American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-02, Issue-03, pp-59-68
www.ajer.us

Research Paper Open Access

Quality of Irrigation Water and Soil Characteristics of Watari Irrigation Project

Adamu G.K
Department Of Geography And Regional Planning, Federal University Dutsin-Ma Pmb 5001 Katsina State, Nigeria

Abstract: This research was carried out in Watari River Irrigation Project, located on the slopes of Watari River valley in Bagwai local government of Kano state with aim of assessing soil properties and quality of irrigation water. A total of 32 representative soil samples were randomly collected from the eight sectors. Seven water samples were also collected from the sectors and the dam. The samples were treated and analyzed for physical, chemical and fertility related indices. Typically, the quality of irrigation water is assessed based on the salt and salt inducing contents, the presence and abundance of micro and macro nutrients, trace elements, alkalinity, acidity, hardness and the amount of suspended solids. The results are grouped into general quality parameters which included salinity and salt inducing cations and anions and pollutants. The Findings indicated that the mean pH ranged from 7.10 to 7.50, while the mean EC values across the sectors ranged from 50 to 60μS/m. The mean metal cations in the water ranged from 15.00 to 20.07; 5.41 to 16.22; 3.29 to 6.57; 14.83 to 15.00cmol/l for Na, Ca, Mg and K respectively. The SAR ranged from 6.87 to 10.17, while the range of TDS values was from 31.00 to 36.00mg/l. The mean carbonates concentration detected in the irrigation water was from 4.00 to 12.00cmol/l, while the mean bicarbonate content ranged from 22.00 to 55.00cmol/l. The ranges for chloride and nitrate were 9.87 to 31.58 and 1.00 to 1.65mg/kg respectively. The residual sodium carbonate (RSC) ranged from 8.00 to 30.69.There was no detectable NH_4 in the irrigation water. The results have shown that all the eight sectors had sand dominated texture. The mean pH in the soil ranged from 5.50 to 5.95. The EC ranged between 0.49 to 1.30cmol/kg, the Cl^- ranged between 0.29 to 1.07cmol/kg and SAR ranged between 0.13to 0.72. The mean soil organic carbon across the sectors ranged between 0.62 to 1.49%. The total nitrogen ranged between 0.0043 to 0.084% while NH_4^+ and NO_3^- Forms of nitrogen ranged between 0.0043 to 0.0065cmol/kg and 0.0025 to 0.0065mg/kg respectively. The CEC ranged between 9.04 to 12.68cmol/kg. The exchangeable bases ranged from 3.13 to 4.25; 1.06to1.73 and 1.28 to 2.08cmol/kg for Ca, Mg and K respectively. The boron content in the soil across the sectors ranged between 4.09 to 6.34mg/kg. It was recommended that adequate drainage with emphasis on surface drainage should be provided and salt and sodium build up should be monitored regularly.

Key words: *Irrigation water, Watari, Physico-chemical properties, Quality, Assessment, Soil properties and, Fertility.*

I. INTRODUCTION

The primary goal of water analysis is to examine the effect of the water on the soil, and ultimately on the plants grown on the soil. As such, much of the interpretation of the water analysis is based on a prediction of the consequences for the soil. Typically, the quality of irrigation water is assessed based on the salt and salt inducing contents, the presence and abundance of micro and macro nutrients, trace elements, alkalinity, acidity, hardness and the amount of suspended solids (U.S. Salinity Laboratory Staff, 1954; Ajayi e tal. 1990).

Poor quality of irrigation water affects both soil quality and crop production adversely (Bello, 2001). Regardless of its source, Irrigation water contains some dissolved salts (Michael, 1985). The amount and characteristics of these dissolved salts depend on the source and chemical composition. The most ordinarily dissolved ions in water are sodium, magnesium, calcium (Ca^{2+}), sulphate (SO_4^{2+}) , nitrate (NO_3^{2-}), chloride (Cl^-), boron (Br), carbonate (CO_3^{2-}) and bicarbonates (HCO_3^{2-})$_2$. The concentration and proportion of these dissolved ions among other things determine the suitability of water for irrigation (Ajayi e tal., 1990).

The function of soil is generally threatened by the increasing and very often conflicting demands of a constantly growing human population and its activities (such as irrigation), as well as by land use and climate change. This leads to a number of physical and chemical degradation processes that affect the sustainable functioning of soils (EEA/UNEP, 2000). Soil degradation can be defined as human-induced deterioration of its quality, which means the partial or entire loss of one or more functions of soil (Blum, 1988). Soil quality then should be related to the potential socioeconomically and ecological soil functions. Irrigation is helpful for sustaining agricultural production in any place; therefore, it is imperative that good quality water should be used so as to sustain the soils. However, continuous use of soil for irrigation may pose some adverse effects on both soil and water quality. Adequate management of soil is required to achieve the Millennium Development Goals of the United Nations of food security by the year 2015. One of such efforts by government to develop land for food production is in the area irrigation scheme.

This paper assessed soil and water conditions in the Watari Irrigation Scheme with a view to making proper recommendations on the implications of the current trend of land use in the irrigation scheme. The results are grouped into general quality parameters which included salinity and salt inducing cations and anions and pollutants.

