NTU Journal of Agricultural and Veterinary Sciences (2025) 5 (4) : 369-376
DOI: https://doi.org/10.56286/737m9628

IRAQI Academic Scientific Journals

JAVS NTU

P-ISSN: 2788-9890 E-ISSN: 2788-9904
NTU Journal of Agricultural and Veterinary Sciences
Available online at: https://journals.ntu.edu.iq/index.php/NTU-JAVS/index

# Assessment and Preparation of Soil Salinity Maps for Some Agricultural Lands in Al-Sharqat City/Salahdin Using GIS."

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## Article Informations

**Received:** 25-12- 2024,
**Accepted:** 11-05-2025,
**Published online**: 28-12-2025

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**Key Words:**
arid lands, soil salinity, GIS (GIS), Soil (Aridisol) Soil (Entisol)

## A B S T R A C T

The study aims to assess soil salinity under the effect of groundwater and prepare spatial distribution maps of water characteristics, and water quality indices using a geographic information system. A total of 40 soil samples were collected from the surface layer at two different locations. The first location included 20 samples from the sedimentary soil unit, while the second location included 20 samples from the calcareous soil unit at wells sites. The samples were analyzed to determine the concentration of dissolved ions in the soil, such as calcium, magnesium, sodium, and potassium, as well as anions such as bicarbonate, chloride, and sulfate. Many soil salinity indices were calculated such as SAR (Sodium Adsorption Ratio), Na% (Sodium Percentage), PS (Potential Salinity), RSC (Residual Sodium Carbonate), TDS (Total Dissolved Solids), and ESP (Exchangeable Sodium Percentage). Spatial distribution maps were prepared using Inverse Weighting Distance (IWD) in ArcGIS software. The results showed that the concentrations of calcium and chloride were high at both locations, while the sodium levels were moderate. Additionally, the value of EC and TDS are high. The water quality in the study area has an effect over time on soil degradation.

## Introduction

Arid lands are environments that face major challenges in agriculture due to their limited fertility and soil salinity, which directly affects the ability of the land to support crops. Soil salinity is one of the main factors that limit agricultural productivity, as excess salts reduce the ability of plants to absorb water and essential nutrients, which leads to a decline in agricultural productivity.[1] [Among the main types of soil in dry areas we find soils. (Aridisol) and (Entisol), which present particular challenges due to soil salinity. (Aridisol) soils are arid soils that often contain salt accumulations due to low rainfall, making them difficult to use in agriculture without effective salinity management strategies. [2] (Entisol) soils are mostly clastic soils that lack fertility due to the absence of nutrient-rich substrate. [3]

The use of geographic information systems is considered (GIS) is an essential tool for assessing soil properties and analyzing soil salinity. Software such as ArcGIS provides

advanced capabilities for analyzing geographic data, allowing researchers to assess the spatial distribution of salinity across land, and thus accurately identify affected areas [4]. Soil salinity maps are a vital tool for guiding land reclamation strategies in arid regions, enhancing the sustainability of agricultural production in those areas.

Through remote sensing techniques, soil salinity levels in areas can be determined. (Aridisol) and (Entisol), which helps improve agricultural productivity in these lands [5] The study aims to study the impact of soil salinity on agriculture in arid lands, understand the challenges associated with it, and how soil salinity affects the ability of plants to absorb water and nutrients. The study also aims to use ArcGIS to create maps to assess soil salinity in arid and semi-arid lands, based on field and cognitive data, to improve land reclamation strategies and enhance the sustainability of agricultural production in these areas.

## Materials and working methods

**Study Area.** An exploratory survey of agricultural lands in Sharqat district was conducted, where two sites were identified to assess the salinity of soil under the effect of well water(table 1). The first site is located between longitudes (43° 18′ 0.00″ and 43° 20′ 0.00″) east, and latitudes (35° 24′ 0.00″ and 35° 22′ 0.00″) north, within the physiographic unit of the alluvial plain. The area is characterized by the cultivation of crops such as : Triticum aestivum Hordeum *vulgare* Zea mays Sesamum indicum Jatropha curcas The slope in the area ranges from flat to slightly, not exceeding 6 meters, with good soil fertility and a mixed alluvial texture. Calcium carbonate content prevails, and the soil is classified as "Torrifluvents".

