Spatial Variation of Sodium Hazard in Kano River Irrigation Project, Nigeria

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Abstract

Sodium hazard in different areas of Kano River Irrigation Project (KRIP) was studied by collecting soil samples from thirty nine sectors. Four samples were collected to a depth of 45 cm from each sector at different points using soil auger. The coordinates of all the sampling points were taken with a Garmin 78 GPS and recorded. The parameters determined were pH, EC and concentrations of Na^+, Ca^{2+}, K^+ and Mg^{2+} ions from the soil saturated extract and appropriate relationships were used to determine Exchangeable Sodium Percentage (ESP). Kriging interpolation was made with the ArcGIS software and six classes of sodic soils were identified. The study revealed that the KRIP is dominated by sodic soil as approximately 85 % of the total area had an ESP greater than 15% while the Non-sodic soils, which were the uncultivated area, covered only 15% of the area. Major crops grown in the area will experience stunted growth and consequent yield reduction due to adverse physical conditions of dispersed soil especially in the eastern sectors. Use of management strategies such as application of gypsum, leaching, provision of drainage, addition of organic matter are recommended for the management of soil under both rain fed and irrigated condition in the study area.

Key words: Exchangeable sodium, Irrigation, River, Sodium, Soil

Introduction

One of the major challenges confronting the world today is achieving food security. However, a limiting factor contributing to this challenge is soil salinity. Soil salinity has a negative impact on crop production, particularly in arid and semi-arid regions (Elbashier *et al*., 2016). The problem manifests itself in these regions with poorly drained soils because of continuous addition of salts from inorganic fertilizer application through irrigation water (Salih *et al*., 2015). This results in salts accumulation in soils which alters the soils' physical and chemical properties such as pH, exchangeable sodium, electrical conductivity, sodium adsorption ratio, hydraulic conductivity and soil available water. Saline and sodic soils are the two different types of salt-affected soils. Sodic soils are low in soluble salts but has high exchangeable sodium and as such are unsuitable for many plants due to high composition of sodium which may cause rooting problem in plants. Under conditions of high sodicity, dispersion occurs when the clay particles swell strongly and separate from each other on wetting (Bannari *et al.,* 2013). On drying, the soil becomes hard and cloddy with a poor structure .This results in reduction of movement of water in the soil and accumulation of salts and other toxic elements (Rengasamy *et al.*, 2010).

Sodicity is a measure of the amount of exchangeable sodium in soil or water and has a strong influence on soil structure (Bannari *et al.*, 2013).When sodium ion is adsorbed by soil particles as exchangeable cations, the soil becomes sodic and the soil structure becomes degraded due swelling and dispersion of clay. The amount of dispersed clay is affected by clay content, organic matter and the constituents of soil solution (Rengasamy *et al.*, 2010). The high amount of sodium (Na^+) occupying exchange complex in sodic soil often results in a pH of 8.5 or above in contrast to the saline soils (McCauley and Jones, 2005). The soils tend to develop poor structure and drainage problem over time due to the effect of sodium ions on clay particles (Davis *et al.*, 2012).

Knowledge of the occurrence of sodicity is very important for the sustainable development of any Irrigation Project. In Kano River Irrigation Project (KRIP), the problem of sodicity was reported by many researchers (Jibrin *et al.,* 2008, Maina *et al.*, 2012 a, Mohammed *et al.*, 2015). For instance, Jibrin *et al.* (2008) reported that sodicity and soil fertility problems associated with sodic soils were widespread as an Exchangeable Sodium Percentage (ESP) value as high as 40.6% was recorded in top soil of KRIP. The high ESP may likely lead to a decline in crop yield and affect sustainability of production unless deliberately chosen techniques oriented towards sustainability are incorporated into the crop production system. Maina *et al.* (2012 a), reported high concentration of sodium in one of the sectors possibly due to heavy application of synthetic fertilizer. Mohammed *et al.* (2015) recorded an ESP greater than 15% in some sectors of the KRIP. The finding led to a caution against continued irrigation activity without careful assessment and monitoring of soil salinity in order to prevent salt accumulation which will lead to decline in crops yield.

