BioGecko Vol 12 Issue 03 2023

ISSN NO: 2230-5807

Spatial distribution of electrical conductivity values in Basra Governorate, based on ground measurements and remote sensing data.

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Abstract:

The study was conducted for the purpose of tracking and evaluating the state of soil salinity in province of Basrah, which is located within the arid zone, between latitudes 29°.06' , 31°.18'N, and longitudes 46°.34' , 48°.36'E. The study relied on the results of laboratory analysis of soil samples, that collected from the study area during September 2020 and April 2021, and compared them with the values of salinity evidence for the sample collection sites calculated from space data, of the ETM $^{+}$ and OLI sensors of the Landsat satellite series, which were obtained from US Geological Surveys Website (USGS). Soil salinity spatial distribution maps and area calculations were prepared using the ArcGIS v.10.7.1 program. The results showed that most of the study area's soils suffer from the problem of salinity, as the area ratios of medium, high and very high salinity soils were 51.79, 30.50 and 9.94%, respectively. While the percentage of soils with low salinity reached 1.03%.The values varied according to the location and depth, as the values ranged in the eastern region from low to very saline, and the values increased as we moved away from the banks of rivers towards river basins.The results showed an increase in average values when heading from the north to the south of the study area, and that the salts were concentrated in the surface layers of the soil and decreased with depth. In the western region, the results showed lower average values compared to the eastern region, as it ranged between low to medium salinity. At the end of the dry season.The results also showed, in general, a decrease in the general rates of electrical conductivity values in the cultivated areas compared to the soils of the non-agricultural areas.

Keywords: Soil Salinity, Salinity Index, Remote Sensing, GIS, Basrah Governorate.

1-Introduction:

The spread of soil salinity on a large scale is one of the most important factors of soil degradation that threatens food security and sustainable development, especially in arid and semi-arid regions. Soil salinity is one of the important indicators that determine the quality of the soil, as the increase in the concentrations of dissolved salts in the root zone leads to the deterioration of soil properties, a decrease in the productivity of agricultural crops, and the spread of desertification around the world (Allbed and Kumar, 2013).Salinity disperses soil particles, erodes them, and decreases their productivity. It also affects the mechanical properties of the soil, which makes it less bearable for the weight of the structures built on it (Abuelgasim and Ammad, 2018).

Litalien and Zeeb (2020) showed that soil salinization processes can be classified into two types: primary salinization processes, which is a natural phenomenon that occurs as a result of the physical and chemical weathering of parent materials rich in salts, or by the movement of groundwater rich in salts towards the surface of the soil and its evaporation, leaving dissolved salts to precipitate at the surface, especially in dry climatic conditions. As for the second type, it is the secondary salinization processes. This type is related to human activities. This type is active in arid and semi-arid regions when irrigation water with certain salt concentrations is used in poorly drained soils under conditions of drought and the activity of the evaporation process.Removing the vegetation cover, changing the use of the land, and using a large amount of irrigation water leads to a change in the state of the water balance, the rise in the ground water level, and its evaporation from the surface due to the

[1]Part of PhD dissertation of the first author

activity of the capillary action and the accumulation of salts in the soil. In addition, the excessive use of chemical fertilizers enhances the processes of secondary salinization.

Saleh (2020), when studying the characteristics of soils affected by salts and their deterioration in Basra Governorate, concluded that the salts accumulated in the soil sector occurred as a result of the secondary salinization process, and that there is an effective mutual relationship between the vegetation cover and the salt accumulation in the soil surface, and that both are strongly affected by the rates of rainfall and that the human factor The greatest effect is in the process of salinization, especially in the rise of ground water or the use of saline irrigation water, and controlling this effect can limit soil salinization and improve vegetation cover despite the lack of rain.

Soil salinity varies temporally and spatially according to different natural conditions and human activities such as rainy seasons, drought, irrigation and drainage operations, the use of salt-rich fertilizers, and the difference in the quality of irrigation water (Hassani *et al*., 2020).The study conducted by Jabr (2022) showed an increase in the electrical conductivity values of the dried marsh soil pedons north of Basra, which ranged between 18.06-62.80, and that the reason for the high electrical conductivity values is due to the method in which the accumulation of salts was dried due to the intense evaporation processes and the activity of the capillary property during the drying processes. The climatic conditions of the region, characterized by high temperatures, low rainfall and low vegetation cover, helped the accumulation of salts in the surface layers of the soil.

Soil salinization leads to the loss of approximately 1.5 million hectares of agricultural land and the deterioration of the productivity of another 20-40 million hectares every year. In order to stop the processes of soil salinization and the deterioration of its productivity and to improve the quality of the soil, it is necessary to monitor and evaluate the cases of soil salinization and its causes, and update the relevant information, which helps in making Sound land use decisions that improve soil management and conservation (zhou *et al*., 2022).

