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Geological Analysis of the Influence of the Euphrates and Shatt al-Arab Rivers on Soil Texture and Density in Northern Basra, Southern Iraq

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I. Abstract

The study aimed to analyze the contrasting geological influences of the Euphrates River and the Shatt al-Arab on the physical properties of the soils in northern Basra. The methodology relied on collecting 18 surface samples from six sites (S1–S6) along both rivers, with a calculated distance from each. A particle size analysis of the soil texture was conducted following Folk's method (1974). Bulk density, particle density, and total porosity were measured and supported by statistical analyses to examine the relationship between these properties and the distance from each river. The results revealed a dominance of fine particles (clay and silt) in the soil texture, reflecting a low energy depositional environment. Statistical correlations indicated two fundamentally different influence patterns. The Euphrates River exhibited a regular and gradual effect, showing a strong negative correlation (r = –0.797) between sand content and distance from the river, as well as a positive correlation for bulk density (r = 0.513) and a negative correlation for porosity (r = –0.495) with increasing distance. This pattern suggests the role of conventional hydraulic processes in grain size sorting. In contrast, the influence of the Shatt al-Arab appeared more complex and nonlinear, dominated by strong correlations associated with fine particles. Clay showed a strong negative correlation (r = –0.840), while silt exhibited a positive correlation (r = 0.729) with increasing distance from the river. This pattern may be attributed to tidal effects that enhance selective clay deposition near the riverbanks over long time periods. Moreover, particle density displayed notable stability, with no significant correlation with either river, indicating a homogeneous mineral source of the soils. The study concludes that the geological influence of the two rivers is integrated yet somewhat complex: The Euphrates controls the spatial distribution of coarse particles and soil porosity structure, whereas the Shatt al-Arab dominates the dynamics of fine particle distribution, collectively shaping the distinctive depositional patterns of the stratigraphic record within the floodplain of the study area.

Keywords: Soil texture, soil bulk density, total soil porosity, Euphrates River, Shatt al-Arab, geological analysis, alluvial plain.

II. Introucation

The Iraqi alluvial plain is considered the youngest geomorphological unit of Iraq in terms of geological formation, as some of its areas such as the marshlands are still in the process of development. This plain was submerged under marine waters in ancient times before gradually receding, leaving behind sediments transported by rivers and floodwaters. Longitudinally, the plain extends from Samarra and Hit to the head of the Arabian Gulf, with a width of approximately 200 km. It is characterized by its flatness and gradual slope from north to south, with elevations ranging from a few centimeters to about 100 meters (Menshed et al., 2021). Geological studies indicate that this plain was formed by the deposits of the Tigris and Euphrates rivers since the Quaternary period and that it was originally part of the ancient Tethys Sea. The basin gradually filled with marine sediments and organic remains that formed limestone rocks, in addition to clastic materials transported by water from elevated regions. The continuous

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subsidence of the plain due to the weight of the accumulating sediments maintained ongoing deposition through time. During successive geological epochs, diverse layers accumulated, such as the Fars and Bakhtiari formations, which were produced by erosion processes and tectonic movements (Jotheri, 2016). Recent research has shown that the Mesopotamian Basin contains sedimentary units of marine origin that extend far inland. Fossils discovered in the Hammar Formation provide evidence of marine organisms, confirming the mixing of marine and fluvial deposits. The Qurna Delta likewise displays clear interactions among marine, lacustrine, and riverine sediments of the Tigris and Euphrates rivers. Erosional and depositional processes have contributed to the formation of multiple geomorphological features, including the floodplain, delta, alluvial fans, and marshes, reflecting complex and shifting depositional environments over time (Al-Shahwan and Al-Najm, 2021). The northern areas of Basra constitute a fundamental part of the southern Iraqi sedimentary environment, where extensive plains have formed under the influence of the Tigris and Euphrates rivers. Despite the high soil fertility that these natural characteristics confer, the region remains vulnerable to multiple environmental challenges. Detailed studies of northern Basra sediments reveal a complex depositional pattern influenced by fluvial and estuarine processes. Furthermore, particle-size distribution analysis contributes to classifying sediments and inferring depositional energy and past environmental conditions (Awadh and Al-Ankaz, 2016). During the Holocene, northern Basra experienced substantial marine influence that led to the formation of tidal flats and saline marshes, reflecting a gradual transition from freshwater to saline environments as sea level rose (Ghafor et al., 2023). The region is characterized by floodplains and swampy areas that form part of the Mesopotamian marshlands, where fluvial and marine influences interact in shaping depositional environments (Issa, 2010). Studies indicate that the soils of the Iraqi alluvial plain have been transported from distant regions by rivers and seasonal streams, and are characterized by high clay and silt contents and low sand content. These materials are deposited in floodplain or aeolian environments, forming deep soils rich in calcium carbonate but poor in gypsum. Salinity often prevails due to high groundwater levels in many areas, and geomorphological processes dominate soil formation processes in central and southern Iraq. Horizontal and vertical variations in soil properties occur depending on proximity to river channels and sediment sources, with textures ranging from fine to medium and coarse, accompanied by high calcium carbonate and low gypsum (Al-Dabbas et al., 2012).

