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Variations in some chemical properties of the Euphrates River deposits using conventional statistical analysis

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Abstract
This study was conducted on the soils of Babylon Governorate, where three sites were selected to represent different depositional environments of the Euphrates River, located within the districts of Al-Musayyib, Al-Hilla center, and Al-Kifl. Three sub-sites were chosen within each district at two depths (0-30 cm and 30-60 cm) to investigate how the distance from the sediment source affects soil properties, using conventional statistical analysis. The results showed a variation in soil texture, with clay content increasing as the distance from the depositional source increased, reflecting changes in the sedimentary environment. Chemically, the soil properties varied significantly between locations and depths. Electrical conductivity (EC) values ranged from 78.19 to 113.75 at the 0-30 cm depth and from 70.56 to 178.98 at 30-60 cm, with noticeable skewness and standard deviation. Soil pH values showed relatively slight variation but high coefficients of variation (CV), indicating sensitivity to site-specific conditions. The Exchangeable Sodium Percentage (ESP) values were highly variable, reflecting differences in sodium accumulation. The $CaCO_3$ and gypsum contents also varied widely across sites and depths, with high skewness and standard deviations, indicating heterogeneity in their distribution. These variations are attributed to differences in physiographic positions, groundwater levels, and soil management practices. The findings highlight the importance of analyzing morphological and chemical soil characteristics when planning for optimal agricultural land use in the Euphrates river environments.

Keywords: Variation of chemical properties, fluvial sediments, spatial distribution

1. Introduction

Their tributaries. These river deposits are stratified sedimentary materials of mixed origin and are recently formed, considered young and undeveloped soils. Their deposition may occur either suddenly or gradually, with no significant genetic relationship to pedogenic processes, which have minimal influence. The geological factor remains the primary force behind their formation (Al-Akaidi, 1989) [10].

Sedimentary soils have played a major role in the development of agriculture since ancient times, even before the advent of fertilization systems. They cover vast areas, particularly along rivers, floodplains, river deltas, and valleys. The nature and conditions of deposition in sedimentary soils lead to variation in their textural classes, ranging from sandy loam to sandy and loamy sand soils. These soils are newly formed and underdeveloped, with dominance of clay and silt fractions and a low proportion of sand. The distribution of soil textures is closely related to the rate of sedimentation, which is affected by the proximity to the sediment source (i.e., the river).

The alluvial plain is mainly composed of newly formed soils resulting from the accumulation of various river deposits over areas with diverse topographic features, as confirmed by(Al-Dulaimi *et al*.,2017) [6]. Moreover, the importance of geostatistics in studying and understanding soil property variations has been highlighted. This field offers a range of statistical tools that allow for the integration of spatial and temporal variations in data processing. These tools support the description and modeling of spatial patterns, prediction of soil property values in unsampled locations, and verification of the accuracy of those predictions (Krasilnikov *et al*., 2008) [22].

This study aims to investigate the spatial variation of selected chemical properties of soil using conventional statistical parameters, in order to facilitate soil survey, classification, and management practices.

