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# Spatial Distribution of Some Soil Characteristics of Ramadi District, Western Iraq

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## ABSTRACT

Studying the spatial variation of soil properties is necessary to predict the productivity of agricultural land, food safety, and environmental status. Therefore, this study was carried out in Ramadi district, the center of Anbar Governorate - Iraq, to study the spatial variation of some soil properties (physical and chemical) using the geo statistical model. Using the predictive model of soil systems and Geographic information to prepare maps of the studied soil properties. The results showed the dominance of the moderately textured class with a percentage of 47.4%, followed by the moderately coarse texture class with a percentage of 34.2%. In addition, moderate variations have been recorded in the soil content of silt and clay, while unclear variation was recorded in the soil bulk density. As for the chemical characteristics, the soil content of organic matter, gypsum, and soil salinity showed very high variation, compared to the soil content of calcium carbonate and soil pH, which indicates the need to take them into consideration when planning the future use of the region's lands to increase their soil capability.

## 1. INTRODUCTION

The land resource is one of the most important natural resources, which plays an important role in economic life, and the sustainability of this resource faces many limitations resulting from climate change and natural disasters. The continued depletion of natural resources from lands with high productive potential will thus lead to their deterioration [1]. Land viability is determined by various characteristics of that land that are critical to productivity such as soil type, geology of the area, topography and hydrology [2].

The differences between the properties of soils at close distances resulting from the parent material reflect differential sedimentation processes resulting from the dynamic activity of the river and anthropic sedimentation resulting from irrigation operations. From the topographic aspect, they are generally characterized as almost level [3].

Al-Mohammadi et al. [4] studied the spatial variation in some soil chemical characteristics in two agricultural districts 5 Al-Nassaf and 17 Al-Bushjal, which were located in the Euphrates River basin. The results showed that the S.O.M content was the most variable among the soil properties of District 17 - Bushjal, with a coefficient of variation 192.02%, while the gypsum content was the most variable at 5 Al-Nassaf district with a coefficient of variation 105.4%, while 17-Bushjal districts excelled in the following chemical properties ECe, pH, $CaCO_3$, ESP, CEC, with a coefficient of variation 92.6, 5.7, 9.3, and 22.9% sequentially.

Studies of spatial variations in soil characteristics are important means of increasing the efficiency of soil surveys and classification, to study variations within a map unit and between map units, and distribution patterns of map units [5].

Spatial variations were divided into categories based on the coefficient of variation into simple variations with a coefficient of variation less than 15%, moderate variations with a coefficient of variation ranging between 15-35%, and severe variations with a coefficient of variation higher than 35% [6], while Aweto [7] divided the variances according to the coefficient of variation into four sections with low variances with a coefficient of variation of less than 25%, medium between 25-50%, high between 50-75%, and very high if it is higher than 75%.

Liu et al. [8] studied spatial variation of some soil characteristics for tobacco fields in central China by examining surface soil samples (0-20 cm) collected from 81 points using the gridding method. The strong spatial dependence was shown in the soil pH, N content, sand, and clay with the coefficient of variation ranging from 16% to 20%. while the moderately spatial dependence recorded in S.O.M, available phosphorus, available potassium, CEC, and silt, with coefficient of variation ranging from 30 to 50%, bout ESP did not show any spatial dependence.

Al-Timimi et al. [9] observed a clear variation in some chemical soil characteristics north of Tikrit in Iraq. Salinity was the most variable, followed by S.O.M, then CEC and finally the soil calcium carbonate content.

To demonstrate the spatial variation in agricultural soil properties in Ethiopia, the coefficient of variation revealed a decrease in the soil pH value of 6.52%.

The reason for the decrease in the value of the coefficient of variation for this characteristic is due to the effect of the high calcium carbonate content of the soil [10].

In some agricultural projects in Iraq, represented by the East Al-Haffar and Al-Majjar Al-Kabir projects, the results of the study of these two projects indicated that the gypsum was more variable, followed by salinity, then the ratio of exchangeable sodium, S.O.M, and $CaCO_3$ and finally soil pH. The values of the coefficient of variation for the chemical properties of the East Al-Haffar project ranged between 4.91 and 80.83%. For surface horizons and 4.67 and 101.98% for subsurface horizons. As for the Al-Majjar Al-Kabir project, the values of C.V was ranged between 4.37-148.43% for surface horizons and 3.68-123.25% for subsurface horizons [11].

Denton et al. [12] reported in their study the spatial variation and mapping of soil properties by geo statistical analysis in Oyo State by estimating the soil content of N, P, K, OC, pH, exchangeable bases, SAR, ESP, Cations and CEC for two depths 0-20 and 20- 40 cm, there was high variation in the available P and K (C.V ≥35%), while moderately variable (C.V=34-15%) was recorded for N, CEC, OC, SAR, and ESP, while low variation (C.V≤ 15%) was showed for soil pH, the recorded differences in soil characteristics are mostly attributed to applied soil management practices and The nature of the parent material from which the soil of the region was formed

A study of different soil sites in China [13] showed that the pH was less variable, with a coefficient of variation of 13.97%, while electrical conductivity was more variable, reaching 22.08%, followed by S.O.M at 17.41%.

Aggag and Alharbi [14] studied soil variations in the Hail region in the Kingdom of Saudi Arabia by examining the soil's physical, chemical, and fertility characteristics for 37 soil pedons. The results showed a highly significant relationship between pH, clay, BD, and AW, as well as a positive relationship for $CaCO_3$, P, K, Fe, Zn, Sand, FC, Mn, and Cu. All studied areas are exposed to environmental risks through the loss of nutrients through soil characteristics. The high sand content, indicates the necessity of determining the amount of fertilizers and irrigation water that are added to these studied land during management practices.

Therefore, this study aims to demonstrate the degree of horizontal variation in some physical and chemical soil properties of Ramadi district lands and the nature of their distribution in this region of Iraq.

## 2. MATERIALS AND METHODS

### 2.1 Study area

Ramadi district was selected, which was located between longitudes 41°26'00"- 44°26'00"and latitudes 32°40'00"- 33°34'00". It is bordered from the north by Lake Tharthar, the south by Lake Al-Razzaza and Karbala Governorate, from the west by Hit and Al-Rutba Districts and from the east by Al-Habbaniya and Fallujah Districts (Figure 1).

Some of studied lands are located within flood plain unit. Its lands are flat their levels ranged from 42-75m a.s.l. The parent material of its soil was from Euphrates River sediments in addition to transported wind sediments. The region's climate is characterized by drought, with annual rainfall 126.9 mm. and average annual temperature 24.4°C.

