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Soil salinity assessment and coping strategies in the coastal agricultural landscape in Djilor district, Senegal

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ABSTRACT

Soil salinity remains one of the most severe environmental problems in the coastal agricultural areas in Senegal. It reduces crop yields thereby endangering smallholder farmers' livelihood. This paper aims to investigate soil salinity pattern and relationship with some environmental factors based on 304 soil sample plots (at 0–30 cm depth) coupled with farm household survey in Djilor district, Fatick Region. Elevation, slope, groundwater depth, and normalized difference vegetation index (NDVI) values of each sample plots were extracted using the ArcGIS. Through statistical analyses, the results showed that bare land, land under fallow, rice plots and Fluvisols (soil type) registered high content of salt. Clay content, soil pH, elevation, distance to river and Fluvisols were significant factors associated with the increased salt content. Contrary to expectations, soil salinity had no relationship with groundwater depth in the study area. Ninety-six percent of the respondents were affected by salinization. Women group engaged in rice farming appeared to be more affected by soil salinity. To cope with the negative impact of soil salinity in the study area, the farmers' strategies are the application of chemical fertilizer and manure, planting and conservation of trees, and installation of soil bunds. Smallholder farmers also expressed their need for support on adaptation and mitigation from the government or any concerned organizations involved in this environmental issue. This study provides a baseline in soil salinity assessment and helps decision makers regarding land management and salt-affected areas restoration.

1. Introduction

Salinization has been one of the main problems for all coastal areas of the world generally due to inundation from sea level rise (Dasgupta et al., 2014, 2015). The study of Rintoul (2018) in the Southern Ocean showed a global increase of sea level rise that will consequently carry saline water and projects salt toward continental lands. This salinization process may further increase as the result of other sources or disturbances either by natural factors such as landform, land use types, soil types as well as water table position or by other anthropogenic variables such as land management practices (Schofield et al., 2001; Fang et al., 2005a; Zhang and Zhao, 2010; Northey et al., 2006; Acosta et al., 2011).

The extent of the effect of salinization is widespread. According to FAO report published in 2000, the global area of salt-affected soils including saline and sodic soils was 831 million hectares (Rengasamy, 2006). Along the coastal area in Senegal, soil salinity constitutes the most complex and common type of soil degradation generally due to seawater intrusion (Fall et al., 2014). Consequently, out of the 3.8 million ha of the cultivable land, 1.7 million ha are affected by salt at the national level (FAO and CSE, 2003). According to the 2003 Directorate of Statistics (DPS, 2004), around 645 000 ha of agricultural lands in Senegal are affected by salinity, which correspond to about 7.25% of 8.9 million ha of the national agricultural land (World Bank, 2009). Furthermore, it was estimated that the seawater intrusion as a result of sea level rise, increased at a rate of about 1.3 $g^{-1} l^{-1}$ per year between 1950 and 1986 (Page and Citeau, 1990). In the Groundnut Basin which covers Kaolack and Fatick provinces, salt affected areas as

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a result of seawater intrusion from the Saloum River represent 17.49% of the soil (Diome and Tine, 2015).

Salinity had reduced soil quality, limited the growth of crops, constrained agricultural productivity, and in severe cases, leaded to the abandonment of agricultural lands in Senegal (Diome and Tine, 2015; Sambou, 2016). Rice production is one of the immediate effects of salinization noticed in the country (Camara et al., 2008). Based on the study of Sow et al. (2016), the country lost about US$22 million per year due to salinity in rice fields. The salinization from the Sine Saloum River is the most serious long-term environmental problem in the country (Sadio, 1991; Faye and Maloszewski, 2005) and covers a high proportion of salts in the Groundnut Basin and in the Fatick region particularly. In fact, 33% (221 441 ha) of the region has been classified as highly acid-salt affected area (Chauvin, 2012). In Djilor district in Fatick region, soil salinity mainly affects the agriculture sector, which plays a vital role for the communities and constitutes the dominant economic activity involving over 70% of the population (ANSD, 2013). Rice farming was one of the main agricultural activities and represented an important resource for food and income in the district. However, because of salinity stress, rice-farming has been significantly reduced and some areas were abandoned. This decline in agricultural lands has made smallholders' farmers the most vulnerable ones to salinity effects and has exposed them to livelihood challenges.

Many studies on salinization have been investigated in the area. Most of them have paid much attention to salinization processes, salt balance and spatial extent (Sambou, 1991; Diome and Tine, 2015; Sene et al., 2014; Marius, 1985; Sadio, 1991; Sambou et al., 2016). The studies on the factors affecting the patterns of soil salinity and coping strategies particularly in coastal agricultural areas remain limited. Filling this information gap is crucial for minimizing its negative impacts especially for local smallholder farmers in Djilor as well as for the whole coastal region of Senegal. Thus, the main objective of this study is to determine the factors associated with soil salinity in a coastal agricultural landscape that may affect smallholder farmers' livelihood. This includes characterisation of the soil salinity pattern under different land uses, soil and crop types, and identification of the farmers' coping strategies.