Taha (2013) indicated that the use of remote sensing techniques is one of the modern methods in diagnosing agricultural problems, as it is possible to follow up on fundamental changes such as drought, soil salinity, sand encroachment, and climate changes as the most important challenges facing the countries of the world, including Iraq. Hussein (2017) indicated the possibility of using satellite data with geographic information systems to analyze spatial data of all kinds and to make maps of its spatial distribution.

Traditional methods of soil salinity mapping require spending a lot of time, effort, and money in order to collect and analyze soil samples, and it is difficult to apply them on large areas, and what makes it more difficult is that soil salinity is a constantly changing characteristic according to different soil conditions and the surrounding environment (El Hafyani *et al*., 2019)

Therefore, the traditional methods of soil salinity mapping have been replaced by digital techniques that are highly efficient and save effort, time and money. These methods are summarized by collecting and analyzing soil samples for a number of ground points and linking the results to the spectral characteristics of the pixels representing the points from which the samples were collected and then using these relationships. To predict the properties of soils affected by salinity based on spectral data for any region and at any time (Taghizadeh-Mehrjardi *et al*., 2021).

his study was conducted for the purpose of monitoring and tracking the spatial distribution of soil salinity in the province of Basra through field measurements and linking them to remote sensing data and geographic information systems for the purpose of reaching the best correlation through which soils affected by salinity can be classified based on the spectral characteristics of the studied area.

2. Materials and Methods

2.1. Study Area

The study was conducted in the province of Basrah, which is located within the arid areas in the western part of the continent of Asia, south of Iraq, between latitudes 29°.06` , 31°18`N and longitudes 34°.46` , 48°.36` East (Fig. 1)The meteorological data of the Al-Hussein neighborhood station in Basrah Governorate during the period 1988-2020 showed that the annual average hours of actual brightness amounted to 8.8 h d^{-1}, with a range between 6.3-11.3 h d^{-1}, while the annual average temperature reached 26.9 degrees Celsius, with a monthly rate that ranged. Between 13.2-36.9 degrees Celsius, the annual rate of precipitation was 124.9 mm y^{-1}, while the annual evaporation rate during the same period was about 2889.1 mm y^{-1}. Northwesterly winds predominate in the study area, which reach their highest rates during the months of June and July, reaching 5.3 m s^{-1}. The soils of the study area are considered to be hyperthermic, because the average annual temperature is more than 22 degrees Celsius, and the moisture system is torric (Aridic), due to the exposure of soils to drought throughout the year.

Administratively, Basra Governorate is part of the Republic of Iraq, as it occupies the southeastern part of it. It is bordered to the north by Maysan Governorate, to the south by the Arabian Gulf and the State of Kuwait, to the west by the governorates of Dhi-Qar and Muthanna, and to the east by the Islamic Republic of Iran. It occupies the southeastern part of the sedimentary plain and the southern part of the Western Desert. Its area is estimated at 19,070 km^2 (1,907,000 ha), which constitutes 4.4% of the total area of the Republic of Iraq, which is 435,052 km2. (Central Statistical Organization - Republic of Iraq, 2020).

2.2. Soil sample collection

For the purpose of collecting soil samples, the study area was divided into two parts, the eastern part, which is located within the southern end of the Mesopotamian plain region, and the soils of this section are classified under the Great Group Typic Torrifluvents, and the western part, which is an extension of the Western Desert, represented by the Dibdaba formations, and its soils are classified under the Great Group Typic Torripsamments (Al-Ali and Al-Atab, 2012) and the contour line 5 m is the dividing line between the two regions. Soil samples were collected from the eastern section and by the free survey method from several paths, which were represented by the areas of riverbanks, river tails, river basins, dried marsh areas and coastal plains. As for the western region, which represents desert soils, it was classified into Cultivated areas and uncultivated areas, then a number of soil samples representing homogeneous soil units were collected to a depth of 1 meter in two stages, the first at the end of the dry season during September 2020 and the second at the end of the rainy season during April 2021. The samples were placed in plastic bags and transferred to the laboratory, then They were air-dried, ground, and passed through a sieve with a diameter of 2 mm, then a 1:1 suspension (water: soil) was made. An EC-meter type WTW model Cond 7110 estimated the electrical conductivity of the soil extract. The figure 1 shows a map of the study area indicating the locations for collecting samples of soil.