Several reconnaissance rounds were conducted, during which soil samples were collected from a depth of 0-45 cm from 38 modeling sites (The selection of the 38 examination sites was based on their economic importance from the agricultural side, as they are agricultural areas adjacent to the Euphrates River, which is given priority in the study compared to remote sites that are characterized by limited agricultural importance, taking into account the security aspects to avoid entering areas that are still under the control of operations. Military because of the security conditions that Iraq went through) using the Augar after determining its geographical locations using. The modeling sites were geographically determined using a GARMEN GPS device (Oregon 650t) with a location accuracy of 15 meters (49 feet) 95% of the time (Table 1). Disturbed samples were obtained and placed in polyethylene bags, in addition to undisturbed samples from the same depth to estimate the soil bulk density, then they were transported to the laboratory to conduct some physical and chemical analyses on them, according to the methods presented in studies [15-17].

**Table 1.** Geographic location of soil modeling locations in the study region

| Sample No. | Administrative District | X | Y |
|---|---|---|---|
| 1 | Albuabid | 43.42667 | 33.47008 |
| 2 | Al-Hamdeia | 43.40237 | 33.47214 |
| 3 | Al-Mooh | 43.37357 | 33.47318 |
| 4 | Al-Jaraishi | 43.34846 | 33.48751 |
| 5 | Al-Sahalit | 43.33197 | 33.46459 |
| 6 | Albudeab | 43.30844 | 33.48462 |
| 7 | Al-Talai | 43.26747 | 33.50154 |
| 8 | Al-Buali Al-Jassim | 43.22134 | 33.49332 |
| 9 | Albu Assaf | 43.19325 | 33.51419 |
| 10 | Tarabsha | 43.15286 | 33.52873 |
| 11 | Abu Tayban | 43.00592 | 33.50943 |
| 12 | Zwiger | 43.03583 | 33.48484 |
| 13 | Al-Dowar | 43.0944 | 33.49048 |
| 14 | Al-Cottney | 43.10802 | 33.51339 |
| 15 | Zankora | 43.18664 | 33.47910 |
| 16 | Tawy | 43.21571 | 33.46533 |
| 17 | Ramadi Municipality | 43.30455 | 33.42354 |
| 18 | Surah and Sufism | 43.35825 | 33.44744 |
| 19 | Zoya Satih | 43.4277 | 33.44408 |
| 20 | Tal Al-Ruyan | 43.35672 | 33.40863 |
| 21 | Zgiab and Al-Baheet | 43.39273 | 33.34793 |
| 22 | Abu Arish and Abu Kayash | 43.33929 | 33.37682 |
| 23 | Al-Mushahid and Al-Dasha | 43.40385 | 33.43388 |
| 24 | Al-Jabal district | 43.24161 | 33.60389 |
| 25 | Al-Wafia province | 42.8888 | 33.25182 |
| 26 | Al-Rahalia | 43.39458 | 32.78333 |
| 27 | Al-Boufraj | 43.28659 | 33.45370 |
| 28 | Krishan | 43.41855 | 33.39492 |
| 29 | Haswia samyia 1 | 42.89001 | 33.48805 |
| 30 | Haswia samyia 2 | 43.10476 | 33.35859 |
| 31 | Haswia samyia 3 | 43.24284 | 33.07605 |
| 32 | Haswia samyia 4 | 43.39700 | 32.94207 |
| 33 | Haswia samyia 5 | 43.14450 | 32.88249 |
| 34 | Haswia samyia 6 | 42.89816 | 33.09772 |
| 35 | Haswia samyia 7 | 42.52194 | 33.22683 |
| 36 | Al-Jabal 1 | 43.18942 | 33.68782 |
| 37 | Al-Jabal 2 | 43.41336 | 33.59989 |
| 38 | Al-Jabal 3 | 43.54487 | 33.52203 |

The research results were subjected to statistical analysis using traditional statistical methods (lowest value, highest value, average, coefficient of variation), comparing averages using the least significant difference test (LSD 0.05), finding the coefficient of variation (C.V), and using Genestal and Excel programs to find statistical relationships according to study [18].

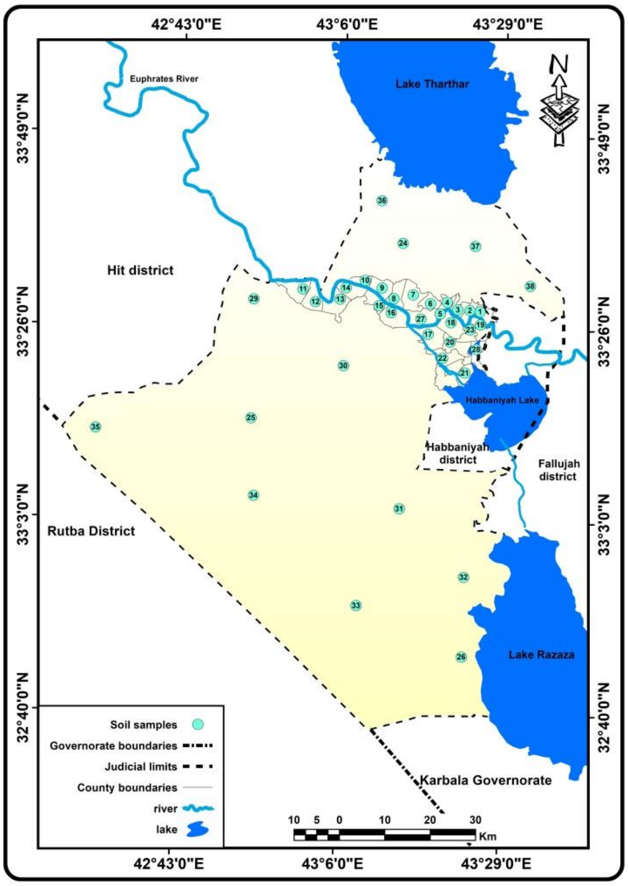


**Figure 1.** The administrative location of the study region, showing the locations of the soil sample modeling

## 3. RESULTS AND DISCUSSION

### 3.1 Soil physical properties

3.1.1 Soil particle size distribution

(1) Sand: Through Table 2 and Figure 2, it is clear that the highest percentage of sand was recorded at Zgiab and Al-Baheet distract (21) at an average 84.5%, while the Al-Jaraishi distract (4) showed the lowest value of this fraction, reaching 14.9%.