2. Materials and methods

2.1. Study area

The study was carried out in Djilor district, in the Fatick province, in the west-central part of Senegal between latitude 13°54 and 14° N and longitude 16°12 and 16°20' W (Fig. 1). Djilor covers 444 km ^{2} and watered by the Saloum River and its tributary, the Sine. It is about 40 km away from the sea and located within the Saloum Delta which combines the characteristics of marine, estuarine and lacustrine landscapes and the forest reserve of *Welo*r. Soil salinity process has been noticed in many parts of the study area, mainly due to seawater intrusion from the Sine-Saloum River and evaporation (Faye et al., 2005) that has a great impact on soil fertility, and crop production and in turn threatening the population's livelihood (Sambou et al., 2016). Groundnuts, millet, maize, sorghum and rice are the main crops in Djilor. The rice fields belong mainly to women and constitute the most salt affected areas (Camara et al., 2008). About 2100 ha of Djilor area fall under different land uses such as mangrove ecosystem, forest, cropland, fallow, salt marshes and plantation (PLD, 2009). The climate is Sudan-Sahelian, characterized by a rainy season from June to October, and a dry season from November to May. Based on the data from 1965 to 2016 collected by the Senegal National Meteorological Agency, the annual mean rainfall is estimated at 546 mm. However, the annual rainfall has fluctuated strongly with a major decrease during the period from 1970 to 1990 followed by a slight increase in annual rainfall from 2008 to 2016.

Based on FAO classification, three dominant soil types were characterised in the study area: Lixisols (tropical ferruginous soils), Gleysols (hydromorphic soils), and Fluvisols (halomorphic soils). Lixisols are weathered soils with subsurface accumulation of low activity clays, mostly developed in dried areas. Gleysols are saturated soils with groundwater within 50 cm from the soil surface and have poor internal drainage. Fluvisols are generally recent soils in alluvial, marine or lacustrine deposits (Spaargaren, 2007; FAO, 2001).

2.2. Data collection

Two types of dataset were collected, that is biophysical and farm household characteristics.

2.2.1. Biophysical data

Fieldwork was conducted from March to June 2017 for soil samples collection. A multi-stage sampling was applied to select the plots where soil samples will be collected (Belay, 2014). Thus, in the first stage, the study area was stratified into two strata: non-saline and saline areas. They were purposely selected representing the whole study area based on the following criteria: (*i*) the location within the district, (*ii*) the presence of salt crystal on the soil surface, *iii*) the soil crusting (compaction), *iv*) the presence of salt tolerant plants and *v*) the distance of the plot to the river. For the second stage, a total of 304 sample plots were randomly selected and established of which 152 were saline and 152 were non-saline. One composite soil sample was collected in each sample plot unit by augering at 0–30 cm depth (Dahal and Routray, 2011). Thus, a total of 304 composites soil samples were collected over the study area with 129, 99, 44 and 32 soil samples in annual crop, grassland, bare land and fallow land, respectively.

For each sample plot, the location was georeferenced using a global positioning system. Soil samples were collected and taken to the laboratory to determine the electrical conductivity (EC), soil pH and granulometry (sand, silt and clay).

Furthermore, the soil map of the study area was collected from the National Institute of Pedology of Senegal at a scale of 1/500,000. The land use type of each plot was identified during the field survey using the exiting land use maps from the Centre of Ecological Monitoring (CSE) in Senegal with 30 m × 30 m resolution. Furthermore, the crop type of each plot was recorded during the field survey with the assistance of the plot owner.

2.2.2. Farm household data

For farm household characteristics, a combination of household survey and focus group discussions were conducted. A total of 304 farmers were randomly surveyed from December 2017 to March 2018 using questionnaire. The key categories of the questionnaire were: 1) households and farming characteristics, 2) land use and coping strategies, 3) crop yields, 4) cropping calendar, and 5) access to agriculture subsidies. Furthermore, five focus group discussions (FGD) were conducted with farmers to obtain general information and perception about soil salinity in the study area. The FGD participants were the same respondents of the survey who were experiencing salinity problem. They were randomly selected. Each FGD was composed of at least five farmers (i.e., three men and two women). The discussions were done in the *Serere* language (the local language), which were translated by the village heads. The guiding questions during the discussions revolve around the topics of: 1) farmers' perception on soil salinity drivers and trends, 2) soil salinity effects on their livelihoods, and 3) their coping strategies.

2.3. Data analysis

The spatial analysis tool in ArcGIS was used to extract elevation, slope, groundwater depth, and NDVI values for each sampled plot. Landform attributes such as slope and elevation were generated from Digital Elevation Model (DEM) (i.e., 30 m × 30 m resolution). DEM was