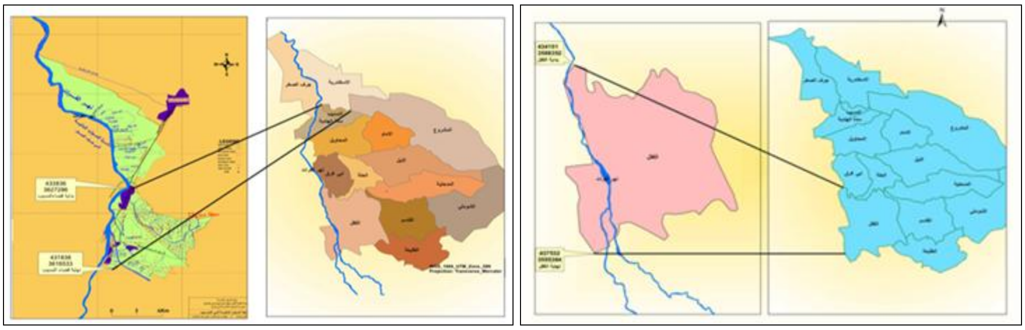
2. Material and Methods

2.1 Study area

The study area is located in Babil Governorate, which covers an area of approximately 4,555 km² and includes Al-Musayyib District, the center of Al-Hillah District, and Al-Kifl Subdistrict. Al-Musayyib District lies within the coordinates 433836E, 3627286N and 431838E, 3616533N, with a total area of 257 km². Al-Kifl is located within the coordinates 434151E, 3588352N and 437532E, 3555384N, covering an area of 526 km². As for the center of Al-Hillah District, it lies within the coordinates 440227E, 3603417N and 439472E, 358643N, with an area of 161 km². These areas were selected because they represent banks of the Euphrates River. Three soil sampling sites were selected along a transect perpendicular to the river. Soil samples were collected from two depths at each site: 0-30 cm and 30-60 cm. The geographic coordinates of each site were recorded using a GPS device (Table 1).The surface and subsurface layers were then exposed and described morphologically according to the guidelines of the Soil Survey Manual (Soil Survey Division Staff, 1993). Samples from each depth were collected and stored in labeled bags for the purpose of conducting the necessary laboratory analyses.

Table 1: GPS Coordinates of Soil Sampling UTM Sites in Babil Governorate

The site	Soil	X	Y
Musayyib	S1	43°17' 88.00" E	36°22' 0.817" N
	S2	43°20' 88.01" E	36°22' 702" N
	S3	43°25' 50.00" E	36°22' 655" N
Al-Hillah	S1	44°76'79" E	35°94' 593" N
	S2	44°79'03" E	35°94' 593" N
	S3	44°80'82" E	35°94' 548" N
Al-Kifl	S1	43°83' 17.00" E	35°71' 838" N
	S2	43°86' 74.0" E	35°71' 838" N
	S3	43°88' 27.9" E	33°71' 838" N



Location of Al-Kifl within Babil Governorate, Location of Al-Musayyib within Babil Governorate

Location of Al-Hillah within Babil Governorate

Fig1: Shows the location of the study areas within Babil Governorate

2.2 Analysis in the Lab

Chemical Measurements

The chemical measurements included the following:

Electrical Conductivity (EC)

Electrical conductivity was measured in the 1:1 soil-water extract using a conductivity bridge device, following the method of (Richards, 1954) [26] as described in USDA (1954).

Soil Reaction (pH) Soil pH was determined in a 1:1 soil-water extract using the method of (McKeague, 1978) [3], as described by (Ryan *et al*., 2003) [27].

Total Calcium Carbonate ($CaCO_3$) the percentage of calcium carbonate was estimated using 1N hydrochloric acid (HCl), and the excess acid was titrated with 1N sodium hydroxide (NaOH), according to the method of (Jackson, 1958) [20].

Gypsum Content (Gypsum) Gypsum was determined using the acetone precipitation method, followed by measuring the electrical conductivity of the precipitate, according to (Richards, 1954) [26].

Exchangeable Sodium Percentage (ESP) ESP was calculated using the following equation:

$$ESP = 6.28 + 0.64 \times SA$$

3. Results and Discussion

Table 2: Morphological Description of Al-Musayyib District in Babil Governorate

Soil	Depth (cm)	Morphological Description
S1	0-30	Brown (10YR 5/3)d;dark brown(10YR 4/3)m;Silt clay loam;strong, medium,subangular blocky; hard, friable, sticky and slightly plastic;common, fine pores; plentiful, fine and coarse roots; clear, smooth boundary.
S1	30-60	Brown (10YR 5/3)d;dark brown(10YR 4/3)m;Silt clay loam;strong, medium,subangular blocky; hard, friable, sticky and slightly plastic;common, fine pores; plentiful, fine and coarse roots; clear, smooth boundary.
S2	0-30	Brown(10yR5/3)m;Silty clay;strong medium sub angular blocky;hard,friable,sticky and plastic;common,fine porse;abundant, fine and coarse roots;gradually, smooth boundary.
S2	30-60	Brown(10yR5/3)m;Silty clay;strong medium sub angular blocky;hard,friable,sticky and plastic;common,fine porse;abundant, fine and coarse roots;gradually, smooth boundary
S3	0-30	Dark brown (10YR3/3) m; clay; strong,medium sub angular blocky; friable, sticky and plastic; many, fine pores; abundant, fine roots;clear smooth boundary.
S3	30-60	Dark brown (10YR3/3) m; clay; strong,medium sub angular blocky; friable, sticky and plastic; many, fine pores; abundant, fine roots;clear smooth boundary.