It is noted from the spatial distribution that the largest percentage, 63.90% of the space of the study region has a high sand content ranged between 57.5-84.5%. The origin of the sand in the study areas is due to sandy and limestone gypsum rocks, as well as transported from desert valleys, which come from desert and mountainous areas that were formed due to weathering and water erosion processes, which the river deposited on both sides of its banks and builds its floodplain from them [19]. The results of the coefficient of variation for the sand separator reached 38.8%, which indicates the presence of a moderate difference according to the classification of the study [7] (25-50%). Table 3 shows the percentage ranges of sand particles in the region soils.

(2) Silt: Table 2 and Figure 3 show that the soil content of the study areas ranges between 60.0-8.0%, the highest content recorded at the site Krishan (28), While the lowest content was recorded at the site Zgiab and Al-Baheet (21), with a coefficient of variation of 52.8%. Which indicates that there is a high difference between the soils of the distracts in terms of their content of this separation, and Table 4 shows the distribution ranges of this particle within the study area which was shown in the Figure 3 and Table 4, it is noted that the range 18.00-21.26% constituted the largest space in the study area, at rate 55.66%, while the range 53.79-70.40% constituted a minimum percentage 0.58% of the area of the studied region.

**Table 2.** Some soil physical properties of the study region

| Sample No. | Practical Size Distribution (%) | | | Texture Class | Bulk Density Mgm$^{-3}$ |
|---|---|---|---|---|---|
| | Sand | Silt | Clay | | |
| 1 | 36.1 | 40.7 | 23.2 | Loam | 1.43 |
| 2 | 36.5 | 45.1 | 18.4 | Loam | 1.34 |
| 3 | 24.5 | 50.7 | 24.8 | Silt loam | 1.41 |
| 4 | 14.9 | 48.5 | 36.6 | Silty clay loam | 1.28 |
| 5 | 41.5 | 38.8 | 19.7 | Loam | 1.34 |
| 6 | 24.4 | 50.5 | 25.1 | Silt loam | 1.33 |
| 7 | 27.5 | 50.1 | 22.4 | Silt loam | 1.42 |
| 8 | 18.6 | 43.3 | 38.1 | Silty clay loam | 1.34 |
| 9 | 31.9 | 44.6 | 23.5 | Loam | 1.34 |
| 10 | 32.4 | 47.4 | 20.2 | Loam | 1.37 |
| 11 | 46.4 | 50.4 | 3.2 | Silt loam | 1.30 |
| 12 | 28.4 | 70.4 | 1.2 | Silt loam | 1.29 |
| 13 | 54.4 | 34.4 | 11.2 | Sandy loam | 1.29 |
| 14 | 40.4 | 52.4 | 7.2 | Silt loam | 1.37 |
| 15 | 56.3 | 40.5 | 3.2 | Sandy loam | 1.20 |
| 16 | 42.2 | 54.3 | 3.5 | Silt loam | 1.34 |
| 17 | 48.3 | 48.2 | 3.5 | Sandy loam | 1.38 |
| 18 | 36.2 | 46.5 | 17.3 | Loam | 1.48 |
| 19 | 41.2 | 45.9 | 12.9 | Loam | 1.36 |
| 20 | 35.5 | 55.0 | 9.5 | Silty loam | 1.33 |
| 21 | 84.5 | 8.0 | 7.5 | Sandy loam | 1.54 |
| 22 | 30.5 | 55.0 | 14.5 | Silt loam | 1.18 |
| 23 | 22.4 | 38.8 | 38.8 | Clay loam | 1.54 |
| 24 | 52.3 | 15.3 | 32.4 | Sandy clay loam | 1.33 |
| 25 | 74.0 | 10.0 | 16.0 | Sandy loam | 1.52 |
| 26 | 68.2 | 14.3 | 17.5 | Sandy loam | 1.50 |
| 27 | 30.3 | 48.6 | 21.1 | Loam | 1.36 |
| 28 | 28.5 | 62.0 | 9.5 | Silt loam | 1.34 |
| 29 | 69.1 | 14.5 | 16.4 | Sandy loam | 1.54 |
| 30 | 67.6 | 15.3 | 17.1 | Sandy loam | 1.51 |
| 31 | 68.3 | 14.4 | 17.3 | Sandy loam | 1.48 |
| 32 | 66.6 | 14.5 | 18.9 | Sandy loam | 1.50 |
| 33 | 67.6 | 15.1 | 17.3 | Sandy loam | 1.49 |
| 34 | 68.4 | 14.5 | 17.1 | Sandy loam | 1.51 |
| 35 | 68.5 | 14.2 | 17.3 | Sandy loam | 1.52 |
| 36 | 51.5 | 16.2 | 32.3 | Sandy clay loam | 1.42 |
| 37 | 52.3 | 15.3 | 32.4 | Sandy clay loam | 1.40 |
| 38 | 52.4 | 15.1 | 32.5 | Sandy clay loam | 1.39 |
| Physical Property | | Min. | Max | Mean | C.V. |
| 38.8 | Sand | 14.9 | 84.5 | 51.1 | 38.8 |
| 52.8 | Silt | 8.0 | 62.0 | 35.8 | 52.8 |
| 54.3 | Clay | 1.2 | 38.8 | 23.9 | 54.3 |

**Table 3.** Soil content of sand particle ranges ratios and their distribution within the study region

| Sand Percentage Range | The Area it Occupies from Total Area(ha) | The Percentage from Total Area |
|---|---|---|
| 14.90-33.23 | 210 | 3.09 |
| 33.24-42.05 | 845 | 12.43 |
| 42.06-57.49 | 1399 | 20.58 |
| 57.50-84.50 | 4342 | 63.90 |
| Total | 6796 | 100 |