II. STUDY AREA

Watari Irrigation Scheme is a medium scale irrigation project located on the slopes of the Watari River valley in Bagwai Local Government, which is about 18km from Bichi. It is located at the Northwestern part of Kano between latitudes $12^0$6' 54.54''N and 12 ^{0} 9' 17.8''N and longitudes 08^o 11' 50.62''E and 08^o 16' 28.05''E.

The main canal is about 10km long, while the command area consists of 5 sectors that are completed, numbered 1 through 4 and sector 8 the kanyu pilot farm. The net irrigable land area in rounded figure per sector is as follows:

Table: 1 The Area of Irrigable Land in Watari River Irrigation Scheme

SECTOR	HECTARE
1	160
2	170
3	216
4	72
8	72
TOTAL	690

Source: KNARDA, 2011

III. METHODOLOGY

A total of 4 soil samples were randomly collected from each of the 8 sectors from a depth of 0-20cm thereby making a total of 32 representative samples which were treated and analyzed for physical chemical and fertility related indices.

Seven water samples were collected and analysed for physiochemical and salinity related parameters. One sample was collected from the Dam water which is the main source of water in the scheme. Six other samples were collected from the sectors: one, two, three, four, five and eight

Particle size distribution was determined using bouyouscos (1957) method. Textural triangle was also used for determining textural classes. Organic carbon was determined using the Walkley-Black (1934) method. Phosphorus (P) content determination was done using the colorimeter method using sodium hydrogen carbonate extract (Adepetu e tal, 2000). Exchangeable bases were extracted by the ammonium acetate extraction technique and determined by flame photometry (Adepetu e tal, 2000). The CEC was determined using ammonium acetate saturation method as described by Hesse (1971). The total nitrogen was determined using Kjeldal method while pH was determined using 1:2.5 $CaCl_2$ dilution method (Adepetu e tal, 2000)

The water samples were analysed according to American public health association standards method for examination of water and waste water (1985). Digital pH meter was used for determining Ph of the samples. Conductivity was determined by using conductivity cell containing platinised electrodes. The Nessle's method was used to determine ammonia. Nitrates were determined by the phenoldisusphoric acid method. Turbidity was determined by spectrophotometric method. Colorimetric method using molybdate was used for determining phosphate and atomic absorption spectrometer was used for the metal analyses. SAR was computed using the appropriate formula.

IV. RESULTS AND DISCUSSION

General Water Quality of the Watari Irrigation Scheme

Part 2: Salinity and Cations

The general quality of the irrigation water in terms of salinity and cations is assessed based on the parameters shown in Table 2. The values are shown for both samples taken from the dam and the water flowing in the canals serving the sectors. The mean pH ranged from 7.10 to 7.50, while the mean EC values across the sectors ranged from 50 to 60µS/m. The mean metal cations in the water ranged from 15.00 to 20.07; 5.41 to 16.22; 3.29 to 6.57; 14.83 to 15.00cmol/l for Na, Ca, Mg and K respectively. There was no detectable NH_4 in the irrigation water. The SAR ranged from 6.87 to 10.17, while the range of TDS values was from 31.00 to 36.00mg/l.

Interpretation

Generally pH values for normal irrigation should be between 6.00 and 7.00, while values above 7.00 are considered as of increasing hazard (Singh e tal.1996, Danko, 1997). The pH is logarithmic, meaning that a change of 1.0 unit is a ten-fold change in either acidity or basicity. Therefore, changes of even less than 1.0 unit may be significant. This characteristic of the water has a significant influence on other characteristics or reactions in the soil and water, as well as the way plants perform.

The concentration of total salt content in irrigation waters is estimated in terms of EC and it may be the most important parameter for assessing the suitability of irrigation waters (Belan, 1985, Ajayi e tal., 1990). It gives an estimate of the total amounts of dissolved salts in the water and the total amount and kinds of salts determine the suitability of the water for irrigation use (Belan, 1985). Generally, the ranges considered for irrigation water suitability are 20 to 70, 70 to 300 and >300µS/cm being normal, increasingly severe and severe with respect to salinity hazards (Schoeneberger, 1998). From this perspective, none of the sectors could be described as under any immediate threat, as even the highest mean recorded at sector 3 was still within the normal range. These low EC values further corroborates the values in the soil which also falls much lower than the ranges described as critical for salinity as shown in Table 2.

The amount of Na ions in the water predicts the sodicity danger of the water (Singh, 2000). Sodium ions are important criteria for irrigation water quality because of its effect on soil permeability and water infiltration (Ajayi, 1990). Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees (cite). Sodium ions cause deflocculation of particles and subsequent sealing of soil pores thereby preventing water passage into the soil (cite). Sodic water causes excess Na to be adsorbed to exchange complex and in the process causes dispersion of aggregates and thereby blocking pores in the soil and preventing or reducing infiltration of applied water. Generally, values greater than 9.0cmol/l in terms of Na concentrations are regarded as posing increasing severity of sodicity especially in soils high in clay content (Davis & Dewest, 1966). The values recorded across all the sectors may therefore be interpreted as posing severe risk factor of sodium toxicity to the soil. The apparent lack of effect as shown by the EC values may be as a result of the fact that the soil is also low in clay content which is the principal particle that deflocculates in the presence of excess sodium. Sodium toxicity to sensitive crops may however not be ruled out with increasing application. Of greater importance in terms of irrigation water quality evaluation than the Na content is the sodium absorption ration (SAR). The SAR relates the relative concentration of Na to the combined concentrations of Ca and Mg ions (Landon, 1991). Increasing sodicity hazards may be associated with values exceeding 6. As SAR is a factor of sodium against calcium and magnesium, the high values recorded may not be a surprise as the sodium values are also relatively high. These further elaborate the risk factor associated with this irrigation water.