The second site is between the longitudes (43° 24′ 30″ and 43° 29′ 30″) East, and latitudes (35° 25′ 30″ and 35° 23′ 30″) North. The area here is characterized by the cultivation of wheat and Zea maiz. The topography in this site ranges from flat to undulating, and the soil has a mixed sandy texture and strong structure, but is poor in fertility and is classified as a "Calcids" group. The area is located within the arid and semi-arid regions, where temperatures in summer reach about 50 degrees Celsius, which leads to burns on crops due to the high concentration of salts in the soil caused by the quality of well water.

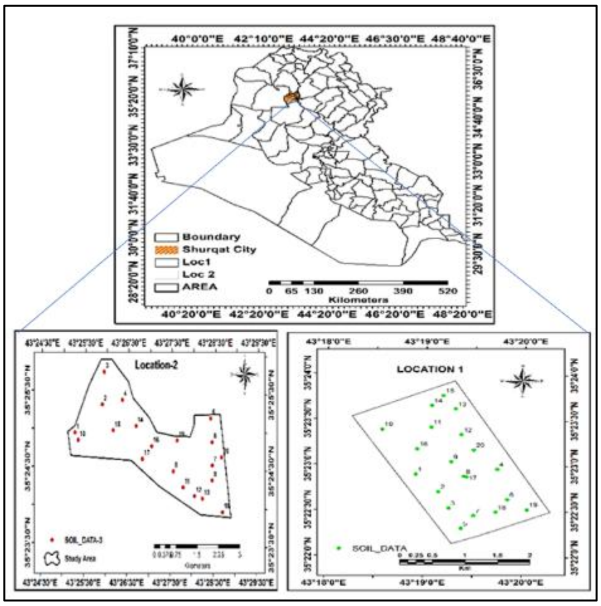


**Figure 1.** Maps of study sites.

Samples and laboratory procedures. 16 soil samples were obtained from the surface layer at the first site, while at the second site, and 13 samples representing the surface layer were collected, distributed as in Figure (1) on 11/5/2023. The samples were collected in polyethylene bags with a capacity of 2 kg for each sample, and the coordinates of the sites were determined using a device Garmin - GPS. After collecting the samples and fixing the information of each sample on the bags, they were transferred to the laboratory for qualitative analyses and tests, which included measuring the electrical conductivity using a conductivity meter in the saturated sample filter and measuring the degree of reaction (pH) using a pH meter. According to the method described before[6] for the dissolved positive ions, calcium and magnesium ions were estimated using the titration method. Sodium and potassium ions were estimated using a device. Flame photometer. Chloride was determined by precipitation with silver nitrate, while bicarbonate and carbonate were determined with 0.01 N sulfuric acid, phenolphthalein indicator, and methyl orange indicator.[7]. American Soil Salinity Laboratory Accredited USGS, (1954)And classification[8]To evaluate irrigation water for agricultural use.

**Soil salinity Quality Evaluation Criteria.**

The following mathematical equations were applied as folowing:

1- Total dissolved salts (TDS). Which is calculated after knowing the degree of electrical conductivity EC expressed in $dSm^{-1}$ as in the following equation [9]

$$TDS(Mgl^{-1}) = EC \times 640$$

2 – Sodium hazard(Na%). The values of (Na%) are calculated from the following equation [10].

$$Na\% = \frac{Na}{Ca + Mg + Na + K} \times 100$$

3- Sodium adsorption rate (SAR) [6]

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

5-Exchangeable Sodium Percentage (ESP) [6]

$$\text{ESP} = \frac{100 \times (-0.0126 + 0.01475\ \text{SAR}}{1 + (-0.0126 + 0.01475\ \text{SAR})}$$

