SALINITY AND SODICITY STATUS OF THE FLOODPLAIN SOILS OF KEBBI STATE, NORTH WESTERN, NIGERIA.

ABSTRACT

Floodplain soils are the sites for most of agricultural activities during dry season. With efficient irrigation facilities such as tube wells and water pumps, they can produce 2-3 short duration crops during a year. However, due to persistent irrigation, these soils are always susceptible to salinization and sodicity hazards. High salt content in the soil inhibits the uptake of plant nutrients and water, while high sodium content in sodic soils destroys soil structure and consequently reducing the rate of permeability and aeration. In view of this, it becomes necessary to assess the level of salinity and sodicity of the floodplain soils of the study area so as to know the appropriate management practices to be applied on these soils. Soluble salts were analyzed and it was observed that the Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^{+}) and Sodium (Na^{2+}), were in the value of 1.90cmol(+)Kg^{-1}, 1.66cmol(+)Kg^{-1}, 0.16cmol(+)Kg^{-1},and 0.34cmol(+)Kg^{-1}, respectively. Salinity and sodicity determinants were also analyzed where pH was observed to be 6.88, electrical conductivity (EC) 0.19dsm^{-1} exchangeable sodium percentage (ESP) 2.09%. The data was subjected to GLM procedure using statistical software to see the relationship between the four local government areas. Based on the concentration of pH, EC and ESP, the soils could be said to be free from salinity and sodicity hazards at least for now. However, due to the high concentration of Mg^{2+}, K^{+} and Na^{+}, the soils could be said to have potential threat to salinity and sodicity problems and therefore proper management strategies should be practiced to prevent their further concentration

Keywords: Salinity, sodicity, irrigation, floodplain and soils

1. INTRODUCTION

Nigeria occupies a total land area of 936,930 square kilometers[1]. [2] reported the total wetland area in Nigeria as 65, 785 square kilometers. Kebbi State occupies a land area of 37,698km^2, 36% (13,745.25km^2) of which is an arable land [3]. [4] estimated a total fadama land area in the State as 1,303.84km^2. The extensive flood plain between Augie and Bunza covered an estimated area of 525, 000 hectares [3].

In the presence of efficient irrigation facilities such as tube wells and water pumps, the floodplain soils are sites for most agricultural activities during the dry season. They can produce

2-3 short duration crops during a year. The common crops grown on the fadama land are rice, onion, garlic, sugarcane, carrot tomatoes, pepper, egg-plant, okro, sweet potatoes, tobacco and a number of leafy vegetables [5]. However, due to persistent irrigation on these soils, they are always susceptible to salinization as well as sodicity.

High salt concentration increases the potential forces that hold water in the soil and makes it more difficult for the plant roots to extract the moisture. During drying periods, salt in soil solution may be so concentrated as to kill crops by pulling water from them, a process known as Exomosis. High concentration of Na ions, in the absorbing complex of the soil solution, makes the soil aggregates, that are more desirable for plant growth to disintegrate and disperse, making the soil impermeable to water. This is because small soil particles that are dispersed are entrapped (logged) in the pores and seal them.

The salinity and sodicity of the soils depend greatly on the levels of soil pH, Electrical conductivity (EC) and Exchangeable Sodium Percentage (ESP) [6]. Soil pH with value of 7.0 is neutral; less than 7.0 indicates the degree of acidity and above 7.0 indicates the degree of alkalinity. Thus saline and sodic soils usually have pH values in the pH range above 7.5. Soil pH controls the availability of basic elements in the soil. EC is a good indicator of salinity hazards due to excessive salt content while ESP is a measure of sodicity hazards caused by high sodium level in the soil.

High salt content in saline soils inhibits the uptake of plant nutrients and water, high sodium content in sodic soils destroys soil structure and consequently reducing the rate of permeability and aeration. In view of these, it becomes necessary to assess the levels of salinity and sodicity because of their detrimental effects on the crop performance and soil physical properties of the study area.

2. MATERIALS AND METHODS

2.1 Kebbi State - Location and Agroclimate

Kebbi State is situated in the extreme north-west of Nigeria between Latitudes $10^{o}06^{1}$-$13^{o}10^{1}$N and Longitudes $3^{o}0^{1}$- $6^{o}03^{1}$E. It shares borders with both Niger and Benin Republics in the west. On the East, it is bordered to Sokoto State and in the South to Niger State[4].

