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Spatial Analysis of the Natural Environmental Factors Affecting the Increase in Soil Salinity

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Abstract

This research analyzes natural environmental factors affecting soil salinity in Al-Qadisiyah, Najaf, Iraq. Using ArcMap 10.6. Key influences, including geological structures, topography, climate, and water quality are examined. Soil and water samples were assessed for pH, electrical conductivity (EC), total dissolved solids (TDS), and ion concentrations. Results showed that EC values ranged from 0.69 to 1.9 Siemens/cm, and TDS values varied from 441.6 to 1216 mg/L, with several sites exceeding the irrigation suitability limits set by the FAO. Alkalinity (HCO_3^-) levels were also evaluated, with values ranging from 126 to 194 mg/L across different locations. pH levels varied significantly, from 7.1 to 8.15, influenced by agricultural runoff and waste. Statistical analysis indicated weak positive correlations (between temperature and EC, $r = 0.12$) and some inverse relationships, such as between temperature and Na^+ concentration ($r = -0.38$), suggesting that high temperatures intensify salinity by increasing evaporation. The results reveal that flat terrain and poor drainage further enhance salt accumulation, making most local water sources unsuitable for irrigation and challenging sustainable agriculture in the region.

Keywords: Geographical phenomenon; Natural factors; Human factors; Topography; Climatic characteristics

1. Introduction

The geographical characteristics in Al-Qadisiyah sub-district are the natural and human characteristics that characterize the region. This section includes the study of the geographical characteristics affecting soil pollution with salts in the study area, represented by the natural characteristics (geological structure, surface characteristics, climatic characteristics, water resources, and soil characteristics) (Almudhafar *et al.,* 2020; Abdil-Ameer *et al.,* 2022). The research problem can be identified by the following question: What is the impact of natural characteristics on the increase of saline elements in the study area? The hypothesis of the study is that natural geographical factors have an impact on the increase of saline elements. The research aims to clarify the impact of natural environmental factors on the high or low salinity of the soil in Al-Qadisiyah, by analyzing and studying the potential factors that affect the level of soil salinity in the study area. The primary objective of this study is to analyze the spatial distribution of natural environmental factors influencing soil salinity in Al-Qadisiyah, Iraq. This research aims to integrate a combination of climatic, topographical, and geological data to better understand how these factors contribute to salinity accumulation. The novelty of this study lies in its comprehensive approach, utilizing advanced spatial analysis techniques to assess a region particularly vulnerable to salinity due to its flat terrain, high temperatures, and limited drainage. Expected outcomes include identifying the primary environmental drivers of soil salinity, assessing water source suitability for irrigation, and providing actionable insights to support sustainable agricultural practices in arid regions affected by salinization. Soil is defined as the crumbling surface layer of the earth's crust, which ranges in depth from several centimeters to several meters, and is a mixture of rocky and organic materials, water and air in which the plant grows and from which it derives its food and on which animals live and on both depends man what needs (Almudhafar *et al.,* 2023a; Almudhafar *et al.,* 2023b). It is defined as the upper layer of the Earth's atmosphere, which originated and developed from the influence of other atmospheres, such as the atmosphere, the hydrosphere and the biosphere, on the rocks and minerals that make up the lithosphere (Hassan *et al.,* 2024; Abdel Wahhab *et al.,* 2023). It is also known as the direct product of weathering processes of various forms, after which natural and human influences are affected from the stages of their derivation from rocks to the late stages of their formation (Almudhafar *et al.,* 2024; Abyss *et al.,* 2022). Salt is the natural element of soil and water. The ions responsible for salinization are sodium, potassium, calcium, magnesium and chlorine. Over time, soil minerals with weathering factors release these salts and then flow or precipitate to the surface of the soil with water (Al-Jashaami *et al.,* 2024a; Almudhafar *et al.,* 2023c). It is the soil that contains a high percentage of salts that are easy to dissolve and concentrated around the roots of plants so that they negatively affect the growth of agricultural crops (Al-Jashaami *et al.,* 2024b; Almudhafar *et al.,* 2023d). The natural characteristics in Al-Qadisiyah have an impact on the natural environment. These characteristics include the geological structure, surface manifestations, and climate characteristics, as well as the characteristics of water resources and surface manifestations. These characteristics produce geological and climatic processes, and it is noted that each affect and is affected by the other.

This study addresses soil salinity because it significantly impacts agricultural productivity and environmental health, especially in regions like Al-Qadisiyah where agriculture is crucial. Soil salinity affects soil quality by accumulating salts that harm crop growth, decrease soil fertility, and reduce water availability for plants, resulting in lower crop yields and economic losses. By analyzing natural factors such as climate, topography, and water quality, this research identifies key contributors to soil salinity and informs better land management practices. The study benefits people by offering insights to improve agricultural sustainability, enabling farmers to adopt practices that minimize salinity-related losses. Moreover, it assists policymakers in formulating strategies to manage and reclaim salt-affected soils, supporting food security and economic resilience for communities that rely on agriculture.

This study utilized a combination of spatial analysis tools, field observations, and laboratory analysis to investigate the environmental factors influencing soil salinity in Al-Qadisiyah, Iraq.