ESP is used as a measure of soil sodicity and is related to top soil structural degradation through clay dispersion from soil aggregates. Information on spatial variation of sodium hazard in different sectors of the study area is important to understand the level of sodicity and to implement ways of mitigation. This research studied the spatial variation of sodium hazard and assessed the extent in different areas of the KRIP.

Materials and Methods

Study area

The study area is the first and largest irrigation project in Nigeria (Yakubu *et al.,* 2018). It is located at an altitude of about 440 m above sea level between latitudes 11°32`N and 11°51`N and longitudes 8°20`E and 8°40`E within the Sudan savannah zone of Northern Nigeria (Figure 1.). The soils in the area are mostly moderately deep and well drained with sandy loam texture at the surface and sandy clay loam subsoil (Jibrin *et al.*, 2008). Vegetation type in the area is Sudan savanna consisting of trees, shrubs, and grassland. The area is well drained by the Kano River formation which is made up of the Hadejia, Katagum and Jama'are rivers that converge to form the River Yobe (Yakubu *et al.*, 2018). The mean temperatures ranges between 21 °C- 31 °C (Zakari *et al.,* 2017).

Average annual rainfall ranges from 635 to 889 mm which is usually between July and September with maximum amounts of

214.0 mm, about 60% of which falls in July and **August and varies considerably from year to year (Maina, et al., 2012 b). The main source of water for the irrigation project is the Tiga dam constructed across the River Kano between 1970 and 1974 with a capacity of 1.968 billion m3, a length of 6 km and a height of 48 m (Maina, et al., 2012 b). Crops grown in the study area are tomato, rice, carrot, pepper, maize, sugarcane, lettuce, cabbage and other vegetable. The project with a total area of 62,000 ha was planned to be implemented in two phases; the Kano River Irrigation Project Phases I and II. Phase I lies on either side of the Kano-Zaria express way about 30 km south of Kano city (Mohammed et al., 2015). KRIP has two main branches: the west and the east branches each having 30 and 17 sectors respectively (Jibrin et al., 2008).**

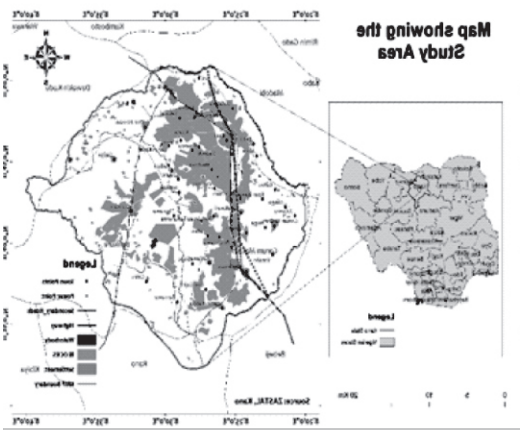


Figure 1. Map showing the location of the study area.
Source: Zonal Advance Space Technology Laboratory, Bayero University, Kano 2019

Soil Samples Collection

Soil samples were collected from 39 sectors in the study area for laboratory analysis in September, 2019. At each sector, four samples were collected at different points. A total of one hundred and fifty six (156) samples were collected from all the sectors. The collection was done with soil auger. The auger was driven to a depth of 45 cm (active rooting depth for the crop grown in the study area). Samples were placed in a properly labelled polythene bags. Care was taken during sampling to ensure that representative samples were collected and areas with clear evidence of salinity were noted. The coordinates of all the sampling points selected at random were taken with a Garmin 78 GPS and recorded. The collected samples were taken to Centre for Dry Land Agriculture (CDA) of the Bayero University, Kano for the analysis.

Prior to sample collection, reconnaissance survey of the study area was carried out which provided useful information for samples collection. Interaction was also done with the farmers and position of the sectors and access roads were also noted during the reconnaissance survey. Other important information obtained during the site visit were canals network, areas with visible evidence of salinity, crops grown in the study area, irrigation system practiced, position of drainages, Water logged areas and sectors under development.