Table 3: Morphological Description of the Center of Al-Hillah District in Babil Governorate

Morphological Description	Depth (cm)	Soil	Study Area
Brown (10YR 5/3) d; dark brown (10YR 4/3) m; Silt clay loam; strong, medium, subangular blocky; hard, friable, sticky and slightly plastic; common, fine pores; plentiful, fine and coarse roots; clear, smooth boundary.	0-30	S1	Center of Al-Hillah District
Brown (10YR 5/3) d; dark brown (10YR 4/3) m; Silt clay loam; strong, medium, subangular blocky; hard, friable, sticky and slightly plastic; common, fine pores; plentiful, fine and coarse roots; clear, smooth boundary.	30-60	S1	
Brown (10yR5/3)m; Silty clay; strong, medium, sub angular blocky; hard, friable, sticky and plastic; common, fine porse; abundant, fine and coarse roots; gradually, smooth boundary	0-30	S2	
Brown (10yR5/3)m; Silty clay; strong, medium, sub angular blocky; hard, friable, sticky and plastic; common, fine porse; abundant, fine and coarse roots; gradually, smooth boundary	30-60	S2	
Dark brown (10YR3/3) m; clay; strong, medium, sub angular blocky; friable, sticky and plastic; many, fine pores; abundant, fine roots; clear, smooth boundary.	0-30	S3	
Dark brown (10YR3/3) m; clay; strong, medium, sub angular blocky; friable, sticky and plastic; many, fine pores; abundant, fine roots; clear, smooth boundary.	30-60	S3	

Table 4: Morphological Description of Al-Kifl Subdistrict in Babil Governorate

Study Area	Soil	Depth (cm)	Morphological Description
Al-Kifl Subdistrict	S1	0-30	Brown(10yR5/3) m;Silty clay;strong medium sub angular blocky;hard,friable,sticky and plastic;common,fine porse;abundant, fine and coarse roots;gradually, smooth boundary
	S1	30-60	Brown(10yR5/3) m;Silty clay;strong medium sub angular blocky;hard,friable,sticky and plastic;common,fine porse;abundant, fine and coarse roots;gradually, smooth boundary
	S2	0-30	Brown (10YR5/3)d;dark brown (10YR)m; clay loam; strong,coarse, subangular blocky; friable, slightly sticky and slightly plastic;common, fine porse; plentiful,fine and coarse roots;wavy smooth boundary.
	S2	30-60	Brown (10YR5/3)d;dark brown (10YR)m; clay loam; strong,coarse, subangular blocky; friable, slightly sticky and slightly plastic;common, fine porse; plentiful,fine and coarse roots;wavy smooth boundary.
	S3	0-30	Dark brown (10YR3/3) m; clay; strong, medium sub angular blocky; friable, sticky and plastic; many, fine pores; abundant, fine roots; clear smooth boundary.
	S3	30-60	Dark brown (10YR3/3) m; clay; strong, medium sub angular blocky; friable, sticky and plastic; many, fine pores; abundant, fine roots; clear smooth boundary.