The normal range of Ca^{2+} in irrigation water should be 0 – 20cmol/l, while that of Mg^{2+} should be between 0 – 5cmol/l (Christenson e tal.1977). By these criteria the calcium content within the sectors could be described as within safe limit. This also applies to the magnesium content except at sectors 3, 4, 5 and 8 where the values exceed the recommended mean. The relatively lower amounts of magnesium compared to the calcium may be good because Mg deteriorates soil structure particularly where waters are sodium-dominated (as is the case with most of the sectors assessed here) and highly saline. The reason for this structural degradation is that high level of Mg usually promotes a higher development of exchangeable Na in irrigated soils and the negative effect of high sodium content in soil is as described above. The Magnesium content of water is also considered as important qualitative criteria in determining the quality of water for irrigation because more magnesium in water will adversely affect crop yields, as the soils become more alkaline. Generally, calcium and magnesium maintain a state of equilibrium in most waters (Christenson e tal., 1977). The combined effect of these two ions is in their countering the negative effect of the sodium by lowering the SAR as shown above. Their cumulative lower value than sodium has contributed significantly to the higher SAR value recorded across the sectors.

The presence of potassium ions in excessive amounts does not constitute any risk and may even supplement crops' needs as only values exceeding 50cmol/l may be considered as posing any serious risk factor with irrigation water.

One of the miscellaneous ions assessed for evaluation of irrigation water quality is the level of ammonium nitrogen (NH_4-N). Values that exceed 30mg/l are regarded as increasingly posing a risk factor in irrigation water (Christenson e tal., 1977). By this standard therefore the sectors may be regarded as critically lacking in this form of ion as each of them records 0.0mg/l. This does not however mean the water is unsafe for irrigation and may even be good especially with the slightly acidic nature of the soil. However its presence may compliment crops' supply.

TDS is also another criterion for the assessment of salt content in the water as salts constitute important part of TDS (FAO,1985). Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts (Michael, 1985). They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals (Belan, 1985). These salts are carried with the water to sites of use. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop.

Irrigation water with total dissolved solids (TDS) less than 450mg/l is considered good, and that with greater than 2000 mg/l is unsuitable for irrigation purpose(FAO,1985). By this therefore, the waters in all the sectors could be considered as falling within the safe limit for irrigation.

Management implication

The results here reveal water that may have the potential to be hazardous to the soil as well as to the crop grown, because the two most important parameters used in assessing the safety of irrigation; namely, Sodium ions and the associated SAR are within the unsafe limits. This is notwithstanding the fact that some other factors of salinity are within safe limit. The implication of these high values is that there is the tendency for the soil to be saline and therefore what are recommended here may be measures aimed at mitigating the development of saline or sodic soil. The following measures are worthy of note and implementation singly or in combination.

1. Provision of adequate drainage with emphasis on surface drainage, as the textural property of the soil indicates soil with potency for good internal drainage. If however, barriers restrict movement of water through the root zone especially in those sectors with appreciable clay content (Table 1) additional emphasis should be given to internal drainage.
2. Although the soil has not as yet indicated clear symptoms of salts development, provision should be made for use of clean water to meet the necessary leaching requirement over- irrigation. This is necessary to avoid build-up of salts in the soil solution to levels that will limit crop yields. Effective rainfall can be considered part of the leaching requirement.
3. The soil should be maintained at high available moisture level (always moist and not soaked) and should not be allowed to become more than moderately dry, since the crop cannot remove all the normally available water due to the higher salt content.
4. Salt and sodium build up should be monitored regularly (every 1 to 2 years). Development of a sodium hazard usually takes time and therefore soil tests for SAR or percent exchangeable sodium can detect changes before permanent damage occurs. Soil samples to be analyzed should represent the top soil and occasionally the sub soil.
5. Soluble calcium such as gypsum should be added to decrease the SAR to a safe value. The gypsum can be dissolved into the water or it can be broadcasted over the field. It should be broadcasted directly before irrigation or thoroughly incorporate into the tillage layer to avoid crusting problems. The soil can alternatively be tested for free lime; and when present elemental sulphur could be broadcasted. The sulphur solubilizes the calcium from the free lime already in the soil. If gypsum is used, the fresh water for leaching may have to be increased.

Table 2: General Irrigation Water Quality Parameters for the Watari Irrigation Scheme (Salinity and Cations)

Sample ID	pH	EC µS/m	Na (cmol/l)	Ca cmol/l)	Mg (cmol/l)	K (cmol/l)	NH_4 (mg/l)	SAR	TDS (mg/l)
DAM	7.10	51.67	15.74	9.01	3.63	15.00	0.00	8.85	31.00
SECTOR 1	7.13	53.33	20.07	12.92	3.97	14.83	0.00	9.77	32.00
SECTOR 2	7.10	50.00	15.00	5.41	3.29	15.50	0.00	10.17	30.00
SECTOR 3	7.40	60.00	15.28	13.52	5.48	15.00	0.00	7.01	36.00
SECTOR 4	7.20	50.00	16.00	16.22	5.48	15.50	0.00	6.87	30.00
SECTOR 5	7.50	50.00	15.28	10.81	6.57	15.00	0.00	7.33	30.00
SECTOR 8	7.10	50.00	15.00	13.52	5.48	15.00	0.00	6.88	30.00

Source: Laboratory analytical data, 2012

Part 2: Anions

The quality of the irrigation water across the sectors in terms of anions is shown in Table 3. The mean carbonates concentration detected in the irrigation water was from 4.00 to 12.00cmol/l, while the mean bicarbonate content ranged from 22.00 to 55.00cmol/l. The ranges for chloride and nitrate were 9.87 to 31.58 and 1.00 to 1.65mg/kg respectively. The residual sodium carbonate (RSC) ranged from 8.00 to 30.69.