Laboratory Analysis of Soil Samples

Parameters determined in the laboratory were pH, Electrical Conductivity (EC) and concentrations of Na^+, Ca^{2+}, K^+ and Mg^{2+} ions from the soil saturated extract. Air-dried soil weighing 150 g was mixed with

300 ml of distilled water (1:2 soil to water mixture) until saturated. The mixture was covered and left for 24 hours to form solution. The soil solution was then extracted using a Buchner funnel apparatus and vacuum. The extracts were stored at 4 ºC until the analysis was carried out. The electrical conductivity was measured with a conductivity meter CM 35+ while the pH was determined by using glass electrode pH meter. Potassium was measured with flame photometer while sodium, calcium and magnesium concentration were measured with Atomic Absorption Spectrometer. The ESP was calculated from this expression below (Mohammed *et al.,* 2014):

$$ESP = \frac{Na^{+}}{Na^{+} + Ca^{2+} + Mg^{2+} + K^{+}} x100$$

Statistical analysis of the laboratory result was carried out. Multivariance analysis of variance (MANOVA) was carried out to test variation of parameters (significant at ≤5%) at different sectors. The mean werecompared using Least Significant Difference (LSD) post Hoc test.

Ordinary Kriging

Spatial interpolation with krige procedure was used to estimate values of ESP at unknown points of the sectors based on the values at sampling points. The kriging technique is based on assumption of the fact that the result of the measured areas of the sectors in the KRIP close to points where samples were not taken have the most influence. The data was used to plot Krige maps presented in Figures 2 and 3 respectively. ArcGIS 10.6 were used as the main GIS packages for running analysis functions to process the data. Generalized Linear Model (GLM) procedure in Statistical Package for the Social Science (SPSS) was also used in the description of data.

Results

The mean, and standard deviation of parameters at different sectors of the Krip are presented in Table 1 while descriptive statistics of soil sodicity is presented in Table 2.

Variation of Parameters obtained from laboratory result among sectors

The Multivariance analysis of variance (MANOVA) estimated shows significant difference in the mean pH value in the sectors at 5% level, thus the highest pH 8.6 was observed at Barnawa while the lowest (pH 5.81) was recorded at Kode sector (Table 1). The Electrical Conductivity (EC), was highest in Kadawa with 0.676 ds/m while the lowest was recorded at Gore north with 0.065; although there was no significant difference in the average EC among all sectors.

The average calcium (Ca) ($P > 0.090$), potassium (K) ($P > 0.381$), magnesium (Mg)($P > 0.327$) and sodium (Na) ($P > 0.053$) recorded did not differ significantly among various sectors. The greatest value for Ca of 4.36 *cmol (+)/kg* was recorded at Maura while the lowest *value of* 0.93 *cmol (+)/kg* was obtained at Agalawa. The highest potassium (K) value was obtained at Dorayi with 0.93*cmol (+)/kg and* the lowest value for K of 0.23*cmol (+)/kg* was recorded at Yakasai. Maura had the highest magnesium (Mg) 2.58 *cmol (+)/kg* and the lowest was recorded at MakwaroTsauni with 0.88 *cmol (+)/kg.* Highest sodium value of 2.02 *cmol (+)/kg* was obtained at Raje while the lowest value of 0.44*cmol (+)/kg* was recorded at Yantomo.