2. Methodology

2.1 Study Area Description

Al-Qadisiyah is located in the southern part of Al-Manathirah district in Najaf governorate, as it is located between two latitudes (31.33 - 31.48 north), and between two longitudes (44.21 - 44.33 east), and 50 kilometers south of Najaf governorate. It is bordered to the north by Mishkab district, Al-Hira sub-district, to the south by Al-Shanafiyah sub-district, to the east by Ghammas, and to the west by Saudi Arabia (Khalid *et al.,* 2023; Noor *et al.,* 2023). The area of the study area is 296.51 square kilometers (Figure 1). The maps were created using ArcMap 10.6 software. The study reveals that Al-Qadisiyah's flat terrain and low regressions, along with high temperatures, minimal rainfall, and intense evaporation, contribute to increased soil salinity. Wind-driven salt deposition and poor drainage further exacerbate this issue. Irrigation using groundwater and surface water with high salt content worsens soil conditions, severely affecting agricultural productivity. Spatial analysis using ArcMap highlights the strong link between geography, climate, and water resources in driving soil salinity. The findings indicate that most local water sources are unsuitable for irrigation, posing challenges to sustainable agriculture.

The research area, covering 296.51 square kilometers, is located in the southern part of the Al-Manathirah district, within the geographical coordinates of 31.33 - 31.48° N and 44.21 - 44.33° E.

2.2 Sampling and Data Collection

In this study, sampling was essential to understand the distribution of soil salinity across Al-Qadisiyah. Samples were taken from various locations, including surface water sources, groundwater, and drainage channels in December, which represents the winter season. This timing was selected because water levels are typically lower in winter, allowing for more precise measurements of salinity levels with minimal dilution from rainfall or seasonal irrigation flows.

The sampling strategy aimed to capture variations in salinity influenced by environmental factors like temperature, evaporation, and the type of water used for irrigation. Each sample site was carefully chosen to reflect areas exposed to different natural and agricultural influences. By analyzing these samples, the study aimed to understand how salinity is distributed across the landscape and identify areas where salt accumulation is particularly high.

2.3 Experimental Design and Chemical Analyses

The experimental design was established to accurately measure various ion concentrations and salinity-related parameters in water samples from the Al-Qadisiyah region. Key devices used include the pH meter for measuring pH levels, calibrated with standard buffer solutions (pH 4.0, 7.0, and 10.0). Senso Direct EC meter was employed to measure electrical conductivity (EC), indicating the salinity of samples. Sodium (Na^+) and potassium (K^+) concentrations were measured using a Flame Photometer (model 2010), which operates on the flame emission principle; samples were placed under the device's probe in 200 mL beakers, and concentrations were read

