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# SEASONAL VARIATION IN SOIL PROPERTIES OF AN IRRIGATED FARM AT THE INSTITUTE FOR AGRICULTURAL RESEARCH (IAR) SAMARU ZARIA, NIGERIA

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## ABSTRACT

Soil properties of an irrigated farm at the Institute for Agriculture Research (IAR), Ahmadu Bello University, Zaria Nigeria were assessed along with the irrigation water at Bomo dam. The study was conducted to assess the seasonal variation of the soil properties as influenced by irrigation water and suggest some management practices for sustainable use of the land. The results showed that pH, ECe, Ca, Mg, K, Na, SAR and ESP in the soils were significantly lower compared to the values in the irrigation water during either dry or rainy season or both seasons. Soil pH, ECe, Ca, Na, exchangeable acidity and effective CEC were significantly higher during dry season compared to the rainy season, and was attributed to increase in content of salts in the soils contributed by the irrigation water. Rain water contributed significantly to leaching of excess salts, thereby reducing salinization and sodication processes in soils of the IAR irrigation farm. For sustainable irrigation; deep ploughing, construction of drainage system and incorporation of organic matter were management practices suggested. Monitoring of salinity and sodicity of the soils and water at periodic intervals was recommended to avert further salt-build up in the farm.

**Keywords**: Soil properties; seasonal variation; irrigated farm; Zaria-Nigeria

## INTRODUCTION

The need to feed and improve the standard of living of the ever-increasing human population of the nation led to the introduction of irrigation schemes by Nigerian governments in the country. This has facilitated the cultivation of the same land throughout the year and has improved the standard of living of many farmers (Malgwi *et. al*., 2002).

In the northern part of Nigeria, irrigation is needed to provide water for all year-round agricultural production. The provision of irrigation water and land, among others, usually involves enormous financial expenses, as seen by the building of multi-million-naira dams, storage reservoirs, canals and other irrigation infrastructures. These irrigation components and infrastructure are provided to address the fundamental agricultural limitation of scarce water resource so as to boost agricultural production (Sangari, 2006 and Abdulkadir, 1996).

Irrigation development is likely going to bring about changes in the existing natural ecosystem including the soil, which is the basic resource for agricultural production. The development of secondary salt-affected soils is one of such changes which have been attributed to irrigation (Brady and Weil, 2005). Secondary salinization occurs in large and small scales irrigation schemes alike, and may be associated with the use of irrigation water containing dissolve salts (Amstrong, 1991). The presence of salts can drastically alter the morphological, physical, chemical and biological properties of the soil and impair its productivity (Brady and Weil, 2005). The global estimates of the already affected irrigated land varies but the problem is seriously growing persistently (Amstrong, 1991). About 1-2% of irrigated land is lost annually as a result of salt-related problems, especially in Arid and Semi-arid areas (Guamieri *et al*., 2005; Xiao Gang, *et al*., 2002). According to Jibrin *et al*. (2008), FAO (2002) and Oldeman (1994), most salt-related land degradation problems are to a large extent humanly induced. Several researches in Sudano- Sahelian region of Nigeria have reported changes in pH, electrical conductivity, exchangeable sodium percent and sodium adsorption ratio of irrigated soils (Jibrin *et al*., 2008; Malgwi *et al*., 2002; Mudiare and Ahmed 1987; Singh and Maurya, 1979).

The capacity of soils to function (soil quality) is dependent on degrading forces such as erosion and compaction. Lal (1998) further buttress this by stating that soil degradation is a severe global issue and the predominant degrading processes are accelerated by soil erosion, depletion of soil organic matter and plant nutrients, decline in soil structure and soil salinization. Salt-related soils vary widely in physical, chemical and hydrological properties in addition to variability in water regime, spatial and seasonal variability in salt content are not uncommon. Soil salinity increase when the influx of salt is greater than the efflux (Brady and Weil, 2005) especially in poorly drained clay soils used for irrigation agriculture. Though soil salinization has not been a major problem to farmers of dry season irrigated crops in the humid zone of south-eastern Nigeria, yet salinization was reported by Anikwe *et al*. (2002) to relate positively and significantly with poor quality irrigation water especially in the heavy clay soils. Adamu (2013) also reiterated that continuous use of soil for irrigation may pose some adverse effects on both soil and water quality. The physical and chemical properties of irrigated soils depend to some extent on chemical composition of water, as poor quality of irrigation water affects the yield of crops, fertility needs and irrigation system performance (Brady and Weil, 2005). According to Adamu (2013), many traditional irrigated agricultural systems in the tropics are characterized by negative mineral element balances essential for plant growth and development. It is therefore important that irrigation water be free from excessive ions which are toxic to plants or in composition that has detrimental effects on soil physical condition.