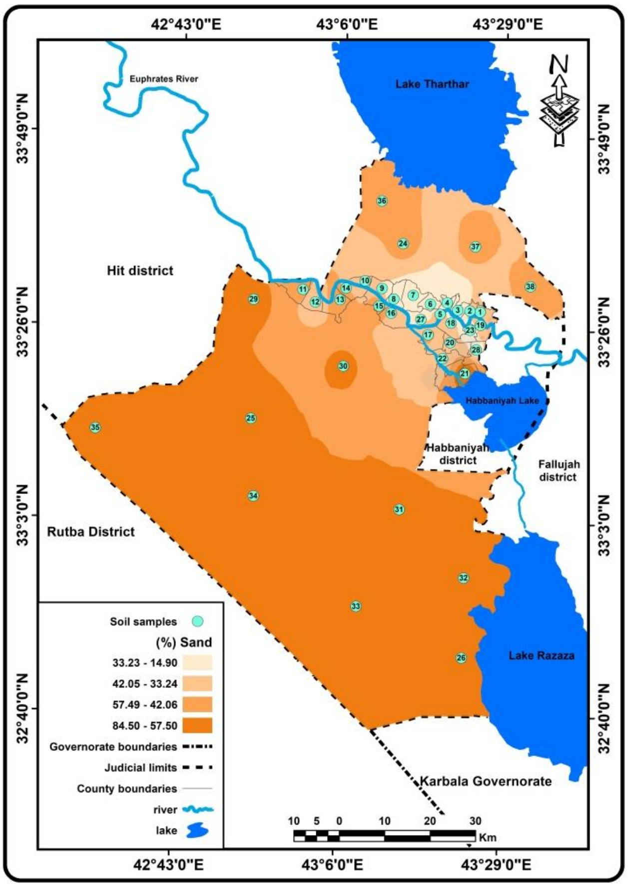


**Figure 2.** Map of spatial distribution of soil sand content ranges within the study region

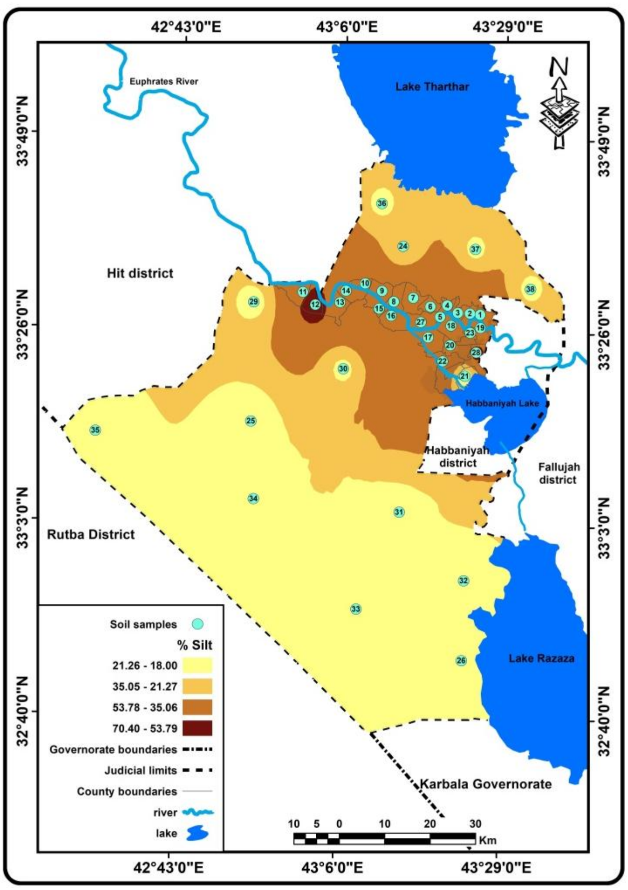


**Figure 3.** Map of spatial distribution of soil silt content ranges within the study region

The high variation in the silt content of the region's soil is due to the depositional nature of sedimentary soils, as silt is part of the soil carried by floods over a varying distance and then deposited when the carrying force of the water decreases, in addition to the effect of torsional belts in the river, the movement of flood waters accidentally, and the effect of anthropic sedimentation processes due to human practices in the irrigation process, in addition to the effect of dust storms coming from the west, which deposited their loads after their strength or momentum decreased, this allowed the sedimentation of fine sediments [20].

**Table 4.** Soil content of silt particle ranges ratios and their distribution within the study region

| Silt Percentage Range | The Area it Occupies from Total Area(ha) | The Percentage from Total Area |
|---|---|---|
| 18.00-21.26 | 3783 | 55.66 |
| 21.27-35.05 | 1605 | 23.61 |
| 35.06-53.78 | 1370 | 20.15 |
| 53.79-70.40 | 39 | 0.58 |
| Total | 6796 | 100 |

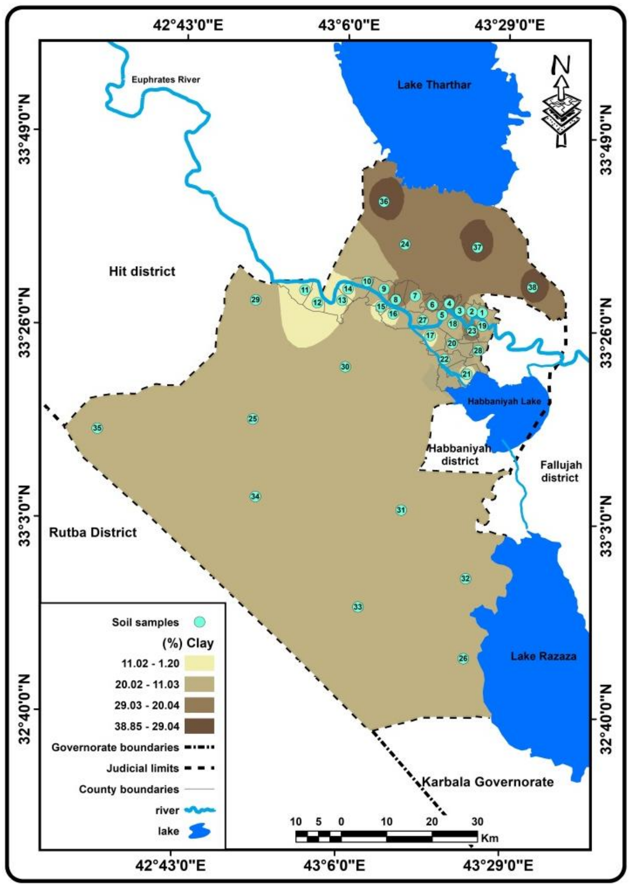


**Figure 4.** Map of spatial distribution of soil clay content ranges within the study region

(3) Clay: It is clear from Table 2 that the presence of clay within the study area ranged between 1.2-38.8%.the highest content was recorded at the Al-Mushahid and Al-Dasha district (23), while the lowest content was recorded at the Zwiger site (12), with a coefficient of variation 54.3%, a high difference between the study distracts, this is due to the small size of the clay separation compared to silt and sand, which allows it to be transported over longer distances in the form of

suspension during floods and as dust during wind erosion, giving a highly variable distribution over large areas [21].