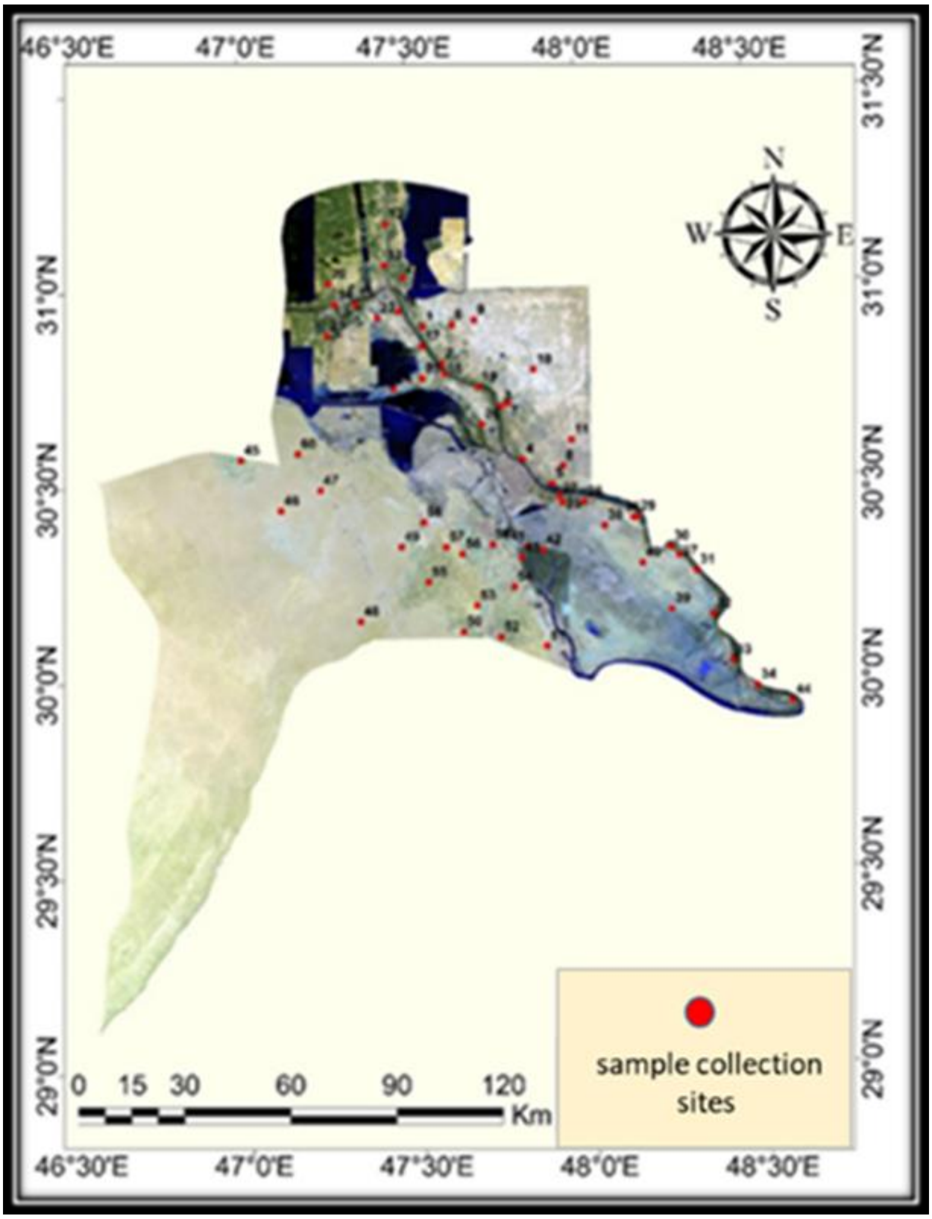

Figure 1 Map of the study area with soil sample collection sites.

Spatial distribution maps and area calculations were prepared using the ArcGIS v.10.7.1 program. General averages of electrical conductivity values were calculated for each site, and the values were entered into the program. Spatial distribution maps were drawn using the inverse interpolation tool for weighted distances. (IDW) For the purpose of tracking the state of salinity in the study area during the period from 2000 to 2021, a number of satellite scenes captured at the end of the dry season (during September in the years 2000, 2013 and 2020) and the end of the rainy season (during April in the years 2001 , 2014, and 2021). Table 1 shows the numbers of satellite visuals used in the study.

Table 1. The satellite data used in the study, with an explanation of the symbols of the visual numbers

1	LE07_L2SP_165039_20000911_20200918_02_T1
2	LE07_L2SP_166038_20000902_20200918_02_T1
3	LE07_L2SP_166039_20000902_20200918_02_T1
4	LE07_L2SP_166040_20000902_20200917_02_T1
5	LE07_L2SP_165039_20010423_20200917_02_T1
6	LE07_L2SP_166038_20010414_20200917_02_T1
7	LE07_L2SP_166039_20010414_20200917_02_T1
8	LE07_L2SP_166040_20010414_20200917_02_T1
9	LC08_L2SP_165039_20130907_20200912_02_T1
10	LC08_L2SP_166038_20130914_20200912_02_T1
11	LC08_L2SP_166039_20130914_20200912_02_T1
12	LC08_L2SP_166040_20130914_20200912_02_T1
13	LC08_L2SP_165039_20140419_20200911_02_T1
14	LC08_L2SP_166038_20140426_20200911_02_T1
15	LC08_L2SP_166039_20140426_20200911_02_T1
16	LC08_L2SP_166040_20140426_20200911_02_T1
17	LC08_L2SP_165039_20200910_20200919_02_T1
18	LC08_L2SP_166038_20200917_20201005_02_T1
19	LC08_L2SP_166039_20200917_20201005_02_T1
20	LC08_L2SP_166040_20200917_20201005_02_T1
21	LC08_L2SP_165039_20210422_20210430_02_T1
22	LC08_L2SP_166038_20210429_20210508_02_T1
23	LC08_L2SP_166039_20210429_20210507_02_T1
24	LC08_L2SP_166040_20210429_20210507_02_T1