The necessity for regular investigation in soils in order to evaluate their quality is essential because of the simple fact that land use and management can change the capacity of the soil to function (Karlen, 1997; USDA, 2002). Irrigation farm of Institute for Agricultural Research (IAR) Samaru, Zaria has been in use for a number of years in both dry and wet seasons and the dominant crops cultivated include cereals, vegetables, and legumes. Couple with the fact that certain crops harvested from previous irrigation studies on the IAR irrigation research farm tends to have abnormal taste which may be associated with certain salts present in high amount (Musa, 2017). As such, there is need to assess the status of soil properties of the farm vis-a- vis the irrigation water as it may be varying with season.

Therefore, the assessment of the soil and water condition plays a vital role in the sustainable use and management of the irrigation farm of the Institute. The study was conducted to evaluate the seasonal variation of soil properties as influenced by irrigation water and suggest some management practices for sustainable use of the land.

## MATERIALS AND METHODS

### The Study Area

The study was carried out at the irrigation farm of the Institute for Agricultural Research (IAR) of Ahmadu Bello University Zaria, Nigeria. The area is within Sub Humid High-plain Agroecological zone of Nigeria (Ojanuga, 2006). The study area is located within Northern Guinea savanna vegetation zone of Nigeria. The farm lies within latitudes 11$^o$11'08.3" N to 11$^o$11'18.8" N and longitudes 070$^o$36'51.4" E to 007$^o$37'01.1" E and covers an area of 4.5ha (Figure 1).

Climate of the study area showed that Samaru, Zaria has mean annual rainfall of 1121.30 mm. The lowest relative humidity was recorded in February as 13.93% and highest as 83.20% in August. The study area has a maximum temperature of 36.55$^o$C in March and a minimum temperature of 15.03$^o$C in December. Evaporation ranged between 176.12mm/month in September and 371.90 mm/month in April, and the total mean annual evaporation was recorded as 3010.92 mm.

### Field Study (Collection of Soil and Water Samples)

Detailed field study was carried out by locating points of sampling and auger used in soil sampling, while global positioning system (GPS; Garmin *etrex 20* model) was used in establishing their geographic coordinates. The layout of the field showing sampling points is presented in Figure 1.

The soil samples were collected at two depth positions: 0-15 cm for the top and 15-30 cm for the bottom at six different points within the irrigation field (A1 -A3, B1 -B3) and two as control points outside the field (C1 and C2) where rainfall was the only source of water for the growing plants (Figure 1). The soil samples were collected at two different periods. The first set was collected during dry season in April, while the second set of soil samples were in the rainy season in the month of August, 2017.

Water samples were also collected on the same day of each period at the source of irrigation water at two points (W1 and W2, about 400m apart) within Bomo dam. The water samples were collected in clean plastic containers for laboratory analysis.