6-Potential Salinity. Calculated according to the following equation proposed by[11]. The values (15-20), (7-15) and (3-7) meq $l^{-1}$ were considered suitable for soils with good, medium and low permeability, respectively.

$$\text{PS}(\text{Meq/L}) = CL + \frac{1}{2} \times \text{SO4}$$

7- Magnesium Hazard(MH):It is calculated from the following equation[6]:

$$Mg\% = \frac{Mg}{Ca + Mg} \times 100$$

## Results and discussion

**Electrical conductivity (EC)**

The results of Table (2) indicate the variation of soil samples in the degree of electrical conductivity expressed in $dSm^{-1}$, which is an important indicator of the state of soil degradation and desertification. Through the results of descriptive statistics, we note that the conductivity values of soil samples for the first path were 3.55-15.33 $dSm^{-1}$, with an average of 9.10 dS $m^{-1}$, and the standard error value reached 3.95, with a coefficient of variation of CV 43.41%. As for the second path, it ranged between 3.30 - 12.50 with an average of 6.40 and the standard error value was 2.64 with a coefficient of variation of 41.26. We note that the salinity levels in the sedimentary soil unit are higher than the calcareous soil unit, perhaps due to the proximity of groundwater to the surface in the first location and with the help of high temperatures in the summer month and high evaporation.

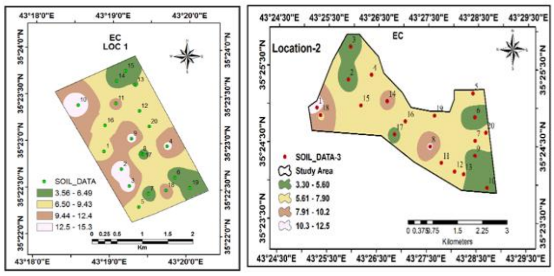


**Figure 2.** Spatial distribution map of electrical conductivity

**pH**

The results of the interaction degree indicate(pH) of the soil solution in Table (2) shows noticeable differences between the first and second paths, reflecting the diversity of soil properties according to their classification. In the first path, which belongs to the order of newly formed soils (Entisol), the pH values ranged between 6.55 and 8, with an average of 7.57, indicating moderate to basic soil. The standard error value of 0.39 and the coefficient of variation of 5.1% also show that there is variability in the values, which may be related to changes in organic matter or mineral deposits. In the second track, which belongs to the dry soil order (Aridisol), the pH values ranged between 7.70 and 8.25, at a rate of 7.97, indicating basic soil. The high pH in these areas was due to environmental factors such as calcium carbonate. However, the standard error (0.17) and dispersion coefficient (1.19%)

values were lower, reflecting greater homogeneity in pH compared to the newly formed soil (Entisol) [12].

**Calcium and magnesium.** The calcium ion concentrations in the sedimentary soil samples ranged from 12.00 to 56.00 meq $l^{-1}$, with a mean of 32.24, with a standard deviation of 13.30 and a coefficient of dispersion of 41.24%. At the second site, the values ranged from 7.00 to 63.00 meq $l^{-1}$, with a mean of 26.23 meq $l^{-1}$, with a standard error of 15.01 and a coefficient of variation of 57.23%. This variability is due to the dominant parent rocks in the sites, which are a major source of calcium, as indicated by [13]. As for the magnesium ion concentration, the values ranged from 10.00 to 41.00 meq $l^{-1}$, with an average of 25.25 meq $l^{-1}$, with a standard deviation of 9.63 and a coefficient of dispersion of 38.14%. At the second site, the values ranged from 7.00 to 36.00 meq $l^{-1}$, with an average of 21.62 meq $l^{-1}$, with a standard error of 7.85 and a coefficient of variation of 36.31% [14].