The State enjoys a semi-arid climate where precipitation is usually less than the normal requirement of most agricultural crops such as millet, guineacorn cowpea and so on. The rainy season consists of a short (May – October) period with rainfall poorly distributed throughout the growing period. Frequent and heaviest precipitation is experienced between August and September. The annual rainfall ranges from 400 to 850mm, increasing both in quantity and intensity within the State from north to south [3]. The continental air mass from Sahara usually brings a season of very cold weather (the harmattan) with very low temperatures at night during the months of November to early February. The harmattan winds during this period are very descanting and blow alot of sand. During the month of March-June, the weather is predominantly hot. [7] stated that areas situated within the semi-arid sub-Saharan region, Kebbi State inclusive, enjoy the mean maximum and minimum temperatures of 40^{o}C and 15^{o}C respectively. [4] gave the mean temperatures for Kebbi State as 23^{o}C with slight variations in different locations of the State.

2.2 Experimental Sites of Soil Sampling

The floodplains in Kebbi State are mostly found along the rivers with many towns and villages adjacent to them (rivers) in the state. For the purpose of this study 16 (towns or villages) which are most actively involved in fadama farming were selected. Four floodplain areas (villages or towns) were selected from each of the four local government areas. In Augie local government area, the floodplain areas (villages) studied were Zagi, Augie, Bubuce and Yola. In Argungu local government area, the selected areas were Argungu, Gulma, Helande and Gotomo. Those in Birnin Kebbi local government area included Birnin Kebbi, Kola, Makera and Ambursa while those in Bunza local government area were Bunza, Zogirma, Maidahini and Banganda floodplain fadama lands.From each of the selected areas, 10 composite samples were collected in May, 2018, Thus 160 samples were collected from the four local government areas (figure 1).

