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Study of the Physical and Chemical Properties of the Soils in the Middle Euphrates Region Using Geographic Information Systems

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Abstract in English

This work used Geographic Information Systems (GIS) to perform an extensive spatial analysis of soils in the Middle Euphrates. The physical and chemical properties of soil samples taken from a depth of (0-30) cm in the study region were analyzed in the laboratory (30 samples). These measurements were then interpolated by GIS-based modelling to make maps showing the spatial variations of the soil variables. According to the study's findings, Geographic Information Systems (GIS) technology provided a clear depiction of the region's features and made it easier to understand how physical and chemical properties were distributed across the study area.

Paper Info

Keywords

Keywords:salinity, soil, GIS, Chemical properties,Soil texture,Electrical connectivity.

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1. INTRODUCTION

The study and analysis of the spatial variation of soil physical and chemical properties in the Middle Euphrates region is important because soil is an important natural resource in sustaining human life. After all, it is the natural medium on which agriculture is based, which contains the nutrients necessary for plant growth, the quality and quantity of which is affected by the physical and chemical properties of the soil such as texture, true density, bulk density, apparent density, porosity, degree of reaction, electrical conductivity, organic matter and other properties. The researcher relied in the study of the soil of the study area on field work and collected (30) samples at a depth of (0-30) cm distributed throughout the area to analyses their characteristics and then show the spatial variation of physical and chemical properties in the study area soils.

2. STUDY AREA

The study area is geographically located between latitudes 33°3′N and 29°4′N, and longitudes 46°56′E and 43°E. This region encompasses five governorates—Babylon, Karbala, Najaf, Qadisiya, and Muthanna—covering a total area of 98,870 km², representing 7.22% of Iraq's total land area of 434,128 km² [1] (see Fig. 1). Field surveys conducted in May 2024 confirmed an arid climate within the study area, characterized by temperatures reaching 45°C and low humidity, with no precipitation recorded.

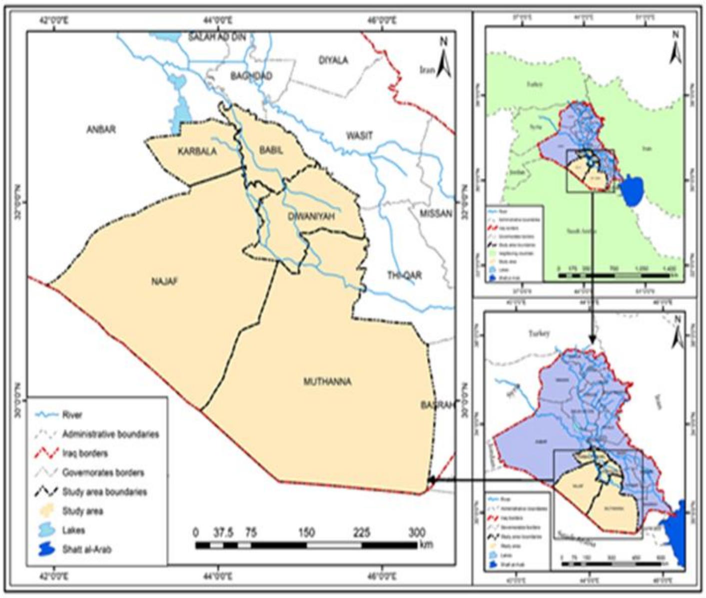


FIGURE 1. The study area

3. MATERIALS AND METHODS

3.1Samples Collection

Fieldwork to measure soil salinity was conducted from May 1, 2024, to June 1, 2024. Thirty soil samples were collected from depths of 0–30 cm at strategically selected locations representative of the study area (GPS coordinates shown in Fig. 2). Each sample was air-dried, sieved through a 2 mm sieve to remove coarse material, and stored in a plastic bag until analysis. Water content, electrical conductivity (ECe), and soil pH (1:1 extract) were determined using an ECe meter and a pH meter [2].