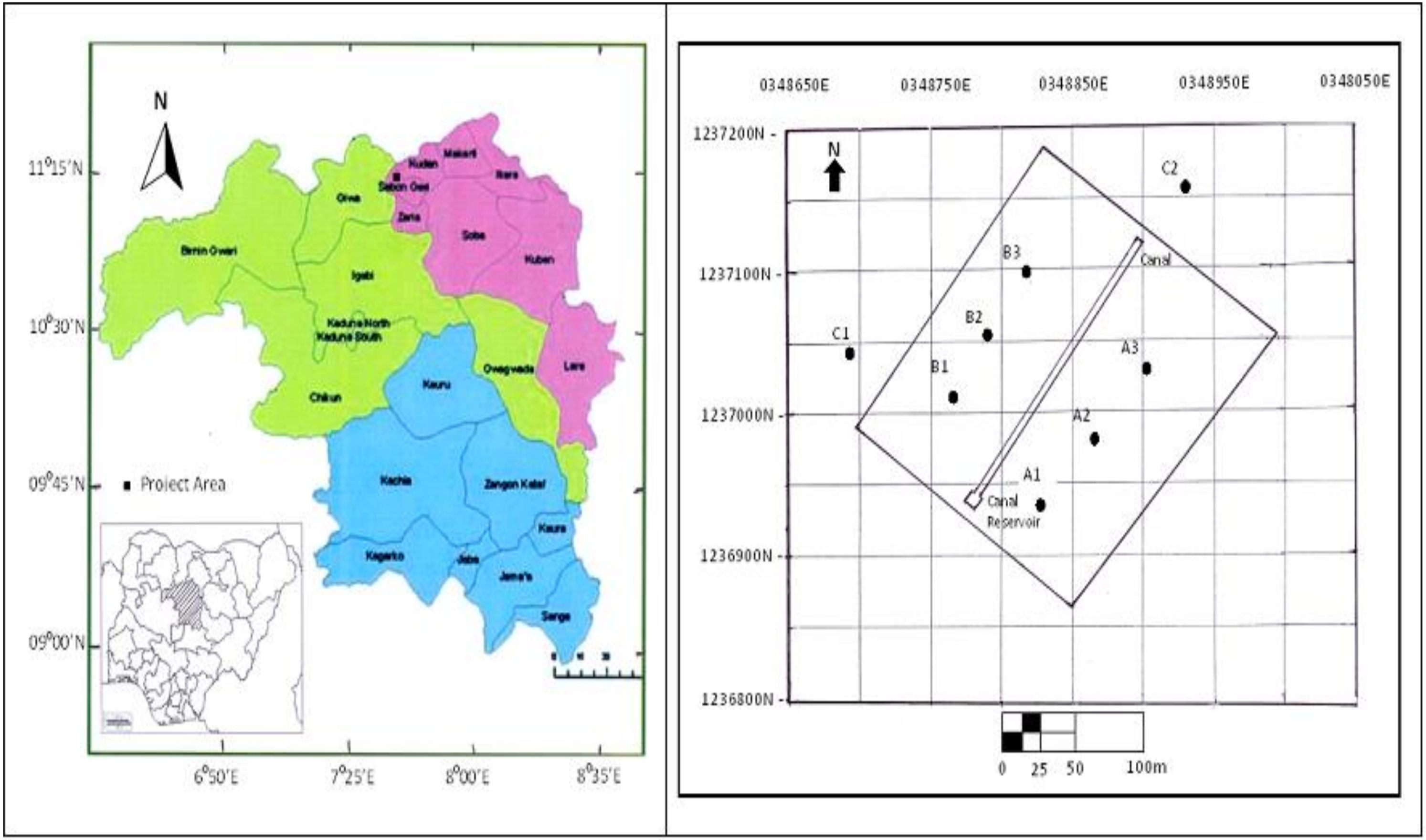

Figure 1: Map of Kaduna State indicating study area and IAR Irrigation Farm layout showing soil sampling points.

## Laboratory Analysis of Soil and Water Samples

To achieve the objectives of the study, both soil and water samples were taken to the laboratory for analysis of physical and chemical properties. The soil samples collected were air-dried in the laboratory, crushed with porcelain pestle and mortar and sieved to remove, material greater than 2mm (gravel). The less than 2mm material was used to carry out Laboratory analysis. Soil samples were analyzed for particle size distribution (Gee and Bauder, 1986), bulk density, total porosity (Blake and Hartge, 1986), pH (Udo *et al*., 2009), electrical conductivity (Udo *et al*., 2009), exchangeable bases (Ca, Mg, K and Na) (Thomas, 1982), and cation exchange capacity (CEC) (Rhoades, 1982). Exchangeable sodium percent (ESP), and sodium adsorption ratio (SAR) were calculated from the exchangeable bases and CEC. The pH and electrical conductivity of the water samples were read directly by pH and Conductivity meters respectively. Exchangeable Ca and Mg were determined using atomic absorption spectrophotometer (AAS), while K and Na were determined from flame emission photometer. Bicarbonate was determined by rapid titration method (Udo *et al*., 2009).

The pH and electrical conductivity of the water samples were read using pH and conductivity meters. Exchangeable cations of Ca and Mg were determined from AAS, while Na and K from flame emission photometer. While SAR of the water samples was obtained from the ratio of the cations. Bicarbonate was determined by rapid titration method (Udo *et al*., 2009).

## Statistical Analysis

Descriptive statistics such as range and mean were used to discuss the results (StatPoint, 2005). Generalized Linear Model one-way analysis of variance (ANOVA) was used to analyze the variation between the locations (A, B and C) and water. Independent t – test was used to assessed difference between the irrigation field and water, and between the seasons. The data of parameters were analyzed using Statgraphic Centurion XV computer soft-ware packages to determine the relationships between the various soil parameters (StatPoint, 2005). Parameters that had significant difference were then contrasted using Fisher's Protected Least Significant Difference (LSD) test. All the statistical analyses were carried out at 95% confidence level.

# RESULTS AND DISCUSSION

## Soil Properties

### *Soil physical properties*

The soils of the study area (IAR irrigation field and control sections) ranged in texture from loam to sandy loam with high proportion of sand (440 to 560 g/kg) and silt (380 to 480 g/kg) fractions, while clay had the least fraction (60 to 100 g/kg).Clay fractions increased from the surface with increase in soil depth and may be attributed either to a vertical or lateral clay translocation or surface erosion (Malgwi, 2001). Bulk density varied between 1.43 and 1.68 $Mg/m^3$ for the entire area (Table 1). The values were generally lower at the topsoil across seasons in all the locations. The total porosity ranged between 30.19and 47.54 percent for the two seasons across the entire area, and was generally higher in the surface soils in both seasons in all the locations. The incorporation of organic matter will reduce the bulk density and improve porosity and drainage of the soils (Adamu, 2013).