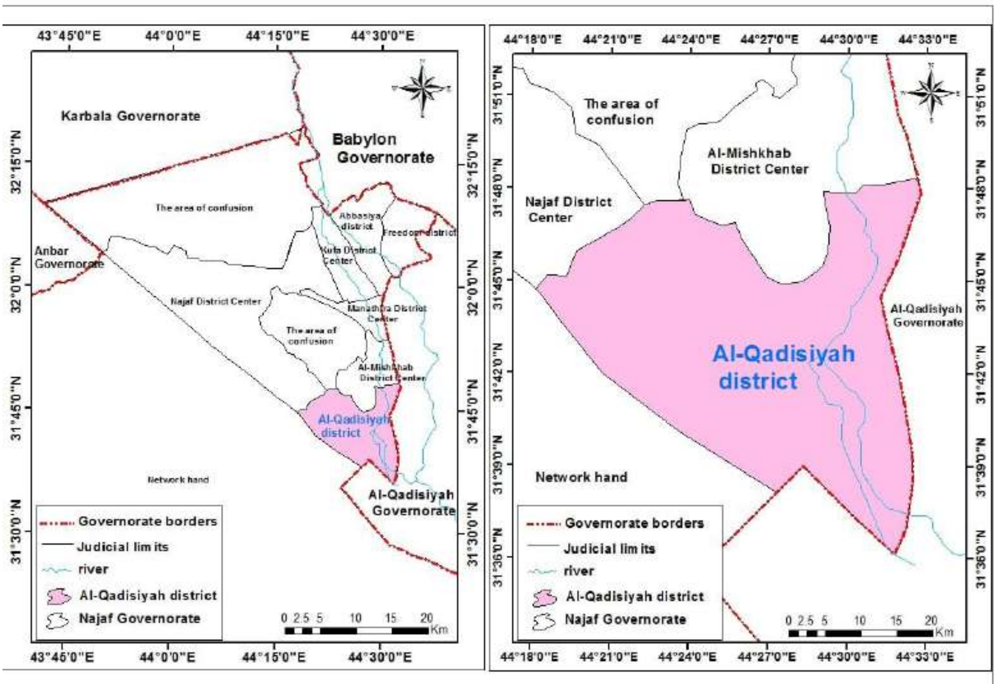

Figure 1. Study area

directly in mg/L. For magnesium ion (Mg^{2+}), concentrations were derived by measuring calcium ion (Ca^{2+}) and subtracting it from total calcium-magnesium content using EDTA titration. This method involved mixing 5 mL of the sample with 20 mL of distilled water and 10 mL of buffer solution. After adding four drops of Eriocrom Black T indicator, the sample was titrated with 0.01 M EDTA until a blue-green color change, with results expressed in mg/L. For sulfate ions (SO_4^{2-}), 2 mL of N1 sulfuric acid was added to 25 mL of the sample, followed by 2 mL of 25% barium chloride solution. After adding 100 mL of distilled water, a white precipitate formed, which, after 45 minutes, was measured using a spectrophotometer, with results in mg/L. Chloride ions (Cl^-) were measured using a titration method with 5% silver nitrate ($AgNO_3$) as the titrant and potassium chromate (K_2CrO_4) as the indicator. In a 200 mL beaker, 5 mL of sample and 20 mL of distilled water were mixed with 10 mL of K_2CrO_4. Titration with $AgNO_3$ continued until the sample turned from yellow to red, with the chloride concentration calculated by multiplying the titrant volume by its normality, then dividing by sample volume and multiplying by 1000 to obtain results in mg/L. Bicarbonate (HCO_3^-) concentration was determined through titration with standard hydrochloric acid (HCl) solution. Thirty mL of the sample was placed in a 500 mL beaker, and diluted HCl was gradually added until the pH dropped below 4, recorded using a Strater Ohaus pH meter. The HCO_3^- concentration was calculated by multiplying the volume of HCl used by its normality, dividing by the sample volume, and multiplying by 1000, with results expressed in mg/L. TDS was calculated by measuring the weight of solids remaining after the evaporation of a known volume of water. This parameter gives an indication of the total concentration of dissolved salts. Using ArcMap 10.6 software, a series of maps was created to analyze topographical, geological, and environmental factors. Elevation, slope, and drainage data were utilized to assess how terrain and water flow influence soil salinity distribution. The geological structure of the study area was examined using geological maps and field observations. The region's surface characteristics, including topography and slope categories, were analyzed. Climatic data, including temperature, rainfall, wind speed, humidity, and evaporation rates, were obtained from local meteorological stations. These factors were analyzed to understand their impact on soil moisture levels and the rate of salt accumulation. Theoretical and actual sunlight hours were also considered, as solar radiation plays a key role in evaporation and soil drying. Spatial distribution maps were used to highlight areas of varying salinity levels and to correlate these with environmental factors like slope, drainage patterns, and irrigation sources. The study also analyzed the irrigation practices in the region, focusing on the sources and quality of water used. Data on the length and capacity of irrigation channels were gathered to understand the extent of water use and its role in soil salinity. The drainage capacity of soils was also evaluated to assess how it influences the accumulation of salts in agricultural areas. By integrating geological, topographical, climatic, and irrigation data, this study provides a comprehensive understanding of the natural factors contributing to soil salinity in Al-Qadisiyah.

2.4 Statistical Analysis

Statistical analysis was conducted to identify correlations between environmental factors and salinity levels. This included calculating correlation coefficients between temperature, evaporation rates, and ion concentrations, enabling the assessment of seasonal variations in soil and water salinity.

3. Results and Discussion

3.1 Geological Structure and Soil Formation and Topographical Influence on Soil Salinity

The geological structure plays a crucial role in shaping the characteristics of any region by revealing the type, composition, and movement of existing rocks, which are influenced by the area's geological history. This structure determines the topography and contributes to soil formation through processes like erosion, decomposition, and transport. Al-Qadisiyah region is part of the Holocene era, with its deposits mainly resulting from Euphrates River floods, which left layers of silt, clay, and rock fragments. These deposits, spread across the region, include weathering products like clay, silt, and sand, along with salt crystallization after evaporation (Figure 2).

The southwestern parts of the study area feature gently sloping terrain, where deposits of mud, silt, sand, and variously sized rocks are found. These materials, sourced from nearby highlands and transported by water or wind, cover small areas and consist mostly of limestone and clay. In the northwestern parts, wind-driven sedimentation impacts the characteristics of groundwater and surface water, contributing to increased salt concentrations. Porous and permeable rock formations allow wind to carry fine particles, soil, and salts from dry regions, depositing them in the area. This process raises groundwater salinity levels as salts infiltrate through the soil. The study area's surface is largely flat, as it lies within a sedimentary plain, with few significant elevations. Figure 3 shows that the highest point in the area reaches about 45 meters above sea level, while the lowest is around 15 meters. The northern and northwestern parts are the highest, and surface conditions influence soil thickness and drainage capacity. Steeper slopes hinder proper water retention, increasing the risk of soil erosion and leading to drought. This evaporation of water from the soil surface under high heat concentrates salts, causing them to rise from deeper layers.

Figure 4 illustrates the area's slope categories: low (0.5), medium (1.5), and very steep (2.5), which impact water flow, soil erosion, and overall salinity.