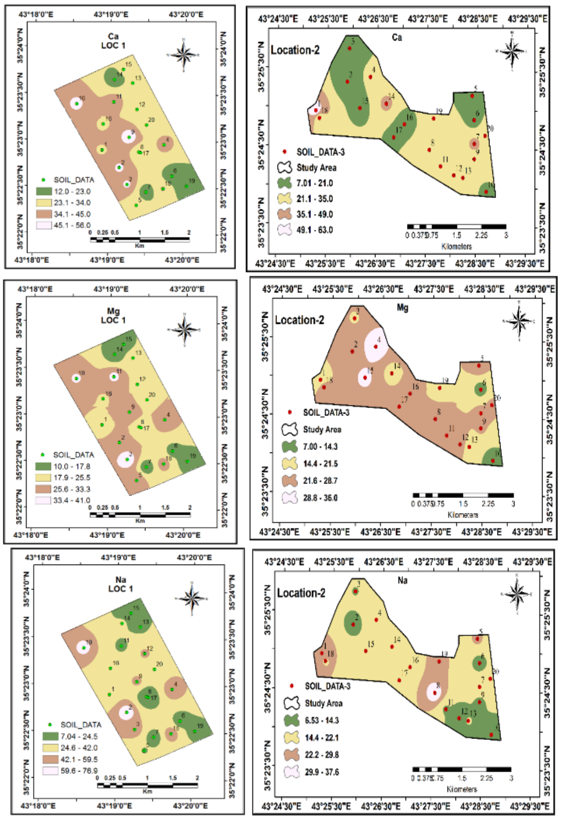


**Figure 3.** Spatial distribution of positive ionsof the study area.

Sodium Na+. Sodium is one of the most dangerous ions affecting the chemical composition of the soil, which is reflected in the condition and health of the plant and the soil physical deterioration of the soil. Chemically. The sodium ion concentration ranged from 7.00 to 77.00 with an average of 33.66 meq l-1, and the standard deviation value was 21.11 with a dispersion coefficient of 62.71%. As for the second site, the sodium concentration ranged from 6.52 to 37.61 with an average of 17.20 a standard error value of 8.51, and a coefficient of variation of 49.49%. This wide variation is related to the quality of irrigation water in the study sites, which is a source of sodium and releases high amounts of it into the soil.

Potassium. The results of Table (2) showed that the concentration of potassium ions at the first site ranged between 0.28 to 6.80 meq l-1. According to the dispersion coefficient, it was observed that the soil samples had a dispersion coefficient of 122.84% with a standard error of 2.16. This is due to the variations in the rock material and geological formations

, which are the main storehouse of nutrients and their dissolved quantity in water. Second site, the concentration of potassium ranged between 0.07 and 1.70 meq $l^{-1}$. According to the dispersion coefficient, it was observed that the soil samples had a dispersion coefficient of 57.91 with a standard error of 0.43. The main reason for the variation in potassium values is the type of rocks.

**Chloride.** The results of Figure (4) indicate a large variation in chloride content between the first and second sites. In the first site, chloride values ranged between 14.10 and 86.83 meq $l^{-1}$, with a dispersion coefficient of 62.91% and standard deviation of 25.96, indicating a large variation in concentration due to several environmental factors [15]. At the second site, values ranged from 12.60 to 50.60 meq $l^{-1}$, with a dispersion coefficient of 48.16% and standard deviation of 10.17, reflecting a more homogeneous distribution of salinity compared to the first site [16]. Overall, the first site shows greater variation in chloride levels, while the second site shows greater stability in chloride content(Table 2).

**Sulfates $SO_4$.** The results of Table (2) and Figure (4) showed that the soil sulfate content in the first site ranged from 17.38 to 65.64 meq $l^{-1}$ and the dispersion coefficient value was 40.52% with a standard deviation of 17.06, which confirms the existence of high dispersion in the values and distribution of sulfates in the study area. As for the second site, the sulfate values ranged from 18.40 to 88.32 meq $l^{-1}$ and the dispersion coefficient value was 44.77 with a standard deviation of 18.22. Therefore, the distribution of sulfates is somewhat homogeneous in this site. Compared to the classification criteria, most of the samples in the study area were within the impermissible limits, which required the use of good management methods to reduce the impact of sulfates.