Interpretation

The normal safe ranking for carbonate (CO_3^{2-}) and bicarbonates (HCO_3^-) are 1.00 and 10.00cmol/l respectively (Landon, 1991). By this criteria therefore, the irrigation water in the sectors assessed could be described as being at severe risk with regards to carbonates and bicarbonates. High carbonate and bicarbonate in water essentially increases the sodium hazard of the water to a level greater than that indicated by the SAR. High CO_3^{2-} and HCO_3^- tend to precipitate calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$), when the soil solution concentrates during soil drying. If the concentrations of calcium and magnesium in soil solution are reduced relative to sodium the SAR of the soil solution tends to increase as stated above.

Another effect of carbonates and bicarbonates is on the alkalinity status of the soil. High alkalinity indicates that the water will tend to increase the pH of the soil or growing media, possibly to a point that is detrimental to plant growth. Low alkalinity could also be a problem in some situations. This is because many fertilizers are acid-forming and could, over time, make the soil too acid for some plant. Another aspect of alkalinity is its potential effect on sodium. Soil irrigated with alkaline water may, upon drying, cause an excess of available sodium. Several potential sodium problems as highlighted above could therefore result.

Among the components of water alkalinity, bicarbonates are normally the most significant concern. Typically, 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. Carbonates become a significant factor as the water pH increases beyond 8.0 and are a dominant factor when the pH exceeds about 10.3(cite).

Chloride (Cl^-) ions are one of the anions in irrigation water for the potential of the water for phytotoxicity. The normal and safe limit for chloride ions in irrigation water should not exceed 30cmol/l (Landon, 1991) by which standard only sector 8 could be described at any potential risk. If the chloride contamination in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or during leaf tissue (cite). These symptoms occur when leaves accumulate from 0.3 to 1.0 percent chloride.

Nitrate (NO_3^-) is also another important anion assessed for irrigation water. The normal ranking for nitrate nitrogen is a maximum of 10mg/l (Landon, 1991) by which standard all the sectors could be described as within safe limit. Although it may seem nitrogen in whatever form may be desirable for plants' growth, the risk associated with excess nitrogen, especially the nitrate form which is not adsorbed at exchange sites is the tendency for it to be leached into underground water or being washed away via drainage water to sundry water bodies where it can cause eutrophication.

The influence of bicarbonate and carbonate on the suitability of water for irrigation purpose is empirically assessed based on the assumption that all Ca^{2+} and Mg^{2+} precipitate as carbonate (Michael, 1985). Based on this, the concept of residual sodium carbonate (RSC) for the assessment of high carbonate waters is used. Waters with high RSC have high pH, and land irrigated with such water becomes infertile owing to deposition of sodium carbonate; as known from black colour of the soil. RSC values more than 2.5cmol/l are considered as unsuitable for irrigation (Landon, 1991). By this standard only sectors 2, 3 and 8 can be regarded as within safe limit for irrigation.

Management Implications

High levels of bicarbonates can be directly toxic to some plant species. Bicarbonate levels above 3.3cmol/l will cause lime (calcium and magnesium carbonate) to be deposited on soils and even on foliage especially when irrigated with overhead sprinklers. This may be undesirable for vegetable plants. Similar levels of bicarbonates may also cause lime deposits to form on roots, which can be especially damaging to many tree species. The most efficient corrective measure for high alkalinity is acidification of the water and the soil (cite). This can be achieved by direct controlled acid injection in the water; or the safer major of incorporation of high levels of organic matter in the soil which on decomposition releases organic acids into the soil that solubilise sodium and prevent its accumulation in the soil(cite).

By the most obvious indications, the soil is not calcareous which will have necessitated the calculation of an adjusted SAR value for the water because of the high bicarbonate and RSC values. The adjusted SAR is calculated for the surface soil and, if a leaching fraction is assumed, can be calculated for the subsoil at the bottom of the root zone. The adjusted SAR will also be useful in estimating the sodium build up in the soil from continued use of the water. The adjusted SAR and knowledge of soil properties help determine management practices when using high bicarbonate water. Further assessment of the soil therefore needs to take care of these factors.