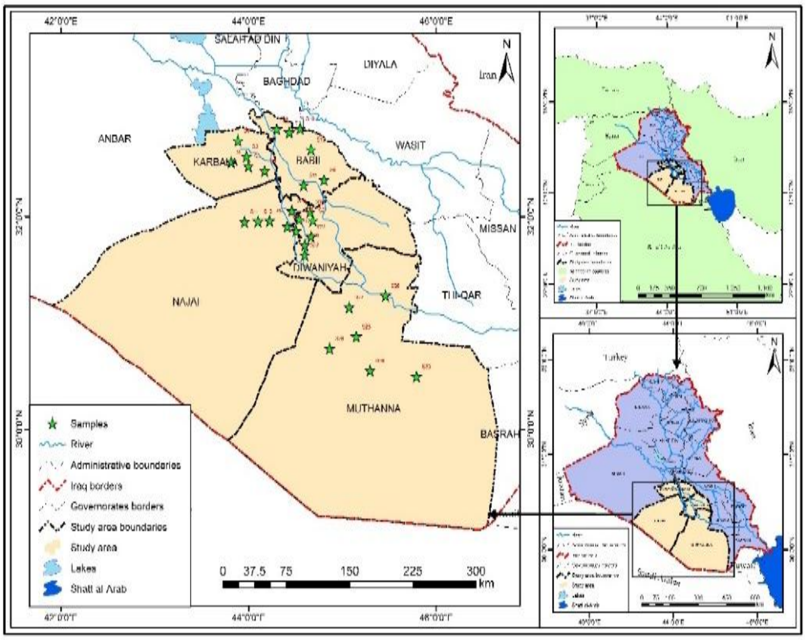


FIGURE 2. GPS locations of the soil samples

Physical and Chemical Properties of Soils in the Middle Euphrates Region.

Physical properties of the soil of the study area: The physical characteristics are important for any region in the world, including the Middle Euphrates region, as the different soil grains and their adhesion to each other as a result of the availability of water, air, mineral and organic compositions contribute to the formation of the final outcome of a full-fledged soil that is of great importance in the practice of agricultural activity, and these characteristics are as follows:

Soil Texture: The term refers to the mechanical structure of the soil, i.e., the sum of the elementary particles that make up sand, silt, and clay [3]. It is the size of all soil fines that are smaller than gravel (less than a millimeter) and is a proxy for how coarse and fine the soil is [4]. Table 1 and with the help of the US soil texture triangle as shown in Fig. 3, Laboratory results indicated that the percentage of sand varied in the majority of soil samples from the study area, reaching (95, 93, 88, and 82)% in samples (S4, S15, S5, and S18), respectively This is because most of the sediments in the area are sandy, especially in the northern and central parts of the study area, as it is highly prevalent in the western plateau, as well as characterized by highly porous and well-ventilated soils due to the predominance of sandstone and the prevalence of limestone and gravel The minimum value of sand in sample S11 was 12 % and Fig. 4.a shows the spatial variation of sand The percentage of silt was low compared to sand, with the highest percentage recorded in sample S16 with 49% , and the lowest percentage recorded in sample S20 with 3% . See Fig.4.b While the percentage of clay decreased in most of the study samples, with the highest percentage recorded in sample S11 with 46 %, due to the nature of river flow and irrigation processes, and the lowest percentage recorded in sample S15 with 5.3%, see Fig.4.c This decrease confirms the impact of climatic extremes on the activity of chemical and physical weathering processes in the region.