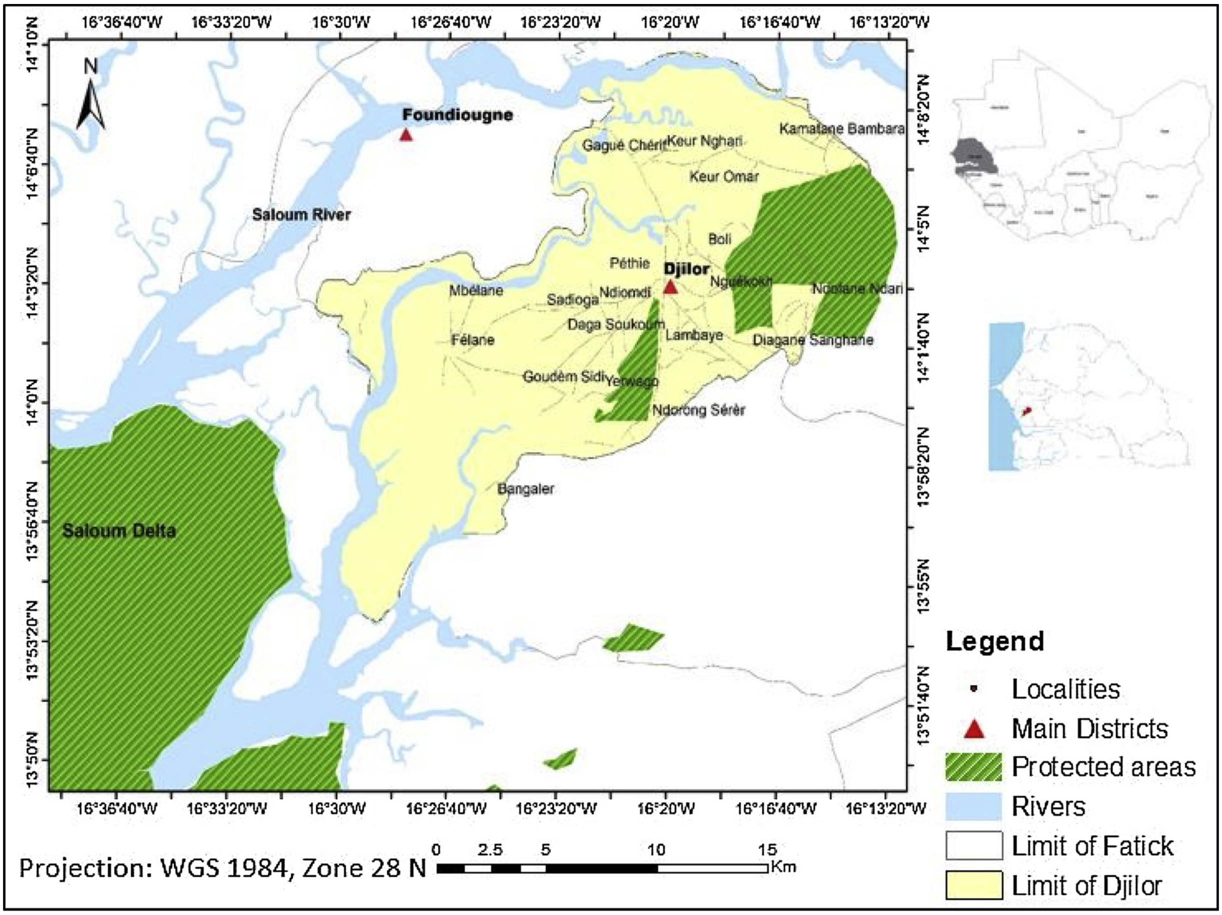

Fig. 1. Map of study area in Djilor district, Fatick Region.
(data source: National Institute of Pedology).

collected from the Directorate of Geographic and Cartographic Services in Senegal. NDVI is computed as following: $NDVI = \frac{Band\ 4 - Band\ 3}{Band\ 3 + Band\ 4}$

The groundwater depth data were used, which were generated from a total of 26 sample wells collected during the dry season by the Local Small-Scale Irrigation Project (PAPIL, 2012). Ordinary kriging (OK) estimator was applied to determine the groundwater depth values of the whole study area.

Soil salinity distribution was compared according to land use types, soil groups and crop types using a one-way analysis of variance (ANOVA). Regression analysis was used to determine the factors associated with soil salinity and build a predictor model of salinity prevalence. In addition, a regression analysis was performed to investigate the relationship between crop yield and measured soil salinity in the sampled plots. The statistical analyses (including multi-collinearity and variance inflation factors tests) were performed. These analyses were used to detect collinearity between independent variables in the regression analysis. The regression model with low variance inflation factor (VIF) was chosen as it gave the best results. Factors having the highest impact were measured using the coefficients size of standardized variables (Villamor et al., 2014).

The survey data were analyzed and summarized in the form of tables and graphs by using descriptive statistics.

3. Results

3.1. Biophysical characteristics

Topographical characteristics (i.e. elevation and slope), soil type, NDVI, and groundwater depth were the main biophysical inputs used in this study (Fig. 2).

The elevation in the study area ranges from 0 to 20 m and a maximum slope of 3% while the groundwater depth ranges between 0.5 and 8 m. It was observed that the lower values of elevation were along the river and within the lowlands. NDVI values range from -0.55 to 0.52.

Moreover, three main soil types were characterised in Djilor (see study area). Based on the laboratory analysis, soils in Djilor are generally poor in organic matter with an average of 0.63% in topsoil. Likewise, Nitrogen contents in topsoil are generally low (Mean N = 0.28%) which correspond to the low ratio between Carbone and Nitrogen (C/N) registered in topsoil (C/N = 13.34). In addition, four major crop types were identified during fieldwork: rice (*Oryza* sp.), maize (*Zea mays*), millet *(Pennisetum* sp.) and groundnut (*Arachis hypogaea*).