Table 1. Mean (± standard deviation) of soil parameter at different locations

Sector	PH (1:1)	EC(Ds/m)	Ca (cmol(+)/kg)	K (cmol(+)/kg)	Mg (cmol(+)/kg)	Na (cmol(+)/kg)	ESP (%)
Agalawa	6.74± 0.90[a]	0.358± 0.287 [a]	0.93± 0.40 [a]	0.37± 0.22 [a]	0.97± 0.28 [a]	1.05± 0.57 [a]	31.03± 6.34[b]
Agolas	7.25± 1.07[a]	0.225± 0.093 [a]	2.11± 1.21 [a]	0.27± 0.04 [a]	0.99± 0.27[a]	0.73± 0.22 [a]	19.2± 6.39[a]
Azore	6.97± 1.19[a]	0.138± 0.115 [a]	1.64± 0.94 [a]	0.45± 0.06 [a]	1.11± 0.34 [a]	1.13± 0.49 [a]	28.2± 13.92[b]
Bangaza	8.07± 0.81[a]	0.268± 0.083 [a]	2.44± 1.33 [a]	0.58± 0.31 [a]	1.78± 1.11 [a]	0.64± 0.36 [a]	15.7± 16.85[a]
Barnawa	8.6± 1.49[a]	0.283± 0.13 [a]	2.28± 1.42 [a]	0.42± 0.20[a]	1.43± 0.54 [a]	0.7± 0.60 [a]	14.29± 8.43[a]
Bunkure East	6.96± 0.29[a]	0.077± 0.055 [a]	2.15± 1.19 [a]	0.32± 0.15 [a]	1.09± 0.57 [a]	0.55± 0.44 [a]	17.6± 18.72[a]
Bunkure West	7.67± 0.83[a]	0.253± 0.204 [a]	2.8± 1.33 [a]	0.44± 0.18 [a]	1.37± 0.39[a]	0.89± 0.24 [a]	17.39± 7.53[a]
Butalawa	6.74± 0.95[a]	0.192± 0.195 [a]	1.77± 1.64 [a]	0.44± 0.21 [a]	1.24± 0.56 [a]	0.91± 0.14 [a]	25.86± 13.6[b]
Cirin	6.91± 1.10[a]	0.129± 0.115 [a]	2.97± 1.00 [a]	0.43± 0.25 [a]	1.44± 0.72 [a]	0.84± 0.27 [a]	15.1± 1.24[a]
Dalili	6.85± 0.79[a]	0.117± 0.064 [a]	2.24± 1.78 [a]	0.41± 0.23 [a]	1.14± 0.65 [a]	1.64± 1.68 [a]	33.3± 23.54[b]
Danbaki	6.85± 0.58[a]	0.106± 0.088 [a]	2.09± 0.97 [a]	0.34± 0.15 [a]	1.09± 0.32 [a]	0.79± 0.48 [a]	16.92± 9.92[a]
Danbala	6.94± 1.16[a]	0.135± 0.096 [a]	3.56± 0.97 [a]	0.5± 0.06 [a]	1.74± 0.34 [a]	0.78± 0.25 [a]	11.89± 2.92[a]
Dorayi	7.35± 0.75[a]	0.198± 0.057 [a]	3.21± 1.89 [a]	0.93± 0.96 [a]	2.19± 1.66 [a]	0.79± 0.53 [a]	15.0± 16.42[a]
Fako	7.91± 1.16[a]	0.308± 0.174 [a]	3.74± 2.10[a]	0.43± 0.10[a]	1.62± 0.45 [a]	0.64± 0.38 [a]	11.89± 6.75[a]
Gafan	6.74± 0.7[a]	0.239± 0.287 [a]	1.25± 0.60[a]	0.38± 0.11 [a]	1.37± 0.61 [a]	1.56± 0.39 [a]	35.87± 7.91[b]
Gayere	6.96± 0.86[a]	0.214± 0.244 [a]	2.63± 1.62 [a]	0.57± 0.23 [a]	1.84± 1.02 [a]	0.85± 0.21 [a]	19.9± 17.48[a]
Gore North	7.26± 1.33[a]	0.065± 0.034 [a]	2.36± 1.16 [a]	0.53± 0.14 [a]	1.57± 0.34 [a]	1.01± 0.20 [a]	20.03± 8.54[a]
Gore South	6.52± 1.07[a]	0.121± 0.036 [a]	3.52± 1.22 [a]	0.67± 0.27 [a]	1.98± 0.68 [a]	0.59± 0.43 [a]	9.66± 7.85[a]
Kadawa	7.53± 1.95[a]	0.676± 1.043 [a]	1.53± 0.31 [a]	0.46± 0.10[a]	1.57± 0.24 [a]	0.63± 0.35 [a]	14.54± 5.51[a]
Karfi	7.69± 1.58[a]	0.332± 0.215 [a]	3.09± 1.10[a]	0.37± 0.13 [a]	1.47± 0.40[a]	0.98± 0.12 [a]	17.58± 5.36[a]
Kode	5.81± 0.43[a]	0.089± 0.036 [a]	2.82± 0.75 [a]	0.45± 0.04 [a]	1.59± 0.39 [a]	0.79± 0.14 [a]	14.48± 4.65[a]
Korawa	6.95± 0.37[a]	0.168± 0.115 [a]	2.09± 1.56 [a]	0.46± 0.10[a]	1.35± 0.61 [a]	0.7± 0.41 [a]	19.47± 16.40[a]
Kosawa	6.99± 1.14[a]	0.26± 0.212 [a]	1.42± 1.48 [a]	0.31± 0.14 [a]	0.98± 0.51 [a]	0.72± 0.48 [a]	26.84± 18.8[b]
Kuruma	7.4± 0.92[a]	0.113± 0.082 [a]	1.98± 1.59 [a]	0.48± 0.11 [a]	1.26± 0.51 [a]	1.04± 0.14 [a]	25.5± 10.73[b]
Lautaye	6.11± 1.04[a]	0.11± 0.086 [a]	1.33± 0.61 [a]	0.52± 0.23 [a]	1.54± 0.96 [a]	0.97± 0.35 [a]	25.46± 15.30[b]
Majabo	6.29± 1.00[a]	0.14± 0.103 [a]	1.95± 1.27 [a]	0.35± 0.14 [a]	1.08± 0.48 [a]	0.75± 0.41 [a]	18.26± 2.69[a]
Makwaro/G	6.88± 0.26[a]	0.311± 0.195 [a]	2.77± 1.24 [a]	0.57± 0.38 [a]	1.77± 1.05 [a]	0.82± 0.25 [a]	15.29± 5.46[a]
Makwaro/T	6.42± 0.83	0.097± 0.053 [a]	1.03± 0.60[a]	0.36± 0.11 [a]	0.88± 0.33 [a]	0.92± 0.19 [a]	31.42± 15.5[b]