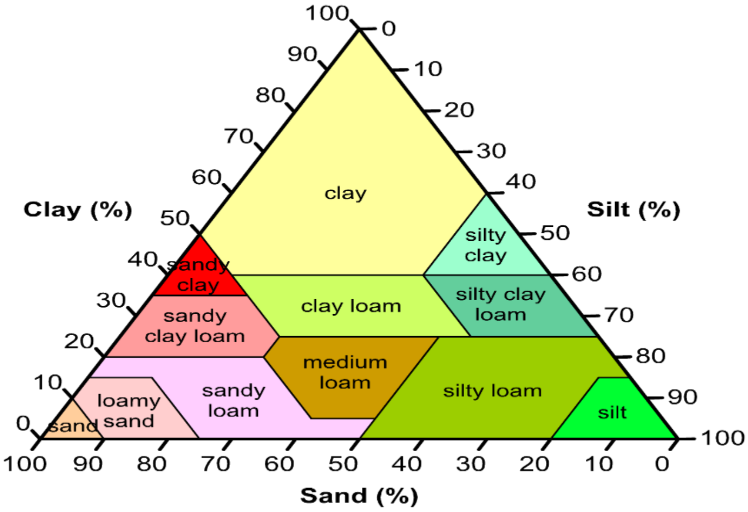
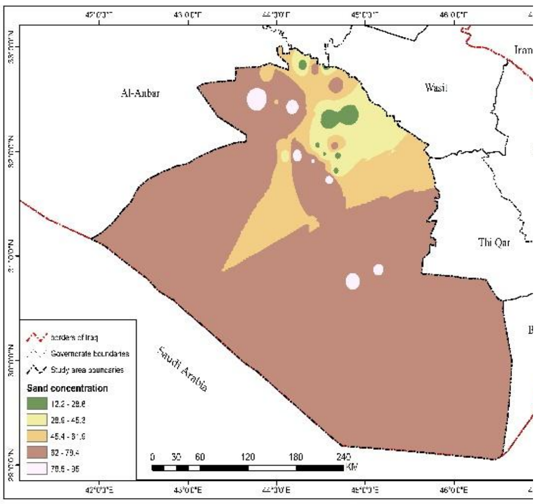
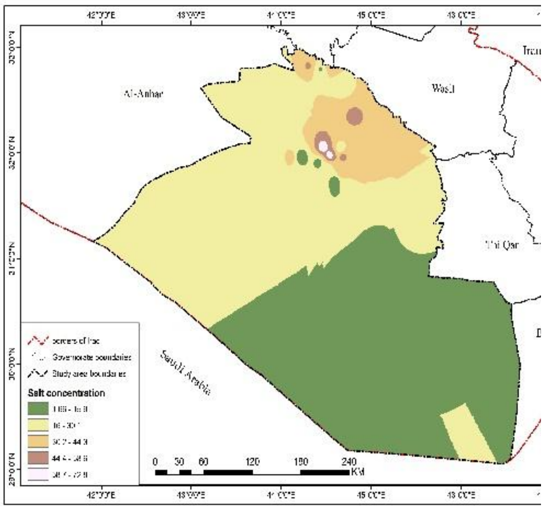


FIGURE 3. The American texture triangle for soil samples in the study area



(a)



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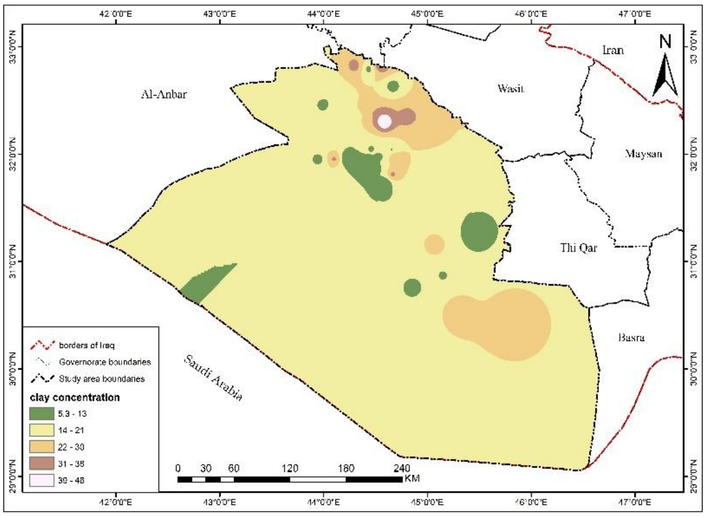

(c)

FIGURE 4. Spatial Variation a-Sand b-Silt c-Clay

Bulk Density: Is the ratio between the mass of the solid parts to the volume of the soil, including clay and pores, and is usually referred to as bulk (dry) density [5]. The study of the change of bulk density in the soil has direct and indirect effects on the physical and mechanical properties of the soil.