Table 3: General Irrigation Water Quality Parameters for the Watari Irrigation Scheme (anions)

Sample ID	CO_3^- (cmol/l)	HCO_3^- (cmol/l)	Cl^- (cmol/l)	NO_3^- (mg/l)	RSC (cmol/l)
Dam	6.67	36.67	9.87	1.00	3.69
Sector 1	6.67	41.67	16.45	1.65	3.44
Sector 2	4.00	20.00	8.88	0.90	1.30
Sector 3	12.00	15.00	14.80	1.50	0.80
Sector 4	8.00	55.00	14.81	1.50	4.13
Sector 5	6.00	40.00	12.83	1.30	2.86
Sector 8	8.00	25.00	31.58	3.16	1.40

Source: Laboratory analytical data, 2012

Part 3: Trace elements

The quality of the irrigation water in terms of trace elements presence in water is as shown in Table 6. No Cu and As were detected across all the sectors, but Cd and Pb were detected at sector 4 and 1at 0.1cmol/l respectively. The ranges of Mn and Fe were 0.00 to 0.06 and 0.00 to 0.17cmol/l respectively.

Interpretation

The maximum levels (ML) allowed for these metals in irrigation water are 1.7, 10, 0.1, 20, 50 and 5.0mg/l for Cu, As, Cd, Mn, Fe and Pb respectively (Landon, 1991). By this standard therefore, none of the sectors is at any potential risk hazard except sectors 4 and 8 in terms of Cd.

This is not unexpected as high concentrations of trace elements are only expected in waste water. However, trace elements in all forms of irrigation water are assessed because they have the tendency to get into surface waters via runoff coming through agricultural fields in which agrochemicals and fertilizers are applied, because they form constituents of many of such chemicals. Monitoring trace elements in irrigation water is as important as monitoring salinity status because of their potential to build up in soil and be absorbed by plants thereby being introduced into food chain. When such happens, they constitute further risks to human and livestock in terms of health and wellbeing.

Management Implication

The fact that the levels in water is much lower than prescribed values does not translate into total safety of the water because the trace amounts detected for some elements is still worthy of consideration and further monitoring to ensure that levels do not exceed what has been detected. Monitoring should be on regular basis and different spatial and temporal settings because they are key factors with which concentrations vary.

Table 4: Concentrations of Trace Elements in the Waters of the Watari Irrigation Scheme

Sample ID	Cu (mg/l)	As (mg/l)	Cd (mg/l)	Mn (mg/l)	Fe (mg/l)	Pb (mg/l)
Dam	0.00	0.00	0.00	0.02	0.03	0.00
Sector 1	0.00	0.00	0.00	0.04	0.12	0.01
Sector 2	0.00	0.00	0.00	0.00	0.00	0.00
Sector 3	0.00	0.00	0.00	0.06	0.17	0.00
Sector 4	0.00	0.00	0.01	0.00	0.05	0.00
Sector 5	0.00	0.00	0.00	0.00	0.00	0.00
Sector 8	0.00	0.00	0.01	0.05	0.17	0.00

Source: Laboratory analytical data, 2012

Soil Assessment

The results of the soils analysis of the various sectors of the Watari Irrigation Scheme are presented in the following Tables 1, 2 and 3. The results are grouped into three sections namely physical properties, salinity and fertility statuses.

Soil Physical Properties of the Watari Irrigation Scheme

The physical condition of the soil was assessed for particle size distributions in the soil and subsequently translated into textural classes. These results are presented in Table 5. Across the eight sectors 3, means and values ranged between 63 – 85%, silt values ranged between 6.5 to 20% and clay values ranged between 10 – 18.5%. The highest sand content was recorded at sector, which correspondingly also had the least content of both sand and clay.

Interpretation

Going by these results, it is evidently clear that the soils in all the eight sectors have sand dominated texture. Furthermore, while Sectors 1, 4, 5, 6 and 7 have sandy loam texture; sectors 2 and 7 have sandy clay loam textures; while sector 3 having loamy sand texture. The predominance of sand particles in arid and semi-arid climates is not uncommon because many of them were formed from aeolian deposits blown from across several thousands of kilometers (Mortimore, 1989). Such deposits are commonly found covering the surfaces of underlying soils that may be formed from other parent materials such as the alluvial deposits common in *fadama* areas such as the one investigated. It may be the influence of the alluvium that must have raised the clay and silt values in sectors 2 and 7.

Management Implications

Sandy textured soils are prone to erosion because of the low silt and clay contents which play very important role in binding particles and creating stable structures that can resist erosive factors such as wind and water (Adamu 1997). Such soils are also prone to excessive leaching of nutrients because of low water holding capacity and limited binding sites for cations. Because of this low water holding capacity, the frequency of irrigation will also have to increase and this will affect water use economy and salinity status of the soil. The best management options for such soils would be conservation tillage which minimizes the impact of machines and tools, enhances structural grade thereby improving water retention as well as improving the overall organic matter content of the soil which will improve the nutrient retention ability of the soil (Omar,2011). The practice may also benefit even those sectors with appreciable clay because it will reduce their proneness to compaction which is a possibility with increased machinery use.

Table 5: Physical Properties of the Watari Irrigation Scheme

Sector	CLAY	SILT	SAND	TEX.CLASS
1	13.5	18	68.5	Sandy loam
2	17	20	63	Sandy clay loam
3	8.5	6.5	85	Loamy sand
4	14.5	10	75.5	Sandy loam
5	12	13	75	Sandy loam
6	10	15	75	Sandy loam
7	18.5	17	64.5	Sandy clay loam
8	13	10.5	76.5	Sandy loam

Source: Lab. analytical data, 2012

Salinity Status of Soils of the Watari Irrigation Scheme

The mean values of the major indicators of soil salinity for the sectors are shown in Table 2. The mean pH in water ranged between 6.13 and 6.48 while in salt it ranged from 5.50 to 5.95. The EC ranged between 0.06 to 0.23dS/m. Na CO_3^{2-} was detected across the eight sectors. While the HCO_3^- mean ranged between 0.49 to 1.30cmol/kg, the Cl^- mean ranged between 0.53 to 1.13cmol/kg. Na mean ranged between 0.29 to 1.07cmol/kg and the SAR ranged between 0.13 and 0.72.

