Electrical Conductivity based Classification and Mapping of Salt affected Soils in Kampe-Omi Irrigation Scheme

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ABSTRACT

Environmental change is a vital issue for human being which is indeed linked with agricultural activities due to its impact on food production. Irrigated agriculture is important to the national economy of a country as it contributes significantly to the production of food. Most irrigation schemes are faced with problem of soil deterioration resulting from increased level of soil salinity and rise in water table. Therefore, mapping of saline soils are essential and important for understanding resource for sustainable soil management and uses. The study presents the mapping out of soil salinity level in Kampe-Omi irrigation scheme as at 2015. Kampe-Omi irrigation scheme, being an irrigated agricultural land was used as pilot study area. Soil samples in OL 18 and OL 20 were collected on 3/11/2015 and analyzed for Electrical Conductivity (ECe). ECe samples were tagged S1 to S30 with their respective coordinates obtained using handheld Garmin GPS, the readings were imported into ArcGIS 9.0 for analysis. Maps of the study area showing areas covered by salts in percentage were generated. The results showed that 0.04 - 0.126 Ds/m occupies 3 %, 0.126 – 0.202 Ds/m occupies 14 %, 0.202 – 0.288 Ds/m occupies 46 %, 0.288 – 0.387 Ds/m occupies 30 %, and 0.387 – 0.500 Ds/m occupies 7 % of the study area. The presence of salt in the soils and its variation expressed in percentage may be as a result of rise in water table and the difference in elevation of the study area. The study confirms that electrical conductivity of extracted soil paste ECe is a good indicator for mapping soil salinity level.

1.0   Introduction

Sometimes, agricultural activities result in adverse effects on their environment. One of the negative impacts caused by agricultural activities is the unstable and reduction of soil quality (Abdelrahman, Natarajan and Hegde, 2016). However, the success of soil management in achieving productivity and maintaining soil fertility is based on the knowledge of how the soil responds to agricultural practices (Dikko, Abdullahi and Ousseini, 2010). The practice of irrigation sometimes have adverse effect on environmental condition otherwise properly monitored, planned and managed. Past record claims that human activities have a strong effect on the natural environment and becoming the main cause of environmental degradation (Rietz, Haynes, and Chidoma, 2001). Most irrigation schemes are faced with problem of soil deterioration resulting from increased level of soil salinity and rise in water table. Soil salinity affects soil chemical, physical and biological characteristics of the soil, fertility and sustainable productivity unless it is properly monitored. Soil salinity has been defined and assessed in terms of laboratory measurements of the electrical conductivity of the extract of a saturated soil-paste sample (ECe) (Rhoades, Chanduvi and Lesch, 1999). According to Maina, Amin, Aimrun, and Sani (2012) saline soil contains soluble salts mostly in quantities sufficient to interfere with the physiological activities of most crop plants. Soil salinity is one of the major severe environmental hazards caused by human activity or induced processes. The effect of salinity is not only an environmental hazard, but it has also been known from past record of crop cultivation that salt have effect on crop yield. In addition, salinity affects other major soil degradation such as soil dispersion and soil erosion. The classification of salt affected soils, assessment of the percentage of severity particularly in its early stage is important in terms of sustainable agricultural management (Farifteh, 2007).

EC is often used to measure soil and water salinity. It is expressed in DeciSiemens per meter (dS/m). Soil salinity is usually measured through electrical conductivity (EC) in soil saturated paste (ECp), its liquid extract (ECe), or using different soil to water suspensions (Sonmez, Buyuktas, Okturen, and Citak, 2008). ECe is more complicated, it requires a saturated paste of the soil from which the water is extracted and the salts are measured. Electrical conductivity (EC) and concentrations of Cl^- and Na^+ are important factors in soil salinity. Thus, ECe is used to categorize soil salinity level as presented in Table 1. Rhoades et $al.,$ (1988) carried out research on the determination of soil salinity from soil electrical conductivity using different models and estimates. They concluded that soil salinity appraisal and mapping can be quite adequately made using field measurements of ECa

and estimates of soil water content, bulk density and surface conductance determined by the field methods.