The clay separations spatial distribution in the study region Figure 4 and Table 5 indicates that it's ranged between 11.03-20.02% constituted the largest percentage of the region, with a rate reaching 83.60%, while the other ranges in their total did not exceed 18%, and they are all concentrated in the northern part between the Euphrates Rivers and Lake Tharthar. This characteristic accompanies the variation in sedimentation and flooding in the region.

**Table 5.** Soil clay particle content ranges ratios and their distribution within the study region

| Clay Percentage Range | The Area it Occupies from Total Area(ha) | The Percentage from Total Area |
|---|---|---|
| 1.20-11.02 | 236 | 3.47 |
| 11.03-20.02 | 5682 | 83.60 |
| 20.03-29.03 | 722 | 10.62 |
| 29.04-38.85 | 156 | 2.31 |
| Total | 6796 | 100 |

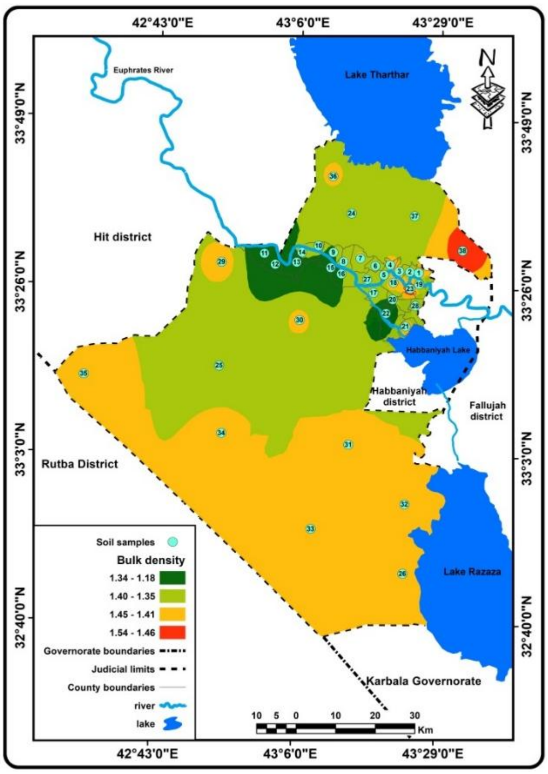


**Figure 5.** Map of spatial distribution of bulk density ranges within the study region

(4) Soil bulk density: It is noted from Table 2 that the values of this characteristic ranged between 1.20 - 1.54 Meg $m^{-3}$, the highest value recorded in the distract Zgiab and Al-Baheet (21), this is due to its soil high content of sand separate, and this is confirmed by the high significant correlation coefficient for this soil physical characteristic with the soil content of sand, which amount r=0.803**, and this is agreed with study [22], while the lowest bulk density of soil was recorded in the district of Zankora (15), and this is attributed to its content of silt separate, which reached an average of 40.5%, and this confirmed the negative significant correlation between this physical characteristic and the soil content of silt, which reached r=-0.632* noting that this characteristic interferes in influencing its values, such as the soil content of clay r=-0.531 and S.O.M content which reached r=-0.289.

In terms of spatial variation, results for this characteristic showed a coefficient of variation of 6.7% (Table 2), which indicates the presence of simple variations within the region. It is observed from Figure 5 and Table 6 that the range of bulk density between 1.45-1.35 Meg $m^{-3}$ was prevalent in the region, and this was due to the low content of studied soils from S.O.M, which has an important role in reducing soil bulk density, and this is agreed with study [23].

It is noted from Table 2 that the dominant texture class was the moderately coarse with 47.4%, followed by the Moderately Coarse class with 34.2%, while the moderately fine class constituted the remaining 18.4%. This is consistent with what was indicated by the study [24].

**Table 6.** Soil bulk density ranges ratios of and their distribution within the study region

| Bulk Density Percentage Range | The Area it Occupies from Total Area(ha) | The Percentage from Total Area |
|---|---|---|
| 1.18-1.34 | 364 | 5.35 |
| 1.35-1.40 | 2919 | 42.95 |
| 1.41-1.45 | 3435 | 50.54 |
| 1.46-1.54 | 79 | 1.16 |
| Total | 6796 | 100 |

**Table 7.** Some chemical characteristics of the study soils

| Sample No. | pH | ECe $dSm^{-1}$ | O.M. $gkg^{-1}$ | Gypsum $gkg^{-1}$ | $CaCO_3$ $gkg^{-1}$ |
|---|---|---|---|---|---|
| 1 | 7.51 | 15.85 | 6.32 | 17.66 | 186.48 |
| 2 | 7.64 | 14.34 | 9.91 | 14.98 | 203.61 |
| 3 | 7.60 | 3.62 | 8.45 | 10.36 | 189.74 |
| 4 | 7.60 | 12.80 | 4.30 | 14.60 | 199.00 |
| 5 | 7.61 | 14.54 | 4.01 | 21.11 | 176.99 |
| 6 | 7.65 | 16.62 | 2.02 | 8.15 | 206.01 |
| 7 | 7.60 | 6.02 | 6.28 | 14.52 | 242.72 |
| 8 | 7.75 | 7.76 | 6.50 | 11.37 | 282.28 |
| 9 | 7.61 | 5.88 | 11.26 | 16.71 | 196.38 |
| 10 | 7.68 | 8.13 | 8.51 | 18.40 | 298.55 |
| 11 | 7.40 | 1.90 | 2.00 | 5.10 | 193.40 |
| 12 | 7.75 | 1.09 | 1.00 | 0.51 | 145.53 |
| 13 | 7.45 | 2.71 | 13.36 | 4.76 | 223.34 |
| 14 | 7.55 | 8.55 | 3.00 | 23.02 | 265.77 |
| 15 | 7.50 | 1.04 | 0.64 | 2.51 | 326.33 |
| 16 | 7.34 | 0.82 | 1.51 | 2.30 | 215.81 |
| 17 | 7.20 | 6.50 | 1.18 | 17.81 | 368.20 |
| 18 | 7.37 | 5.75 | 0.83 | 15.03 | 370.35 |
| 19 | 7.32 | 2.58 | 1.42 | 10.58 | 155.22 |
| 20 | 7.50 | 6.80 | 0.08 | 18.53 | 266.72 |
| 21 | 7.35 | 4.34 | 1.08 | 18.51 | 292.83 |
| 22 | 7.70 | 25.50 | 0.68 | 33.50 | 299.22 |
| 23 | 7.23 | 2.16 | 3.24 | 305.57 | 213.29 |
| 24 | 7.23 | 2.16 | 3.24 | 305.57 | 213.29 |
| 25 | 7.72 | 4.31 | 1.52 | 78.54 | 193.01 |
| 26 | 7.60 | 1.41 | 2.42 | 70.65 | 180.00 |
| 27 | 7.59 | 2.66 | 3.52 | 14.82 | 256.91 |
| 28 | 7.42 | 4.02 | 0.71 | 39.53 | 262.53 |
| 29 | 7.80 | 1.43 | 2.61 | 71.11 | 180.21 |
| 30 | 7.90 | 1.62 | 2.43 | 70.81 | 181.11 |
| 31 | 7.50 | 1.54 | 2.52 | 70.33 | 180.21 |
| 32 | 7.30 | 1.43 | 2.33 | 70.52 | 181.23 |
| 33 | 7.50 | 1.32 | 2.34 | 70.31 | 182.00 |
| 34 | 7.40 | 1.41 | 2.64 | 70.51 | 180.15 |
| 35 | 7.80 | 1.32 | 2.50 | 70.73 | 181.23 |
| 36 | 7.22 | 2.18 | 3.26 | 37.55 | 214.33 |
| 37 | 7.24 | 2.22 | 3.29 | 306.56 | 212.28 |
| 38 | 7.27 | 2.29 | 3.32 | 309.44 | 215.28 |