Interpretation

The pH readings across the eight sectors in both water and salt were all within the slightly acid (pH in salt) to very slightly acid (pH in water). The EC values are very much within safe limit, much lower than the 4dS/m prescribed for alkaline and salt affected soils (Landon, 1991). This corroborates the pH values further. The lack of carbonate in the soil and the low (for sectors 1, 2, 3, 4, 7 and 8) to very low (for sectors 5 and 6) concentrations of the bicarbonate further supports the acidity in the soil because it implies that most of the dissolved carbon dioxide and carbonates must have been reduced to either carbonic acid (H_2CO_3) or in the transitional state of bicarbonate. The low sodium (for sectors 1, 2, 3, 4 and 5) to medium (for sectors 6, 7 and 8) concentrations and a variable concentration of Chloride with sectors 1, 2, 3, 4, 7 and 8 having low and sectors 5 and 6 having very low concentrations. There was seemingly a fall in sodium concentration in areas with high chloride ions and a high sodium concentration in areas with low chloride ions; except in sector 7 which seems to have appreciably high concentrations of both. The probable explanation for this condition may be the fact that due to the slightly acid nature of the soil, sodium ions may have been solubilised as carbonates and bicarbonates and leached out of the soil, which explains the low SAR value in all the sectors except sector 7, which has highest amounts of sodium. It also further supports the low EC values across most of the sectors. The higher chloride ions could have originated from the use of chlorinated pesticides and agrochemicals, which are not uncommon in irrigated areas under cultivation year round.

Management Implication

As an area of land under irrigation, the parameters measured in relation to salinity have indicated a soil that is far from being saline or even alkaline. The slightly acid nature of the soil 5will enhance the availability of nutrients and as shown above may further facilitate the solubilisation of sodium ions which are the primary agents of salinization and alkalinisation in irrigated soils (Alhasan,1996).

Caution should however be exercised over the results shown here because of the delicate balance that exists between different soil properties. For example, the sandy textured nature of the soil as shown above may necessitate higher irrigation frequency which in semi-arid climate like the area under study may not be desirable because of the tendency of excessive evaporation which may precipitate salts on the surface of the soil and which may be disadvantageous to non-tolerant varieties. Furthermore, the tendency for chloride build up in the soil, especially in sector 7 where the sodium concentration is equally appreciable may, in addition to the probability of chloride ions approaching toxic levels, also lead to further salt formation, even in those sectors where the sodium ions are not very high.

There is also the added fear of pH falling further low for reasons associated with nitrogen forms in the soil as will be explained in the next section. When this happens, the tendency for exchangeable bases' concentration to fall and that of micro-nutrients such as Cl and Fe to rise may not be ruled out, and these will cause nutritional complications for crops being grown in the sectors.

Irrigation, fertilizer and agrochemicals management, as well as close monitoring of soil and water conditions should be adopted as strategies to maintain and/or improve the salinity status of the sectors. Extension should focus on water use efficiency, soil conservation practices such as incorporation of organic residues and conservation tillage practices.

Table 6: Soil Fertility Status of the Watari Irrigation Scheme

Sector	pH in H_2O	pH in $CaCl_2$	EC (dS/m)	CO_3^{2-} (cmol/kg)	HCO_3^- (cmol/kg)	Cl^- (cmol/kg)	Na^+ (cmol/kg)	SAR
1	6.35	5.95	0.20	0.00	0.68	1.05	0.29	0.17
2	6.13	5.50	0.17	0.00	1.30	1.13	0.36	0.23
3	6.50	5.90	0.06	0.00	0.70	1.00	0.20	0.13
4	6.48	5.85	0.09	0.00	0.85	1.33	0.28	0.19
5	6.28	5.78	0.06	0.00	0.60	0.48	0.32	0.22
6	6.48	5.93	0.12	0.00	0.49	0.53	0.72	0.49
7	6.45	5.88	0.18	0.00	0.83	0.80	1.07	0.72
8	6.48	5.88	0.23	0.00	1.00	1.08	0.59	0.37

Source: Lab. analytical data, 2012

The assessment of the fertility status of the soils of the Watari Irrigation Scheme was based on the parameters whose means are shown in Table 3. Organic carbon was used as indicator of organic matter content in the soil, and total nitrogen was further fractionated into ammonium and nitrate forms due to the implication of each to the soil and water. The CEC of the soils was determined and the concentrations of exchangeable bases was also determined as indicators of percent base saturation (PBS), being a more important fertility indicator than the total CEC.

The results shown in Table 4 indicate the mean organic carbon across the sectors to range between 0.62 to 1.42%. Total nitrogen ranged between 0.035 to 0.084% while the NH_4^+ and NO_3^- forms of N ranged between 0.0043 to 0.0065cmol/kg and 0.0025 to 0.0065mg/kg respectively. The range of available P was between 10.20 to 52.94mg/kg. The CEC ranged between 9.04 to 12.68cmol/kg and the ranges for the exchangeable bases were 3.13 to 4.25; 1.06 to 1.73 and 1.28 to 2.08cmol/kg for Ca, Mg and K respectively. The Boron content in the soil across the sectors ranged between 4.09 to 6.34mg/kg.