Table 1: Classification of soil salinity based on Electrical Conductivity (ECe)

Class	ECe (dS/m)	Description
Salt free	ECe < 4	No Visible salt on the soil surface.
		Crop growth remains uniform.
Slightly saline	4 < ECe > 8	Visible salt on the soil surface.
		Crop growth is uneven and patchy.
Moderately saline	8 < ECe > 15	Salt are fairly visible on the soil surface.
		Plant growth is very patchy and restricted.
Strongly saline	ECe > 15	Soil surface is fluffy
		Salt are fairly visible
		Soil supports indigenous vegetation
		Salt tolerant crops are possible to grow.

Source: Ghassemi, Jakeman and Nix (1995)

Soil information is one of the areas that needed a robust data for study. The application of GIS in soil analysis transformed the conventional approach, being simpler and accurate in terms of analysis and the production of different maps in theme and layers for soil information. Soil information on soil salinity helps the farmers to manage their farmlands effectively. Goslee, (2011) stated that Geographic Information System (GIS) is one of the tool that is capable of analyzing, storing and displaying information. Therefore, applying GIS in the determination of soil information provide fundamental information to support in decision making on farmlands to be able to reduce problems caused by improper management.

2.0   Materials and Methods

Kampe - Omi irrigation scheme is located in Yagba West Local Government Area of Kogi State, Nigeria. According to Adeniran *et al.* (2010) it is about one hundred and forty six kilometres (146 km) from Ilorin, the capital of Kwara State. It lies on longitudes $6^o 37^1$ to $6^o 42'$ E and latitudes $8^o 34^1$ to $8^o 38'$ N. The study area falls within guinea savannah region of Nigeria. The slope of the land enhances water flow by gravity to various fields for irrigation purposes. The soil of the study area consist of six types, namely Lithosols, Cambisols, Luvisols, eroded soils, alluvial soils and Arenosols (Oriola, 2012). The soils in the area are predominantly coarse textured, ranging from loamy to sandy loam in the surface horizons and from sandy loam to clay in the subsurface horizon (Adejumobi, Ojediran, & Olabiyi, 2014). The study area is used for agricultural purpose. The irrigation

scheme was conceived in 1979 while construction works began in 1983 and was completed and commissioned on the 12th of May, 1999. The scheme was designed to serve purposes such as irrigation of farmlands, generation of hydro-power and its supply, but it is being restricted to only the irrigation of farmlands (Adeniran *et al.,* 2010).

The scheme has an area of 4,100 ha expanse of irrigable land. Construction of dam in the scheme has an impounding capacity of 250 million m^3 of water, with 39 kilometre main canal length and about 300 kilometres of feeder and supplementary drainage system (Oriola, 2012). The method of irrigation in practice is mainly basin irrigation on operating land (OL) 18 and operating land (OL) 20, and the major crops being cultivated on OL 18 includes: maize, vegetables sweet potato, while sorghum, okra and rice were planted on OL 20. The map of the study area in relation to Nigerian and Kogi are shown in Figures 1 and 2. Soil sample on operating lands (OL 18 and OL 20) were collected from the study area in zigzag to determine the corresponding value of Electrical Conductivity (ECe). Soil sample were taken at an average depth of 0 – 30 cm. The samples were collected at 30 locations with a soil auger. In all, 30 samples were collected in the study area. Samples were taken to laboratory for chemical analysis. The determination of electrical conductivity (ECe) was made with a conductivity cell by measuring the electrical resistance of a 1:5 soil: water suspension. Equation 1 was used to calculate the ECe values (Rayment and Higginson, 2010).

$$EC_{25}(\text{dS/m}) = \frac{\text{K}}{\text{S } X \text{ } 0.708} \qquad\qquad 1$$

Where;