### 3.2 Soil chemical properties

3.2.1 Soil pH

Results of the Table 7 noted that the values of this characteristic ranged between 7.20-7.90, lowest average was recorded in Ramadi Municipality district (17), while the Haswia Samyia district 3 (31) showed the highest value, the measured values for this soil property were located within the class of neutral to inclined to alkalinity soils according to study [25].

This is due to the high $CaCO_3$ content of the region's soils, which contributes to the high values of this characteristic. This was confirmed by the positive correlation between the pH of the soil and its content of calcium carbonate, which reached r=0.329. This is agreed with study [19] which observed a distinctive characteristic of the Iraq's soils, and with study [26] which indicated that the pH values of soils in dry and semi-arid regions range between 7.2 and 9.3.

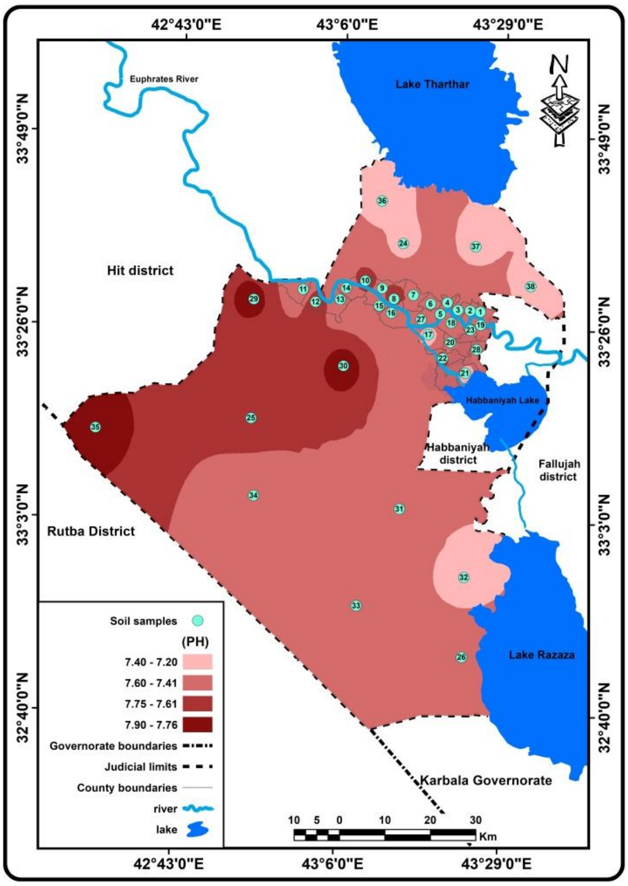


**Figure 6.** Map of spatial distribution of soil pH ranges within the study region

**Table 8.** Cartographical analysis of soil pH spatial distribution map

| Soil pH Range | The Area it Occupies from Total Area(ha) | The Percentage from Total Area |
|---|---|---|
| 7.20-7.40 | 692 | 10.18 |
| 7.41-7.60 | 4278 | 62.95 |
| 7.61-7.75 | 1534 | 22.57 |
| 7.76-7.90 | 293 | 4.30 |
| Total | 6796 | 100 |

In terms of the spatial distribution of this characteristic shown in Figure 6 and the cartographic analysis of it in Table 8, it exceeds the range 7.41-7.60 in terms of the area it occupies 4278 ha (62.95%) from the study area. As for the soils with high pH within the range 7.76-7.90, it constituted a minimum area of 293ha or 4.30%, concentrated in specific areas in the western part of the region.

3.2.2 Soil electrical conductivity

It is noted from Table 7 that the values of this chemical property in the region soils ranged between 0.82 and 25.5$dSm^{-1}$, which indicates that it ranged from a very little effect by salinity class to highly affected class according to study [25], with a very high coefficient of variation 101.7%. The lowest ECe was recorded at Tawy district (16), while the highest values were recorded at Abu Arish and Abu Kayash district (22). It is noted from Figure 7 and Table 9 that the high percentage study region (77.29%) is within the salinity class ranged between 0.82-4.44 $dSm^{-1}$, that has no effect on all agricultural crops, the spatial distribution showed that was located in the western regions of Ramadi district and is attributed to this is because it is not exposed to secondary salinization resulting from irrigation.

The reason for this variation in soil ECe is attributed in the first place to the difference in the geomorphological location and to exposure of the surface soil horizons to evaporation, which was leaving the salts on the soil surface, in addition to soil management practices which has a major role in this reason. These results agree with what was confirmed by study [27], which found that among the chemical characteristics, there is the highest variation. It is salinity when studying the variation in electrical conductivity values of Iraqi alluvial soils in southern Iraq.