3.2. Soil salinity characteristics

Fig. 3 and Table 1 show that salt content varies significantly under different land uses (grassland, annual crop, bare land and fallow), soil types (Fluvisols, Gleysols and Lixisols) and crop types (rice, maize, millet and groundnut) (p = 0.000). For the land use types, land under fallow (10 dS/m) and bare land (9 dS/m) registered the highest median values of EC (Fig. 3a). Additionally, fallow and bare land showed the highest upper quartile (10 dS/m), suggesting that 25% for both lands have salt content greater than 10 dS/m. The general trend of soil salinity according to land use types is fallow > bare land > grassland > annual crops. For soil type, the median EC is greater in Fluvisols (8 dS/m) in comparison to Gleysols (7 dS/m) and Lixisols (7 dS/m) (Fig. 3b). In terms of crops, salinity was higher in the soils from rice

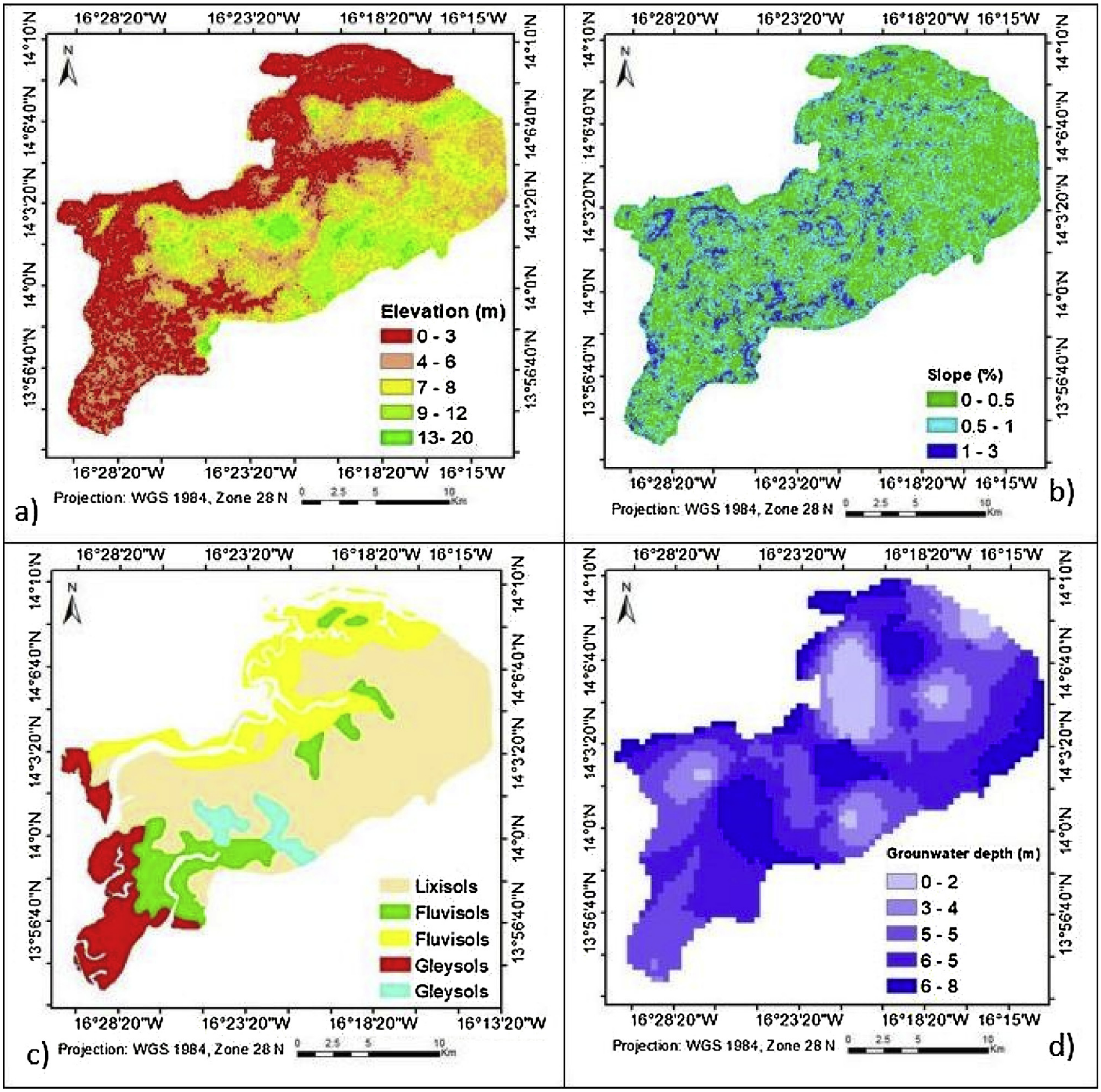

Fig. 2. Elevation (a); slope(b), soil type(c); groundwater depth(d) maps of Djilor district.
(Source: National Institute of Pedology, Directorate of Geographic and Cartographic Services).

fields (10 dS/m) than in the soils from the plots of maize (8 dS/m), millet (7 dS/m) and of groundnut (6 dS/m) (Fig. 3c).

3.3. Determinants of soil salinity

Table 2 summarizes the factors associated with the increased soil salinity in the study area. Among the significant variables associated with increasing soil salinity include elevation, clay content, pH, distance to river and Fluvisols. Clay content is the only variable positively correlated with soil salinity ($p = 0.000$), suggesting that salinity increases with increasing clay particles in the soil. In contrast, elevation shows a significant negative relationship with measured soil salinity ($p = 0.000$) suggesting that the lower the elevation of the area, the higher the salinity. Similar tendency was assessed with the distance from the river ($p = 0.000$), suggesting that the nearer the farm plots to the river, the higher the plots' salt content. In addition, soil pH and Fluvisols were found negatively correlated with salinity. Among these significant variables, clay content and distance to river were assessed to have the highest impact (measured in coefficients size of standardized variables).