MAP OF KEBBI STATE

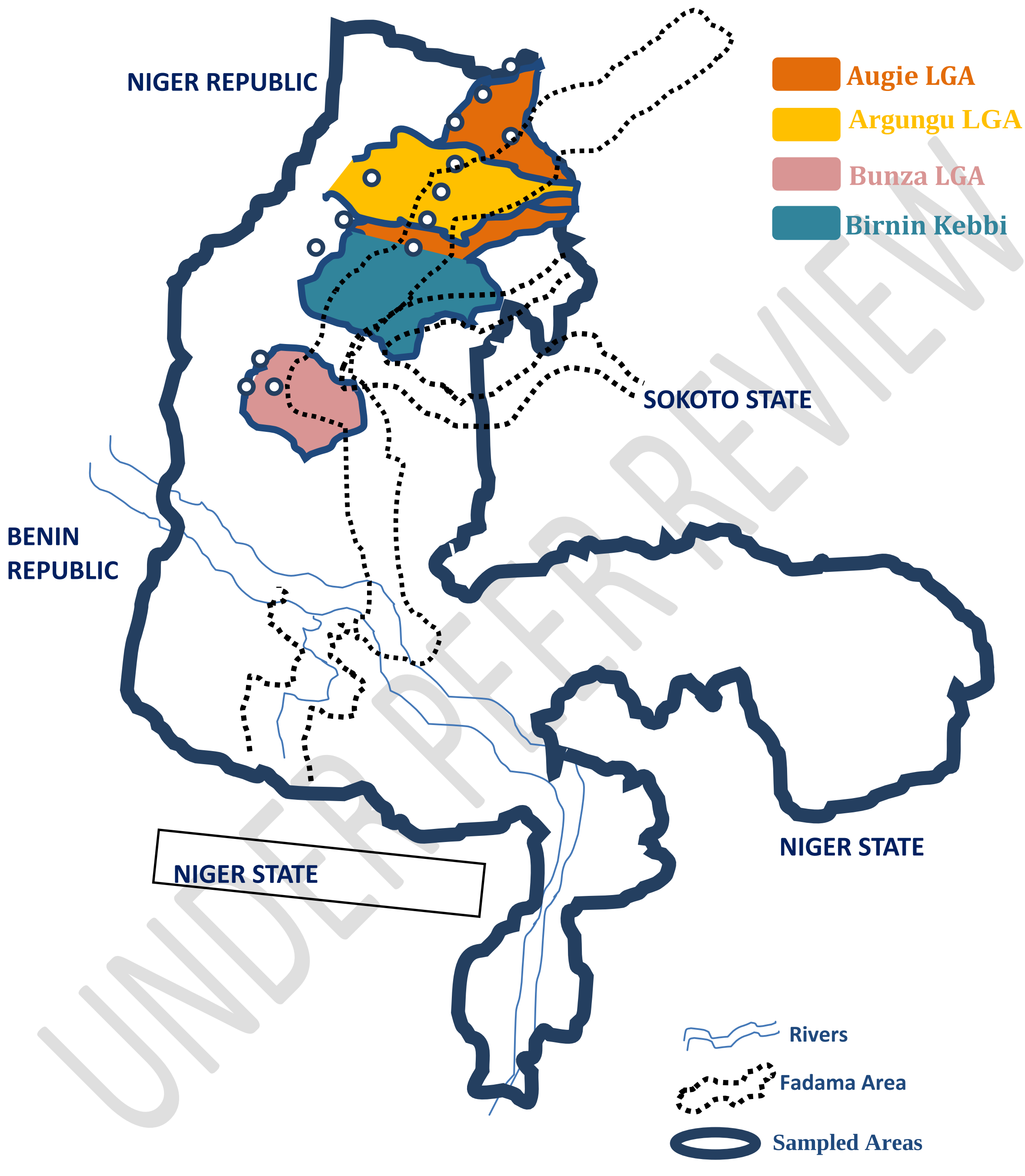

Figure 1: Map of Kebbi State showing the selected Local Government Areas

SOURCE: Office of the surveyor general, Kebbi State (2010)

From each village (town) ten farms were randomly selected. One hectare was demarcated as a sampling unit from within and around the area being cultivated. An interval of 200 meters was used between one sampling unit and another. From each of the two sides (East and west) of the river, 5 hectares were demarcated. From each sampling unit a composite sample of 16 borings of 25 meters interval was collected with the help of soil auger at a depth of 0-15cm. The size of each composite sample was reduced by successive quartering to manageable and portable quantity.

Each composite sample was labelled and put in a clean plastic bag for easy conveyance and avoidance of contaminants. The sample was then air dried, ground using porcelain pestle and mortar and sieved through 2mm sieve for analyses.

2.3 Analytical Procedures

pH was determine using pH meter in a ratio 1:2 soil water moisture as recommended by [8]. Cation exchange capacity was determined by ammonium saturation method as described by [9]. Potassium (K) and sodium (Na) concentrations in solution were determined by flame photometry method [10]. Calcium (Ca), and magnesium (Mg) were determined by EDTA titration method as described by [11].

Electrical conductivity (EC) was also determined in a ratio 1:2 soil water at $25^{o}C$ on a conductivity meter. The result was multiplied by a conversion factor of 2.063 as suggested by [8] to obtain the saturation extract. The exchangeable sodium percentage ESP was calculated as follows:-

$$\frac{\text{Exchangeable } Na^{+}}{\text{CEC}} \times \frac{100}{1}$$

Where Na^{+} and CEC were in cmol $(+)kg^{-1}$of soil. .

2.4 Statistical Analyses

The data were subjected to GLM procedure using [12] to see the relationship between the four local government areas studied. Significant means were separated using Duncan New Multiple Range Test at 5% level of significance to observe the specific sports where the differences exist.

3. RESULTS AND DISCUTION

Table 1: Ratings for soil fertility classes in Nigeria savanna soils

Parameter	Rating		
	Low	Medium	High
Organic C(g/kg-^{1})	<10	10-15	>15
Total N (g/kg^{-1})	<1.5	1.5-2.0	>2
Avail. P (mg/kg^{-1})	<10	10.20	>20
Ca^{2+} (cmol(+)kg^{-1})	<2	2-5	>5
Mg^{2+}(cmol(+)kg^{-1})	<0.3	0.3-1	>1
K^{+} (cmol(+)kg^{-1})	<0.15	0.15-0.3	>0.3
Na^{+} (cmol(+)kg^{-1})	<0.1	0.1-0.3	>0.3
CEC (cmol(+)kg^{-1})	<6	6-12	>12
BS(%)	<30	30-80	>80