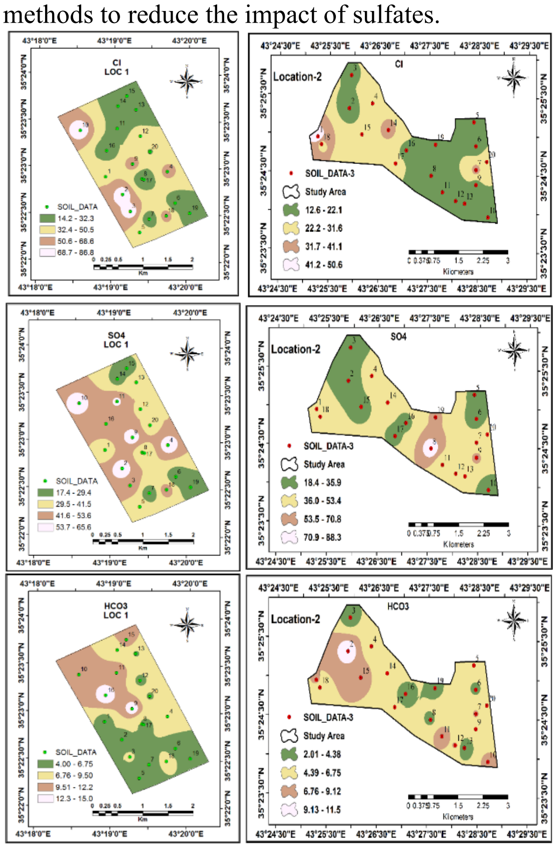


**Figure 4.** Spatial distribution of negative ions the soils of the study area.

**Bicarbonate HCO3.** The results of the figure indicate (4). There was a variation in the concentration of bicarbonate in the soil between the first and second sites, reflecting a difference in the chemical properties of the soil at each site. At the first site, the bicarbonate concentration values ranged between 4.00and 15.00 meq $l^{-1}$, with a dispersion coefficient of 41.87% and a standard deviation of 3.45. This variance reflects the effect of the lime content in the soil, as high lime content in the soil often contributes to an increase in bicarbonate concentration, due to chemical reactions that occur between lime and groundwater or dissolved salts. As for the second site, the bicarbonate concentration values ranged between 2.00 and 11.50 meq $l^{-1}$, with a dispersion coefficient of 43.80% and a standard deviation of 2.56. Although the concentration of bicarbonate at the second site is generally lower compared to the first site, the dispersion coefficient at the second site is close to the first site, indicating a similar variation in the distribution. This variation may be due to geographical factors or the chemical composition of the soil(Table 2).

**Sodium adsorption ratio (SAR).** The results of the study indicate a large variation in SAR values between sites. At the first site, SAR values ranged from 1.30 to 12.49, in the first site with a dispersion coefficient of 50.90 %, indicating a large variation in the effects of sodium. While at the second site, values ranged from 1.29 to 6.81, with a dispersion coefficient of 39.99, reflecting greater stability. The large variation in SAR at the first site may indicate potential negative effects on the soil due to sodium accumulation. SAR is a vital indicator in assessing the effect of salinity in soil properties, as it reflects the ratio of sodium to calcium and magnesium in the soil solution(Figure 5; Table 3)

**ESP**. The results of Table (3) and Figure (5) indicate a clear variation in the exchanged sodium ratio between the different sites. In the first site, the exchanged sodium value ranged between 0.65 and 14.65, with a dispersion coefficient of CV was 55.23 and standard deviation was 0.11. This large variation reflects a significant effect of exchangeable sodium on the soil, as a higher ratio indicates a higher concentration of sodium compared to calcium and magnesium, which can lead to soil degradation and reduced permeability and water retention capacity. At the second site, exchangeable sodium ranged from 0.64 to 8.08, with a dispersion coefficient of 50.38 and standard deviation of 1.89. The variation here is lower than at the first site, indicating greater stability in soil sodium content. Although the variation is lower, the correlation between ESP and SAR is not mentioned in the sources, which may indicate the absence of specific criteria for this value in previous studies. In general, the first site shows greater variation in exchangeable sodium ratios, which may pose challenges in water and soil management, while the second site reflects relative stability, but without specific criteria for comparison.