When its value increases in the soil, the amount of water retained in it decreases. In addition to the high-water conductivity and poor hydration, it is also used to determine the porosity of the soil, which determines the nature of the movement of water and air in the soil, as well as the nature of water and air movement in the soil.

It is clear from the Table 1 that the highest bulk density rate recorded in sample S6 was 1.51 in the river shoulder area in Najaf Governorate, the reason for this high rate is due to the nature of the fabric and the increase in the proportion of sand and the lack of organic matter, and the lowest rate recorded in sample S19 was 1.16 in the basins of Muthanna Governorate, and this discrepancy is due to the different size distribution ratios of fine particles, clay and silt in the soil.

Particle Density: It is defined as the mass of the unit volume of solid soil particles [6], and can be studied to know the nature of the mineral composition of soil particles and their content of organic matter, so its value is higher in soils poor in organic matter and when the proportions of heavy metals increase in soils with high specific weight [7], it is clear from Table 1 that the highest rate of real density was recorded in sample S18 by 2.66 g/cm^3 and the lowest rate was recorded in sample S14 by 2.55 g/cm^3.

Porosity: Refers to the ratio between the size of the voids in the soil and its total volume, and its value is extracted based on the results of physical analysis to determine the apparent and real density of the soil, and its accuracy gives a clear picture of the nature of the pore size. Porosity is a key indicator of water retention in the soil, as well as determining soil aeration and drainage, and its relationship with determining the growth and spread of plant roots, and thus indirectly determining the productivity of cultivated crops [8]. It is clear from Table 1 that the highest rate of soil porosity was recorded in sample S16 by 66.35 in the soil of Najaf Governorate due to the nature of the tissue and the presence of vegetation cover, and the lowest rate was recorded in sample S5 by 43.75.The porosity rate varies from one soil to another, depending on its tissue and organic matter content.

Chemical properties of the soil of the study area: The chemical properties of the study area vary according to the factors that affect them, such as the original material, climate, terrain, organic matter, and time. By knowing these properties, it is possible to determine the availability of nutrients for plants in the soil and thus its suitability for agricultural production, as follows:

Soil Reactivity Degree (pH): The degree of reaction of the soil represents the negative logarithm of the hydrogen ion activity and is called the acidic and basic values of the soil. The soil is acidic when the pH values are less than 7 and basic when more than 7, while if the pH values are equal to 7, it is called neutral [9]. According to the results of laboratory analyses of soil samples in the study area, as shown in Table 1 and Fig. 5, there is little spatial variation in pH values. The highest value is recorded in the stony desert soils in sample S6 with a value of 8.9, and the lowest level is recorded in sample S3 with a value of 6.5, and through these results it is clear that the reaction degree of the soil of the study area is characterized by alkalinity due to its dryness, which caused increased presence of calcium carbonate and variation of the salinity ratio.