Geomorphological analyses indicate that variations in erosion and deposition rates lead to notable differences in sand, clay, and gypsum content between higher and lower terrains. Desert areas in southern Iraq exhibit coarse textures due to wind and flood transported sediments, whereas lower areas tend to develop clayey–silty soils with increased susceptibility to waterlogging and salinity. Newly formed soils also occur in some drained marshlands, showing fine texture and elevated bulk density and calcium carbonate content (Al-Gburi et al., 2017). Mineralogically, the major clay minerals in the sedimentary soils include smectite, illite, kaolinite, and chlorite, with variations depending on the depositional environment. These minerals are influenced by moisture, paleoclimate, and parent material, and the cation exchange capacity and texture class are closely linked to the mineralogical composition of clay in various fluvial settings (Al-Khalf and Al-Saad, 2016). Arid and saline environments in Southwest Asia also display a marked role in the formation of palygorskite and smectite minerals (Awadh and Al-Ankaz, 2016). Jassim and Goff (2006) noted that the sediments covering Basra Province, including the study area, are primarily recent deposits dating to the Quaternary period especially the Holocene comprising deltaic sediments produced by the hydrodynamic influences of the Tigris and Euphrates rivers. Al-Lawy and Al-Assady (2022) further showed that soil texture in Basra is significantly influenced by the movement of water and air, with coarse soils offering less resistance to flow compared to clayey soils, which slow or impede water and air movement. Research by Hussein and Al-Jaberi (2023) on sediments extending from Hilla to the Shatt al-Arab revealed that fine and very fine sand decrease from Hilla toward Basra, while silt content increases in the same direction due to declining flow energy. Their results also showed that light minerals constitute 95.7% of total grains, compared with 4.3% for heavy minerals. Issa (2025) concluded that the sedimentary textures in the region fall into three categories silt, sandy silt, and clay with silt being the most widespread. Shell remains indicate depositional environments ranging from

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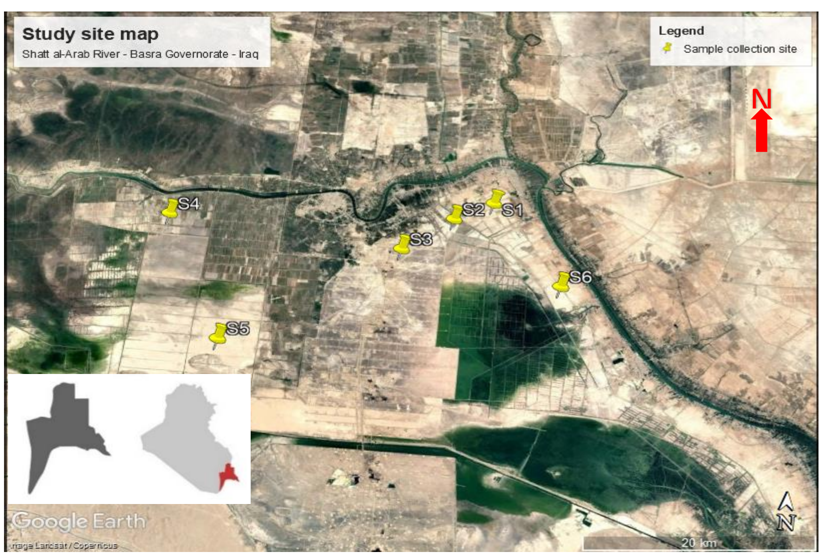
estuarine to marsh, lacustrine, and freshwater river settings. Al-Hasab et al. (2025) investigated the influence of mineral composition on the geotechnical properties of clayey soils in the Qurna district of Basra and found that montmorillonite dominates at 31.5%, followed by kaolinite and illite, alongside high proportions of non-clay minerals such as calcite and quartz. Particle size analysis classified the soils as silty clay with plasticity indices ranging from 12% to 37%, placing them within the CL, CH, and ML categories of the Unified Soil Classification System.