Al-Musayyib District is located within the floodplains of the Euphrates River, which serves as a primary source of irrigation and agriculture. The presence of small streams and tributaries also contributes to the water flow used for irrigating agricultural lands. The topography of the area is generally low to moderately elevated, consisting of fertile plains. The climate is characterized by extremely hot summers and moderately cold winters. Rainfall is limited during winter, making agriculture highly dependent on irrigation water. The soils of Al-Musayyib are known for their high fertility due to the sediment deposits brought by the Euphrates River. The region also supports a diverse vegetation cover. As for the center of Al-Hillah District, it lies within a soil zone influenced by climatic conditions, dominant vegetation, and geological composition. The soil texture varies from clayey to sandy, with mixed soils containing different proportions of sand and clay, and are often rich in minerals. These soils typically have light brown to gray colors, and may appear warm and dark in areas with a high organic matter content. In some areas, the soil is medium to light in texture, allowing good water drainage but requiring careful agricultural practices to avoid drought stress. The arable surface layer generally ranges from 20 to 60 cm in thickness. Regarding Al-Kifl Sub district, which is part of Babil Governorate and located in the southern region of Iraq, it is characterized by several geographical and morphological features. The area is relatively low in elevation and includes numerous plains and valleys crossed by small rivers and streams. The Euphrates River passes through the sub district, enhancing the fertility of its lands. Due to the influence of the river, soils in Al-Kifl are fertile and highly suitable for agriculture, especially for irrigated farming. The soils are predominantly clayey or sandy loam. The climate is hot and dry during the summer, with temperatures reaching extremely high levels, while the winter is relatively moderate to cold, especially due to the proximity of the Euphrates River. There are several swamps and small water bodies along its edges, which enhance the ecological diversity of the region. According to the results of the morphological description (Tables 2, 3, and 4), the surface layer depth was consistent across all soils at 0-30 cm. This consistency is likely due to the influence of agricultural practices—especially tillage—as well as the nature of the sedimentation process. As for soil color, the hue in all depths was 10YR, and the observed differences were only in value (lightness) and chroma (color intensity), ranging from Dark Brown to Brown. This variation is attributed to the relatively higher organic matter content in the surface layer compared to the subsurface layer, which results from agricultural activity, root systems, and organic matter accumulation. (Baumann *et al*., 2016) [35] Pointed out that soil color is determined by a number of morphological features that reflect the overall condition and composition of the soil. (Asgar, 2020) also stated that natural drainage, soil use, and the type of exploitation have a significant impact on soil color. Therefore, soil color is considered a crucial morphological characteristic that reflects various internal and external factors affecting soil properties. It holds great importance for farmers and soil scientists alike, as it helps reveal critical conditions influencing plant growth, such as organic matter content, mineral composition, drainage, and aeration. Regarding soil texture, the following variations were recorded: Site S1 (close to the Euphrates River) showed a silt clay loam texture at both depths. Site S2 exhibited a silty clay texture. Sites S3 in Al-Musayyib and Al-Hillah, which are farther from the river, had clay texture In Al-Kifl Subdistrict, textures varied as follows:S1: Silty clay S2: Clay loam S3: Fine-textured clay. This variability is mainly due to the nature of the sediment materials carried by the Euphrates River and the difference in flood intensity. When the flood is strong, it has a greater transport capacity and carries coarser materials that may be deposited farther from the source. In contrast, when the flood is weak, its carrying capacity is reduced, and thus the transported sediments tend to be finer and settle closer to the river. As a result, when the flood intensity is lower, its carrying capacity is reduced, and therefore the transported materials are mostly fine-textured. With the continued sedimentation process under varying flood intensities, this leads to noticeable—though sometimes slight—differences in soil texture classes among the study sites. This observation was also confirmed by (Reza *et al*., 2016). Additionally, the nature of alluvial deposits in the floodplain, which result from river sedimentation, leads to the formation of stratified alluvial soils with heterogeneous textures, as emphasized by (Al-Mashhadani, 2024). In another study, Asaad A. (Al-Duraye, 2022) [12] noted that there are two main depositional environments within the study area:A calm aquatic environment, which allows for the deposition of fine and medium particles. A high-energy and high-velocity environment, which facilitates the deposition of coarse particles. (Al-Sultani, 2018) indicated that the characteristics of sedimentary soils formed by river flooding vary across locations. The textures gradually shift: From coarse-textured soils found along river levees and irrigation canals, Tomedium textures in river basin units, and finally to fine textures in depressions and lowlands. (Chenxia *et al*., 2019) [14] Studied the impact of topography and land use on certain soil properties in Zhujiagou, Northwest China. The study found significant differences in soil characteristics across topographic positions, especially regarding clay content. As for soil structure, it was found to be similar across all study sites. It was consistently classified as strong, medium to coarse, and subangular blocky. This finding aligns with (Al-Ghanimi, 2015). The presence of plant biomass and organic matter plays a crucial role in improving soil structure. However, in cases of degraded structure, the use of agricultural machinery may also influence structure—either improving or deteriorating it depending on usage.Soil consistency was assessed in three moisture conditions for the surface layer (0-30 cm): dry, moist, and wet. For the subsurface layer (30-60 cm), consistency was evaluated under moist and wet conditions. There was a clear variation in consistency classes, as this property is primarily influenced by soil texture, organic matter, and moisture content. Under dry conditions: the soils were hard Under moist conditions: they were friable Under wet conditions: they ranged from sticky to slightly sticky, and from slightly plastic to plastic .These results highlight the variation in fundamental soil components—especially clay content, which greatly influences consistency. There was no significant effect from plant biomass on consistency, as also noted by (Al-Akaidi, 1989) [10]. Therefore, soil consistency is considered a comparative property between soil horizons, as it reflects the state of variation and uniformity in soil composition. It also indicates the activity of one or more pedogenic processes. Moreover, consistency can serve as a useful indicator to predict the soil's resistance to erosion and to determine the most suitable tillage practices that can or should be applied to a specific soil. As for soil pores, they ranged from common to many, and were generally fine in size. This is likely due to agricultural activities and possibly the use of agricultural machinery, which may lead to soil compaction. Regarding root distribution in the studied soils, especially in areas with active plant biomass, root abundance ranged from plentiful to abundant. Root sizes varied from fine to plentiful and even coarse. This variation is attributed to the soil texture class and how the soil is managed. Plant roots tend to grow more effectively in loamy soils compared to clayey or silty clay soils, mainly due to smaller pore sizes and poor aeration, as noted by (Abdul-Kadhim, 2020) [4]. In general, the nature of the boundaries were clear, gradual, and wavy. The topography of the horizon boundaries was nearly smooth in most of the studied soils. Regarding chemical properties, soil salinity is commonly expressed through electrical conductivity (EC), which tends to vary due to processes such as dissolution, leaching, addition, and sedimentation. According to the results presented in Table (5), the EC values in the surface layer (0-30 cm) ranged between 2.17 and 8.46 dS/m, with an average of 4.77 dS/m. The highest EC value was recorded in soil sample S3 from the Al-Musayyib site, while the lowest was in soil sample S1 from the Al-Kifl site. As for the subsurface layer (30-60 cm), EC values ranged between 2.28 and 9.04 dS/m, with an average of 5.63 dS/m. Similarly, the highest value was found in soil sample S3 from Al-Musayyib, and the lowest in S1 from Al-Kifl. The coefficient of variation (C.V.) for the surface samples ranged between 78.19 and 113.75, and for the subsurface samples between 70.56 and 178.98, indicating high variability. The distribution of EC values exhibited positive skewness in the normal distribution curve for both layers, with skewness values ranging from -0.56 to 1.72 and -0.72 to 1.59, respectively. This indicates a non-normal distribution, which is further supported by the standard deviation values, ranging from 1.77 to 2.37 for the surface layer and 2.15 to 3.04 for the subsurface layer. This variation in EC values may be attributed to differences in physiographic positions, groundwater levels, and significantly, soil management practices. These results are consistent with the findings of (Abass *et al*., 2013) [1], who reported a 1% coefficient of variation for both surface