3.4. Households characteristic and perception of salinity

3.4.1. Characterization of households

Table 3 presents the descriptive statistics of the farm households. The majority of the sampled plots were owned by male-headed households (81%). Females are mostly engaged in rice farming, about 65% of the sampled rice plots. The female headed households are generally widows or their husbands migrated to other places. The average household size (or household members) is 13 with an average farm plot size of 1.6 ha. Most of the respondents have land access through inheritance (86.5%). Agriculture is the main source of income.

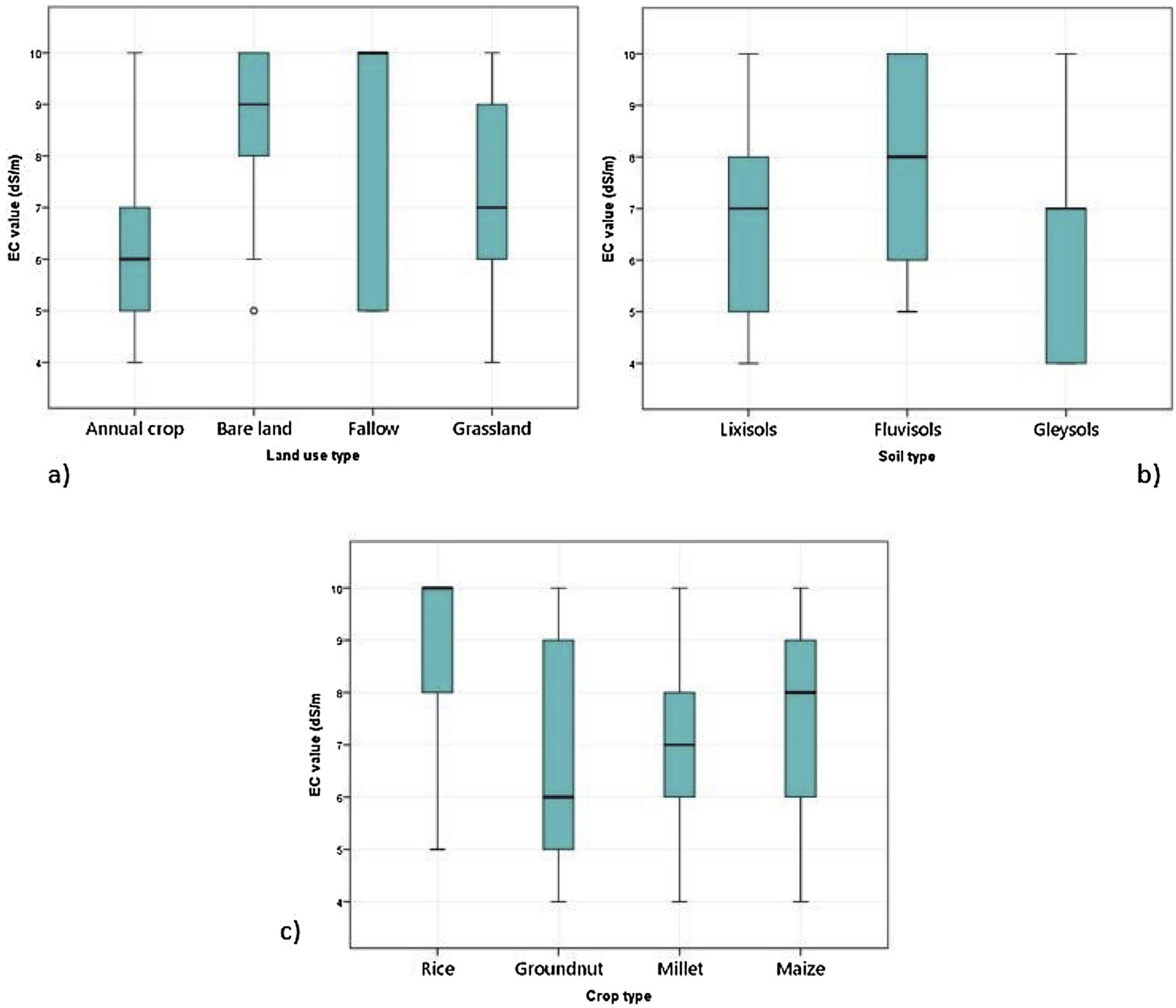

Fig. 3. Soil salinity variation in different land use (a), soil type (b), and crop type (c) in a coastal agricultural area in Djilor district.

Table 1
Soil salinity for different land use, soil and crop types.

	Mean ± StdDev. (ds/m)	Min.	Max.	Skewness	Kurtosis
Land use types	**ANOVA*** (p = 0.000 at 95% CI)**				
Annual crop	6.13 ± 1.849	4	10	0.701	−0.184
Grassland	7.18 ± 1.881	4	10	0.020	−1.077
Fallow	8.00 ± 2.739	5	10	−0.609	−3.333
Bare land	8.47 ± 1.391	5	10	−1.006	0.723
Soil types	**ANOVA*** (p = 0.000 at 95% CI)**				
Lixisols	5.8 ± 1.941	4	10	−0.046	−1.328
Fluvisols	7.97 ± 1.740	5	10	−0.173	−1.503
Gleysols	6.36 ± 1.891	4	10	0.302	−0.520
Crop types	**ANOVA***(p = 0.000 at 95% CI)**				
Rice	9.00 ± 1.477	5	10	−1.390	1.211
Groundnut	6.67 ± 1.993	4	10	0.433	−1.082
Millet	6.96 ± 1.751	4	10	−0.060	−0.958
Maize	7.45 ± 2.179	3	10	−1.254	−0.102

Note: StdDev = Standard deviation; Min = minimum; Max = maximum; Skewness = coefficient of Skewness, Kurtosis = coefficient of Kurtosis, ANOVA = analysis of variance, *** = statistical significance at the 0.05 level; CI = confident interval.