Interpretation

The mean organic carbon content in most of the sectors could be considered as low because only sector 2 and sector 7 have their mean within the medium range. Generally values <1% are regarded as low and 1 – 1.5% are regarded as medium (Adamu, 1997). The direct implication of this low organic carbon content in the soil is that organic matter is also low. This is not unexpected in tropical environments because generally addition of organic residues which determines the organic matter content in the soil is low and their lost through mineralization is high (Binns e tal, 2003).

In contrast however, the N content of all of the sectors were high because the range considered as high starts from 0.02% or 0.03% in extreme cases (Landon, 1991). Most of the N is however in the ammonium form as can be observed in Table 3. The high N content, despite the low levels of organic matter across the sectors indicate the probable effect of application of N-fertilizer especially the ammonium forms which explains the higher concentration of its form in soil as indicated by the result. The effect of the clay content and the little organic matter in the soils could be seen, especially in sector 2, in terms of retention of the ammonium form of nitrogen.

The conditions of the soil favour the retention of this form of N and the loss of the nitrate form through leaching. This also significantly relates to the pH of the soil because ammonium N is associated with acidification of soils.

The available P content for most of the sectors was within the medium range, except in sectors 5 and 7 were it is low. The P content in the soil is also another factor that disagreed with the organic matter content of the soil (Adamu, 2008). That is with low organic matter in the soil, the N and P may likely be low because mineralization of organic matter is known to significantly contribute to the concentrations of both. The most probable explanation for this deviation may also be attributed to fertilizer use, and in the case of the phosphorus, the mild pH might have significantly favoured its solubility from the various pools in the soils.

The CEC values in all the sectors could be regarded as medium despite the apparent variability from sector to sector which is not unexpected giving the nature of the soils especially in terms of clay and organic matter content which are the principal determinants of CEC. The soil CEC must have been significantly contributed to by the clay content, because of the poor state of the soil in terms of organic matter (Alhasan, 1996).

The Ca values across all the sectors are generally low because values of 5cmol/kg and below are generally considered low (Landon, 1991). The Ca values have slightly deviated from the fairly moderate to high values generally found in soils under irrigation. The low values recorded here are as result of the slightly acidic pH, because soils with pH values within the range of neutral to slightly alkaline are associated with high values. 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.

The Mg values are however within the medium range across all the sectors. The K values are however fairly high. The high amount of K in the soil may have also contributed to the low Ca and Mg values because of its better competitive ability for exchange sites, although their values are not however extremely bad (Foloronsho,1998). Both Ca and Mg are hovering above the Na concentration the advantage of which is their effect in lowering the SAR values as shown in Table 2. This may significantly offset the salinity condition in the soil.

The theory of the CEC being contributed to by the clay content is further validated by the amounts of basic cations held in the exchange complex, which has translated into a very good index of percent base saturation (PBS) (Alhasn,1996). The fact that all of the sectors have their PBS above 50% is an indicator of fertile soil only if the all the cations are within the medium to high range.

The boron condition in the soil is also mild. The major fear in the concentration of boron in irrigated soils is its toxicity in some crop varieties when it exceeds the maximum tolerable range (Floronsho, 1998). This is why it is always one of the parameters being evaluated in irrigation water as well as the soil.

Management Implication

The result is indicative of only marginally fertile soil. This is not unexpected in areas under continuous cultivation. Fertility decline in those types of soils is accelerated with high loss of organic matter and insufficient fertilization (Young, 1976). Apart from phosphorus and potassium whose values in many of the sectors are medium to high respectively, either low or just marginally above the low values for virtually all the indices of fertility were recorded. The major implication of this is the tendency for crops grown to exhibit deficiency if not properly fertilized, especially with nitrogen fertilizer. Fertilizer application should however follow agronomic recommendations based on crops' needs and the physico-chemical properties of the soil. For example, it is shown above that a larger concentration of the soil N is in ammonium form and with further increase; there is the tendency for the mild pH to fall further low, thereby affecting the balances of other nutrients. As already mentioned, the soils of all the sectors would definitely benefit from addition of organic matter, with its advantage of slow release of nutrients, especially nitrogen and phosphorus.

Table 7: Soil Fertility Status of the Watari Irrigation Scheme

OC%	TN%	AP mg/kg	Ca cmol/kg	Mg cmol/kg	K cmol/kg	CEC cmol/kg	B mg/kg	NH4+N cmol/kg	NO_3^-N mg/kg
0.76	0.06	52.94	4.25	1.73	2.08	12.6775	5.34	0.007	0.006
1.43	0.08	42.66	3.43	1.37	1.64	10.2475	5.58	0.005	0.005
0.63	0.04	32.38	3.73	1.30	1.56	10.435	5.29	0.005	0.004
0.62	0.04	23.63	3.13	1.09	1.30	9.035	5.00	0.005	0.005
0.63	0.05	11.81	3.40	1.07	1.28	9.5275	4.09	0.005	0.004
0.75	0.05	24.06	3.28	1.06	1.28	9.8475	4.66	0.004	0.003
1.02	0.05	10.50	3.18	1.22	1.46	10.23	4.85	0.005	0.004
0.52	0.04	36.75	3.80	1.37	1.65	11.4	6.34	0.007	0.006

Source: Lab. analytical data, 2012

REFERENCES

[1] Alhasn, J. (1996).Determination of CEC and exchangeable bases (Ca, Mg, K and Na) of soils from Sokoto-Rima River Basin at Kwalkwalawa: A B Sc. project submitted to the department of soil science and Aric. Usman Dan Fodio University, Sokoto.