LXSS_LLLL_PPPRRR_YYYYMMDD_yyyymmdd_CC_TX

L	Landsat
X	Sensor (C = Combined OLI/TIRS, T = TIRS-only (if Landsat 8 or higher), T = TM (if Landsat 4-5), O = OLI-only, E = ETM, M = MSS)
SS	Satellite (09 = Landsat 9, 08 = Landsat 8, 07 = Landsat 7, ... 01 = Landsat 1)
LLLL	Processing Correction Level (L2SP = Level-2 Science Product - includes Surface Temperature (ST) and Surface Reflectance (SR), L2SR = Level-2 Surface Reflectance (SR))
PPP	WRS Path
RRR	WRS Row
YYYYMMDD	Acquisition Date expressed in Year, Month, Day
yyyymmdd	Processing Date expressed in Year, Month, Day
CC	Collection Number (02)
TX	Collection Category (RT = Real Time, T1 = Tier 1, T2 = Tier 2)

A merger was made of four scenes for each period for covering the study area, and then a cutoff was made for the study area. A number of salinity indicators shown in Table 2 and contained in Kholdorov *et al*. (2022) were calculated, and then a comparison was made between them by conducting a regression analysis of the values of the corresponding salinity indicators. The electrical conductivity values of the surface soil layer obtained from ground measurements.

Table 2.Salinity indicators used in the study.

$SI1 = \sqrt{BLUE * RED}$ --------------------------------1
$SI2 = \sqrt{Green * RED}$ -------------------------------2
$SI3 = \frac{BLUE*RED}{GREEN}$ --3
$SI4 = \frac{RED*NIR}{GREEN}$ ---4
$SI5 = \frac{BLUE+GREEN+RED}{2}$ ------------------------------5

In order to reduce the effect of moisture content and soil texture difference on the test results, the values were tested for each season separately, and samples from the western region were tested in isolation from the eastern region. The table 3 shows the values of the regression coefficient (R^2) for the relationship between the electrical conductivity values measured in the field and the salinity indicators used in the study.

Table 3. values of linear, exponential and polynomial regression coefficients (R^2) between the values of a number of spectral indicators of salinity and the electrical conductivity values of soil samples in the study area at the end of the dry season (September 2020) and the end of the rainy season (April 2021)

season	region	Regression model	SI1	SI2	SI3	SI4	SI5
September 2020	Eastern region	polynomial	0.89	0.85	0.84	0.88	0.86
		linear	0.71	0.67	0.63	0.73	0.73
		exponential	0.80	0.76	0.75	0.79	0.79
	Western Region	polynomial	0.83	0.79	0.77	0.80	0.82
		linear	0.83	0.79	0.77	0.79	0.82
		exponential	0.82	0.78	0.76	0.79	0.80
April 2021	Eastern region	polynomial	0.88	0.84	0.81	0.62	0.88
		linear	0.66	0.62	0.60	0.53	0.71
		exponential	0.73	0.69	0.70	0.57	0.75
	Western Region	polynomial	0.89	0.84	0.84	0.47	0.80
		linear	0.77	0.72	0.68	0.47	0.78
		exponential	0.78	0.74	0.70	0.46	0.79
mean		polynomial	0.87	0.83	0.81	0.69	0.84
		linear	0.74	0.70	0.67	0.63	0.76
		exponential	0.78	0.74	0.72	0.65	0.78
General Average			0.80	0.76	0.74	0.66	0.79

Based on the results of the regression analysis shown in the table 3, the given salinity index was adopted according to the following relationship

$SI = \sqrt{BLUE * RED}$,

Which represents the best correlation with the electrical conductivity values measured in the field in the study area, and this is consistent with the findings of Gorji *et al*. (2017). The correlation relationships shown in the figure 2 and the table 4 were used for predicting the electrical conductivity values during the period covered by the study.