Three main types of plot acquisition were identified in the study area: 1) newly and freely cleared land, 2) inherited land, and 3) use right given by local leaders. 73.9% of female have got their lands through inheritance, 26.1% via right given by local leaders whereas most of the men (90.7% of men) had newly and freely cleared their lands.

Table 2
Factors associated with soil salinity in Djilor.

Explanatory Variables	Intercept	Std. Err.	95% Conf. Interval	
Distance to river (m)	−0.000	0.000***	0.000	0.000
Elevation (m)	−0.215	0.026***	−0.267	−0.163
Clay context (%)	0.129	0.009***	0.110	0.147
Soil pH	−0.203	0.079***	−0.360	−0.047
Groundwater (m)	0.117	0.066	−0.012	0.247
Fluvisols	−1.208	0.232***	−1.665	−0.751
Gleysols	−0.233	0.260	−0.745	0.279
Lixisols	−0.057	0.198	−0.447	0.333

Note: n = 304, R-squared = 0.87, Prob > F = 0.000, *** = statistical significance at the 0.05 level, Soil type = dummy variable: 1 = Lixisols, 2 = Fluvisols and 3 = Gleysols.

Based on focus group discussion, participants noted that rice farming is the most affected land use type by salinity in the study area. As subsistence farmers, they recognised that the increase of soil salinity will cause excessive agricultural losses and consequently induce severe food insecurity in the area. Even though they adopted some strategies, they still need government support to have access to agricultural

Table 3
Descriptive statistics of farm households in Djilor.

Variable	HH	N	Mean	Std. Dev.	Min.	Max.
Age (years)	Total	304	53.4	13.08	25	86
	Female	46	57.7	12.29	35	85
	Male	258	52.6	13.09	25	86
Household size	Total	304	13	7.16	3	80
	Female	46	13	5.77	5	32
	Male	258	12	7.39	3	80
Group membership	Total	304	0.3	0.46	0	1
	Female	46	0.4	0.49	0	1
	Male	258	0.3	0.46	0	1
Farm plot size (ha)	Total	304	1.6	0.74	0.5	4
	Female	46	1.6	0.72	0.5	4
	Male	258	1.6	0.72	0.5	4
Rice plot size (ha)	Total	304	1.9	0.85	0.5	4
	Female	46	1.9	0.83	0.5	3
	Male	258	2	0.92	1	4
Maize plot size (ha)	Total	304	1.6	0.66	0.5	3
	Female	46	1.5	0.52	1	2
	Male	258	1.6	0.75	0.5	3
Millet plot size (ha)	Total	304	1.7	0.77	0.5	4
	Female	46	1.6	0.67	1	3
	Male	258	1.7	0.77	0.5	4
Groundnut plot size (ha)	Total	304	1.6	0.80	0.5	4
	Female	46	1.6	0.78	1	3
	Male	258	1.6	0.81	0.5	4

Note: N = sample size (i.e. number of respondents); group membership = dummy variables (0 = yes, 1 = no).

subsidies (e.g., salt tolerant crop varieties such as *Nerica* sp. also known as the *New rice for Africa*) and to mitigate soil salinity. Furthermore, farmers in Djilor observed that the salt affected areas expanded as the result of drought and inundation events respectively, in 1972 and 2012 that led to the abandonment of many agricultural lands.

3.4.2. Effects on farmers' livelihood and their coping strategies

Ninety-six percent of the respondents are affected by salinity and reported a negative effect of salinity to crop yields (Table 4). In non-saline plots, the highest median crop yield was 800 kg/ha, whereas in saline plots the median of crop yield is almost zero (Fig. 4).

About 65% of the rice plots are owned by female farmers, suggesting that they are highly vulnerable to the impact of increasing soil salinity. Furthermore, Fig. 5 shows that the plots with higher median EC (9 ds/m) belongs to female group in comparison with the men' plots (median EC = 7 dS/m).

The farmers in Djilor are applying various coping strategies to mitigate the negative effects of soil salinization. A total of seven coping strategies were recorded within the study area (Fig. 6). The most important coping strategies in the study area are the application of chemical fertilizer (20%) and the planting and conservation of trees (20%), followed by the use of organic manure (18%) and installation of soil bunds (16%).

Table 4
Factors affecting crop yields in Djilor district.

Explanatory Variables	Intercept	Std. Err.	95% Conf. Interval	
Number of trees in farm (trees/ha)	21.9	3.92***	14.138	29.657
Salinity content (dS/m)	−41.69	5.92***	−53.394	−29.987
Amount of seeds (kg/ha)	0.61	0.36	−0.11	1.335
Fertilizer (kg/ha)	0.78	0.18***	0.420	1.142
Number of female household members	−5.96	2.59 ***	−11.083	−11.083

Note: n = 153, R-squared = 0.46, Prob > F = 0.000, *** = statistical significance at the 0.05 level.