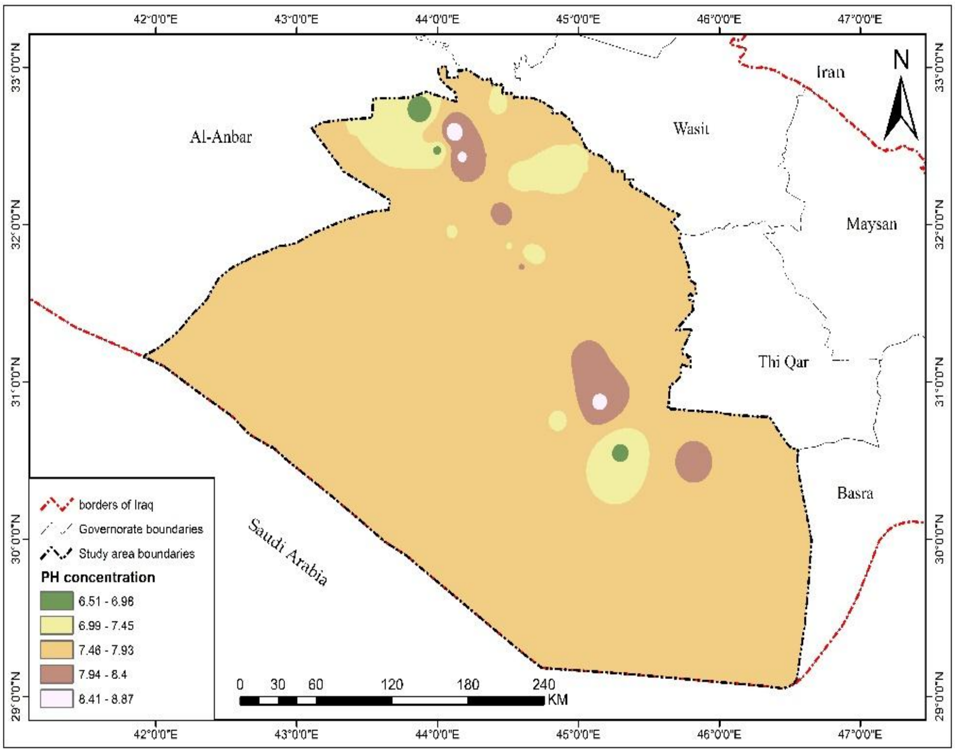

FIGURE 5. Spatial variation pH

Electrical Connectivity (ECe): Salinity is one of the characteristics of arid and semi-arid regions. Soils with salinity between 4-0 ds/m are non-saline soils, while if the salinity values are more than 15 ds/m, they are highly saline soils [10], This salinity is one of the soil issues that specialists have made efforts to find the best ways to reduce its spread or develop agricultural varieties that are able to tolerate the salinity of a number of soils. Land that is irrigated by flood irrigation with no efficient drainage system will inevitably lead to salinization conditions, especially in clay soils, which are heavy and poorly drained heavy soils [11]. From the results of the chemical analysis of soil samples in the study area as shown in Table 1 and through the Fig. 6, it is clear that there is a spatial variation in the geographical distribution of ECe values, the highest rate was recorded in sample S13 at 40 ds/m, and the lowest rate in sample S29 at 0.6 ds/m. According to the criterion of the degree of soil salinity, Table 1 and Fig. 6 we find that the values of electrical conductivity of the soil samples of the study area are (low to high salinity), and the high salinity is attributed to the use of large quantities of irrigation on the one hand, the high rate of evaporation on the second hand, and the high level of groundwater on the third hand.