Maura	7.9± 1.51 ^{a}	0.504± 0.672 ^{a}	4.36± 2.98 ^{a}	0.72± 0.32 ^{a}	2.58± 1.29 ^{a}	0.53± 0.25 ^{a}	6.74± 1.17 ^{a}
Raje	6.7± 1.00 ^{a}	0.191± 0.091 ^{a}	1.81± 1.41 ^{a}	0.44± 0.18 ^{a}	0.96± 0.83 ^{a}	2.02± 1.52 ^{a}	40.43± 21.5 ^{b}
Rakauna	6.8± 0.53 ^{a}	0.116± 0.114 ^{a}	2.24± 2.02 ^{a}	0.50± 0.40 ^{a}	1.34± 0.99 ^{a}	0.86± 0.47 ^{a}	28.11± 25.6 ^{b}
Samawa	7.7± 0.3 ^{a}	0.301± 0.107 ^{a}	2.82± 1.14 ^{a}	0.33± 0.08 ^{a}	1.29± 0.45 ^{a}	0.63± 0.37 ^{a}	12.5± 5.78 ^{a}
Shiye	6.35± 0.51 ^{a}	0.123± 0.087 ^{a}	1.98± 1.23 ^{a}	0.52± 0.33 ^{a}	1.34± 0.40 ^{a}	0.68± 0.51 ^{a}	16.14± 11.5 ^{b}
Turba	6.21± 1.1 ^{a}	0.078± 0.033 ^{a}	3.35± 0.67 ^{a}	0.45± 0.06 ^{a}	1.65± 0.28 ^{a}	0.44± 0.25 ^{a}	7.64± 3.86 ^{a}
U/Rimi	7.17± 0.35 ^{a}	0.082± 0.092 ^{a}	1.48± 0.93 ^{a}	0.37± 0.04 ^{a}	0.92± 0.20 ^{a}	1.02± 1.05 ^{a}	24.6± 17.48 ^{a}
Waire	7.51± 0.9 ^{a}	0.217± 0.089 ^{a}	2.06± 1.91 ^{a}	0.59± 0.22 ^{a}	1.72± 1.16 ^{a}	1.22± 0.39 ^{a}	26.1± 12.23 ^{a}
Yadakwari	7.19± 1.16 ^{a}	0.229± 0.155 ^{a}	1.62± 0.75 ^{a}	0.46± 0.38 ^{a}	1.29± 0.77 ^{a}	0.46± 0.08 ^{a}	14.03± 6.06 ^{a}
Yakasai	6.87± 1.63 ^{a}	0.232± 0.131 ^{a}	2.43± 0.74 ^{a}	0.23± 0.13 ^{a}	1.04± 0.44 ^{a}	0.74± 0.28 ^{a}	17.21± 5.11 ^{a}
Yantomo	6.15± 1.04 ^{a}	0.303± 0.255 ^{a}	3.02± 0.61 ^{a}	0.65± 0.28 ^{a}	2.00± 0.86 ^{a}	0.44± 0.22 ^{a}	7.12± 2.77 ^{a}