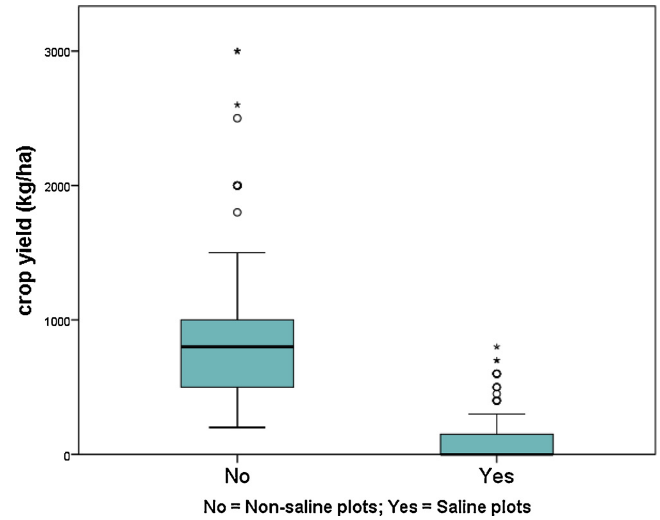

Fig. 4. Effects of soil salinity on crop yield in Djilor district.

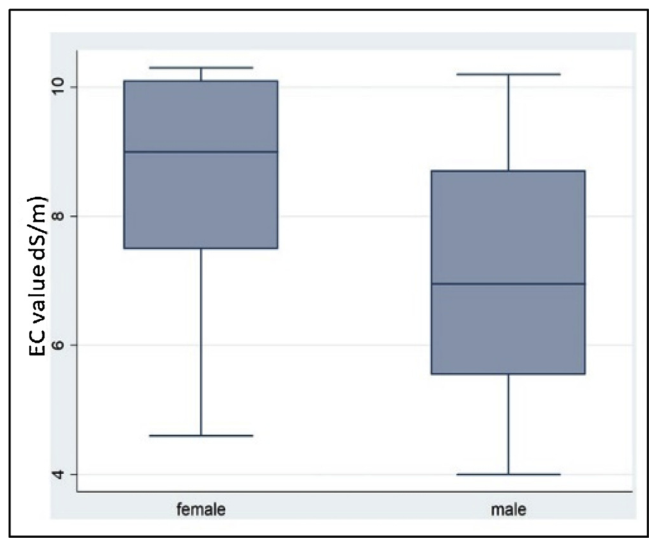

Fig. 5. Soil salinity and gender in Djilor district.

4. Discussion

4.1. Soil salinity pattern in land uses, soil and crop types

The statistical and laboratory analyses of the soil samples showed a variation of salt content in relation to land use, soil and crop types. Rice plots are the most affected among the crops types; whereas, Fluvisols has the highest salt content by salt water intrusion. Similar findings were observed in Senegal by Sambou et al. (2015) who reported that most of the salt affected areas are related to abandonment of rice fields. Related studies showed that rice is sensitive to salt through their geomorphological position (lowland) and edaphic need (generally silt clay) (Barbiéro et al., 2001; Nhan et al., 2010). Thus, rice is more exposed to salt water intrusion compared to groundnut and millet fields which are more upland crops.

Among the soil types, Fluvisols has the highest salt content. The same finding was observed by Fang et al. (2005b) that salt content in Fluvisols was significantly higher than in Gleysols. In Senegal, Fluvisols belongs to the saline acid sulphate soils also known as "*tann*" which are usually found in low areas subject to tidal flooding, and mostly confined to lacustrine and marine deposits (Sadio and van Mensvoort, 1993).

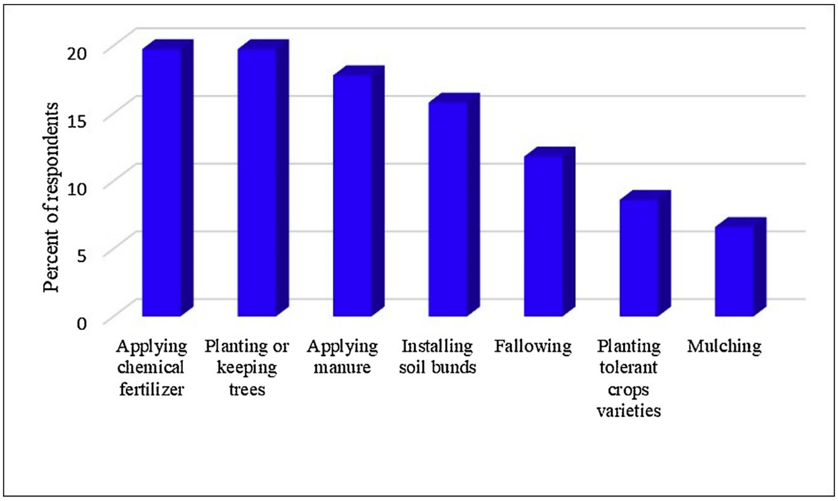

Fig. 6. Coping strategies to mitigate the negative impact of soil salinity in Djilor.

4.2. Determinants of increased soil salinity in coastal agricultural area

Soil salinity in the study area is associated with various biophysical factors. Clay content was positively associated with the salinity in agricultural areas because of its high ionic capacity to retain high amounts of salts (Busenberg and Clemency, 1973). This finding corroborates with the studies of Zhao et al. (2016) in Heihe River, Northwestern China and Yu et al. (2014) in the coastal zone of the Yellow River Delta, China, which both indicated that soil texture affects soil salinity variation and therefore constitutes a good predictor for soil salinity. The distance to the river and elevation are obvious factors associated with the increased soil salinity, which were observed in other studies as determinants for soil salinity (Yahiaoui et al., 2015; Qian et al., 2017). Furthermore, the distance to river has an important effect on soil salinity extent because of the sea water intrusion (Rossa et al., 2011). As a coastal area, salt affected areas in Djilor were mostly related to the inundation from sea level rise. This finding confirms that soil salinity in this coastal agricultural landscape is principally due to seawater tides flood, depositing salts on the land surface (Fall, 2017; Sow et al., 2016).