     K = Measured resistance of KCl solution

     S = Measured resistance of suspension

Soil sampling locations were tied to their corresponding coordinate values using Garmin handheld GPS. Values were downloaded into ArcGIS 9.0 environment for analysis to generate soil sampling location map overlaid with raster image of the scheme. The ECe values were also imported into ArcGIS 9.0 for analysis to generate salinity distribution (ECe) map of the study area.
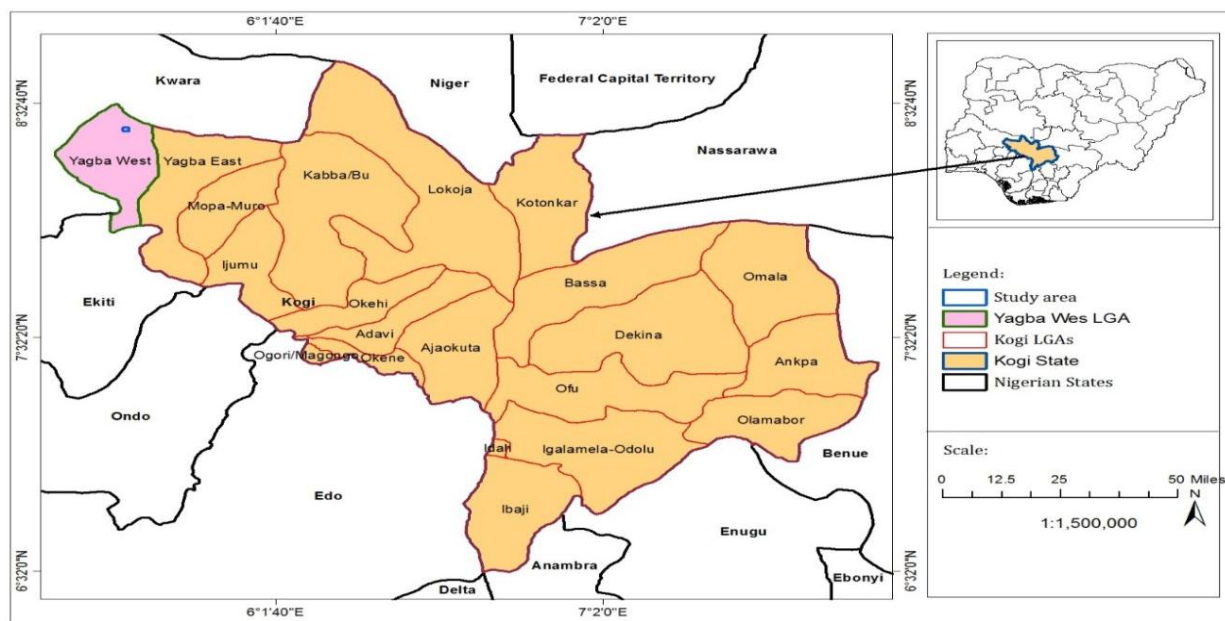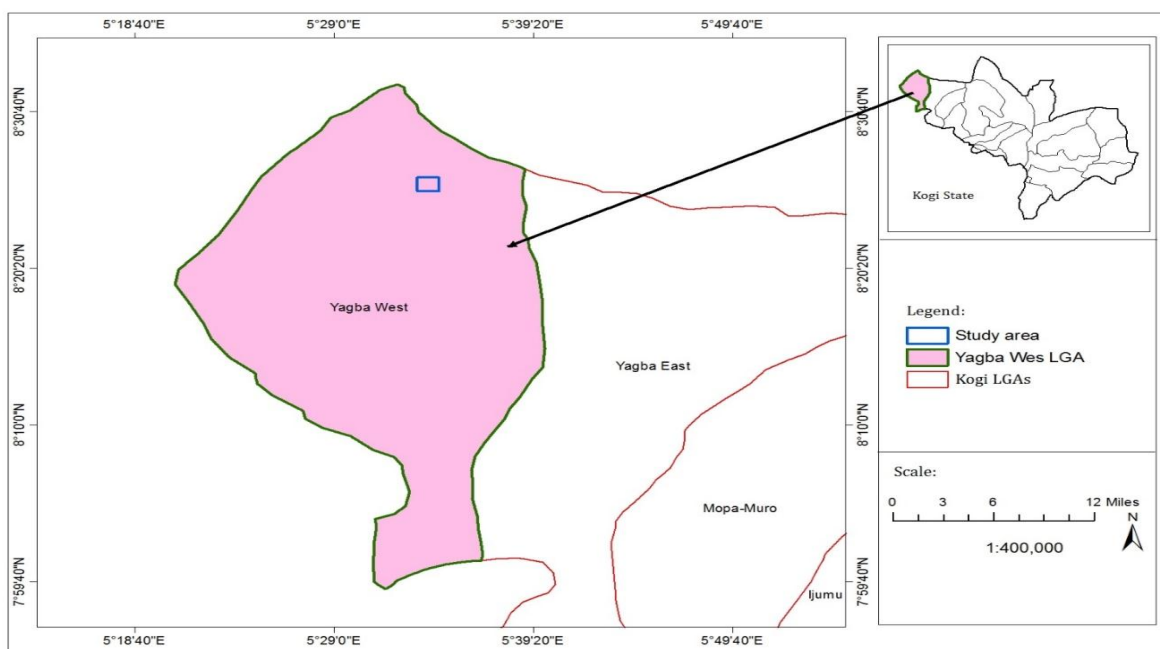
Figure: 1: Map of the study area in relation to Nigeria