### *Soil chemical properties*

Soil reaction (pH) from both sections of the field and the area not under irrigation for the dry season ranged from5.82 to 6.90 (Table 2), and is classified as moderately acid to neutral. The pH values indicated that the soils are within normal range for the growth and development of most crops. The electrical conductivity of the soils ranged between 0.007 and 1.30 dS/m for both seasons, and was within similar range reported by Malgwi *et al*. (2002).The ECe of the soil from the two sections of the irrigation farm as well as the area not under irrigation were within the acceptable limit for soil salinity range (Brady and Weil, 2005).The ESP values for the entire area varied between 3.10 and 11.23 % for all the seasons, and were rated as non sodic (Brady and Weil, 2005). The finding was within range reported by Malgwi *et al*. (2002) on soils of Kura-Kadawa area in Kano State, Nigeria. Sodium adsorption ratio of the irrigation farm varied between 0.202 and 0.403 for all seasons (Tables 2 and 3). The values for the different seasons were within the acceptable limit for soil sodicity (Brady and Weil, 2005).

### *Exchangeable bases and cation exchange capacity*

Calcium ranged between 2.10 and10.10 cmol(+)kg during the different seasons for the whole field, and was rated as medium to high. Magnesium content of the soils varied between 0.33 and 0.68 cmol/kg and was rated as medium. Potassium in the soil ranged between 0.11 and 0.36 cmol(+)kg across the study area and throughout the different seasons. The values of K in the soils vary from low to high across the locations. However, the soils had adequate supply of exchangeable K during rainy season and hence there will be no deficiency under rainfed cultivation. The sodium content of the soil varied between 0.23 and 0.89 cmol(+)kg for the two seasons, and the values were rated as medium to high throughout the locations. The ECEC of the soil for the irrigation and non-irrigated field ranged between 3.83 to12.83 cmol(+)kg for both seasons across the area and the values were rated as medium to high and low to medium for both dry and rainy seasons respectively. Incorporation of organic residues can be applied to increase cation exchange capacity of the soils.

## Properties of Irrigation Water

### *Water reaction, Salinity and Sodicity*

The pH of the dam water used for irrigation ranged between 6.50 to 6.90 with a mean value of 6.69 (Table 4) across the seasons showed that the water quality is within the acceptable limit for irrigating most crops although there was slight change in pH during the rainy season. The values are far below 9.0 which are considered to contribute towards structural stability (Frenkel and Shainberg, 1980). Though, Shainberg and Oster (1978) noted that pH for irrigation water is not an accepted criterion for its quality because it tends to be buffered by the soil, this was supported by the variation in pH within the seasons which might be due to the amount of calcium, magnesium and potassium content of the water during those periods. The variation may also be attributed to leaching of soluble salts influenced by amount of rainfall in the area.

Electrical Conductivity (EC) is an indication of the total salt content and salinity hazard of irrigation water. The EC of the water ranged between 0.007 and 0.010 dS/l for both dry and wet seasons, and were within moderate class (FAO, 2006), and has no threat of salinity hazard for irrigation (USDA, 2002).

Sodium Adsorption ratio of the irrigation water varied between 2.73 and 5.12 percent for the two seasons (Table 4) with a mean value between 3.19 and 5.10 respectively for dry and rainy seasons. The values showed that there is no potential hazard of SAR in the irrigation water quality for both seasons, as the value were within 3-9 percent which is referred to as excellent for irrigation (FAO, 2006), and therefore no sodicity threat to the soils of the area.