The present study focuses on six selected sites in northern Basra Province to clarify the primary role of the Euphrates River and the Shatt al-Arab in controlling soil texture, bulk density, and total porosity. Accordingly, the aim of this research is to conduct a geological analysis of the influence of these rivers on grain size distribution and soil properties within the study area.

III. Materials and Methods

2.1. Location of Study Area

The study area is located in southern Iraq, within the northern part of Basra Governorate. It extends between latitudes 30°10′47″–30°17′02″ N and longitudes 47°30′78″–47°30′91″ E, as illustrated in the location map (Fig. 1).



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Soil samples	Longitude (°E)	Latitude (°N)	Repeated

The northern Basra region and southern Iraq constitute part of the major alluvial plain formed by the long term depositional processes of the Tigris and Euphrates Rivers over extensive geological periods. The characteristics of these rivers such as their water discharge and sediment load directly influence the texture and both bulk and particle densities of the soils in the areas through which they flow and over which their effects extend (Al-Ansari, 2018).

2.2. Geological Setting

Geologically, the northern Basra region is primarily composed of Quaternary deposits, ranging in age from the Pleistocene to the Miocene, and has been significantly influenced by tectonic activity and fluvial processes (Yacoub, 2011).

2.3. Methodology

Eighteen surface sediment samples were collected from north of Basrah, the principal methodology used in this work includes:

1. **Fieldwork**

The samples were collected at 24/5/2025 from recent sediments represented by surface deposits at a depth of 50 cm from six stations (S1, S2, S3, S4, S5, S6) located in northern Basra Province, as shown in Fig. (1). Three samples were collected from each station, as presented in Table (1). The distances between the sampling points and the Euphrates River and the Shatt al-Arab were then calculated using Google Earth Pro, as shown in Table (1).

Table 1: Coordinates of the sampling locations

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https://iasj.rdd.edu.iq/journals/journal/issue/18682 https://doi.org/10.54174/ktf0b953

S1	**47.425179**	**30.94313**	**1**
			2
			3
S2	**47.386695**	**30.92409**	**1**
			2
			3
S3	**47.33711**	**30.8896**	**1**
			2
			3
S4	**47.103049**	**30.91291**	**1**
			2
			3
S5	**47.170286**	**30.78893**	**1**
			2
			3
S6	**47.494681**	**30.8605**	**1**
			2
			3

2. Laboratory Work

1. Grain size

A total of 18 samples were subjected to particle size analysis, distributed across six stations (S1, S2, S3, S4, S5, S6), with three replicates collected at each site. The objective was to separate the sand fraction from the clay and silt fractions using the wet sieving method with a 230 mesh sieve. The remaining sand retained on the sieve was then collected and dried in an electric oven at a temperature of 50°C. Based on the methodology of Folk (1974), the grain size distribution of silt and clay was determined by placing their suspension in a graduated cylinder. A dispersing agent (Galgon) was added at a concentration of 20 mg per 1000 ml to ensure particle separation and prevent flocculation. After thoroughly shaking the cylinder to achieve uniform dispersion of clay particles, the pipette method was performed at specific time intervals as described by Folk (1974). The results of the clay and silt analyses were processed by constructing a cumulative curve to determine the percentages of sand, silt, and clay. Folk's (1974) triangular classification diagram was used to determine sedimentary texture. Statistical grain size parameters were then calculated for the samples following the methodology of Folk and Ward (1957).

2. Soil Density and Total Porosity

Bulk density, particle density, and total porosity were determined using the method described by Blake et al. (1965). Undisturbed soil samples were collected to estimate bulk density using a core sampler equipped with a metallic cylinder of dimensions 5 × 5 cm. Particle density was measured using the pycnometer method. Total porosity was then calculated based on the relationship between bulk and particle densities.

3. Statistical Analysis

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SPSS software (version 19) was used to calculate Pearson correlation coefficients between soil properties (sand, clay, silt, bulk density, particle density, and total porosity) and the distance from the Euphrates River and the Shatt al-Arab River, as shown in the following table.