Mean with different superscript within the same column are significantly different at ($P \leq 0.05$) using LSD means of separation

Spatial Variation of Sodium Hazards

Figure 2 shows six classes of sodicity which were considered based on equal intervals method of classification with the ArcGIS software and the area covered by each class. The non- sodic class (C1) with an ESP values ranging from 0.00 – 7.56 covers an uncultivated area of 347.12 ha which is approximately 0.5% of the total area.

Figure 3 shows the variation of sodium hazard in the scheme and the area covered by each class. It can be seen that only 15% of the total area was non-sodic, therefore the soil in the KRIP is dominated by sodic soil as approximately 85% of the total area had an ESP greater than 15%.

Figure 2. Map Showing ESP in different Areas of the KRIP

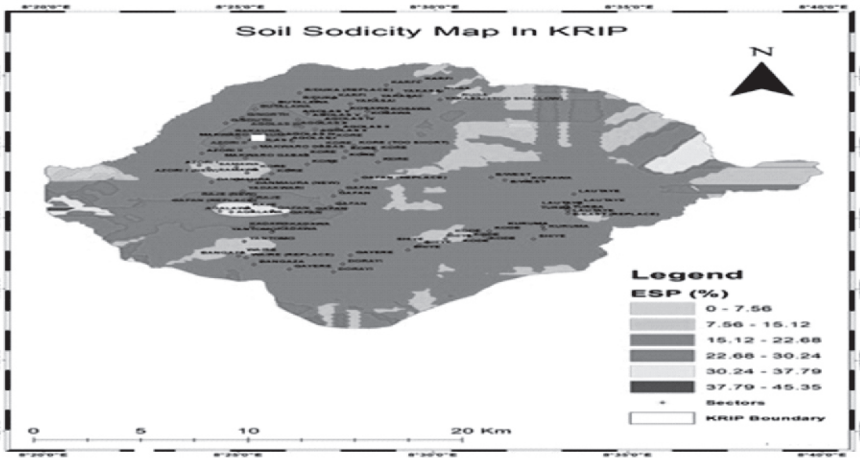
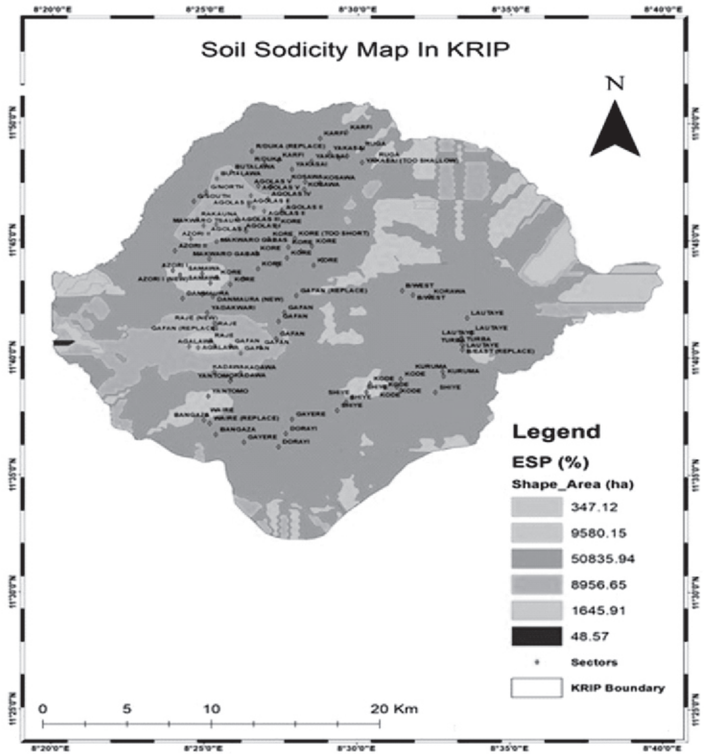