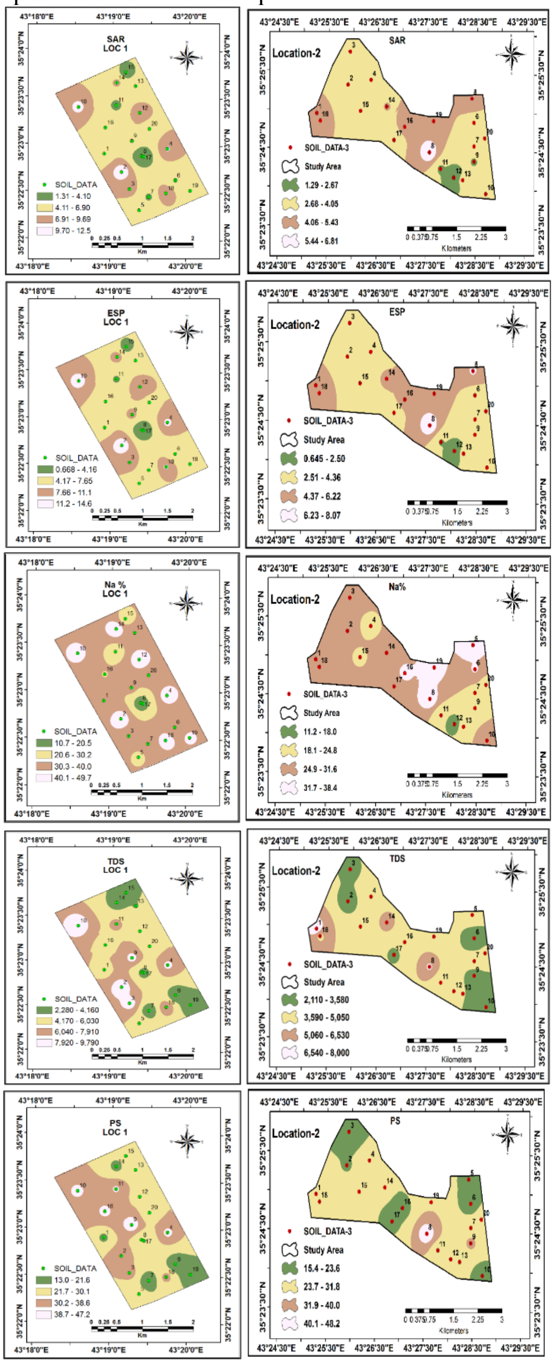

**Figure 5.** shows the spatial distribution of soil quality parametersin study area.

**Sodium hazard (Na%).** The results of Figure (5) and Table (3)indicate a variation in the risk ratio of sodium.(Na%) between the two sites. At the first site, the ratio ranged from 10.64% to 49.74%, with a dispersion coefficient of 30.99% and a standard deviation of 10.74, reflecting a large variation in the distribution of sodium in the soil, indicating an irregular effect that may lead to soil degradation. At the second site, the ratio ranged from 11.19% to 38.44%, with a dispersion coefficient of 29.39% and a standard deviation of 7.68, indicating greater stability in sodium levels compared to the first site. However, there remains a risk of sodium affecting the soil if accumulation continues at both sites.

**Total dissolved salt TDS.** The results of Figure (5) indicate a variation in total dissolved salts between the two sites. In the first site, the values ranged between 2272.00 and 9792.00 with a standard deviation of 2527.73 and a dispersion coefficient of 43.41, reflecting a large variation in the concentration of dissolved salts in the soil. As for the second site, the values ranged between 2112.00 and 8000.00 with a standard deviation of 1691.19 and a dispersion coefficient of 41.26, indicating less variation compared to the first site. This variation in salt concentration can affect the soil properties and quality in both sites..