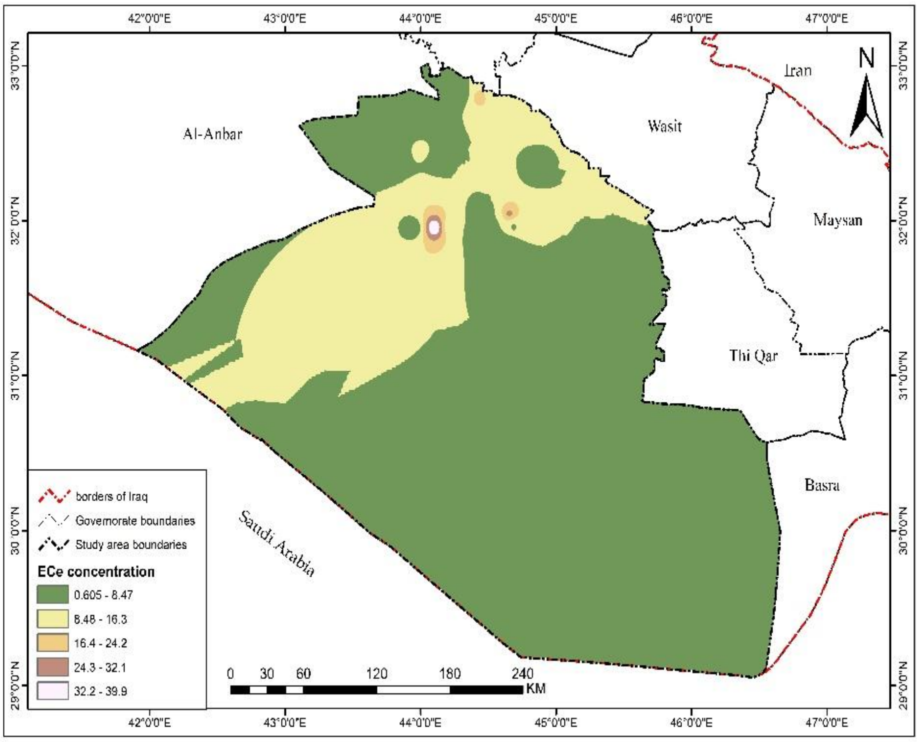

FIGURE 6. Spatial variation ECe

Organic Matter (O.M): It is one of the most important parts of the solid part of the soil, and arises from the remains of plants, animals and microorganisms, which resulted from the decomposition of these materials that took a long time and consists of many elements, including carbon, oxygen, nitrogen, sulfur and phosphorus, in addition to microbial cells. Organic matter plays a key role in increasing soil fertility and plant growth, as well as increasing the productive capacity of agricultural land through its effect on physical properties [12]. It is clear from Table 1 and Fig. 7 that there is a spatial variation in the percentage of organic matter in the study area, where the highest percentage in sample S21was 16.2, while the lowest percentage in sample S7 was 0.12. The reasons for the variation in the studied organic matter values are due to the fact that some sites had better vegetation cover than other sites, with different agricultural services that the soil received, especially the addition of fertilizer, which had a positive effect in raising organic matter percentages in these sites, without others.