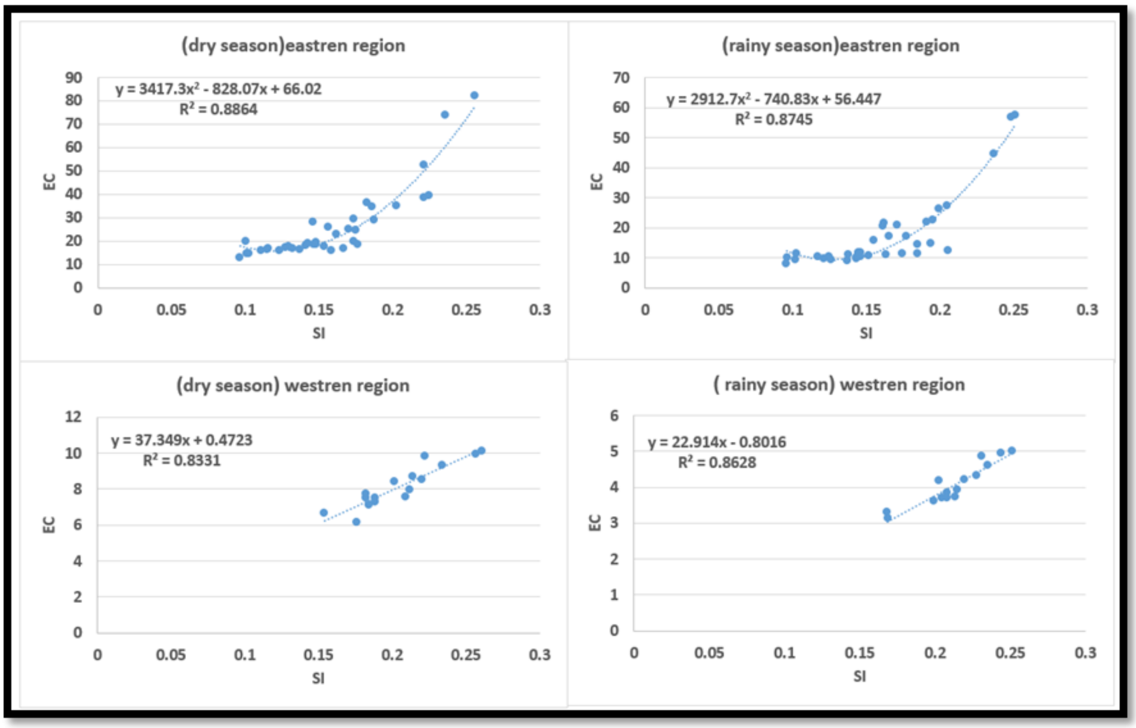

Figure 2. The relationship between soil electrical conductivity values and salinity index values during the dry and rainy seasons in the eastern and western regions of the study area

Table 4. Relationships used in calculating electrical conductivity values based on salinity index values

season	region	R^2	function
dry season	eastern region	0.88	$EC = 3417.3(SI)^2 - 828.07(SI) + 66.02$
	western region	0.83	$EC = 37.349(SI) + 0.4723$
rainy season	eastern region	0.87	$EC = 2912.4(SI)^2 - 740.72(SI) + 56.447$
	western region	0.86	$EC = 22.91(SI) - 0.8016$

The figure3 shows the relationship between the electrical conductivity values calculated according to the relationships contained in the table 4 and the electrical conductivity values of the field-measured surface soil layer.

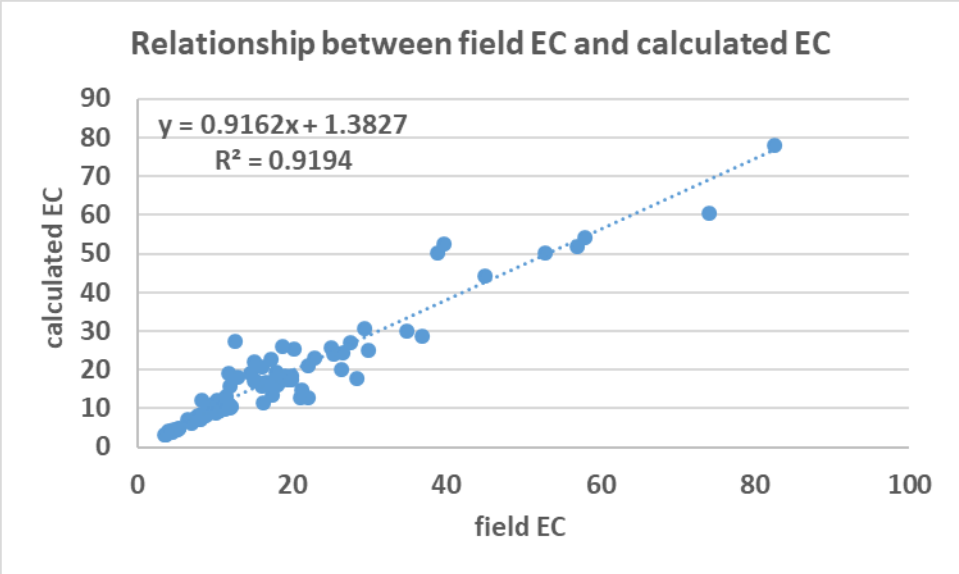

Figure 3. The relationship between the electrical conductivity values of the field-measured surface soil layer and the values calculated based on the equations in Table 4

Soil salinity maps were drawn during the period covered by the study after it was classified into four categories depending on the effect of electrical conductivity values on plant growth, as shown in the table 5.