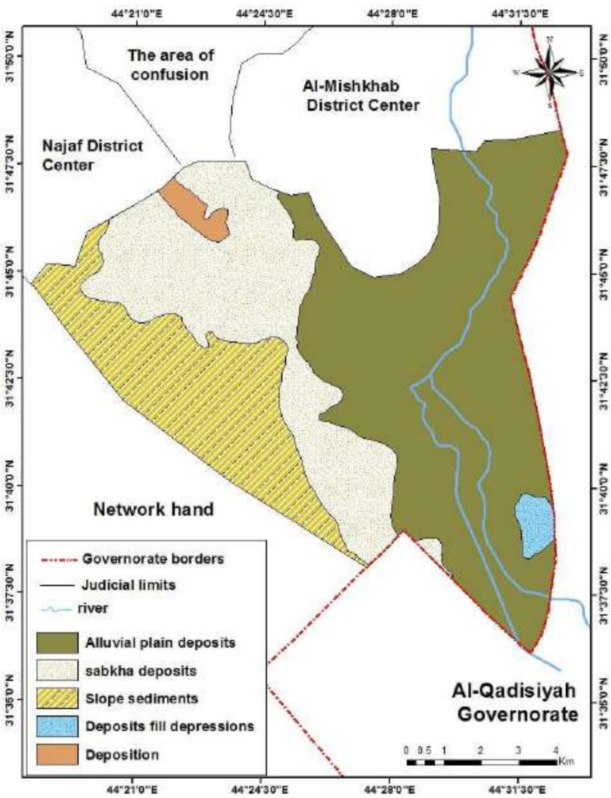

Figure 2. Geological Study Area

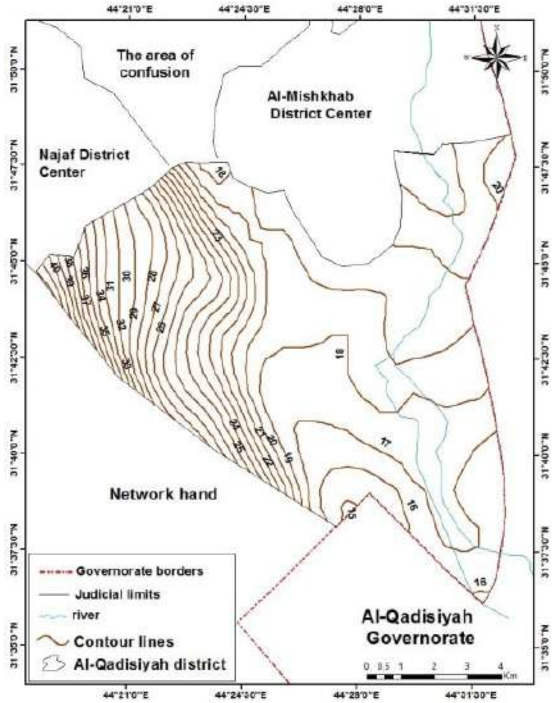

Figure 3. Variation in elevations in the region

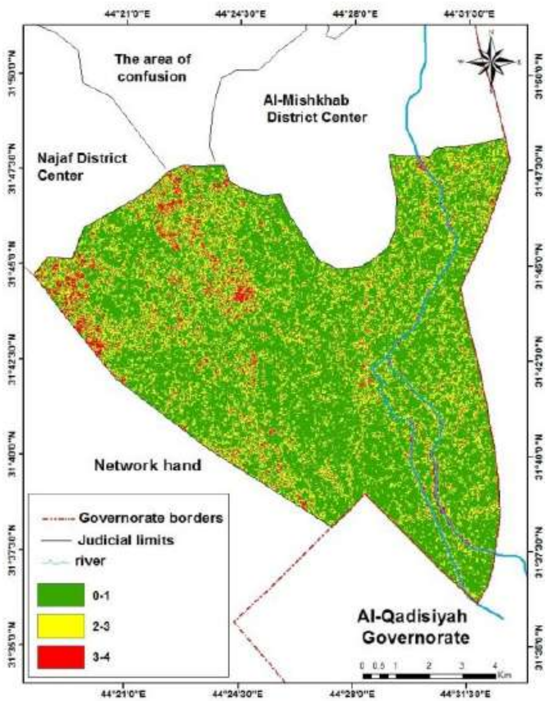

Figure 4. General slope (Regression Lines) in the study area

3.3 Climate Impact on Soil and Water Salinity

Climate influences soil salinity through various factors, including solar radiation, temperature, wind, rainfall, humidity, and evaporation rates. These factors either directly or indirectly affect soil conditions and their environmental consequences. Solar radiation plays a key role as the primary energy source, determining heat levels in the region and influencing temperature and atmospheric pressure. The region's astronomical position also affects solar radiation, including the angle at which sunlight strikes the Earth and the duration of daylight. As shown in Table 1, theoretical sunshine hours increase from 10.2 hours in January to a peak of 14.2 hours in June due to the sun's alignment with the Tropic of Cancer. December sees the lowest theoretical sunshine hours at 10 hours per day. The actual sunlight hours follow a similar pattern, increasing from 6.1 hours in January to 11.3 hours in July, aided by the minimal cloud cover and the sun's near-vertical angle. By December, actual sunlight decreases to 5.8 hours, and the annual average of actual sunlight hours in the region is 8.6 hours. This variation between summer and winter solar radiation impacts temperature patterns. In summer, intense solar radiation and high temperatures lead to rapid soil moisture evaporation, causing the soil to dry out. As moisture evaporates, salts left behind accumulate in the soil, reducing its ability to retain water. Over time, this excessive salt buildup deteriorates soil quality and negatively impacts plant growth.