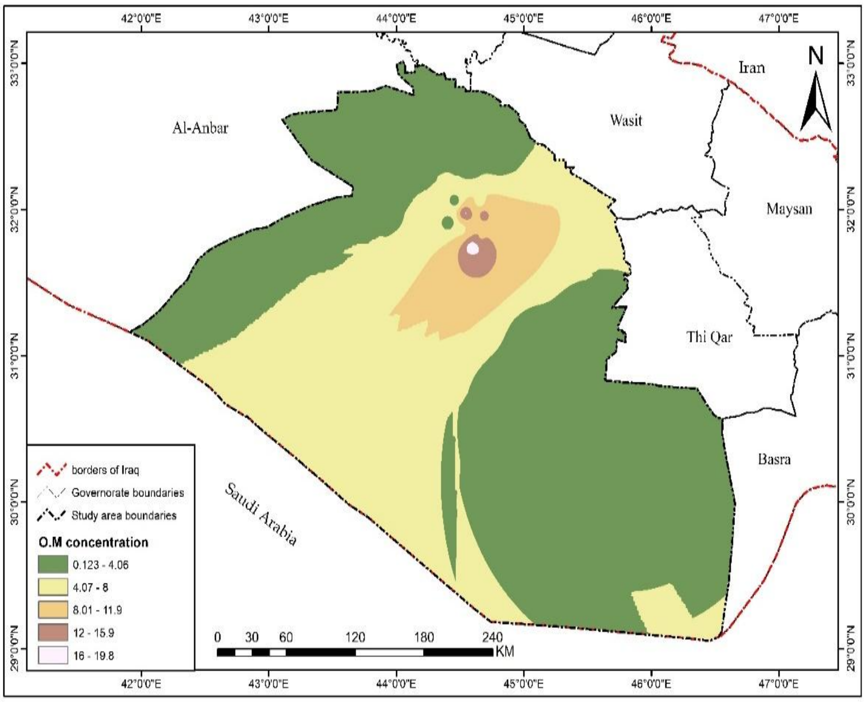

FIGURE 7. Spatial variation O.M

Calcium carbonate (lime) Caco3: poorly soluble salt with a solubility of 3%, and calcareous soil is a non-saline soil whose carbonate content increases by (20-30%) as a result of dry climatic characteristics [13], and it is often spread in arid and semi-arid areas, as its composition is due to the material of origin, which is usually calcareous or rich in calcium, such as basalt rocks, The succession of moisture and drought and its continuation and the lack of rainfall naturally leads to precipitation on the surface in a way that leads to the formation of calcium carbonate and increase the proportion of sodium ions in the soil solution, as reflected in the spread of soil fines and then low permeability and poor aeration, so the process of estimating carbonate in the soil becomes necessary, as it can determine the seriousness of sodium and its impact on various soil characteristics [14]. It is clear from Table 1 that there is a variation in calcium carbonate values throughout the study area, with the highest value of 2.81 in sample S23. The reason for the significant increase in concentrations in river basin soils is due to the presence of calcium carbonate in quantities that exceed the soil of river shoulders, and the increased concentration affects the lack of water readiness in the soil, as it is in the form of a solid layer with reduced permeability that keeps water on the soil surface, which exposes it to evaporation due to increasing temperature rates. The lowest value in the river shoulder area in sample S9 of 0.23 is due to fluvial deposits, parent material, and soil joint heterogeneity.

Calcium Sulphate (Gypsum) CaSO4: The most common sulphate-containing salts due to its high solubility compared to other sulphates; their solubility exceeds that of calcium carbonate, and its presence in the soil is considered beneficial. It is a major source of calcium and sulphate, but when it occurs in dense deposits, the soil suffers from management issues related to irrigation and fertilization that preclude its economic viability. Gypsum (calcium sulphate) is found in varying amounts in most soils and is formed by the reaction of sulphuric acid with calcium ions. The importance of gypsum in soil formations is evident in that it works to reduce the apparent density of the soil by forming hard and cohesive layers that hinder the growth and spread of roots on the one hand, and on the other hand it works to worsen air quality by closing the effective pores in the soil and reducing its permeability and not allowing water to pass through it and thus reducing the groundwater level on the other hand, which ultimately leads to the cessation of plant growth and consequently their death [14].

It is clear from the table 1 that the percentage of sulphate varies from one region to another, the soil of Kutuf Al-Anahar came in decreasing quantities compared to the previous one, the reason is due to the nature of the river sediments as well as the material of origin that consists of them, as the soil of Babylon Governorate came S11 with a concentration of 0. 05, as for the soils of the western plateau, they also varied, but they have a high concentration, the reason for this is that gypsum deposits were formed as a result of increasing temperature rates and lack of rain, which made them form a layer on the soil surface that negatively affects the ability of the soil to retain water, especially in gypsum soils in Najaf Governorate by 8.87, while the concentration of sulfate in gypsum soils in Muthanna Governorate was about 6.67, while the stone desert soil reached its highest concentration in Najaf Governorate also by 8.92.

TABLE 1. Physical and chemical properties of soil samples in the study area.

Code state	Sand %	Silt %	Clay %	Bulk density g/cm^3	Particle density g/cm^3	Porosity %	PH	Ece ds/m	O.M %	Ca SO4	Ca CO3
S1	60	30	10	1.31	2.53	51.78	6.8	4	0.3	1.2	0.44
S2	70	20	20	1.21	2.54	48.52	7.8	3.4	0.23	1.8	0.45
S3	57	20	16	1.33	2.37	54.11	6.5	7.4	0.3	7.21	1.35
S4	95	30	15	1.35	2.4	56.25	7.3	3.1	0.25	7.54	1.43
S5	88	24	20	1.5	2.48	60.48	8.5	3.4	0.28	4.83	0.81
S6	75	20	18	1.31	2.44	53.69	8.9	3	0.26	8.2	1.5
S7	75	14	11	1.5	2.6	57.69	7.1	2	0.12	0.95	0.74
S8	20	47	33	1.42	2.11	61.44	7.7	15	0.51	0.12	0.24
S9	19	49	32	1.3	2.06	63.11	7.1	3.5	0.56	0.19	0.23
S10	16	45	39	1.46	2.56	57.03	7.9	5	0.95	0.72	2.42
S11	12	42	46	1.48	2.55	58.04	7.2	1.2	0.97	0.05	0.25
S12	74	16	10	1.49	2.49	59.11	7.8	35	0.5	0.07	0.2
S13	30	40	31	1.22	2.55	47.84	7.4	40	4.1	8.87	1.48
S14	72	16	12	1.19	2.32	46.55	7.7	28.5	2.9	8.34	1.39
S15	93	1.6	5.3	1.51	2.59	47.1	7.5	1	5.1	8.78	1.67
S16	25	73	13	1.18	2.44	46.55	8.3	2.5	2.5	8.11	1.59
S17	71	19	10	1.19	2.6	45.77	7.4	3.5	6.5	8.92	1.67
S18	82	6	10.8	1.48	2.63	56.27	7.7	2.4	1.4	5.43	0.67
S19	75	16	13	1.42	2.22	56.44	7.5	2	6.7	0.45	0.39
S20	93	3	5	1.4	2.11	66.35	8	13	20	0.44	0.35
S21	25	70	12	1.41	2.66	53.01	7.9	1.1	16.2	2.42	0.67
S22	72	14	13	1.37	2.47	52.87	7.7	4.8	11.9	2.36	0.58
S23	21	40	32	1.47	2.47	59.51	7	7.1	11.8	2.92	2.81
S24	20	50	30	1.39	2.55	59.11	7.9	7.9	13	2.88	2.25
S25	80	7	13	1.15	2.58	44.57	8.5	14	1.9	4.8	1.13
S26	71.6	19.4	9.5	1.34	2.45	54.69	7.7	30	0.81	4.35	0.7
S27	63.3	12.7	24	1.12	2.56	43.75	8	0.6	0.95	6.67	1.62
S28	80	7.5	12.5	1.3	2.07	62.8	7.4	8	1.6	6.39	1.59