Table 5. Soil salinity classes and their effect on crops (USDA, 2017)

Salinity class	EC(ds m^{-1})	salinity effects on crops
Slightly saline	0-4	Yield loss for very sensitive crops
moderately saline	4-8	Many crops are affected and their yield is restricted
Highly saline	8-16	Only tolerant crops bear this condition
Extremely saline	>16	Only a few very tolerant crops resist

3. Results and discussion

3-1-Spatial distribution of soil salinity in the study area

The table 6 shows the general averages of the results of the laboratory analysis of the electrical conductivity values of the study area during the two periods of the end of the dry season (September 2020) and the end of the rainy season (April 2021). It appears from the table 6 that the entire study area suffers from the problem of salinity in varying degrees, as it is noted that the values are high for the soils of the eastern region. The soft texture compared to the coarse-texture soils of the western region. It is also noted that the rates of values are higher in the surface layers compared to the sub-surface layers in both regions. This is due, of course, to the nature of the prevailing climatic conditions in the region, represented by the high rates of evaporation and the lack of precipitation, which causes the activity of the capillary feature that leads to movement Soil solution from the bottom of the soil sector towards the surface, and then the water evaporates, leaving the salts to precipitate at the surface. Especially in the dry season. In the rainy season, the rain dissolves part of the salts deposited at the surface and filters them into the soil body. Because of the lack of rainfall compared to the amount of evaporation, this process works to redistribute the salts within the soil sector without getting rid of them completely.

Table 6. General averages of the electrical conductivity values of the study area.

sesson	depth / saite	Number of Profile	0-10	10-30	30-60	60-90	>90	MEAN
Dry	River Banks	21	17.24	10.20	8.48	7.86	8.09	9.48
	River Tails	6	30.60	18.24	14.83	15.09	15.54	17.24
	River Basins	6	72.87	50.70	44.52	44.00	45.33	48.52
	Dried Marshes	7	28.56	18.11	11.81	11.07	11.43	14.49
	Coastal Areas	4	42.68	39.00	31.70	30.05	31.00	33.69
	Cultivated Desert	9	8.07	5.02	4.18	3.90	4.02	4.64
	Uncultivated Desert	7	8.24	4.94	4.33	4.08	4.20	4.76
WET	River Banks	21	10.44	9.74	8.37	7.68	7.25	8.53
	River Tails	6	18.78	17.77	14.79	14.88	14.06	15.74
	River Basins	6	55.18	51.58	48.25	46.00	43.25	48.44
	Dried Marshes	7	19.91	18.03	13.67	11.96	11.06	14.39
	Coastal Areas	4	37.13	32.85	29.65	26.85	25.28	29.76
	Cultivated Desert	9	3.80	4.16	3.23	3.67	3.47	3.63
	Uncultivated Desert	7	4.36	4.57	3.82	4.33	4.12	4.21

Figure 4 shows the spatial distribution of the electrical conductivity values of the soils of the study area as general rates up to a depth of 1 meter. It is noted that most of the soils of the western region fell within the second category, which represents moderately saline soils with a rate of 51.79% of the area of the study area (Table 7). The presence of salts in these the areas are due to the use of irrigation water with high salinity, accompanied by high rates of evaporation, which causes the accumulation of salts in the surface layer of the soil. The rain, despite its scarcity and the high permeability of the soil, contributed to maintaining the salt balance within the moderate limits in these areas, while the soils of the eastern region were distributed between the third and fourth classes, which represent high and very high salinity soils, with rates of 30.50 and 9.94% of the study area. For the two classes and according to the order, the reason for the high rates of salinity in these areas is mainly due to the proximity of the salty groundwater to the surface and the prevailing bad weather conditions represented by high evaporation rates, lack of rainfall, and the use of irrigation water of poor quality, as well as the nature of the soil of the region, which is characterized by the predominance of fine particles. And the decrease in the values of the water conductivity of the soil and the activity of the capillary property, which leads to the accumulation of salts, especially in the surface layer of the soil,

In addition, increases the difficulty of the washing process of the salts. It is noted that the soils of high salinity were concentrated in areas with soft-textured soils and low elevations relative to sea level, which are often devoid of agricultural activities and far from fresh water sources with their lack of drainage networks, as the movement and distribution of salts on the surface and within the soil sector reflects the prevailing conditions of balance. Water and depth of groundwater. Therefore, precipitation and evaporation along with the characteristics of the soil sector are important for the distribution of salts on the surface and within the soil sector. In general, the decrease in precipitation and the increase in evaporation-transpiration rates cause an increase in the salinity of the soil affected by salinity under the conditions of arid and semi-arid regions.