and subsurface horizons when studying spatial variability in soil properties across a 40-hectare field in northern Tikrit. These results also align with (Abbas, 2020) [2], who found a coefficient of variation (C.V.) of 43.40% in a study of different soils covering an area of 700 hectares in Basrah Governorate. Additionally, (Abed & Al-Jubouri, 2023) [5] found that soil salinity is subject to spatial variation due to differing salt concentration levels across locations. Salt tends to accumulate at varying levels depending on water volume, movement, leaching, and drainage conditions. Topography also plays a key role in salt accumulation, especially in low-lying areas or locations with frequent irrigation, where groundwater levels tend to be higher. Furthermore, drought and evaporation processes contribute to capillary rise of water and salt accumulation at the soil surface. This was confirmed by (Jabbar, 2023) [19]. Irrigation method, type of crops planted (whether cereals or vegetables), and whether organic or mineral fertilizers are used all affect EC values. These findings are in agreement with those of (Al-Shammari *et al*., 2024) [24], who attributed increased EC values to the higher salinity of organic fertilizers compared to mineral fertilizers—a conclusion also supported by (Idan *et al*., 2024) [18]. Data analysis also showed that soil salinity levels were very low, but the coefficient of variation for salinity was very high. Moreover, ECe variation was found to be one of the highest among soil properties studied, as noted by (Elbeh, 2021). Descriptive statistics revealed considerable variability in soil properties of the surface soil samples. There was a significant gap between the minimum and maximum values for certain soil properties, such as ECe and ESP, as reported by (Okashaa, 2023) [25]. Salinity is often closely linked to the parent material, which plays a central role in shaping soil characteristics, along with soil management practices and land use (Tedeschi *et al*., 2023) [31]. Climate also significantly influences electrical conductivity. Rainfall tends to dissolve soluble salts, particularly from the surface layer, thereby reducing the number of mobile ions. In addition, EC increases with higher clay content, not only due to the mobility of ions in water-filled soil pores but also due to exchangeable ions, as reported by (Kim & Park,2024) [21]. As for soil pH, it was generally within the alkaline or near-alkaline range, which is expected given that most Iraqi soils are calcareous and have a high calcium carbonate ($CaCO_3$) content. High $CaCO_3$ concentrations reduce crop productivity by decreasing the availability and cycling of nutrients, increasing soil pH (usually between 7.0 and 8.5), and lowering microbial activity (Davey *et al*., 2021). The results presented in Table (5) showed that pH values for the surface layer (0-30 cm) ranged between 7.06 and 8.03, with an average of 7.47. The highest value was recorded in soil sample S3 from Al-Kifl, while the lowest was found in S1 from Al-Hillah. For the subsurface layer (30-60 cm), pH values ranged between 7.14 and 8.25, with an average of 7.57. The highest value was in S2 from Al-Kifl, and the lowest in S1 from Al-Hillah. The coefficient of variation (C.V.) for surface samples ranged between 0.07 and 0.65, and for subsurface samples between 0.05 and 0.21—indicating relatively high variability for a property that typically shows low variation. The distribution of pH values exhibited positive skewness in both depth layers, ranging between -1.15 and 0.64 for surface samples and -1.68 and 1.69 for subsurface samples. This suggests that the values do not follow a normal distribution, supported by standard deviation values ranging from 0.072 to 0.22 (surface) and 0.06 to 0.133 (subsurface). According to (Salah *et al*. 2024), soil pH typically shows low variability (CV < 5%), while sand content displays moderate variation (CV < 25%), and the rest of the soil properties range from high to very high variation. Skewness values for studied soil properties ranged from -0.89 to -0.41 (negative) and 0.85 to 2.59 (positive), depending on the property. Most of the studied soils were found to be slightly too moderately alkaline, with very low C.V. values, as also indicated by Okashaa (2023) [25]. These results are consistent with the findings of (Abdel-Fattah, 2018) [3], who reported a coefficient of variation (C.V.) of 3.3% when studying the spatial variability of certain chemical properties in the Arab Republic of Egypt. They also align with the results of (Bai *et al*., 2016) [13], who observed a C.V. of 6.52% while investigating the spatial variability of soil properties in some agricultural lands. Moreover, agricultural land use and management practices were found to influence soil pH, as demonstrated by (Gaeid *et al*., 2023) [17]. Additionally, the influence of soil texture class and carbonate mineral content on pH was confirmed by the findings of (Mohammed, 2022) [22].