Table 2: Chemical properties of soils of the study area in the dry season

| Sample | Depth | pH | | ECe | Ca | Mg | K | Na | AlH | ECEC | ESP | SAR | Cl | $HCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | $H_2O$ | $CaCl_2$ | $dSm^{-1}$ | ← | | cmol(+)$kg^{-1}$ | | | → | % | | mg/kg | |
| A1a | 0 – 15 | 6.1 | 5.8 | 0.90 | 7.60 | 0.55 | 0.18 | 0.85 | 0.4 | 9.58 | 8.87 | 0.298 | 0.6 | 0.80 |
| A1b | 15 - 30 | 6.5 | 5.7 | 1.30 | 6.30 | 0.35 | 0.15 | 0.78 | 0.4 | 7.98 | 9.77 | 0.302 | 0.5 | 0.80 |
| A2a | 0 – 15 | 6.7 | 5.9 | 0.75 | 8.14 | 0.42 | 0.22 | 0.64 | 0.4 | 9.82 | 6.52 | 0.219 | 0.5 | 1.20 |
| A2b | 15 - 30 | 6.6 | 5.6 | 1.00 | 7.37 | 0.43 | 0.16 | 0.70 | 0.6 | 9.26 | 7.56 | 0.251 | 0.6 | 0.40 |
| A3a | 0 – 15 | 6.8 | 5.9 | 1.00 | 6.00 | 0.42 | 0.21 | 0.84 | 0.4 | 7.87 | 10.67 | 0.332 | 0.3 | 1.80 |
| A3b | 15 - 30 | 6.7 | 5.7 | 0.85 | 5.93 | 0.37 | 0.16 | 0.70 | 0.6 | 7.76 | 9.02 | 0.279 | 0.5 | 0.80 |
| B1a | 0 – 15 | 6.9 | 5.8 | 1.10 | 9.92 | 0.53 | 0.30 | 0.74 | 0.6 | 12.09 | 6.12 | 0.229 | 0.5 | 0.80 |
| B1b | 15 - 30 | 6.5 | 5.6 | 1.00 | 10.9 | 0.6 | 0.19 | 0.74 | 0.4 | 12.83 | 5.77 | 0.218 | 0.4 | 0.80 |
| B2a | 0 – 15 | 6.6 | 5.7 | 0.85 | 6.32 | 0.35 | 0.28 | 0.89 | 0.6 | 8.44 | 10.55 | 0.345 | 0.6 | 0.40 |
| B2b | 15 - 30 | 6.9 | 5.8 | 0.90 | 7.37 | 0.43 | 0.16 | 0.83 | 0.6 | 9.39 | 8.84 | 0.297 | 0.5 | 1.00 |
| B3a | 0 – 15 | 6.8 | 5.9 | 1.20 | 10.5 | 0.50 | 0.31 | 0.79 | 0.6 | 12.70 | 6.22 | 0.238 | 0.5 | 0.80 |
| B3b | 15 – 30 | 6.7 | 5.6 | 1.00 | 10.5 | 0.55 | 0.26 | 0.67 | 0.4 | 12.38 | 5.41 | 0.202 | 0.5 | 1.00 |
| C1a | 0 – 15 | 6.4 | 5.8 | 1.30 | 5.35 | 0.29 | 0.11 | 0.74 | 0.4 | 6.89 | 10.74 | 0.312 | 0.5 | 0.60 |
| C1b | 15 – 30 | 6.5 | 5.5 | 0.75 | 7.95 | 0.43 | 0.13 | 0.79 | 0.6 | 9.90 | 7.98 | 0.273 | 0.4 | 0.60 |
| C2a | 0 – 15 | 6.8 | 5.7 | 1.20 | 10.1 | 0.48 | 0.13 | 0.56 | 0.4 | 11.67 | 4.80 | 0.172 | 0.6 | 0.60 |
| C2b | 15 – 30 | 6.7 | 5.8 | 1.10 | 6.10 | 0.33 | 0.15 | 0.23 | 0.6 | 7.41 | 3.10 | 0.091 | 0.3 | 0.60 |