S29	62.5	12.4	25.1	1.34	2.38	54.22	6.9	7.5	1.9	7.21	1.35
S30	62.5	12.5	25	1.16	2.64	43.94	8	3.9	0.77	4.35	0.7

4. CONCLUSION

The results of the spatial distribution analysis of soil properties in the Middle Euphrates region using Geographic Information Systems (GIS) showed a significant variation in the properties between the locations within the study area. Some areas recorded high sand percentages and low organic matter, which affects soil permeability and fertility. The highest sand percentage was recorded in sample S4 at 95%, located in the northern part of the region, while the highest clay percentage was recorded in sample S11 at 46% in the south. The highest percentage of organic matter was observed in sample S21 at 16.2%, which has good vegetation cover. The salinity level varied significantly due to ineffective irrigation and drainage methods, with the highest electrical conductivity value recorded in sample S13 at 40 ds/m, while the lowest was in sample S29 at 0.6 ds/m. The soils tend to be alkaline, with the pH value in sample S6 reaching 8.9 in the Najaf desert. These results confirm the importance of integrated soil management according to its local characteristics and the establishment of a comprehensive irrigation and drainage system to deliver water to all parts of the governorate, as well as to mitigate soil salinity, reduce groundwater levels, improve the physical properties of the soil, and maintain existing irrigation and drainage projects, especially in orchards. It is preferable to irrigate at night to reduce water excess due to sudden temperature rises and to decrease the salinity that accumulates on the soil surface after water evaporation. The importance of activating the role of agricultural extension to educate farmers and inform them about the negative impacts of incorrect agricultural practices that lead to soil degradation, encouraging farmers to use organic fertilizers and plant crops that enhance soil fertility, and adopting crop rotation or mixed farming systems.

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Abstract in Arabic

استخدم هذا العمل نظم المعلومات الجغرافية (GIS) لإجراء تحليل مكاني شامل للتربة في منطقة الفرات الأوسط. تم تحليل الخصائص الفيزيائية والكيميائية لعينات التربة المأخوذة من عمق (0-30) سم في منطقة الدراسة في المختبر (30 عينة). ثم تم استيفاء هذه القياسات بواسطة نمذجة قائمة على نظم المعلومات الجغرافية لإنشاء خرائط توضح التباينات المكانية لمتغيرات التربة. ووفقًا لنتائج الدراسة، قدمت تكنولوجيا نظم المعلومات الجغرافية (GIS) وصفًا واضحًا لخصائص المنطقة وسهلت فهم كيفية توزيع الخصائص الفيزيائية والكيميائية عبر منطقة الدراسة.
