4	28	39
11	S_5	1.19±0.02	13.0±0.3	0.83±0.02	3.47±0.06	24±2	54	77
12	S_6	0.97±0.04	8.7±0.4	0.83±0.01	2.85±0.05	25±3	34	53
13	T_1	1.19±0.05	187.8±0.5	14.10±0.08	5.49±0.05	48±6	391	435
14	T_2	0.97±0.03	109.5±0.6	15.00±0.05	4.77±0.06	23±2	476	566
15	T_3	1.78±0.03	52.2±0.3	4.16±0.04	4.80±0.05	52±2	100	121
16	T_4	2.73±0.05	112.2±0.4	11.60±0.05	5.11±0.09	25±4	449	527
17	T_5	0.36±0.02	36.5±0.6	0.83±0.2	1.06±0.05	24±3	152	161
18	S_6	1.30±0.06	40.0±0.5	1.66±0.04	2.38±0.06	24±2	167	189
19	T_7	1.90±0.07	41.7±0.3	1.66±0.03	3.08±0.07	25±3	168	193
20	T_8	1.07±0.03	38.3±0.8	4.16±0.6	4.29±0.08	67±5	57	71
21	T_9	1.78±0.05	125.1±0.8	3.33±0.04	4.54±0.05	25±2	500	539
22	T_{10}	0.83±0.02	44.3±0.2	0.83±0.01	1.67±0.04	25±4	177	191
23	T_{11}	1.42±0.01	68.7±0.5	0.83±0.02	1.50±0.05	24±3	286	302
24	Q_1	0.97±0.06	18.3±0.2	0.83±0.03	1.76±0.06	25±6	73	87
25	Q_2	0.36±0.02	8.7±0.8	0.83±0.02	3.00±0.03	46±5	19	28
26	Q_3	0.36±0.04	15.7±0.2	0.83±0.01	2.38±0.04	21±2	75	92

*ND: Not Determined

T_4 were obtained has been turned to a mining field for common salt and potash by local women.

The exchangeable K status ranged from 0.36 ± 0.02 to 2.73 ± 0.05 $cmol_cKg^{-1}$. Most of the values fell in the medium (0.3 to 0.6 $cmol_cKg^{-1}$) to high category (0.6 to 1.2 $cmol_cKg^{-1}$) (Awotundun, 1973). The ranges obtained are in agreement with those reported by Shukla and Ibrahim (1998) for the sandy soils (Inceptisols) and clayey soils (Vertisols) of Borno State, in the north eastern Nigeria (0.19 to 0.72 $cmol_cKg^{-1}$) and (0.34 to 2.51 $cmol_cKg^{-1}$) respectively.

The exchangeable Mg concentration was within the range 1.06 ± 0.05 to 5.49 ± 0.05 $cmol_cKg^{-1}$. The values are randomly distributed into low (0.5 to 1.5 $cmol_c$ Kg^{-1}), medium (1.5 to 3.0 $cmol_cKg^{-1}$) and high category (3.0 to 8.0 $cmol_cKg^{-1}$) (Awotundun, 1973). The values are higher than those recorded by Ibrahim and Dikko (1999) for Wurno irrigation project area (0.16 to 1.16 $cmol_cKg^{-1}$).

The exchangeable Ca concentration fell between 0 and 15 ± 0.05$cmol_cKg^{-1}$ (Table 2). The values are mostly low (0 to 5 $cmol_cKg^{-1}$) to medium (5 to 10 $cmol_cKg^{-1}$).