Figure: 2: Map of the study area in relation to Kogi State

3.0   Results and Discussion

Electrical conductivity has being reported as a good indicator of soil salinity (Rhoades *et al.*, 1999). It is a measure of dissolved salt in the soil. The values of ECe of the operating lands obtained vary from 0.04 dS/m to

0.5 dS/m as shown in Figure 2. The ECe values falls within the acceptable range of low saline soils (ECe < 4d S/m) as classified by (Ghassemi *et al.,* 1995). The study area showed very low presence of salt and plant grows uniformly. Sampling point S_{22} with X-coordinate 6.653311, Y-coordinate 8.599293 has the least EC value of 0.04 ds/m, while the sampling point locations S_{14} and S_{29} with X-coordinate 6.653395, Y-coordinate 8.603634 and X-coordinate 8.66254, Y-coordinate 8.605717 respectively have the highest EC value of 0.5 ds/m. The maximum values of ECe obtained at S_{14} and S_{29} may be as a result of high elevation in OL 18 and OL 20. Also, the increase in ECe value of OL 20 is due to waterlogging in the area. Ojo, (2013) reported that Irrigated areas with high elevation and waterlogging are prone to soil salinity.

These were developed based on the values of ECe determined from laboratory analysis. Figure 3 shows Soil salinity distribution (ECe) with sampling location of the study area, while the spatial distribution of salt affected area in the study location is presented in Figure 4. Low saline soils are shown in pinkish colour on the False Colour Composite. They are also shown in few red or pink mottled textures. They also show as fine texture with few mottled spots of other colour in the sample soils on the field. On the Standard False Colour Composite 4-3-3, the highly salt-affected areas are mostly represented in very bright colour with some small amounts of other colours; in this case there is absence of this. The texture of these areas is very fine. Although there are traces of salt appearance on the study area, however, the distribution of the soil in the study area falls under low-saline soil classification compared to FAO standards of saline soil classification irrespective of their colours (Ochieng *et. al.,* 2013).
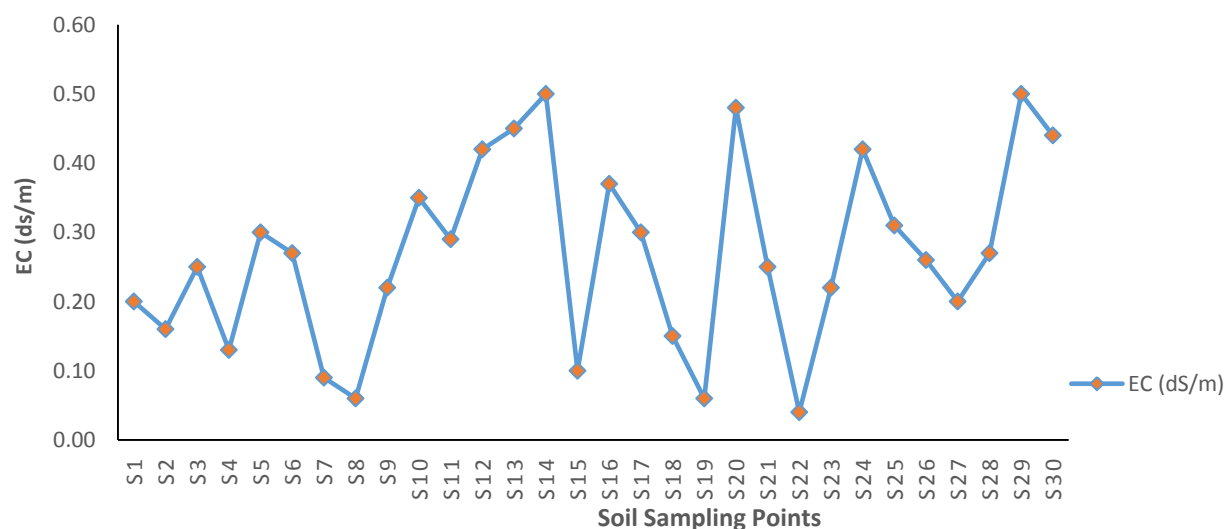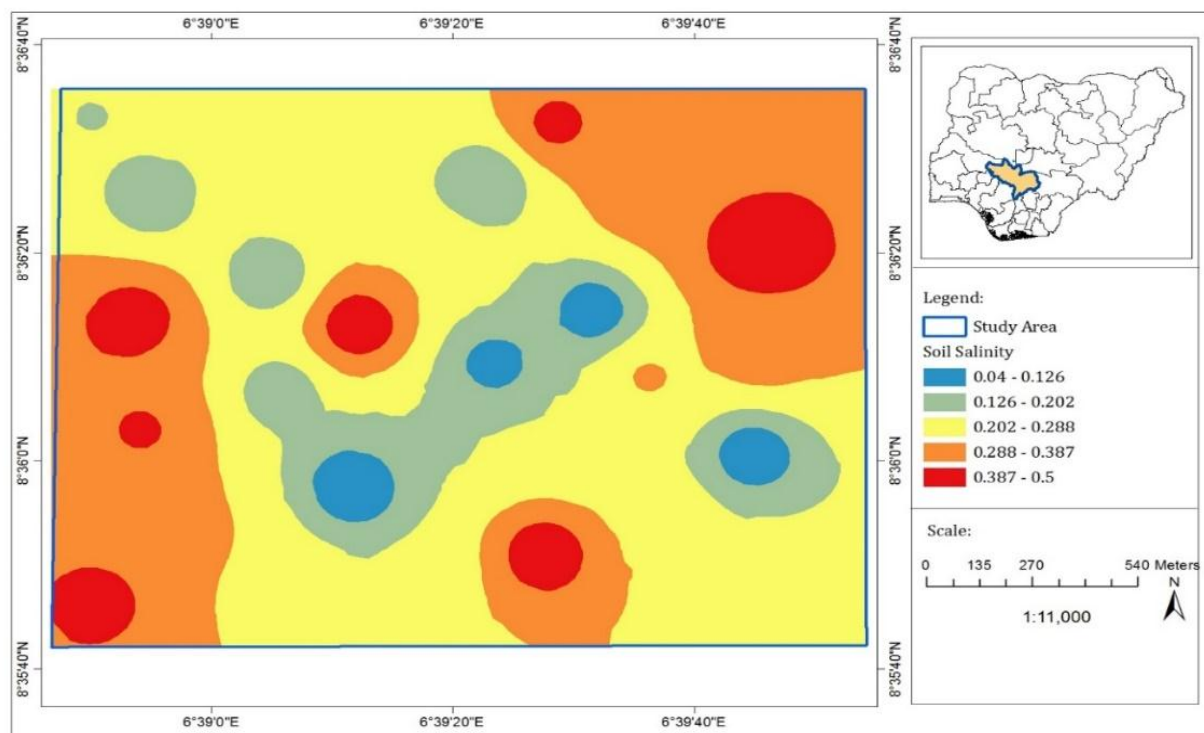
Figure 3: ECe versus sampling points