Sources: [13] and [14]

Table 2: Mean values of Ca^{2+}, Mg^{2+}, K^{+} , Na+ and CEC of the floodplain soils of the four local government areas studied

LGA	No of samples	Ca^{2+} Cmol(+)kg^{-1}	Mg^{2+} Cmol(+)kg^{-1}	K^{+} Cmol(+)kg^{-1}	Na^{2+} Cmol(+)kg^{-1}	CEC(cmol (+)kg^{-1})
Augie	40	2.20a	1.51c	0.17	0.16b	8.016a
Argungu	40	1.71c	1.56bc	0.17	0.16b	7.78bc
B/Kebbi	40	1.71c	1.86a	0.15	0.16b	7.49c
Bunza	40	2.00b	1.70b	0.15	0.91a	8.27a
Overall means	**10**	**1.90**	**1.66**	**0.16**	**0.34**	**7.88**
SE		**0.04**	**0.05**		**0.04**	**0.12**

abc = Means bearing different letters along the same column differ (P<0.05)

Table 3: Mean values of pH, EC and ESP of the floodplain soils of the first four local government areas studied

LGA	No of samples	pH	EC (dSm-1)	ESP %
Augie	40	6.65ab	0.21a	2.03
Argungu	40	6.63b	0.17b	2.05
Birnin Kebbi	40	6.96a	0.19ab	2.21
Bunza	40	6.51b	0.20ab	2.00
Overall means	40	6.68	0.19	2.07
SE		0.11	0.01	

ab = Means bearing different letters along the same column differ (P<0.05)

Table 4: Mean values of pH, Electrical Conductivity (EC) and Exchangeable sodium percentage (ESP) of the floodplain soils of the first sixteen sampled areas

Sample Area	No of samples	pH	EC(dSm-1)	ESP (%)
Zagi	10	7.00a	0.27ab	2.24b
Augie	10	6.87ab	0.34a	2.72a
Bubuce	10	6.76ab	0.14c	1.72c
Yola	10	6.00c	0.12c	1.47d
SE		**0.11**	**0.03**	**0.07**
Argungu	10	6.61ab	0.19a	2.01c
Gulma	10	6.49b	0.20a	2.12a
Helande	10	6.15c	0.13c	2.00c
Gotomo	10	7.27a	0.17b	2.10b
SE		**0.13**	**0.02**	**0.12**
B/Kebbi	10	6.43c	0.32a	1.97d
Ambursa	10	7.17a	0.19b	2.07c
Makera	10	7.07b	0.12d	2.27b
Kola	10	7.19a	0.15c	2.55a
SE		**0.09**	**0.01**	**0.15**
Bunza	10	7.02a	0.29a	2.04b
Zogirma	10	5.61c	0.17c	1.71d
Maidahini	10	6.85ab	0.19b	1.99c
Banganda	10	6.58b	0.17c	2.26a
SE		**0.14**	**0.01**	**0.09**
Overall means				
Augie		**6.65**	**0.21**	**2.03**
Argungu		**6.63**	**0.17**	**2.05**
BirniKebbi		**6.96**	**0.19**	**2.21**
Bunza		**6.51**	**0.20**	**2.00**

abcd = Means bearing different letters along the same column differ (P<0.0

The obtained values of calcium in table 2 of the soils of the study area was 1.90 cmol(+)kg^{-1}. Although, the Ca^{2+} value of 1.90 cmol(+)kg^{-1} indicated low content of this cation as per rating scale Table 1, Ca is still the dominant cation in the soils of the study area

Mg^{2+} was discovered to be next to Ca^{2+} in abundance in the soils of the study area valued 1.66cmol(+)kg^{-1} (Table, 2). Based on the rating scale Table I, the soils of the study area were rated high in Mg^{2+} content.

Almost all soils of the study area are rich in magnesium content. Such appreciably high concentration of this element might be as a result of irrigating the soils with water of higher Mg^{2+} content as well as hot semi-arid weather condition of the area.

Leaching and drainage should be encouraged in such areas to arrest the salt build up. Also salt tolerant corps such as sugarcane wheat tomato, cabbage and carrot should be grown in such areas [15].