3.4 Water Quality and Suitability for Irrigation

Al-Qadisiyah's climate is arid, with hot summers and mild winters. The average annual temperature is 24.16 °C, peaking at 35.72 °C in August and dropping to lows around 10.99°C in January. High temperatures increase evaporation, leading to salt buildup in soil, which degrades its quality over time. Winds, averaging 2.47 m/s annually, peak in April and May, further enhancing evaporation and salt accumulation. Rainfall is sparse, totaling only 0.15 mm per year, primarily occurring from November to February. The dry summer months of June through August experience no rainfall, intensifying soil drying and salinization. Low annual humidity, averaging 53.64%, drops to 44.7% in June, amplifying evaporation rates and leaving salts behind in the soil. Evaporation rates, highest in July (9.74 mm) and lowest in December (1.97 mm), are a key factor in salt concentration cycles. High summer evaporation leads to salt accumulation, while winter's lower rates provide slight relief. Due to limited rainfall, irrigation in Al-Qadisiyah depends mainly on surface water from Shatt Al-Kufa River branches, which contain dissolved salts. Key irrigation sources, such as the left branch of Shatt Al-Kufa and Abu Kuraisa, irrigate

Table 1. Climate elements data for Al-Qadisiyah in the year (2022)

Month	Theoretical Brightness (h)	Actual Brightness (h)	Temperature	Min. Temperature	Max. temperature	Wind Speed m/s	Humidity %	Rain (ml)	Evaporation (ml)
January	10.2	6.1	10.99	4.67	17.31	2.71	51.55	0.17	2.97
February	11.1	7.2	13.4	4.59	19.51	2.95	47.17	0.35	3.38
March	12	8	19.25	11.98	26.52	2.07	46.59	0	5.08
April	12.6	8.2	23.47	15.04	91	2.69	84	0.058	6.76
May	13.6	9.4	27.13	18.84	35-43	3.21	45.99	0	8.27
June	14.2	11	33.90	25.4	73	2.75	44.7	0	9.41
July	13.5	11.3	35:07	26.48	43.66	2.93	44.98	0	9.74
August	13.1	10.8	72	94	43.51	2.22	76	0	8.20
September	12.1	10.1	31.94	23.13	76	2.18	54.26	0	6.91
October	11.4	8.2	27.16	18.37	36.06	1.63	81.	0	4.92
November	10.4	7.2	19.59	13.34	25.93	1.56	93	0.51	2.72
December	10	5.8	12.40	6.09	18.71	1.82	69-60	0.75	1.97
Average	**12**	**8.6**	**24.16**	**16.32**	**31.83**	**2.47**	**53-64**	**0.15**	**5.86**

thousands of dunums but contribute to soil salinity due to these salts.

In summary, high evaporation rates, low rainfall, and saline irrigation water drive soil salinity in Al-Qadisiyah, negatively impacting soil health and agricultural productivity over time.

Table 3 indicates pH values vary by site, with sites A4, A10, A7, and A6 showing higher pH levels, whereas A3, A2, A9, and A8 recorded lower values. All sites meet FAO irrigation standards (pH 5 – 9), though some exceed Iraqi standards (pH 6.5 – 8.5), likely due to agricultural waste and runoff affecting surface water quality. Electrical conductivity (EC) and total dissolved solids (TDS) values also vary. Sites like A8 meet low-salinity standards, while others (A1, A5, A7, A10) display high salinity levels, potentially affecting crop suitability. The high Na^+, K^+, Mg^{2+}, and Ca^{2+} concentrations observed at several sites exceed FAO and Iraqi irrigation limits, especially in summer when evaporation rates increase, concentrating salts in the soil. Chloride (Cl^-) and sulfate (SO_4^{2-}) levels are mostly within permissible limits, except for a few sites with elevated chloride, which could increase soil salinity if used for irrigation.

Overall, salinity levels vary significantly across sites, with most exceeding international and national standards. Continued use of this water in irrigation is likely to raise soil salinity levels, negatively impacting soil quality and crop productivity.

The soil in Al-Qadisiyah varies in its chemical and physical properties due to changing climatic factors and the composition of the geological structure and water resources. The main types of soil in this area are: These soils are located in the southwest of Al-Qadisiyah, as they consist of sand, clay and silt deposits, and their content of sand reached (67.5), clay (12.8) and clay (19.7), which is a soil with mixed sandy fabric, according to the triangle of soil fabric. These soils in the northern and northeastern part of the study area (Figure 5) and they are characterized by a sand content of (13.2%), silt (28.2%) and clay (58.6%).