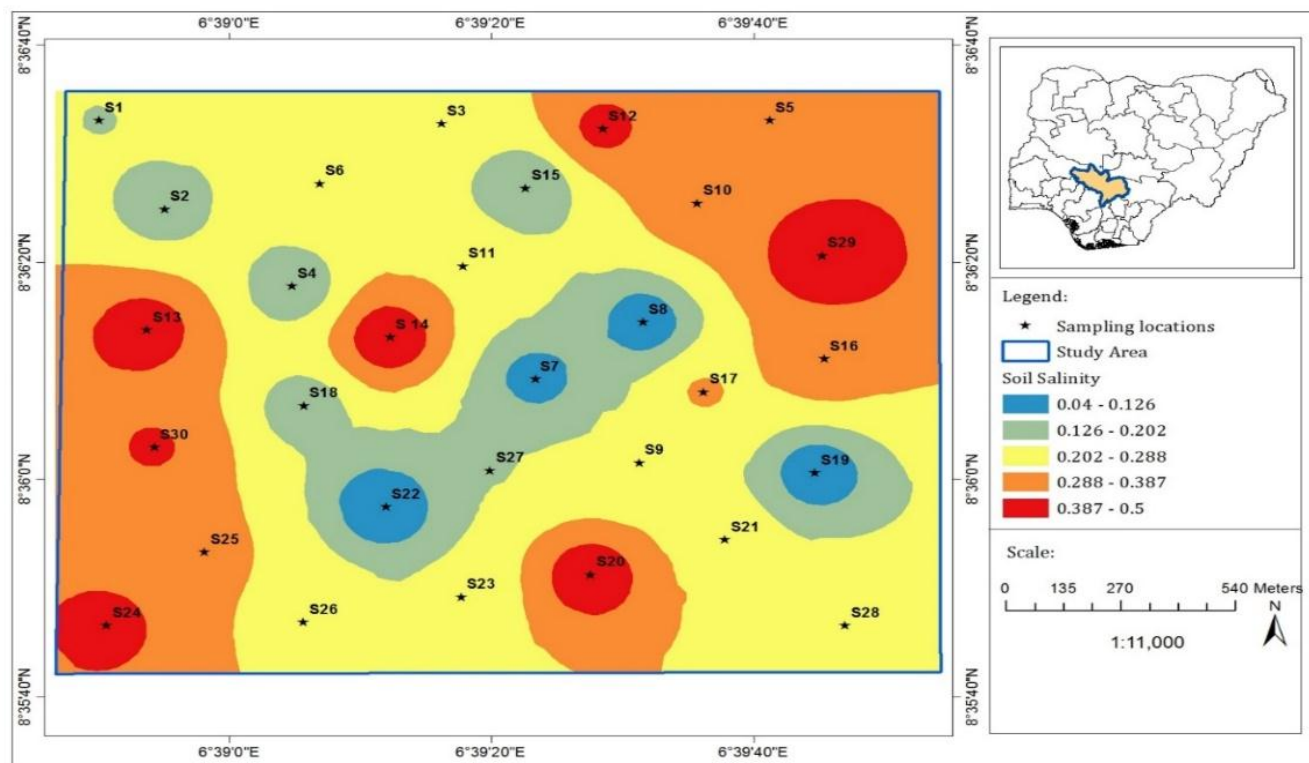Figure 4: Soil salinity distribution (ECe) map of the study area