The obtained mean K^+ value was 0.16cmol (+)kg^{-1}(Table 2). Based on the rating scale Table 1, the soil was categorized as medium in K content.

The overall mean CEC value of the soils of the study area was 7.88cmol(+)kg^{-1}. Based on the rating scale (Table 1), the soils were classified as medium in CEC content. The medium CEC content of the soils of the study area revealed clearly that the soils could provide a conducive physico-chemical environment for crop growth under good management practices. .The obtained Na value was 0.34cmol (+)kg^{-1} (Tables 2). Based on the rating scale Table 1, the soils rated medium to high in Na content. Such a reasonably medium to higher Na^+ contents might be attributed to the hot arid weather condition as well as irrigation of the soils with water high in sodium content [6].

3.1 Indicators of salinity and sodicity

The parameters that help in assessing the level of salinity and sodicity of the soil are the pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP). Based on the degree of concentration of these parameters, soil could be classified as saline, saline-sodic and or sodic.

3.1.1 pH

The soil pH controls the availability of basic cations in the soil. When a high proportion of exchange sites are occupied by Na^+ ions, soil can become very basic with pH values of 8.5 and above and the soil aggregates, that are desirable for plant growth, disintegrate and disperse. At low pH, there is preponderance of ion (Fe), manganese (Mn) and aluminium (Al) in the soil, which may be toxic to plants as well as further reduce phosphorus (P) availability through fixation as insoluble phosphate.

The overall pH value obtained in the soils of the study area was 6.68. It was slightly acidic to neutral in reaction. Birnin Kebbi local government area tested significantly higher ($P<0.05$) in pH with mean values of 6.96. It was then followed by Augie local government area with pH mean value of 6.65. Argungu and Bunza local government areas tested statistically the same with mean values of pH as 6.63 and 6.51, respectively (Table 3). On individual sampling units, pH value of 6.68 is similar to 6.0-6.8 as recorded by [16] for arid and semi-arid soils. [17] reported similar pH value of 6.1-8.2 (mean 7.2) for the soils around Kandoli Shela stream valley.

3.1.2 Electrical conductivity (EC)

Electrical conductivity (EC) measures the total quantity of soluble salts in the soil. The overall EC level of the soil of study area was 0.19dsm^{-1}. High electrical conductivity (EC) value of 0.21dsm^{-1} was obtained in Augie local government area. It was then followed by Bunza and Birnin Kebbi local government areas with EC mean values of 0.20 and 0.19dsm^{-1}, respectively. Argungu local government area was significantly lowest (P>0.05) with mean EC value of 0.17dsm^{-1} (Table 3).

Based on individual sampling units; *Augie, Birnin Kebbi* and *Bunza* tested significantly higher (P<0.05) in EC content with mean values of 0.34, 0.32 and 0.29dsm^{-1}, respectively (Table 4). These areas appeared to be potentially saline, especially that white salt (white alkali) crust was conspicuously present on some spots of the soil surface of these area. They are therefore of great concern. They are then followed by Zagie with mean EC value of 0.27dsm^{-1}. 50% of the same areas tested low EC of between 0.12-0.17dsm^{-1} (Table 11). Such soils are free from salinity problems at least for now. These areas are Bubuce (0.14), Yola (0.12), Helande (0.13) Golomo (0.17), Makera (0.12), Kola (0.15), Zogirma (0.17), and Bangadan (0.17). . All values are in dsm^{-1}.

The overall obtained EC value of 0.19dsm^{-1} was within the EC values of 0.1-16.8)dsm^{-1} as reported by Singh (1999a) while carrying out similar work in Kebbi State. [18] reported low EC value of 0.01-0.02dsm^{-1} for soils around River Rima in Sokoto.

3.1.3 Exchangeable Sodium Percentage (ESP)

ESP refers to the degree of saturation of the soil exchange complex with sodium. As mentioned earlier, if a high proportion of exchange sites is occupied by Na^+ ions, soil can become very basic with pH values of 8.5 and above and all the soils aggregates that are needed for the plant growth would disintegrate and disperse. These soils can become impermeable to water because small soil particles that are dispersed by Na^+ are entrapped (lodged) in the pores and seal them [19].