Consequently, the groundwater depth did not show as a significant factor for soil salinity. Our finding contrasts with most of the studies that had reported as a highly significant factor affecting soil salinity (Triki Fourati, 2017; Grabau, 2012). This is because our study area is a coastal zone where most of the salt come from seawater intrusion through inundation and less available groundwater due to capillary rise. Further, the non-significant relation of groundwater depth with soil salinity may be due to the low variability of groundwater depth of the sampled plots ranging between 1 to 5 m.

Most of the studies had built a soil salinity model predictor by considering all the soil profile depths such as 0–30, 30–60, and 60–90 cm and were mostly conducted in irrigated areas (Asfaw et al., 2016; Qian et al., 2017; Guan et al., 2013). In contrast, we considered only the topsoil with soil depth of 0–30 cm. This is because the topsoil is the most important component in farmlands, and generally subject to various fluctuations that induce salt accumulation (Yu et al., 2014; Li et al., 2011). However, this could be considered as a limitation of this study.

4.3. Impact and coping strategies

Soil salinity in Djilor has gender aspect. From our study, women appear to be affected by soil salinity due to their dominance in rice farming, which in turn may affect their household's food security. Similarly, a study in Bangladesh showed that women are more concerned of and suffered more from soil salinity problem than men (Rahman, 2010). Moreover, soil salinity constitutes a real threat to local smallholder farmers' livelihood and food security in the area, as earlier revealed by Sambou (2016) study in Fatick Region. Indeed, staple foods in the area are generally cereal based such as rice, millet, groundnut, maize, and sorghum, as well as root crops, fruits, and vegetables. However, due to soil salinity, majority of the households interviewed in the study area agreed that their crop production had reduced. Our findings corroborate with the study in Bangladesh, which showed a negative impact of soil salinity on household food security (Szabo et al., 2016). Furthermore, our results showed a strong and negative relationship of salinity content with crop yield as observed by Nguyen et al. (2016) in coastal region of Vietnam. This is not surprising because yield largely depends on soil fertility or nutrients, which are severely degraded by salt accumulation in the root zone (Shrivastava and Kumar, 2015).

In order to reduce the negative impact of soil salinity to the livelihoods in our study area, households have adopted various coping strategies based on their traditional knowledge in agriculture and sometimes with the assistance of implemented projects such as the International Union for Conservation of the Nature. These traditional coping strategies employed include application of manure, planting and conserving trees (e.g., *Eucalyptus alba*, *Faidherbia albida*) establishment of soil bunds, fallowing, planting tolerant crop varieties (e.g., new variety of rice named *Nerica*) and mulching. Among these strategies, Fall (2017) noted the mulching strategies as the most efficient method to reclaim salt affected areas in the Saloum river basin. It was also found that application of chemical fertilizer is one of the top coping strategies identified. In a study of Dah-gbeto and Villamor (2016) in Benin, it also showed that application of chemical fertilizer is the most preferred coping strategy to mitigate the impacts of climate variability (e.g., droughts and floods) in the agricultural lands. However, coping strategies are also site or context specific (Haider and Hossain, 2013; Machado and Serralheiro, 2017). Nevertheless, farmers' responses to salinity in Djilor are encouraging as they are all conscious of the phenomenon and most of them had started implementing strategies. Nevertheless, farmers still need assistance from the government or NGOs to be able to improve their strategies and somehow install other strategies.

5. Conclusions and recommendations

The soil salinity pattern, its associated factors and the coping strategies of the smallholder farmers in the coastal agricultural area in Djilor have been investigated in this paper. Land use, soil and crop types affected the pattern of salt in the study area. Fallow land, bare land, rice plots and Fluvisols soil registered higher salt content. The regression results showed that soil EC was significantly associated with clay content, distance to river and elevation. Soil salinity had no correlation with groundwater depth suggesting that the accumulation of salt in coastal agricultural lands was not significantly related to capillarity rise from groundwater contrary to most of the studies. Senegal as a coastal area, soil salinity is mostly caused by inundation and deposits of salt from the seawater intrusion. Its immediate negative effect is the low crop yields particularly on rice production that are mainly cultivated by female farmers. To cope with the increasing negative effect of soil salinity, farmers in the study area are using a wide variety of coping strategies such as using chemical fertilizer, manure, planting and conservation of trees, and soil bunds.

As sea level rise is projected to increase in the future, it is recommended to further investigate the soil salinity pattern in the region in the next coming decades as well as its gender dimension. Furthermore, the identified factors associated with salinity are useful factors or indicators for developing soil salinity risk maps for the whole study area. Moreover, as the number of trees was positively related to crop yield, it is recommended to plant more trees on farm and thereby improve vegetation cover for a better soil salinity management in Djilor.

Finally, the findings of this study provide a baseline understanding of soil salinity in Djilor and may help decision makers and smallholder farmers to improve soil salinity management and their livelihoods.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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