Table 3: Chemical properties of soils of the study area in the rainy season

| Hor. | Depth | pH | | ECe | Ca | Mg | K | Na | $Al^{3+}H$ | ECEC | ESP | SAR | Cl | $HCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | $H_2O$ | $CaCl_2$ | $dSm^{-1}$ | ← | | cmol(+)$kg^{-1}$ | | | → | % | | mg/kg | |
| A1a | 0 – 15 | 6.06 | 5.17 | 0.033 | 2.10 | 0.49 | 0.21 | 0.43 | 0.60 | 3.83 | 11.23 | 0.378 | 0.70 | 0.60 |
| A1b | 15 - 30 | 6.30 | 5.44 | 0.0085 | 5.16 | 5.16 | 0.26 | 0.56 | 0.20 | 6.90 | 8.12 | 0.247 | 0.60 | 0.80 |
| A2a | 0 – 15 | 6.22 | 5.20 | 0.010 | 4.49 | 0.62 | 0.19 | 0.53 | 0.40 | 9.82 | 5.40 | 0.332 | 0.40 | 0.40 |
| A2b | 15 - 30 | 6.22 | 5.25 | 0.0087 | 3.23 | 0.45 | 0.22 | 0.43 | 0.40 | 4.73 | 9.09 | 0.317 | 0.50 | 0.60 |
| A3a | 0 – 15 | 6.10 | 5.33 | 0.008 | 3.74 | 0.68 | 0.23 | 0.55 | 0.20 | 7.66 | 7.18 | 0.370 | 0.50 | 0.60 |
| A3b | 15 - 30 | 6.21 | 5.12 | 0.009 | 3.74 | 0.52 | 0.24 | 0.45 | 0.20 | 5.20 | 8.65 | 0.308 | 0.5 | 0100 |
| B1a | 0 – 15 | 6.16 | 5.42 | 0.010 | 4.30 | 0.57 | 0.28 | 0.44 | 0.20 | 5.79 | 7.60 | 0.282 | 0.40 | 0.80 |
| B1b | 15 - 30 | 6.37 | 5.57 | 0.010 | 5.06 | 0.48 | 0.36 | 0.57 | 0.40 | 6.87 | 8.30 | 0.342 | 0.50 | 0.40 |
| B2a | 0 – 15 | 6.24 | 5.40 | 0.040 | 3.21 | 0.42 | 0.21 | 0.36 | 0.40 | 4.6 | 7.83 | 0.267 | 0.50 | 0.60 |
| B2b | 15 - 30 | 6.41 | 5.46 | 0.0054 | 5.21 | 0.65 | 0.21 | 0.69 | 0.20 | 6.96 | 9.91 | 0.403 | 0.50 | 0.80 |
| B3a | 0 – 15 | 6.16 | 5.43 | 0.007 | 3.90 | 0.55 | 0.35 | 0.51 | 0.40 | 5.71 | 8.93 | 0.342 | 0.30 | 0.60 |
| B3b | 15 – 30 | 6.35 | 5.63 | 0.007 | 5.21 | 0.63 | 0.18 | 0.55 | 0.40 | 7.00 | 7.86 | 0.322 | 0.60 | 0.80 |
| C1a | 0 – 15 | 5.82 | 4.82 | 0.010 | 2.54 | 0.39 | 0.21 | 0.42 | 0.40 | 3.96 | 10.61 | 0.347 | 0.60 | 0.60 |
| C1b | 15 – 30 | 5.85 | 4.91 | 0.011 | 4.66 | 0.56 | 0.27 | 0.46 | 0.40 | 6.35 | 7.24 | 0.285 | 0.80 | 0.80 |
| C2a | 0 – 15 | 6.06 | 5.24 | 0.010 | 2.94 | 0.42 | 0.15 | 0.48 | 0.40 | 4.39 | 10.93 | 0.370 | 0.50 | 0.60 |
| C2b | 15 – 30 | 5.89 | 5.15 | 0.012 | 4.82 | 0.65 | 0.22 | 0.57 | 0.40 | 6.66 | 8.56 | 0.345 | 4.82 | 0.40 |

Table 4: Chemical properties of the water samples in both dry and rainy seasons

| Parameter | Unit | Dry Season (April) W1 (upstream) | W2 (downstream) | Rainy Season (August) W1 (upstream) | W2 (downstream) |
|---|---|---|---|---|---|
| pH | - | 6.90 | 6.73 | 6.50 | 6.76 |
| EC | $dSl^{-1}$ | 0.009 | 0.010 | 0.007 | 0.0075 |
| $HCO_3$ | mg $l^{-1}$ | 0.50 | 0.70 | 1.40 | 1.20 |
| Cl- | mg $l^{-1}$ | 2.00 | 1.70 | 1.30 | 1.20 |
| Ca | mg $l^{-1}$ | 48.40 | 43.50 | 11.00 | 11.10 |
| Mg | mg $l^{-1}$ | 0.586 | 1.044 | 0.554 | 0.5 |
| K | mg $l^{-1}$ | 6.30 | 8.90 | 13.70 | 13.70 |
| Na | mg $l^{-1}$ | 13.50 | 17.17 | 12.30 | 12.20 |
| SAR | - | 2.73 | 3.64 | 5.12 | 5.07 |
| ESP | % | 19.62 | 24.32 | 32.75 | 32.53 |

### *Basic Cations and Anions*

The content of basic cations Ca, Mg, K and Na varied between 11.00 and 48.40 mg/l, 0.50 and 1.04 mg/l, 6.30 and 13.70 mg/l, and 12.20 and 17.17 mg/l respectively. The values of all the cations for both dry and rainy seasons were within the acceptable range of irrigation water as reported by (Landon, 1991).

The amount of chloride in the irrigation water ranged between 1.20 and 2.00 mg/l for both seasons, and was within acceptable standard value for irrigation water. The bicarbonate value ranged between 0.50 and 1.40 mg/l for the seasons with mean of 0.60 and 1.30 mg/l respectively for dry and rainy seasons.

### **Variation between Soils and Irrigation Water Properties**

The amount of pH and bicarbonate on locations for both soils and dam water analyzed during the dry season were not significantly different (Table 5). However, there was significant difference for ECe, Ca, Mg, K, Na, SAR and ESP between the soils and water during the dry season. Locations A and B within the irrigation field and the control farm were significantly lower than the irrigation water at Bomo dam for dry season (Table 5).