Table 5: Chemical Properties of the Study Sites

Location	Soil	Depth	EC	PH	ESP	CaCo3	CaSo4.2H2O
Al-Musayyib	Soil 1	0-30	4.3	7.40	0.56	242.2	1.45
		30-60	5.01	7.44	0.63	208.1	1.88
	Soil 2	0-30	4.39	7.36	1.47	339.4	1.50
		30-60	5.7	7.31	1.22	287.5	1.76
	Soil 3	0-30	8.46	7.26	9.52	302.2	0.13
		30-60	9.04	7.32	5.20	268.1	0.12
Al-Hillah	Soil 1	0-30	2.63	7.06	7.3	258.41	0.63
		30-60	3.04	7.14	7.6	262.26	0.74
	Soil 2	0-30	3.42	7.20	8.3	263.14	0.81
		30-60	3.84	7.26	8.2	272.32	1.61

	Soil 3	0-30	6.02	7.42	9.5	283.12	1.63
		30-60	8.67	7.18	9.2	294.47	3.14
Al-Kifl	Soil 1	0-30	2.17	7.59	0.62	260.8	0.23
		30-60	2.28	8.23	0.71	201.5	0.33
	Soil 2	0-30	4.88	7.91	1.32	292.6	1.4
		30-60	5.59	8.25	1.27	230.2	1.6
	Soil 3	0-30	6.71	8.03	1.62	330.4	1.4
		30-60	7.57	8.01	3.05	327.2	1.2

Regarding Exchangeable Sodium Percentage (ESP), the study results presented in Table (5) show that values for the surface layer (0-30 cm) ranged from 0.56 to 9.52, with an average of 4.467. The highest value was recorded in soil sample S3 from the Al-Musayyib site, while the lowest value was also from S1 of the same site. For the subsurface layer (30-60 cm), ESP values ranged from 0.63 to 9.2, with an average of 4.12. The highest value was found in S2 from Al-Hillah, and the lowest in S1 from Al-Musayyib. The coefficient of variation (C.V.) for surface samples ranged between 14.50 and 631.65, while for subsurface samples it ranged from 7.84 to 262.93, indicating very high variability. The distribution of ESP values showed positive skewness in the normal distribution curve for both depths, ranging from -1.09 to 1.66 (surface) and 0.72 to 1.62 (subsurface), confirming that the data do not follow a normal distribution. Standard deviation values ranged from 0.51 to 4.93 and 0.80 to 2.48 for the surface and subsurface layers, respectively. This variability in ESP may be attributed to differences in soil management practices, agricultural use, parent material, and geomorphological factors, as indicated by (Fadhil, 2009) [16]. Regarding Calcium Carbonate ($CaCO_3$), the data in Table (5) show that values for the surface layer (0-30 cm) ranged from 242.2 to 339.4 g/kg, with an average of 285.80 g/kg. The highest concentration was found in S2 from Al-Musayyib, while the lowest was in S1 from the same location. For the subsurface layer (30-60 cm), $CaCO_3$ values ranged from 201.5 to 327.2 g/kg, with an average of 261.29 g/kg. The highest value appeared in S3 from Al-Kifl, and the lowest in S1, also from Al-Kifl.The coefficient of variation (C.V.) for surface samples ranged from 64.13 to 816.45, and for subsurface samples from 98.28 to 1715.19, indicating extremely high variability. $CaCO_3$ values displayed positive skewness in both depth layers, with skewness values ranging from -0.68 to 1.48 (surface) and -1.31 to 1.36 (subsurface), once again indicating a non-normal distribution. Standard deviation ranged from 13.11 to 49.04 (surface) and 16.47 to 65.87 (subsurface), confirming the high variability. The results indicate that $CaCO_3$ content was generally higher in the subsurface horizon, which may be due to in-situ formation resulting from the precipitation of calcium ions transported via groundwater. Overall, the distribution of $CaCO_3$ content across the study sites shows clear variability, reflecting the differences in the nature of the parent materials, which are influenced by their physiographic locations. This variability is also mirrored in the general soil properties. The results confirm that the sedimentary parent materials are rich in carbonates due to the calcareous nature of the sediments. Additionally, the highest $CaCO_3$ percentages were observed in Tigris River deposits. Compared to the Euphrates River deposits. This is due to the fact that the Tigris River flows through areas with a higher percentage of calcium carbonate. These findings are consistent with the results of(Al-Quraishi,2012) [8], who studied spatial variability of soil properties in the central part of the alluvial plain and reported C.V. values of 12.46% and 7.40% for the Ap and C1 horizons, respectively. In addition, sand content plays a major role in increasing carbonate minerals, as confirmed by (Jabbar *et al*., 2023) [19]. Calcium carbonate ($CaCO_3$) is also considered an example of a soil property that follows a normal distribution. It has a small positive skewness value of -0.66, close to zero, indicating that the $CaCO_3$ data do not deviate significantly from normal distribution (ESRI, 2019). As for calcium sulfate (gypsum), the results in Table (5) show that for the surface layer (0-30 cm), and gypsum values ranged from 0.13 to 1.63 g/kg, with an average of 1.02 g/kg. The highest value was recorded in S3 at Al-Hillah, and the lowest in S3 at Al-Musayyib. For the subsurface layer (30-60 cm), gypsum values ranged from 0.12 to 1.88 g/kg, with an average of 1.37 g/kg. The highest value was recorded in S1 at Al-Musayyib, and the lowest again in S3 at the same location. The coefficient of variation (C.V.) for surface samples ranged from 27.76 to 58.79, and for subsurface samples from 40.41 to 80.67, indicating moderate to high variability.