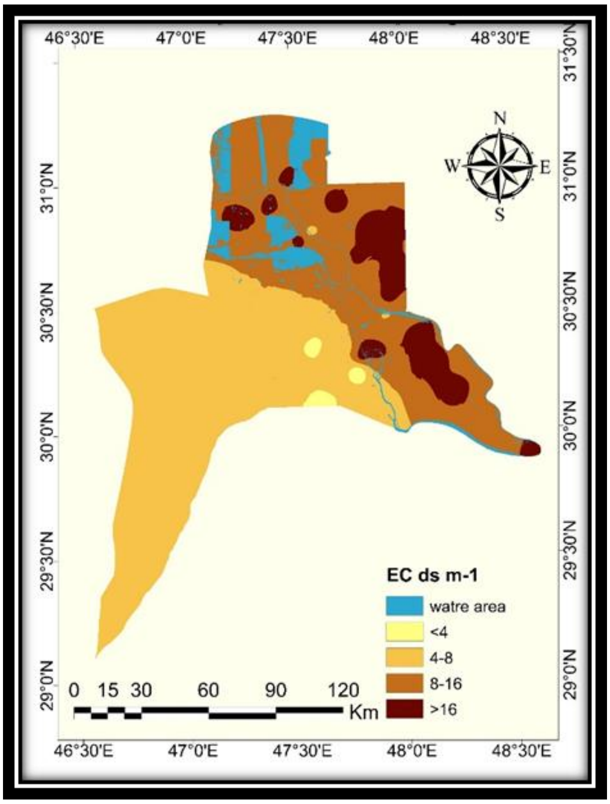

Figure 4. The spatial distribution of soil salinity classes in Basra Governorate according to its effect on plant growth

Table 7. weight of soil salinity classes with area and percentage of each class in the study area.

area %	area km^2	weight	EC ds m^{-1}	class
6.73	1283.41	-	-	water area
1.03	196.91	1	< 4	low
51.79	9877.20	1.5	4-8	moderate
30.50	5817.17	1.8	8-16	high
9.94	1895.31	2	> 16	very high

3-2-Variation in soil salinity during the period(2021-2000)

Figure 5 shows the spatial distribution of soil salinity in the study area during the period from 2000 to 2021, where it is noted from the figure 5 that most of the study area suffers from the problem of salinity and that there is a temporal and spatial variation in the electrical conductivity values, as it can be noted through Figure 5 and Table 8 The difference in the proportions of areas occupied by each variety in different seasons, as it tends to increase the area of soil with high salt concentration at the end of the dry season compared to the end of the rainy season. To reduce the salt concentration in the surface layers, especially in the western region of the study area, the table 8 clearly shows a decrease in the proportions of lands that suffer from severe and very severe salinization at the end of the rainy season, accompanied by an increase in the percentage of lands with low and medium salinization.

The percentage of lands that suffer from severe salinization at the end of the dry period was 48.76, 45.42, and 40.37% in the years 2000, 2013, and 2020, respectively, while the percentages decreased at the end of the rainy season to become 39.79, 30.58, and 32.44% of the study area during the years. 2001, 2014, and 2021, respectively. The percentage of lands suffering from medium salinization decreased from 50.69, 51.60, and 46.82, to become at the end of the rainy season 6.52, 12.12, and 8.78% of the study area during the same times and in the order, while an increase is noted. In the area of land that suffers from low salinity and moderately saline, the proportion of moderately saline lands was 50.81, 21.97 and 41.229 at the end of the rainy season in the years 2001, 2014 and 2021, respectively.After it was 0.50, 2.59, and 9.79% of the area of the study area at the end of the dry season and before the start of the rainy season for the same period, and when tracking the state of salinization during the studied period, we notice that there is a state of balance between the leaching and accumulation of salts in the surface layer of the soil. The high rates of salinization during the dry season are accompanied by the removal of salts from the surface layer during the rainy season, and the removal process depends largely on the amount of rainfall and because of the low rates of precipitation in the study area, the removal process is not complete, but a redistribution of these salts takes place within the soil sector Which leads to its accumulation again by the dry season. It seems that the leaching and desalting process is more effective in the western region, whose soils are characterized by coarse texture and high permeability, while the leaching process is less effective in the eastern region. Thus, we note that the study area suffers from a high percentage of land. Which suffers from severe and very severe salinization even during the rainy season, as is evident through the spatial distribution maps of soil salinity varieties (Figure 5).