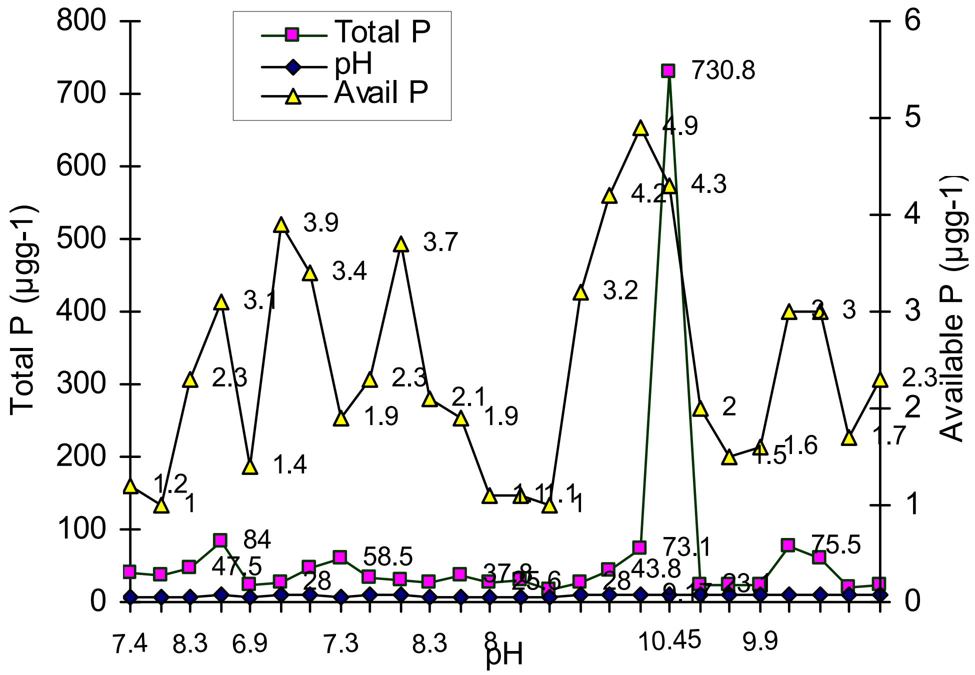

Fig 2. Two y-axes graph of total and available P as a function of pH

The dominant cation in the soils is Na^+. In all the dry season samples, P_1 to P_6, the exchangeable cations were leached after heavy rains. Na^+ was leached most since out of 37% of exchangeable cations leached, 27% was the monovalent cation. Sodium is lost more readily in leaching process than K^+, Ca^{2+} or Mg^{2+} due to the low energy by which it is held by the soil colloids (Pitty, 1979). Investigation has shown that the initial experimental farms were located in the site and the level of accumulated salts has become so high that the rainfall levels cannot adequately leach the ions (Agbenin, 1995b). The trend of leaching observed was $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ Complete leaching of Ca^{2+} was also observed in certain samples where the whole analytical concentration of Ca^{2+} was reduced to zero (Table 2). Even though the leaching of exchangeable Na^+ is favorable to the soil, the corresponding leaching of Ca^{2+} and Mg^{2+} is damaging as it results in poor growth (Ramalingam, 1993). It is worth mentioning that for soils under natural vegetation the relative abundance of the cations is in the following order $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ (Agbenin, 1995a).

The cation exchange capacity ranged from 20 $\pm$ 2 to 86 $\pm$ 5cmol$_c$Kg^{-1} (Table 2). The high CEC in the soils could be due to clay since clayey soils contain more exchangeable K^+ than sandy soils or silt (Shukla and Ibrahim, 1998) and the results showed high exchangeable K^+ with high CEC values. Also, the total organic content (Table 1) was low in the soils indicating that the high CEC values cannot be attributed to organic matter.

The total C content ranged from 0.02$\pm$ 0.01to 0.72 $\pm$ 0.02 % (Table1) which fell in the low category (0.00 to 0.75%) (Awotundun, 1973). Similarly, the total N content ranged from 0.04 to 0.2% (Table 1) with majority of the values being in the low category (0.00 to 0.15%) while the C: N ratios were low (Table 1) ranging between 0.2 and 11.0, indicating susceptibility to leaching. However, C:N ratio of 10 was reported for British arable crop fields (Pitty, 1979). Aseyeva and Velikzhanina (1966) reported C:N ratios of 8 to 12 for representative soils in the U.S.S.R.

The available K^+ values ranged from 8±0.02 to 138±6μgg^{-1} (Table 1) which are largely low (0 to 100 μgg^{-1}) and inadequate for crop production (Awotundun, 1973). Only 17% of the total K was available to plant. Potassium is normally fixed by most clay minerals in a form non-available to plants (Pitty, 1973).

All the total P values were in the range 17.1±0.7 to 730.8±0.6μgg^{-1} which fell in the low category (0 to 100 μgg^{-1}) with exception of the total P content of T_1 which was very high (>400μgg^{-1}). The available P ranged from 1.0 to 4.9 μgg^{-1} which was also noted to be low (1 to 10 μgg^{-1}) (MAFF, 1988). From the above results the NPK capacity is poor for good crop yields. There is a general increase in the concentration of the available P during the rainy season which may be due to application of phosphate fertilizers (Gladushko, 1979; Olofin, 1991).