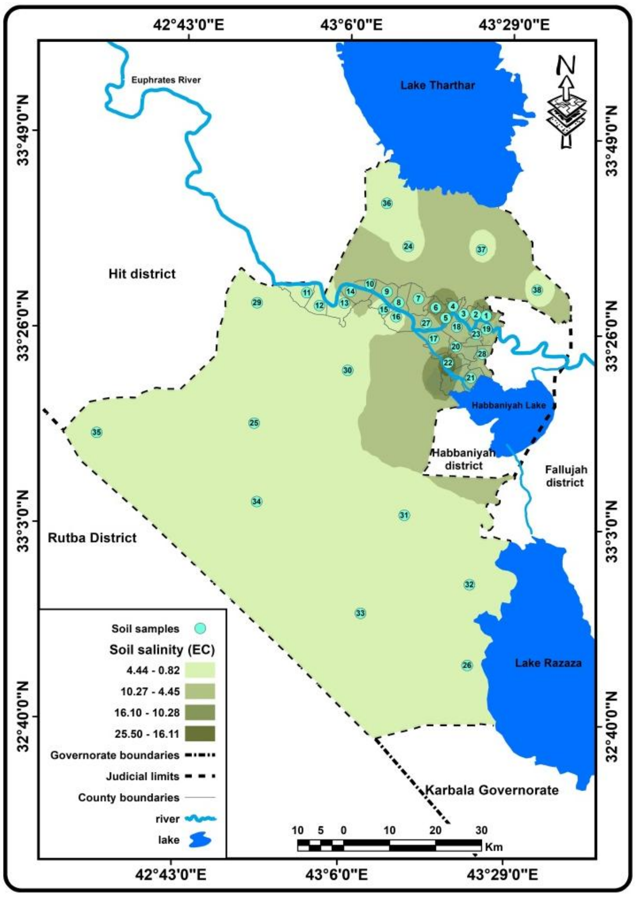


**Figure 7.** Map of spatial distribution of soil electrical conductivity ranges within the study region

**Table 9.** Cartographical analysis of soil ECe spatial distribution map

| ECe $dSm^{-1}$ Range | The Area it Occupies from Total Area(ha) | The Percentage from Total Area |
|---|---|---|
| 0.82-4.44 | 5253 | 77.29 |
| 4.45- 10.27 | 1409 | 20.73 |
| 10.28-16.10 | 118 | 1.73 |
| 16.11-25.50 | 15 | 0.25 |
| Total | 6796 | 100 |

3.2.3 Soil organic matter content

The results of Table 7 indicate that the content of the study region soils from this component ranged between 13.36 - 0.08 $gkg^{-1}$, with a very high coefficient of variation of 85.8%. The observed variation in the soil content of S.O.M is due to the fact that some areas are characterized by the presence of denser vegetation cover than others, in addition to the difference in service operations to which the land is exposed, such as adding fertilizers. In general, the decrease in region soils content from S.O.M which was recorded is due to the lack of vegetation cover, high temperature and decreased amount of rainfall, in addition to the wrong practices of farmers and the security conditions that the governorate has experienced during the past years, which prompted residents to leave their lands or leave them without agricultural use.

It is clear from Figure 8, the spatial distribution of this component, that the range of S.O.M content 2.134-3.990 $gkg^{-1}$ constituted the highest area, amounting to 76.64% (Table 10), which indicates that most soils of the study region are suffering from low content from this component.

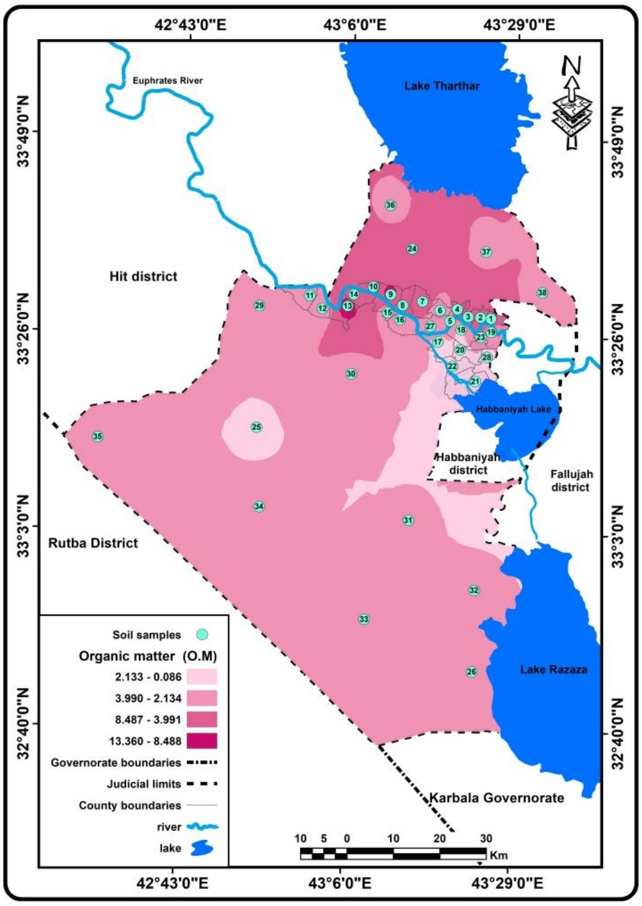


**Figure 8.** Map of spatial distribution of soil organic matter content ranges within the study region

**Table 10.** Cartographical analysis of the spatial distribution map of S.O.M. content

| O.M $gKg^{-1}$ Range | The Area it Occupies from Total Area (ha) | The Percentage from Total Area |
|---|---|---|
| 0.086-2.133 | 685 | 10.07 |
| 2.134-3.990 | 5209 | 76.64 |
| 3.991-8.487 | 882 | 12.97 |
| 8.488-13.360 | 20 | 0.32 |
| Total | 6796 | 100 |

3.2.4 Gypsum content of the soil

The results of Table 7 showed that soil gypsum content was ranged between 0.51- 309.44 g $kg^{-1}$, with a coefficient of variation 148.7%, which indicates that there is a very high difference between the test sites in terms of their gypsum content. The lowest content of this content was recorded in Zwiger district (12), while the highest content was recorded in Al-Jabal 3 district (38). The large spatial variation in the gypsum content in the soil of the region is due to the fact that gypsum has the ability to dissolve in irrigation water and move into the soil body with different degrees of solubility depending on the salinity of the water used for irrigation. This confirms the positive correlation between the soil content of gypsum and soil salinity reached r=0.214.

The results of the Figure 9 and Table 11 show that the soil content of gypsum range 53.74-121.76 $gkg^{-1}$ constituted largest area 67.07%, in comparison to the range of 121.77-306.56 $gkg^{-1}$, which had the lowest area within the study region of 256 hectares (3.76%), which indicates to a decrease in the gypsum content of the region's soil. This result agreed with study [28].