Table 8. Percentage distribution of soil salinity during the period from 2000 to 2021 in the study area

dry season	9/2000		9/2013		9/2020	
EC $ds.m^{-1}$	km^2	%	km^2	%	km^2	%
<4	10.05	0.05	74.52	0.39	575.82	3.02
4-8	95.87	0.50	493.66	2.59	1866.06	9.79
8-16	9666.22	50.69	9839.44	51.60	8929.32	46.82
>16	9297.86	48.76	8662.38	45.42	7698.81	40.37
rainy season	4/2001		4/2014		4/2021	
EC $ds.m^{-1}$	km^2	%	km^2	%	km^2	%
<4	549.42	2.88	6737.61	35.33	3335.76	17.49
4-8	9688.55	50.81	4190.21	21.97	7873.26	41.29
8-16	1243.81	6.52	2310.44	12.12	1674.77	8.78
>16	7588.23	39.79	5831.74	30.58	6186.21	32.44

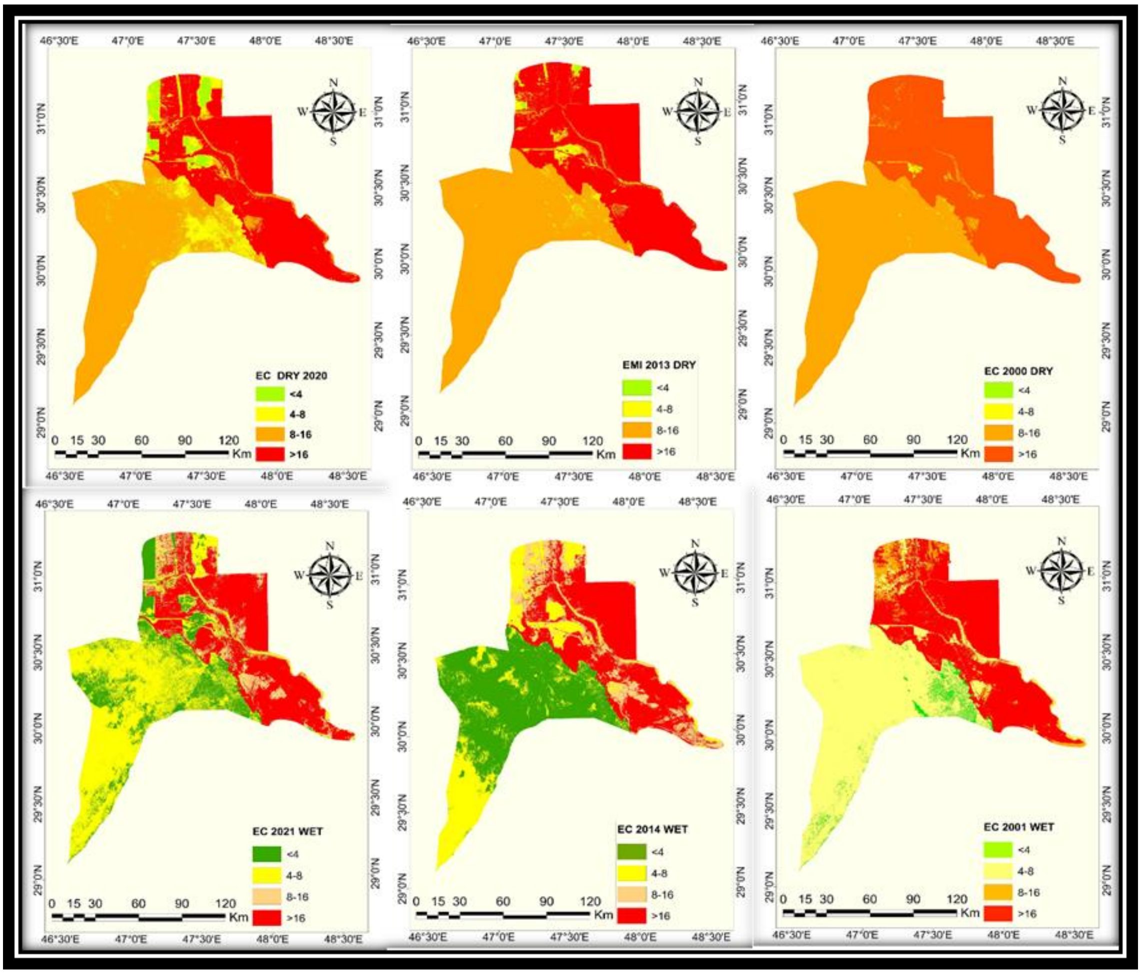

Figure 5. The spatial distribution of electrical conductivity classes of the surface soil layer in the study area during the period from 2000 to 2021.

4-Conclusions:

It can be concluded from the spatial distribution maps of soil salinity in the province of Basra that all the soils of the province of Basra suffer from the problem of salinity in varying degrees, which requires the mobilization of all possible capabilities to address this problem and reduce its effects on soil and plant growth.

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