[2] Ajayi, F., M. Nduru and A.Oningue,(1990). Halting the salt that kills crops African Farmer No.4, pp 10-12

[3] Adamu G.K. (1997).An assessment of erodibility of selected soils under different land management systems at Bayero University, Kano New campus: Unpublished PGD Project Soil evaluation: BUK.

[4] Adamu G. K..(2008).N P K level in multiple crop land in a small holder farmland in Kano closed settled zone: Biological and environmental sciences journal for the tropics. Vol.5. BUK.

[5] Adepetu, J. A., Nabhan, H.,Osinubu A. (2000) :Simple soil, water and plant testing techniques for soil resources management: proceedings of a training course held in Ibadan, Nigeria,16- 27 september 1996: Ibadan,IITA,168pp

[6] Belan F. I. (1985). Water treatment. Mir Pulishers Moscow, USSR, 232P.

[7] Blum, W. E. H. (1988). Problems of Soil Conservation. Nature and Environment, 40.

[8] Strasbourg: Council of Europe.

[9] Binns J. A.; Machonachie, R. A., and Tanko A. I.(2003). Water, Land and Health in Urban and Peri-urban food production: The case Kano,Nigeria; www.cityfarmer.org. Accessed June, 2005.

[10] Bello,, S. (2001). Quality of irrigation water and soil characteristics of wetlands in sokoto metropolis. Unpublished B.Sc. Project. Department of Soil Science and Agricultural Engineering, Usman Danfodio University, Sokoto. Pp 69.

[11] Christenson, J.E., E.C. Olsen, and L.S. Willardson,(1977). Irrigation water quality evaluation. Journal of irrigation and Drain Div. A and CIR 2.proc. paper 13015

[12] Danko, M.M (1997). Comparative analysis of variables of irrigation water quality along river Rima. B. Agricultural project, Department of soil science and Agricultural engineering, Usman Danfodio Sokoto.pp.45

[13] Davis, S W. and Dewest,R.J.M. (1966).Hydrology John Willey and Sons. New York 463p.

[14] Dawaki U.M.(1996). Determination of organic carbon, available Nitrogen, available Phosphorus, pH Textural class of irrigated soils along the Rima River Basin at Kwalkwalawa, Sokoto, A B Sc. Agric. Research project submitted to the department of soil science and Aric. Usman Dan Fodio University, Sokoto.

[15] EEA/UN EP (2000). Down to Earth: Soil degradation and Sustainable Development in Europe – a Challenge for the 21st Century. Environmental Issue Report 16. Copenhagen: EEA and United Nations Environment Programme Regional Office for Europe.

[16] FAO, (1985). Guidelines. Land evaluation for Irrigated Agriculture. Soil Bull. No 55, FAO Room Italy.

[17] Foloronsho, E. (1998).Evaluation of soil fertility status Under Irrigation in Jakara River Valley: A case study of Air-Port Road-Katsina Road, Kano Metropolis; Post Graduate Diploma in Land Resources Thesis; Geography department, Bayero University, Kano

[18] Hesse, P.R. (1970): A textbook of soil chemical analysis. John Murray Ltd, London Kano Agricultural and Rural Development Authority (KNARDA, 2011)

[19] Landon, J. R. (ed) (1991).Booker Tropical Soil Manual, John Wiley and Sons Inc.; New York.

[20] Mortimore M. (1989). Adapting to drought: farmers, famine and desertification in West Africa: Cambridge University Press.

[21] Machael, A. M. (1978). Irrigation principles and practices. Vikas publishing house Ltd. New Delhi, India Pp702-720.

[22] Machael, A. M. (1985). Irrigation principles and practices. Vikas publishing house ltd. New Delhi, India.Pp702-720.

[23] Omar, G. (2011). Assessment of the Fertility Status of some Irrigated Fluvisols in Northern Guinea Savannah of Nigeria: Department of Soil Science, Faculty of Agriculture, Bayero University, Kano.

[24] Shoeneberger,P. J. ,D. A Wysocki, E. C. B enham., W.D. Broderson (Eds) . (2002). Field Book for Describing and Sampling soils Version 2.0 National soil Survey Center , National Resources Conservation Services, U. S. Department of Agriculture, Lincoln.

[25] Singah, B. R. (2000). Quality of irrigation water in Fadama lands North-western Nigeria. I. Ground and Surface Water in Kebbi State. Nig. J. Basic. And Apl. Sci. 9:133-148

[26] U. S. Salinity Laboratory Staff (1954). Diagnosis and Improvement of saline and alkali soil .L.A. Richard (Ed,) Agricultural Handbook No. 60.United State Dept. of Agriculture, US Government printing office, Washington DC., USA. Young, A.(1976).Tropical soils and soil survey; Cambridge University press.