Table 2. Main and sub-tables in Al-Qadisiyah for 2024

No	Water table	Length (km)	Drainage (m^3/s)	Irrigated Area	Matrix Type
1	Ajanbah Alusra	6.1	7.5	1400	Subsidiary
2	Abu Kreisah	3.4	3	400	Subsidiary
3	Abu Kahiwa	1.7	2	1005	Subsidiary
4	Abu Maki	2.4	1.5	600	Subsidiary
5	Al-Ziyadi	1.8	1.5	600	Subsidiary
6	Alouh	3	2	850	Subsidiary
7	Mukhair	3	2	900	Subsidiary
8	Nuguishia River Bazaiz	7.7	5	3400	main
9	Bazayez Shatt Al-Ghazali	3.5	2	950	main
10	Al-Lithawi	4.1	2	950	main
11	Al-Ehmair	5.2	9	2500	main
12	Al-Ghazali	1.2	0.5	150	Subsidiary
13	Al Yawa Al Saghir	5.4	2	900	main
14	Al-Jazarah	3.3	2	1200	main
15	Bazayez Tabar Mahdi	2.8	4	500	Subsidiary
16	Abu Dajeej River	3.3	7	750	main
17	Hamade	9	10	13500	main
18	Al Jawasim River	3	3	1300	main
19	Cheblawi	6.9	10	8500	main

Table 3. Chemical properties of the water of the study area in December

Element	Unit	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	Standard Deviation
pH	----	7.67	7.10	7.20	8.15	7.44	8.01	8.13	7.10	7.20	8.09	7.30	0.44
EC	Siemens/cm	1.52	0.86	0.78	1.5	1.9	1.4	1.14	0.69	0.85	1.7	0.94	0.41
TDS	mg/L	972	768	499	960	1216	896	729	441	544	1088	1024	255
Na^+	mg/L	186	234	131	124	132	126	116	120	136	206	239	47
K^+	mg/L	73.8	70.7	85.6	75.3	88.5	79.3	82.6	100.2	98.6	89.4	72.2	10.2
Mg^{+2}	mg/L	152	124	234	150	132	225	167	208	201	138	103	43
Ca^{2+}	mg/L	413	143	107	372	108	92.5	125	102	112	203	128	112
Cl^-	mg/L	351	384	232	380	235	337	288	341	364	267	360	56
HCO_3^-	mg/L	136	178	128	194	146	188	171	126	129	145	155	24
SO_4^{2-}	mg/l	218	230	360	185	242	138	123	237	214	189	314	68

This soil is considered clay tissue according to the soil tissue triangle. This type of soil spreads over small areas in the northern regions. This type of soil is formed under dry conditions represented by lack of rainfall and increased evaporation. Also, these soils are not limited to sand atoms, as they include a percentage of clay (3.8) and silt (10.0%) and (86.2%) of sand. This soil is also characterized by coarse tissue due to the large size of its constituent atoms. These soils were formed by the sediments brought by the Euphrates River, as the river deposits in the reduced areas far from the banks fine micro-atoms of clay, silt and sand, and this soil contains an average of (11.2%) of sand and (29.4%) of silt, and (59.4%) of clay.

3.5 Statistical Correlations and Temporal Variations

The table 7 shows a clear temporal variation in the statistical relationship between water temperature and the distribution of saline elements in the study area. During the winter (January), an increase in water temperature is associated with a rise in saline element levels. The strongest positive relationship was observed with the pH element, showing a correlation of (0.49), a regression of (0.24), and an explanatory factor of (0.251), indicating a weak influence. Conversely, the weakest relationship was with the electrical conductivity (EC) element, with a correlation of (0.12), a regression of (0.055), and an explanatory factor of (0.0140), indicating a very weak relationship. In the same month, the strongest inverse relationship was observed with the sodium (Na) element, with a correlation of (-0.38), a regression of (- 20.0), and an explanatory factor of (0.1410), showing a very weak inverse influence. The weakest inverse relationship was with the magnesium (Mg) element, with a correlation of (- 0.08), a regression of (- 8.625), and an explanatory factor of (0.0067), indicating a

Table 4. Permissible limits for water for irrigation according to FAO and Iraqi standards (FAO, 1999, Ministry of Environment, 2007)

Element	Permissible Limits FAO	Permitted Limits Iraqi Standard
pH	9-5	8.5 - 6.5
EC	3- 0	Less than 3.5
TDS	2000.0	----
Na^{+}	0-920	520
K^{+}	0-78	80
Mg^{+2}	0-150	0 - 150
Ca^{2+}	0-400	0 - 400
Cl^{-}	0-250	350
HCO_3^{-}	0-610	520
SO_4^{2-}	0-500	500

Table 5. Classification of water according to its suitability for irrigation according to the standard of the American National Advisory Committee (Siemens/cm) (Report of the Committee of Water Quality Criteria, 1968)

Type of water	EC	Suitability for irrigation	Crops that can be grown
Brackish	Below 0.75	A hall to irrigate all agricultural crops in all types of soil	Cultivation of all agricultural crops
Medium salinity	0.75-1.5	Suitable for irrigation of some crops that tolerate relatively salinity in soils with good drainage	Suitable for growing wheat, barley, rice, corn, tomato, vegetables, pomegranate and olives
high salty	1.5-3	Suitable for irrigation of crops that withstand salinity, provided that the soil is taken care of and well drained	Suitable for growing cotton, palms, beets, etc.
Very high for salinity	3-7.5	It can be used to irrigate some crops while taking care of soil drainage	Valid for palm and jet cultivation
Excessively salty	More than 7.5	It cannot be used to irrigate crops even when soil with good drainage is available	Not suitable for planting any crop

very weak inverse effect. In summary, while an increase in water temperature slightly raises the levels of saline elements, the effect remains minimal. This statistical relationship between soil temperature and saline elements aligns with laboratory analysis, confirming that saline element concentrations increase with higher water temperatures.