Figure 3. Sodicity Map showing the Affected Areas in Hectares



The standard deviation of 13.36 as presented in Table 2 explains the spatial heterogeneity of the ESP in the study area. Considering a kurtosis value greater than 3 and positive skewness (1.00), the distribution of ESP clustered around the mean value of 19.74 %. The mean ESP value of 19.74% explains the dominance of sodic soil in the area.

Table 2: Descriptive Statistic of Soil Sodicity in KRIP

Statistical Parameters	% (ESP)
Countexca	155.00
Minimum	0.00
Maximum	60.47
Mean	19.74
Standard Deviation	13.36
Skewness	1.00
Kurtosis	3.29
Quartile1	10.26
Median	16.02
Quartile3	26.37

Discussion

In moderately sodic (C3) and sodic classes (C4) with values 15.12 - 22.68%, and 22.68 - 30.34% respectively, there is slight to moderate restriction with respect to sodium composition as the ESP values are within the range of 15 -30 %. Sodium sensitive and semi-tolerant crops such as carrot, lettuce, onion, tomato etc. are affected by an ESP greater than 15% (Mohammed *et al.*, 2015). Moderately tolerant crops like rice will also experience a stunted growth due to both nutritional factors and adverse soil conditions at an ESP greater than 20%. Care should be taken in the choice of crops to be grown under extremely sodic condition as in highly sodic (C5) and extremely sodic classes (C6) where the ESP is within the range of 30.24 – 37.79 and 37.79 - 45.35 respectively (Figure 2). Soil with an ESP above 30% will usually have too poor physical structure not favourable for crop production. The ESP value has detrimental effect to both sodium sensitive crops such as maize, cowpeas, bean, and semi-tolerant such as tomato**,** lettuce, carrot, onion sugarcane due to an ESP value greater than 15% (Mohammed *et al.*, 2015). Extremely sensitive crops such as citrus are affected by low ESP values within the range of 2- 10 %. In the non-sodic class (C2), the ESP ranges from 7.56 -15.12 %.

Maina *et al.* (2012) reported high risk of sodicity development in some of the sectors of the KRIP due to heavy application of synthetic fertilizer on loam textured soil and recommended the replacement of synthetic fertilizer with the application of organic manure. Jibrin *et al.* (2008), observed an ESP value of 40.6% in top soil and noticed visual evidence of salinity such as crusting, hard setting and water logging in many farmers fields in some part of the KRIP. Mohammed *et al.* (2015) recorded an ESP value above 15% in the irrigation water and reported possible deterioration of soil structure and infiltration of water in soil. The findings of this study in which an ESP as high as 45% was observed is in agreement with previous research conducted by Jibrin *et al.* (2008), which submitted that the soil in the KRIP has high sodicity and relatively low electrical conductivity. The soil in the KRIP is therefore, non-saline sodic due to the low value of the EC of the soil saturation extract. The difference is that, the current research classified sodicity and the area covered by each class which were related to a referenced position in the KRIP compared to the previous researches conducted (Figure 3).