The distribution of gypsum values exhibited positive skewness in both layers, with skewness values of -1.73 to 1.51 (surface) and -1.02 to 0.78 (subsurface), suggesting a non-normal distribution. Standard deviation values ranged from 0.53 to 0.77 (surface) and 0.64 to 1.21 (subsurface). These results are in agreement with (Saleh, 2017) [29], who classified soil C.V. into three categories: Low variability (C.V. < 15%) Moderate variability (15% < C.V. ≤ 35%) High variability (C.V. > 35%). In ArcGIS 10.2.2, the studied soil data were georeferenced to their sample locations. Various spatial distribution maps were generated using ArcMap GIS 10.2.2, displaying soil property variations including pH, organic matter (OM), $CaCO_3$, gypsum, ECe, CEC, ESP, and texture, through geostatistical analyses (ESRI,2019). Gypsum is known to occur mainly in arid climatic regions, as noted by (Blackburn *et al*., 2020). It can precipitate in various crystalline forms, with differing chemical compositions and accumulative properties. Moreover, it may coexist with other minerals, such as carbonates and soluble salts (Casby-Horton *et al*., 2015) [34]. In South America, gypsiferous soils are mainly found in the arid regions of Patagonia (Argentina) and the Atacama Desert (Chile). (Marengo and Bernasconi, 2015) [33] Reported drought-like conditions in northeastern Brazil, exacerbated by severe drought and salinity, contributing to soil degradation. In light of the pivotal role that soil quality plays in agricultural productivity, it is essential to consider the effects of gypsum on soil classification (Vidal-Torrado *et al*., 2020) [32]. It has been confirmed that shallow-rooted plants utilize the crystallization water of gypsum as a primary water source, while deep-rooted species rely on free water located in the deeper soil layers (De la Puente *et al*., 2021). The results revealed that the study soils exhibit high spatial variability in their physical and chemical properties.

The range of soil property values spanned from 1.20 to 63.86. The mean values of the studied properties ranged from 0.29 to 93.83, while the standard error (SE) ranged from 0.05 to 2.08, and the standard deviation (SD) ranged from 0.29 to 13.17. The coefficient of variation (CV%) varied between 3.47% and 179.78% across all soil properties (Salah *et al*., 2024).

3. Conclusion

There is variability in the sediment load carried by the river, which caused the coarser particles to settle in areas near the Euphrates River, while the finer particles were deposited in more distant regions.

These sediment deposits contributed to the variation in physical soil properties, particularly in the particle size distribution of soil separates, both vertically and horizontally.

Additionally, the chemical properties of soils formed by Euphrates River sediments were also affected. The variations were especially evident in: Electrical conductivity (EC) Total carbonate mineral content Exchangeable sodium percentage (ESP) Gypsum content. These differences were observed both between sites near and far from the river and with soil depth

4. References

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