The overall ESP value of the soils of the study area was 2.07% (Table 9). All the local government areas are statistically the same in exchangeable sodium content (Table 3). However, on individual sampling units, Augie tested significantly higher in ESP with mean ESP values of

2.72%. The lowest ESP values came from Yola with mean ESP value of 0.12% (Table 4). All other sampling units are within the ESP range of 0.12 to 2.72%.

The reported ESP value of 2.07 was higher than 1.30% ESP value being reported by [20] for the irrigated fadama soils of Sokoto State. However, high ESP value of 9% was reported by [21] for the soils in Wurno irrigation project area in Sokoto State.

[22] stated that ESP value of 15 is a critical limit for classifying the salt affected soils. According to him, saline soil has ESP of <15 while saline sodic and sodic soils both have ESP of >15. Based on this criterion, all the soil of the study area are free from sodicity hazards, at least for now.

3.2 Salinity and sodicity status

Assessment of soil salinity and sodicity is important because of their effects on crop performances and soil physical conditions. While high salt content in saline soils inhibits the uptake of plant nutrients and water, high sodium content in sodic soils destroys soil structure consequently thereby reducing the rate of permeability and aeration [15].

Table 3 indicates that the pH, EC (dsm^{-1}) and ESP (%) valued 6.68, 0.19 and 2.09, respectively. According to the criteria mentioned set by Rechard, (1954) that soils with EC >4dsm^{-1}, ESP <5 and pH <8.5 are saline, those with EC >4 dsm^{-1}, ESP>15 and pH <8.5 are saline-while those with EC <4 dsm^{-1}, ESP >15 and >8.5 are sodic. As per this criteria, the soils of the study area with EC 0.19(dsm^{-1}), ESP (2.07%) and pH 6.68; could be said to be free from salinity and sodicity problems at least for now. However, with appreciable Mg^{2+}, K^{+} and Na^{+} contents these soils could be said to have potential treat to salinity and sodicitiy problems except if measures are taken to arrest the salt build up.

4. CONCLUSION

The parameters used in assessing salinity and sodicity status were the pH, EC (dSm^{-1}) and ESP (%). The overall mean pH was 6.68, an indication that the soils were slightly acidic to neutral in reaction. It was thus within the medium pH level which is needed by most agricultural crops and soil microorganisms. The overall EC value was 0.19dsm^{-1} an indication that he soil was salt free. Under this EC level, the salinity effects are negligible except for the most sensitive crops. The obtained ESP value was 2.07% an indication that all the soils were free from sodicity hazards.

Based on the concentration of the three parameters above, the soils could be said to be free from salinity and sodicity problems at least for now. However, due to the high concentration of

Mg^{2+}(1.66cmol(+)kg^{-1}), K^+ (0.16cmol(+)kg^{-1}) and Na^+ (0.34cmol(+)kg^{-1}), they could be said to have potential threat to salinity and sodicity problems, and therefore proper management strategies should be taken to prevent their further concentration..

5. RECOMMENDATIONS

- The study revealed high concentration of Mg^{2+} in the oil. Such high accumulation of Mg^{2+} could lead to the salt build up which would consequently lead to salinity hazards in the near future. In view of that, leaching and drainage should be encouraged so as to arrest the salt build up. Salt tolerant crops could also be grown in such areas e.g sugarcane, wheat, tomatoes, carbage and carrots.

- Majority of the soils in the study area appeared medium in K content.

- With respect to Na^+ content, the soils rated medium to high in Na^+ (0.16Mgkg^{-1}) and therefore the farmers could be advised to ensure proper tillage to facilitate its leaching. This is to prevent its further accumulation to the detrimental level of sodicity hazard

- The soils appeared to be free from salinity and society problems. They can therefore be used for the production of many agricultural crops. However, due to the fact that they contain appreciable Mg^{2+}, K^+ and Na^+ ions, the soils could be said to have potential treat to salinity and sodicity problems in the near future. There is therefore a need to adopt appropriate management strategies such as provision for leaching and drainage particularly on portions with fine textured poorly drained soils to arrest salt accumulation and further deterioration of the soil quality. Also farmers should be advised to grow salt-tolerate crops and refrain from excessive irrigation.

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