Table 2: Correlation analysis between distance from the Euphrates and Shatt al-Arab rivers and soil properties

Correlations			
		Distance from the Euphrates River km	Distance from the Shatt al-Arab River km
Sand g/kg	Pearson Correlation	-.797	.115
	Sig. (2-tailed)	.000	.650
	N	18	18
Silt g/kg	Pearson Correlation	.314	.729
	Sig. (2-tailed)	.204	.001
	N	18	18
Clay g/kg	Pearson Correlation	-.047	-.840
	Sig. (2-tailed)	.854	.000
	N	18	18
Bulk Density g/cm	Pearson Correlation	.513	.154
	Sig. (2-tailed)	.029	.542
	N	18	18
Particle Density g/cm	Pearson Correlation	-.126	-.016
	Sig. (2-tailed)	.618	.951
	N	18	18
Total Porosity %	Pearson Correlation	-.495	-.144
	Sig. (2-tailed)	.037	.570
	N	18	18

IV. Results and Discussion

Soil Texture at the Study Sites

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The results presented in Table 3 for the grain-size analysis of soil samples (S1–S6) indicate clear variation in the proportions of sand, silt, and clay among the sites, reflecting differences in depositional environments and geomorphological conditions. Examination of the particle size fractions shows that clay constitutes the largest proportion in sites S1, S2, and S6, where its content ranges between 437–670 g/kg. This resulted in most replicates being classified within the Clay or Silty Clay texture classes, indicating fine grained deposition in low energy environments such as quiet floodplains or stagnant water zones. In contrast, silt dominates the fractions in sites S3, S4, and S5, where its proportion exceeds 500 g/kg in many replicates, while clay content remains within a moderate range (270–360 g/kg). These conditions classify the soils of these sites as Silty Clay Loam, with a high degree of uniformity among the three replicates. This pattern suggests environmental stability and repeated, slow silt deposition. The variation observed among replicates particularly in S2 and S6 reveals subtle differences in particle size distribution that may be attributed to micro topographic variations, sampling depth, or multiple phases of sedimentation. Overall, the findings demonstrate that the dominance of fine grained fractions (silt and clay) is a prevailing characteristic across all sites, reflecting a calm and persistent sedimentary environment. This texture directly influences the hydrological and geotechnical properties of the soil, especially reduced permeability, increased moisture retention capacity, and higher compressibility.

These soils are transported from distant regions by rivers and valleys and are characterized by high clay and silt content and low sand content (Al-Daraji et al., 2024). Such materials are deposited in floodplain or Aeolian environments, leading to the development of deep soils rich in calcium carbonate and poor in gypsum. Salinity is also common due to elevated groundwater levels in many locations. Geomorphological processes strongly affect soil formation in the study area, causing horizontal and vertical variations in soil properties depending on proximity to river channels and sediment sources. As a result, soil texture ranges from fine to medium and coarse, accompanied by high calcium carbonate and low gypsum content (Al-Dabbas et al., 2012).

Table 3: Soil texture classification and fractions of sand, silt, and clay.

Soil samples	Repeated	Sand g/kg	Silt g/kg	Clay g/kg	USDA Texture
S1	1	98	302	600	CLAY
	2	165	310	525	CLAY
	3	132	306	563	CLAY
S2	1	150	349	501	CLAY
	2	67	496	437	SILTY CLAY
	3	109	423	469	SILTY CLAY
S3	1	97	537	366	SILTY CLAY LOAM
	2	83	563	354	SILTY CLAY LOAM
	3	90	550	360	SILTY CLAY LOAM
S4	1	185	470	345	SILTY CLAY LOAM
	2	120	545	335	SILTY CLAY LOAM

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	3	153	508	340	SILTY CLAY LOAM
S5	1	53	664	283	SILTY CLAY LOAM
	2	44	682	274	SILTY CLAY LOAM
	3	49	673	279	SILTY CLAY LOAM
S6	1	56	470	474	SILTY CLAY
	2	53	277	670	CLAY
	3	55	402	544	SILTY CLAY