A fairly concurrent rise in the values of both the total and available P with pH was observed in the soils (Fig 2). It is therefore evident that the mineralization of total P, which gives rise to available P takes place despite the low values of the two chemical properties since the availability of the inorganic form of P is dictated mainly by pH (Youdeowei *et al.*, 1986).

In an attempt to rank the 15 less polluted soils namely in order of fertility, namely the P, S and Q samples, four quartile ranking model was used. In the ranking calculations, a quartile value is obtained by dividing the numerical difference between the minimum and the maximum value of a chemical property by the number of quartiles, usually 4. The quartile value is added to the minimum value which corresponds to the lowest limit of the first quartile, to obtain the highest limit. For the second quartile, the highest limit of the first quartile becomes the lowest limit onto which, in a similar manner as above, the quartile value is added to obtain the highest limit and so on.

Information gathered from the table shows that EC_e having the highest total property score is highest in the soils. This negative property has crippling effect on the soil fertility. Larson and Pierce (1991) indicated that soils with EC_e > 4dSm^{-1} are liable to have 50% yield decline. The order of decreasing chemical property observed was ECe > pH > Mg^{2+} & K^+ > Avail. K > Avail P > Na^+ > CEC > C & N > Ca^{2+}

pH value is the second to EC_e. The implication is that high pH values translate into sodicity problem (Pitty, 1979; Rowell, 1994). Unfortunately, Ca^{2+} an essential macronutrient, is the most lacking in the soils. The second least in the ranking includes total C and total N whose proportion indicates poor mineralization in the soils (Youdeowei *et al.*, 1986).

Considering the total value scores (Table 3) the fertility ranking below was deduced for the soils P_4 >P_6, S_4, S_5 >P_3 >P_5, S_6, Q_2 >P_1, P_2 >S_1, S_2 > S_3 > Q_1 > Q_2

One striking observation is that the

Table 3. Evaluation of soils by the four quartile ranking model

Soil Sample	Chemical Property value Score											Total value	Rank order
	pH	EC_e	Na	Ca^{++}	Mg^{++}	K^+	CEC	C	A P	A K^+	N		
P_1	4	4	1	1	1	4	4	1	1	2	1	24	5*
P_2	2	4	1	2	1	2	4	1	1	2	4	24	5*
P_3	2	4	1	1	3	4	2	1	2	4	2	26	3
P_4	2	3	1	4	4	4	4	3	3	2	1	31	1
P_5	4	2	1	4	4	4	2	1	1	1	1	25	4**
P_6	1	3	1	4	4	2	1	2	4	1	4	27	2***
S_1	1	3	4	1	1	1	1	1	4	4	2	23	6!
S_2	4	4	2	1	1	2	1	3	2	2	1	23	6!
S_3	2	4	2	1	2	2	1	3	2	2	1	22	7
S_4	2	3	2	2	3	2	2	1	4	3	3	27	2***
S_5	3	4	3	1	3	3	1	3	2	3	1	27	2***
S_6	2	4	4	1	3	2	1	1	2	2	3	25	4**
Q_1	3	4	1	1	1	2	1	1	1	2	1	18	8
Q_2	4	3	4	1	3	1	2	4	1	1	1	25	4**
Q_3	4	1	2	1	2	1	1	1	1	1	1	16	9
Total property score	40	50	30	26	36	36	28	27	31	32	27	363	

samples Q_1 to Q_3, taken 500m away from the dam and earlier intended to be used as control samples, though irrigated by well water, were found to be the least fertile. This is an indication of pollution by massive leaching of soluble Na salts into the well water.

The negative impacts of irrigation arrived at in this study raise the question as to whether proper environmental impact assessment was carried out before choosing the area as an irrigation site.

CONCLUSION

The analytical results indicated high sodicity and high deficiency of Ca^{2+} in the soils. The addition of gypsum, $CaSO_4.2H_2O$ could help in reclaiming the soil via replacement of Na^+ with Ca^{2+}. The high salt accumulation in the irrigation site as indicated by the EC_e results calls for discontinuation of irrigation in the area. Proper pre-treatment of the waste water discharges from industries along the Jakara River would improve the water quality of the Jakara dam.

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