**Potential salinity.** The results of Table (3) and Figure (5) indicate a variation in the percentage of PS between the two sites. At the first site, the ratio ranged from 24.29% as the lowest value to 74.76% as the highest value, with a dispersion coefficient of 29.12 and a standard deviation of 14.58, reflecting a large variation in the PS ratio and its effect on the soil, especially with the high sodium ratio compared to calcium and magnesium.

In contrast, at the second site, the ratio ranged from 26.98% to 48.96%, with a dispersion coefficient of 18.83 and a standard deviation of 7.28, indicating greater stability in the soil compared to the first site. From these results, it is clear that the first site has higher PS values and greater variation than the second site, which may indicate a greater effect of sodium on the soil at the first site.

Magnesium Hazard. Figure (5) shows a variation in the magnesium hazard ratio between the two sites. In the first site, the ratio ranged between 34.21% and 53.85%, with a dispersion coefficient of 12.89 and a standard deviation of 5.70, reflecting a relative stability in the effect of magnesium on the soil. The overall average of the magnesium hazard ratio was 44.21%. As for the second site, the ratio ranged between 19.23% and 78.13%, with a dispersion coefficient of 35.52 and a standard deviation of 16.79, indicating a greater variation in the effect of magnesium on the soil. The overall average in the second site was 47.29%. Based on these results, it is clear that the second site shows a greater variation in magnesium hazard ratio than the first site, which may indicate more variable effects on magnesium availability in the soil.

## Conclusions

1. In the first track, the soil was more saline with electrical conductivity ranging from 3.55 to 15.33 dS/m, with apH ranging from 6.55 to 8.00 (moderate to basic). In the second track, salinity was significantly lower, and the soil was basic to alkaline due to high levels of calcium carbonate.
2. The first track recorded higher concentrations of sodium, calcium, potassium, chloride, and sulfate, reflecting the influence of groundwater, while these elements were lower in the second track.
3. The first track showed a large variation in the concentration of chloride ions (14.10 - 86.83 mEq.L-1) and SAR (1.30 and 12.49), indicating a risk of soil

degradation. In contrast, these indicators were more stable in the second track.

1. The first track ranged TDS between 2272.00 and 9792.00, reflecting variation in salt accumulation. While TDS in the second track was lower, indicating greater stability in the chemical composition of the soil.

## Recommendations

The study recommends careful water management in sites affected by high concentrations of dissolved salts. Especially in the first site, where a large variation in these indicators was observed. Effective irrigation techniques such as drip irrigation should be applied to reduce salt accumulation, in addition to improving soil properties using amendments such as organic fertilizers. It is also advisable to continuously monitor indicators such as SAR And the percentage of sodium exchange to ensure the stability of soil properties and prevent soil degradation. In the second site, although the indicators are stable, the magnesium risk should be monitored to improve the balance of nutrients. In general, the situation requires implementing careful management strategies to reduce the effects of salinization and desertification and ensure the sustainability of soil fertility.

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**Table 1.** Statistical criteria for properties of irrigation water quality.

| Statistical | pH | EC dSm$^{-1}$ | Ca | Mg | Na | K Meq l$^{-1}$ | $HCO_3$ | Cl | $SO_4$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Location-1 | | | | | |
| Min | 6.60 | 3.80 | 22.50 | 7.50 | 9.70 | 0.06 | 2.30 | 6.75 | 26.57 |
| Max | 7.20 | 10.00 | 67.50 | 28.00 | 23.39 | 0.27 | 8.20 | 33.00 | 64.03 |
| Mean | 7.01 | 6.27 | 35.38 | z14.92 | 14.35 | 0.17 | 5.43 | 18.33 | 41.05 |
| Std | 0.19 | 2.13 | 13.65 | 6.55 | 4.74 | 0.07 | 1.79 | 7.80 | 13.02 |
| CV % | 2.70 | 34.04 | 38.59 | 43.86 | 33.04 | 42.48 | 32.97 | 42.56 | 31.72 |
| | | | | Location-2 | | | | | |
| Min | 6.20 | 4.20 | 19.00 | 8.00 | 9.43 | 0.11 | 2.10 | 8.25 | 30.60 |
| Max | 6.90 | 7.70 | 43.00 | 21.00 | 15.78 | 0.22 | 7.50 | 25.50 | 45.18 |
| Mean | 6.60 | 5.70 | 32.25 | 12.68 | 12.58 | 0.15 | 5.18 | 16.91 | 35.56 |
| Std | 0.21 | 1.10 | 7.41 | 4.39 | 1.99 | 0.04 | 1.90 | 6.31 | 4.40 |
| CV% | 3.25 | 19.22 | 22.98 | 34.61 | 15.83 | 25.02 | 36.74 | 37.29 | 12.36 |