Soil and water salinity, primarily caused by salts, affects approximately one billion hectares of land globally, posing significant threats to agriculture and soil health. Factors such as intensive irrigation, rising temperatures, drought, water scarcity, and inadequate drainage exacerbate salinization, while seawater intrusion and unpredictable rainfall further contribute to soil degradation. High sodium adsorption ratios (SAR) also damage soil chemistry and physical structure. Addressing these issues is critical to support food security and economic stability, especially for populations dependent on marginal water quality for irrigation. This study discusses the distribution of salt-affected soils (SAS), causes and characteristics of salinization, crop production losses, economic impact, and management strategies for SAS rehabilitation to enhance food security, improve livelihoods, and curb future migration (Basak *et al.,* 2022). Chhabra (2021) provided a comprehensive examination of salt-affected soils, emphasizing their classification and database management, critical for assessing their scope and informing sustainable reclamation practices. Key factors, including temperature, cations, and anions, are explored for their influence on salt solubility, leachability, and the formation of saline and alkali soils. The researcher compares regional classification systems, such as those of the USDA, FAO-UNESCO, and India, which are based on pH and salinity metrics, and introduces novel terms, epihalic and epinatric, to specify surface salinity and sodicity. Furthermore, the application of remote sensing and GIS technologies is discussed for effective mapping and monitoring, alongside the establishment of benchmark sites for tracking soil conditions and addressing anthropogenic impacts on soil salinization. Paz *et al.,* (2023) discussed the growing issue of salt-affected soils, which threaten global soil health and farm sustainability due to land mismanagement and climate change, affecting approximately 1,000 Mha, primarily in arid regions. These soils can be classified as saline, sodic, or saline-sodic,

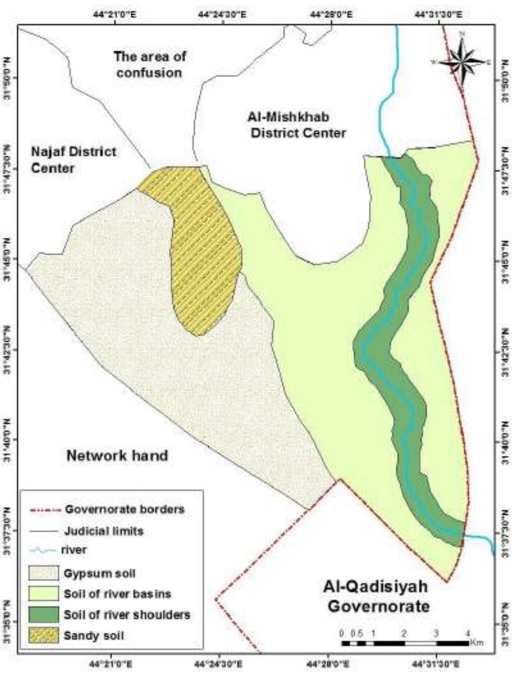

Figure 5. Soil Types in the Study Area

Table 6. Statistical analysis of the summer season for the effect of water temperature with salt

Element	Correlation Coefficient	Regression	Interpretation type	Correlation type
pH	0.49	0.240	0.241	Weak (Positive)
EC	0.12	0.055	0.0140	Very Weak (Positive)
TDS	0.26	103.1	0.067	Very Weak (Positive)
Na^{+}	- 0.38	- 20.0	0.1410	Very Weak (Negative)
K^{+}	0.32	3.625	0.100	Very Weak (Positive)
Mg^{+2}	- 0.08	- 8.625	0.0067	Very Weak (Negative)
Ca^{2+}	0.07	3.375	0.0047	Very Weak (Positive)
Cl^{-}	- 0.27	- 21.12	0.0750	Very Weak (Negative)
HCO_3^{-}	0.25	7.500	0.0614	Very Weak (Positive)
SO_4^{2-}	- 0.30	- 18.875	0.0899	Very Weak (Negative)

with various management strategies proposed for prevention, mitigation, and adaptation. Preventive measures include proper irrigation management, water quality monitoring, and appropriate scheduling. Mitigation strategies involve chemical and bioremediation techniques, while adaptation focuses on crop selection, microbial management, and organic matter enhancement. The document highlights the need for innovative practices, such as developing region-specific irrigation guidelines and improving soil-microbe interactions.