An ESP value of 15% has been in used in many countries as threshold above which the sodium level becomes a problem. However, in countries like Australia, Zimbabwe, Russia and South Africa, it has conclusively been shown that the critical value depends on soil and other factors (Laker and Nortje, 2019). For instance, in South African research has shown that in soils that are very prone to crusting, dispersion and crusting occur at extremely low ESP levels. According to Laker and Nortje, (2019), research conducted has shown that reduction in water infiltration, due to surface sealing of the soil can occur at an ESP as low as 1% provided that water with low electrolyte content is used.

The main problem with high sodium concentration is its effects on soil permeability and water infiltration. Loss of permeability due to reduction in pore space can severely restrict movement of water resulting in plant stress (Dan, 2010).

Sodium also contributes to total salinity of water and may be toxic to sensitive crops such as fruit crops. Excess sodium causes swelling and dispersion of soil clays, surface crusting and pore plugging. This results in degraded soil structural condition which in turn obstructs infiltration and increase runoff (Mohammed *et al.,* 2014). Plugging of pores can also reduce the amount of water available to plants, and increase waterlogging potential (Rengasamy *et al.*, 2010). A decrease in the downward movement of water into and through the soil implies that actively growing plants roots may not get adequate water, despite ponding of water on the soil surface after irrigation. According to Rengasamy*et al.*, (2010), high sodicity causes reduction in the water holding capacity of subsoil thereby limiting water supply to the root at later stages of crop growth. Therefore, major crops grown in the area will experience stunted growth and consequent yield reduction due to degraded structure, poor aeration and water logging conditions of soil especially the eastern sectors of the study area due to high ESP value.

Management of sodic soil is important in order to render the degraded soil suitable for agriculture (Salih *et al*, 2015). Management strategies such as application of gypsum, leaching, provision of drainage, addition of organic matter etc. are needed to prevent deterioration of soil structure (Mohammed *et al.*, 2015. Choice of sodium tolerant and semi- tolerant crops such as barley, alfafa carrot, lettuce, sugarcane, onion, rice, tomatoes etc. will also help in management of soil under both rain fed and irrigated condition in the study area.

Leaching is the basic management tool for salinity control. It prevents the accumulation of salts in the root zone by applying sufficient quantity of water to flush the salts beyond the root zone and meet the plant requirements (Gokalp *et al.,* 2010). It reduces the salts in soils and the water must be relatively free of salts particularly sodium salts. The frequency of leaching varies with degree of salinization, evaporative demand and crop tolerance. The process is necessary for a successful irrigation but requires large quantity of water and effective drainage. Drainage is essential to control water table and salt level in the soil. Water applied to leach excess salt must drain down beyond the root zone and in areas with poor drainage or shallow water table, an artificial drainage system must be installed (Machado and Serralheiro, 2017). Salih *et al.* (2015) reported that the use of gypsum on either saline-sodic or sodic soils results in the improvement of most properties of soil such as infiltration rate and helps in leaching the salts.

Irrigation water should be tested periodically to assess possible salt hazard on soil (Mohammed *et al.*, 2014). A soil water test can provide information to any constituent that may be toxic. Identifying areas with high salinity and sodicity problems is crucial if the aim is to develop a sustainable irrigation scheme. The first step in managing salt affected soil is to identify the problem and cause. Identifying the cause is always difficult if several factors are involved. A measurement of the amount of dispersion can be used as an indicator of soil sodicity (Rengasamy *et al.*, 2010).

Conclusion

The study revealed that the study area is dominated by sodic soil as approximately 85 % of the total area had an ESP greater than 15% and major crops grown in the area will experience stunted growth and consequent yield reduction due to adverse physical conditions of soil especially in the eastern sectors of the study area.

Recommendation

Based on the findings, management strategies such as application of gypsum, leaching, provision of drainage, addition of organic matter etc. are recommended to prevent deterioration of soil structure. Choice of sodium tolerant crops and soil water tests will also help in management of soil.

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