**Table 2.** Statistical criteria for dissolved ions in the soils of the study area.

| Stat. | pH | EC dsm | Ca | Mg | Na | K meq l$^{-1}$ | $HCO_3$ | Cl | SO4 |
|---|---|---|---|---|---|---|---|---|---|
| | | | Location 1 | | | | | | |
| Min | 6.55 | 3.55 | 12.00 | 10.00 | 7.00 | 0.28 | 4.00 | 14.10 | 17.38 |
| Max | 7.95 | 15.30 | 56.00 | 41.00 | 77.00 | 1.80 | 15.00 | 86.83 | 65.64 |
| Mean | 7.57 | 9.10 | 32.25 | 25.25 | 33.66 | 0.95 | 8.25 | 41.26 | 42.09 |
| Std | 0.39 | 3.95 | 13.30 | 9.63 | 21.11 | 0.47 | 3.45 | 25.96 | 17.06 |
| CV% | 0.05 | 0.43 | 0.41 | 0.38 | 0.63 | 0.50 | 0.42 | 0.63 | 0.41 |
| | | | Location 2 | | | | | | |
| Min | 7.70 | 3.30 | 7.00 | 7.00 | 6.52 | 0.07 | 2.00 | 12.60 | 18.40 |
| Max | 8.25 | 12.50 | 63.00 | 36.00 | 37.61 | 1.70 | 11.50 | 50.60 | 88.32 |
| Mean | 7.97 | 6.40 | 26.23 | 21.62 | 17.20 | 0.74 | 5.85 | 22.25 | 40.70 |
| Std | 0.17 | 2.64 | 15.01 | 7.85 | 8.51 | 0.43 | 2.56 | 10.71 | 18.22 |
| CV% | 2.19 | 41.26 | 57.23 | 36.31 | 49.49 | 57.91 | 43.80 | 48.16 | 44.77 |

**Table 3.** Descriptive statistical of soil salinity criteria in the study sites.

| Stat. | TDS | PS | SAR | Na% | ESP | (MH) |
|---|---|---|---|---|---|---|
| | | | Location 1 | | | |
| Min | 2272.00 | 12.99 | 1.30 | 10.64 | 0.65 | 34.21 |
| Max | 9792.00 | 47.20 | 12.49 | 49.74 | 14.65 | 53.85 |
| Mean | 5822.40 | 29.30 | 6.15 | 34.65 | 7.09 | 44.21 |
| Std | 2527.73 | 10.56 | 3.13 | 10.74 | 3.92 | 5.70 |
| CV% | 43.41 | 36.04 | 50.90 | 30.99 | 55.23 | 12.89 |
| | | | Location 2 | | | |
| Min | 2112.00 | 15.36 | 1.29 | 11.19 | 0.64 | 19.23 |
| Max | 8000.00 | 48.16 | 6.81 | 38.44 | 8.08 | 78.13 |
| Mean | 4098.46 | 26.20 | 3.53 | 26.16 | 3.76 | 47.26 |
| Std | 1691.19 | 8.54 | 1.41 | 7.68 | 1.89 | 16.79 |
| CV% | 41.26 | 32.60 | 39.99 | 29.37 | 50.38 | 35.52 |