During the rainy season, mean values of EC and exchangeable Mg were not significantly different across the various soils of the study locations with the irrigation water (Table 5). However, there was significant difference for pH, Ca, K, Na, $HCO_3$, SAR and ESP between the soils and water during the rainy season. The mean values of these properties were significantly lower in the various soils compared to the irrigation water (Table 5). Soil pH varied between locations as well as depth during the rainy season. The variation trend of soil reaction was influenced by the distribution trend of dissolved salts and increase in salt concentration (Ca) within the locations. The trend of variations in the soil properties implied that the use of Bomo dam water for continuous irrigation of the IAR farm may have degrading effect in form of salinization and sodication if not monitored. There is need for deep ploughing to break subsoil clay pan formation observed with increase in bulk density in the subsoil horizons. Construction of drainage structure may be required as the soils in section B of the irrigation farm are showing mottles which indicate poor drainage condition that will impair crop growth and promote salt accumulation.

Table 5: Comparison of means of properties of location for both soil and water during dry and rainy seasons

| Properties | Units | Loc. A | Loc. B | Control | Water | SE± | P (Value) | LOS |
|---|---|---|---|---|---|---|---|---|
| | | | | Dry Season | | | | |
| pH (water) | - | 6.57 | 6.73 | 6.60 | 6.77 | 0.16 | 0.414 | NS |
| ECe | dS/m | 0.97a | 1.01a | 1.01a | 0.01b | 0.14 | 0.000 | ** |
| Ca | cmol/kg | 6.89b | 9.25b | 7.38b | 45.10a | 1.52 | 0.000 | ** |
| Mg | cmol/kg | 0.42b | 0.48b | 0.38b | 0.82a | 0.96 | 0.005 | ** |
| K | cmol/kg | 0.18b | 0.25b | 0.13b | 7.60a | 0.40 | 0.000 | ** |
| Na | cmol/kg | 0.75b | 0.78b | 0.58b | 15.34a | 0.58 | 0.000 | ** |
| ESP | % | 8.74b | 7.15b | 6.65b | 21.97a | 1.93 | 0.000 | ** |
| SAR | - | 0.28b | 0.25b | 0.21b | 3.19a | 0.15 | 0.000 | ** |
| $HCO_3$ | cmol/kg | 0.97 | 0.80 | 0.60 | 0.60 | 0.26 | 0.303 | NS |
| | | | | Rainy Season | | | | |
| pH (water) | - | 6.19b | 6.28b | 5.91c | 6.63a | 0.0894 | 0.000 | ** |
| ECe | dS/m | 0.013 | 0.013 | 0.011 | 0.002 | 0.0084 | 0.437 | NS |
| Ca | cmol/kg | 3.74b | 4.48b | 3.74b | 11.05a | 0.7871 | 0.000 | ** |
| Mg | cmol/kg | 1.32 | 0.55 | 0.51 | 0.53 | 0.9211 | 0.594 | NS |
| K | cmol/kg | 0.23b | 0.27b | 0.21b | 13.70a | 0.0436 | 0.000 | ** |
| Na | cmol/kg | 0.49b | 0.52b | 0.48b | 12.25a | 0.0691 | 0.000 | ** |
| ESP | % | 8.28b | 8.41b | 9.34b | 32.64a | 1.2351 | 0.000 | ** |
| SAR | - | 0.33b | 0.33b | 0.34b | 1.30a | 0.0368 | 0.000 | ** |
| $HCO_3$ | cmol/kg | 0.63b | 0.67b | 0.60b | 0.86a | 0.1285 | 0.000 | ** |

LOS (P): NS > 0.05, ** ≤ 0.01; Note: Means followed by the same letters in the rows are not significantly different at 5% LOS

## Seasonal Variation of Soil and Irrigation Water Properties

The results of comparing means of soil and water properties between dry and wet seasons are presented in Tables 6. The soil physical properties (bulk density and total porosity) were not significantly influenced by seasonal variation. Similarly, Mg, ESP, Cl and $HCO_3$ were also not significantly different based on the differences in seasons. Soil pH, ECe, Ca, Na, exchangeable acid and effective CEC were significantly higher during dry season compared to rainy season, and may be attributed to increase in content of salts in the soils contributed by the irrigation water. Anikwe *et al*. (2002) reported that the type and quantity of cations and anions added through irrigation water affect the soil reaction (pH). Adejumobi *et al*. (2014) also reported change in soil pH influenced by type of irrigation practice. However, only K and SAR were noted to be significantly higher during rainy season compared to dry season. These were associated to transportation of burnt ashes in surface runoff water and leaching of Ca and Mg in the soils respectively.