Figure 5: Soil salinity distribution (ECe) with sampling location of the study area
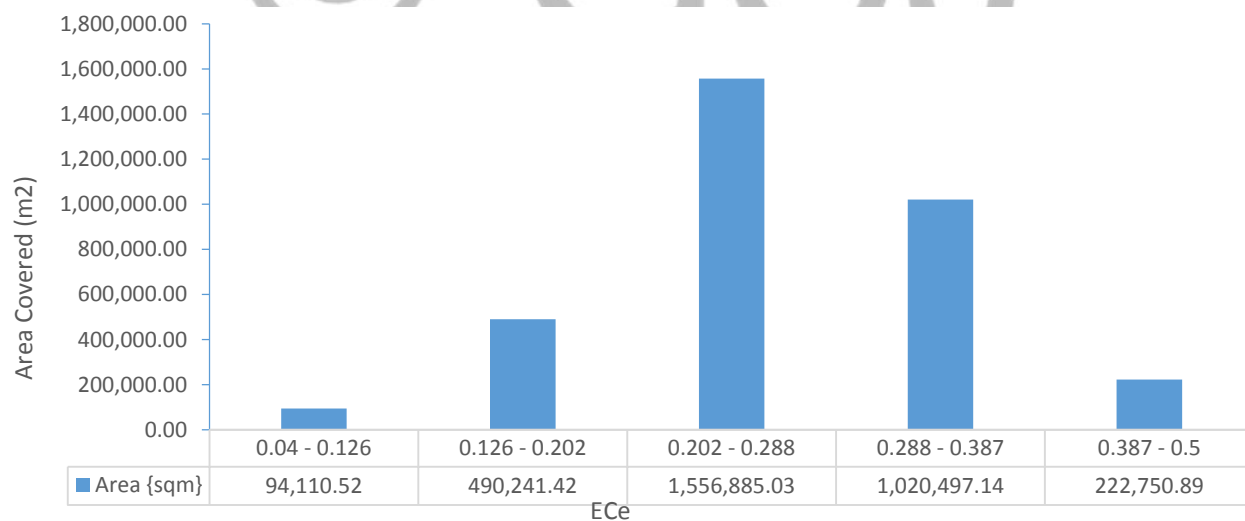

	0.04 - 0.126	0.126 - 0.202	0.202 - 0.288	0.288 - 0.387	0.387 - 0.5
Area {sqm}	94,110.52	490,241.42	1,556,885.03	1,020,497.14	222,750.89

Figure 6: ECe value Versus Area covered

Table 2: Classifications based on field ECe values

Salinity Classes	Salinity Ranges (dS/m)	Area (m^2)	Percent-age	Map colour representation	Salinity Status (%) low to moderate (< 4 dS/m)
1	0.04 – 0.126	94,110.53	3	Blue	
2	0.126 – 0.202	490,241.42	14	Grey	
3	0.202 – 0.288	1,556,885.03	46	Yellow	100
4	0.288 – 0.387	1,020,497.14	30	Brown	
5	0.387 – 0.500	222,750.89	7	Red	
	Total	3,384,485.00	100		

Total land of the study area is 338.44850 ha. The areas are represented in yellow, grey, blue, pink, and brown colour in the map. The blue region has ECe value ranges from 0.04 – 0.126 dS/m, it covers 3% of the total area as shown in Table 2. The area represented in grey region has EC value ranges between 0.126 – 0.202 dS/m it covers 14% out of the total area. The ECe value of the yellow portion ranges from 0.202 – 0.288 (dS/m), it covers 46% of the total area under study. The brown colored portion ranges from 0.288- 0.387 dS/m, it covers 30% of the area as well. The pink colour area has ECe value ranges from 0.387 – 0.5 dS/m as shown in Table 2. Figures 5 and 6 shows the chart of ECe plotted against the area cover, it was observed that the yellow portion with EC values of 0.202 – 0.288 covers the largest portion while the area with 0.04 – 0.126 dS/m covers the smallest part of the study area. The result obtained was compared to FAO standard for soil salinity; it was shown that it was within the acceptable range of non-saline soils classification since the values were below 4 dS/m. (Ochieng *et. al.,* 2013, Ojo and Ilunga, 2018).

 Conclusion

The study concluded that the soil of the area is slightly salt affected as the little accumulated salt is not visible on soil sur-

face. It should be noted that during chemical application and irrigation in the study area, care has to be taken in considering the results obtained which showed the slightly concentration of soil salts in order to avoid accumulation that may cause high soil salinity and degradation. The study has contributed to available ECe database of the study area. In addition, the scheme manager, planners, farmers and Government agency in order to develop a smart agricultural plan for the area, can use the soil salinity map developed.

Acknowledgment

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