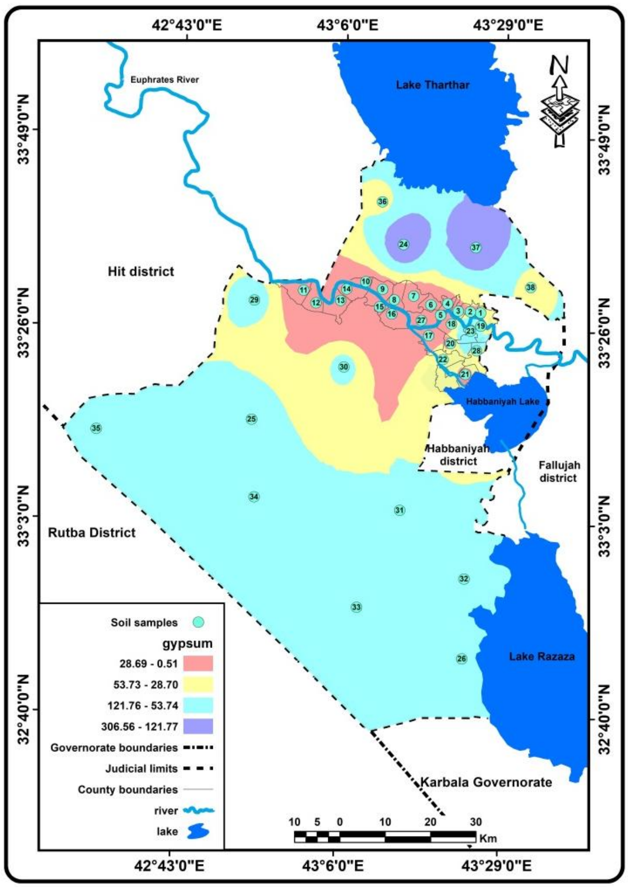


**Figure 9.** Map of spatial distribution of soil gypsum content ranges within the study region

**Table 11.** Cartographical analysis of the spatial distribution map of soil gypsum content

| Gypsum gkg$^{-1}$ Range | The Area it Occupies from Total Area (ha) | The Percentage from Total Area |
|---|---|---|
| 0.51-28.69 | 725 | 10.67 |
| 28.70-53.73 | 1257 | 18.50 |
| 53.74-121.76 | 4558 | 67.07 |
| 121.77-306.56 | 256 | 3.76 |
| Total | 6796 | 100 |

3.2.5 Soil content of calcium carbonate

It is clear from Table 7 that the soil content of this component ranged between 176.99- 370.35gkg$^{-1}$. The lowest content was recorded in Al-Sahalit district (5), while the highest component was recorded in the Surah and Sufism district (18), with a coefficient of variation of 24.4%, which indicates moderate variations between the study districts in terms of their calcium carbonate content.

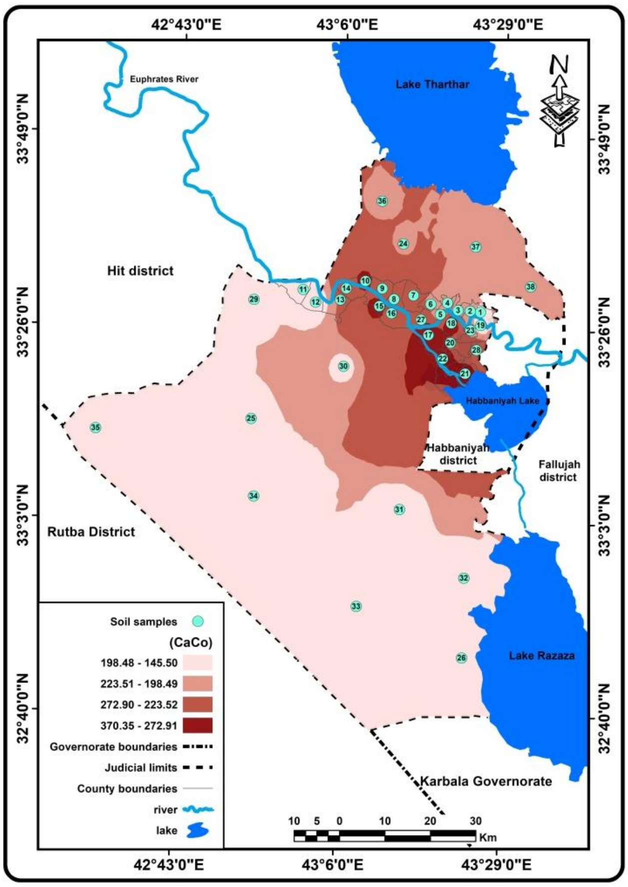


**Figure 10.** Map of spatial distribution of soil carbonate content ranges within the study region

**Table 12.** Cartographical analysis of the spatial distribution map of soil $CaCO_3$ content

| Carbonate gkg$^{-1}$ Range | The Area it Occupies from Total Area (ha) | The Percentage from Total Area |
|---|---|---|
| 145.50-198.48 | 4146 | 61.00 |
| 198.49-223.51 | 1351 | 19.88 |
| 223.52-272.90 | 1113 | 16.38 |
| 272.91-370.35 | 186 | 2.74 |
| Total | 6796 | 100 |

It is noted from Figure 10 and Table 12 that the range of soil carbonate content 145.50-198.48 gkg$^{-1}$ was constituted the largest area in the study region, amounting to 61.00%, while the high content 272.91-370.35 gkg$^{-1}$ constituted the smallest area, 186 hectares (2.74%). The presence of carbonates in this region of Anbar Governorate is due to the parent material nature from which these sediments were transported by the Euphrates River, and this is consistent with study [24] when he was studied the spatial distribution of some soil properties within the Euphrates River Basin in Anbar Governorate.

## 4. CONCLUSIONS

1- Identifying and mapping the spatial distribution of soil properties helps farmers make effective management decisions based on their understanding of soil properties under different land uses. Which helps in providing recommendations for best management practices in the study region.

2- The moderate variations in soil physical characteristics, indicates the necessity of choosing suitable tillage equipment and application methods to the soil of the region.

3- The very high spatial variation in soil salinity, S.O.M and gypsum indicates need to take them into account when planning land use in the region. Compared to soil pH and its calcium carbonate content.

4- The study enhances food security by describing and analyzing soil characteristics in an agriculturally important area in Iraq, which leads to determining its fertility status, increasing the productivity of the dominant crops grown in the region, and improving appropriate agricultural and irrigation techniques, which helps meet the needs of the growing population and preserve the environment from deterioration in the future.

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