There was a highly significant reduction in the concentration of Ca in the water during the rainy seasons (Table 6), and the variation might be attributed to higher concentration of the ion in water during dry season due to reduction in amount of water in the reservoir by evaporation process, while in the rainy season there was dilution of the salt associated with increase in water in dam reservoir. Similarly, Na content in the water was higher during the dry season compared to rainy season. Malgwi *et al*. (2002) reported increase in basic cations in irrigation water during dry season in Semi-arid Savanna. However, K significantly increased during rainy season as compared to the dry season (Table 6), and was attributed to the activities of farmers causing inflow of potash from ash by bush burning, fertilizers and herbicides into the dammed irrigation water during rainy season. The concentration of Mg during the rainy season tends to increase compared to dry season, and may be associated to application of fertilizers containing Mg ions carried along in surface runoff water. The mean value of SAR in the irrigation water was significantly lower in dry season than rainy season, and the trend was noticed in the soils mean values. However, seasonal variation did not significantly influence chloride anion in the irrigation water. The significant increase in bicarbonate in the water during the rainy season was attributed to rain water been charged with carbon dioxide dissolves carbonate minerals, as it passes through soil and rocks to give bicarbonates. This might be due to dissolved minerals in the water at the period, although, the primary source of carbonate and bicarbonate ions in groundwater is the dissolved carbon dioxide in the water (Brady and Weil, 2005).

Table 6: Comparison of means of properties of soils and water between the seasons

| Properties | Units | Dry Season | Rainy Season | SE± | P (Value) | LOS |
|---|---|---|---|---|---|---|
| | | | Soils | | | |
| Sand | % | 47.63 | 47.63 | 1.34 | 0.935 | NS |
| Silt | % | 45.13 | 45.13 | 1.10 | 0.802 | NS |
| Clay | % | 7.25 | 7.25 | 0.59 | 0.780 | NS |
| Bulk Density | $Mg/m^3$ | 1.54 | 1.60 | 0.29 | 0.127 | NS |
| Total porosity | % | 41.72 | 39.62 | 1.08 | 0.126 | NS |
| pH ($H_2O$) | - | 6.64a | 6.15b | 0.06 | 0.000 | ** |
| pH($CaCl_2$) | | 5.74a | 5.28b | 0.05 | 0000 | ** |
| ECe | dS/m | 1.01a | 0.01b | 0.04 | 0000 | ** |
| Ca | cmol/kg | 7.80a | 4.02b | 0.55 | 0000 | ** |
| Mg | cmol/kg | 0.44 | 0.83 | 0.32 | 0.268 | NS |
| K | cmol/kg | 0.19b | 0.24a | 0.02 | 0.004 | ** |
| Na | cmol/kg | 0.72a | 0.50b | 0.04 | 0000 | ** |
| Exch. Acid | cmol/kg | 0.50a | 0.35b | 0.04 | 0.001 | ** |
| ECEC | cmol/kg | 9.75a | 6.03b | 0.66 | 0.000 | ** |
| ESP | % | 7.62 | 8.59 | 0.77 | 0.244 | NS |
| SAR | - | 0.25b | 0.33a | 0.02 | 0.001 | ** |
| Cl | cmol/kg | 0.49 | 0.80 | 0.29 | 0.298 | NS |
| $HCO_3$ | cmol/kg | 0.81 | 0.64 | 0.08 | 0.118 | NS |
| | | | Water | | | |
| pH | - | 6.77 | 6.63 | 0.14 | 0.422 | NS |
| ECe | dS/l | 0.01 | 0.00 | 0.07 | 0.312 | NS |
| Ca | mg $l^{-1}$ | 45.95a | 11.05b | 2.45 | 0.005 | ** |
| Mg | mg $l^{-1}$ | 0.82 | 0.53 | 0.23 | 0.338 | NS |
| K | mg $l^{-1}$ | 7.60b | 13.7a | 1.30 | 0.043 | * |
| Na | mg $l^{-1}$ | 15.34 | 12.25 | 1.84 | 0.235 | NS |
| SAR | - | 3.19b | 5.10a | 0.46 | 0.052 | * |
| Cl | mg $l^{-1}$ | 1.85 | 1.25 | 0.16 | 0.063 | NS |
| $HCO_3$ | mg $l^{-1}$ | 0.06b | 1.30a | 0.14 | 0.038 | * |

LOS (P): NS > 0.05, ** ≤ 0.01, *** ≤ 0.001 Note: Means followed by the same letters in the rows are not significantly different at 5% LOS.

## CONCLUSION

The study has shown that ECe, Ca, Mg, K, Na, SAR and ESP were significantly lower in the soils compared to the irrigation water during the dry season. Similarly, pH, Ca, K, Na, $HCO_3$, SAR and ESP were significantly lower in the soils compared to the water during the rainy season. Irrigation water influenced soil pH, ECe, Ca, Na, exchangeable acid and effective CEC, and were significantly higher during dry season compared to rainy season. However, rainfall contributed significantly to regulation of salt accumulation via leaching of excess salts, thereby reducing salinization and sodication processes in soils of the IAR irrigation farm. To effectively manage the soils for sustainable use, some management practices suggested include deep ploughing, construction of drainage system and incorporation of organic matter, as well as monitoring of the salinity and sodicity state of the soils and water at periodic intervals to avert salt-build up in the farm.

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