4. Conclusion

This research demonstrates that natural factors significantly influence the increased salt concentrations in the soil of the study area. The geological conditions play a key role in determining the rock types from which the soil is derived, thus affecting its chemical properties. Additionally, surface features, particularly flat areas with low regressions, contribute to the accumulation of saline elements in the soil. Climatic factors also affect soil salinity and its changing characteristics. Analysis of surface and groundwater samples shows that most of the water is unsuitable for irrigation under normal conditions, and poor drainage over time exacerbates soil salinity. To manage and improve soil salinity in the study area, policies should target the mitigation of natural influences and the enhancement of water quality and drainage. Effective land management practices, such as building levees or ridges, can help improve drainage in low-lying areas, preventing the accumulation of salts. Additionally, using high-quality, low-salinity water sources and implementing alternative irrigation methods, like drip irrigation, can minimize water use and reduce soil salinity over time. Applying soil amendments, such as gypsum, along with selecting salt-tolerant crops, can further support soil health and productivity. Consistent monitoring of soil and water salinity levels is essential to track changes and adapt management strategies accordingly. Lastly, educating farmers and land managers on best practices for salinity control, including irrigation techniques and soil management, will be crucial for long-term success. These policies, taken together, can foster sustainable land use, reduce soil salinity, and improve agricultural productivity and environmental quality in the region.

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References

Abdil-Ameer Noor T, Almudhafar SM, Almayahi BA. Environmental assessment of solid waste collection sites in Najaf Governorate. Int J Ecomedical Public Sci (IJEPS). 2022; 5(4): 1-5.

Abdil-Ameer NT, Almudhafar SM, Almayahi BA. The natural characteristics affecting the environmental pollution contrast at the center of Al-Manathira District. Int J Acad Multidiscip Res. 2023; 7(1): 166-175.

Abyss KD, Almudhafar SM, Almayahi BA. The right of disabled children in Iraq. Int J Health Sci (IJHS). 2022; 6(S4): 47269-47276. https://doi.org/10.53730/ijhs.v6Ns7.13129

Al-Jashaami SHK, Almudhafar SM, Almayahi BA. A spatial analysis of the influence of environmental factors on the growth and proliferation of pathogenic fungi in the Manathira River. Kurdish Stud. 2024; 12(2): 5450-5461.

Al-Jashaami SHK, Almudhafar SM, Almayahi BA. The effect of climate on the variation of pathogenic bacteria in the waters of the Manathira River. Kurdish Stud. 2024; 12(2): 2330-2341.

Almudhafar SM, Abdulameer NT, Almayahi BA. Environmental assessment of surface water contamination with pathogenic bacteria in the Manathira District Center. J Chem Health Risk. 2023; 13(3): 1067-1077.

Almudhafar SM, Abdulameer NT, Almayahi BA. The impact of pathogenic fungi on soil contamination in the center of the Al-Munadhirah District. J Chem Health Risk. 2023; 13(3): 1056-1066.

Almudhafar SM, Almayahi BA, Jawad HH. Effect of environmental parameters on soil salinity on plant. Int J Pharm Res. 2020; 24(5): 4247-4253.https://doi.org/10.37200/IJPR/V24I5/PR2020140

Almudhafar SM, Mohsen RA, Almayahi BA. Environmental assessment of the impact of water pollution in Bahar Al Najaf on plants. J Chem Health Risk. 2023; 13(3): 1036-1046.

Almudhafar SM, Rahim MA, Almayahi BA. Spatial analysis of household waste's impact on soil and air pollution. Indian J Environ Prot. 2024; 44(2): 52-685.

Almudhafar SM, Sweihi AR, Almayahi BA. Spatial analysis of surface water contamination with pathogenic fungi resulting from sewage sites in Najaf Al-Ashraf Governorate. J Chem Health Risk. 2023; 13(3): 996-1011.

Basak N, Rai AK, Barman A, Mandal S, Sundha P, Bedwal S, Kumar S, Yadav RK, Sharma PC. Salt affected soils: Global perspectives. In Soil Health and Environmental Sustainability: Application of Geospatial Technology 2022 Sep 28 (pp. 107-129). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-09270-1-6.

Chhabra R. Nature and origin of salts, classification, area and distribution of salt-affected soils. Salt-Affected Soils and Marginal Waters: Global Perspectives and Sustainable Management. 2021: 1-47.

FAO. Guidelines for irrigation water quality. Ministry of Environment, Human Resource Development and Employment, Department of Environment. USA; 1999.

Hassan AA, Almudhafar SM, Al Atabi IA, Almayahi BA. Environmental factors affecting surface water in Al Mishkhab District. Migration Letters. 2023; 20(7): 261-276.

Kadhim KR, Almudhafar SM, Almayahi BA. An environmental assessment of the non-living natural resources and the available capabilities and their investment in Al-Najaf Governorate. HIV Nursing. 2023; 23(3): 265-273.

Ministry of Environment, Planning and Follow-up, Central Agency for Inspection and Quality Control, Agricultural Activity Unit. Draft standard specifications (3241). 2007.

National Technical Advisory Committee of Interior. Report of the Committee of Water Quality Criteria. Washington, DC: National Technical Advisory Committee of Interior; 1968. p. 170.

Paz AM, Amezketa E, Canfora L, Castanheira N, Falsone G, Gonçalves MC, Gould I, Hristov B, Mastrorilli M, Ramos T, Thompson R. Salt-affected soils: Field-scale strategies for prevention, mitigation, and adaptation to salt accumulation. Italian Journal of Agronomy. 2023 Aug 22; 18(2).

Wahhab HS, Almudhafar SM, Alalaq AS, Almayahi BA. Social Environment and its Effects on Domestic Violence. Revista de Gestao Social e Ambiental. 2023 Jul 19; 17(7): e03536-.