Fig. 2 illustrates the general trends of soil fractions (sand, silt, clay) in the samples S1–S6, visually confirming the patterns reported in Table 3 regarding the dominance and variability of fine fractions across the sites. The curve shows that silt and clay are the prevailing components in all samples, with silt ranging approximately between 300–700 g/kg and clay between 250–600 g/kg, while sand values remain very low compared to the other fractions, generally between 40–180 g/kg. A noticeable increase in silt is observed in S3, S4, and S5, consistent with the classification of these sites as Silty Clay Loam, whereas clay content rises significantly in S1, S2, and some replicates of S6, corresponding to the Clay and Silty Clay categories. The pronounced fluctuation in clay content within S6 reflects evident heterogeneity in particle weights, indicating variations in depositional conditions or slight differences in sampling depth. This pattern aligns with the depositional dynamics of the Qurna Delta, which is clearly influenced by the interplay of marine, lacustrine, and fluvial sediments of the Tigris and Euphrates rivers. Erosional and depositional processes have contributed to the formation of diverse geomorphological features, including floodplains, deltas, alluvial fans, and marshes, reflecting complex and temporally variable depositional environments (Al-Shahwan and Al-Najm, 2021). Overall, the depositional environment is characterized by a calm, low energy regime, which has led to the accumulation of high amounts of silt and clay, resulting in soils with low permeability and high moisture-retention capacity typical features of floodplain soils.

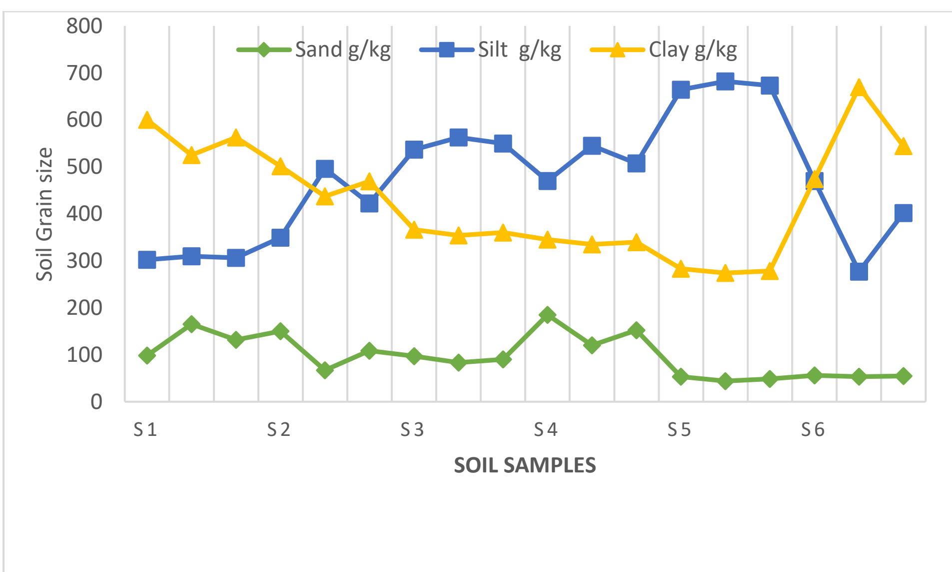

Fig. 2: Distribution of soil particle fraction variations at the studied sites.

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https://iasj.rdd.edu.iq/journals/journal/issue/18682 https://doi.org/10.54174/ktf0b953

Effect of the Euphrates and Shatt al-Arab rivers on Soil Grain size

Distance from the Euphrates River Fig. 3 illustrates the relationship between soil fractions (sand, silt, clay) and the distance from the Euphrates River, showing the spatial trends of soil texture variation along the study transect. The soil fraction analysis reveals a clear spatial correlation between increasing distance from the Euphrates and changes in sand, silt, and clay proportions, reflecting the influence of hydraulic sorting processes that govern deposition patterns across the floodplain. The results indicate that sand content decreases markedly with increasing distance from the river, as confirmed statistically by a strong negative correlation (r = –0.797, p = 0.000). This implies that areas close to the river receive higher sand deposition due to the greater hydraulic energy of the channel, which gradually diminishes toward the interior, leading to reduced sand deposition. In contrast, the silt fraction shows no significant correlation with distance from the Euphrates (r = 0.314, p = 0.204), consistent with the observed fluctuations, as silt distribution is influenced by local factors within the floodplain, such as micro topography and flood current direction, rather than linear distance alone. Similarly, clay exhibits no significant statistical correlation (r = –0.047, p = 0.854), indicating an irregular distribution along the transect, which aligns with the sharp increases observed at some distant sites, such as S6. These patterns suggest that the influence of the Euphrates River is primarily manifested in sand sorting, while the distribution of silt and clay is more complex and depends on flood dynamics and low energy deposition outside the main channel influence. Overall, the results demonstrate that the effect of the Euphrates on soil texture is clearly reflected in the regular decline of sand with distance, whereas silt and clay show no clear linear relationship, indicating the superimposition of additional depositional factors within the floodplain (Al Baghdady and Alabadi, 2021).

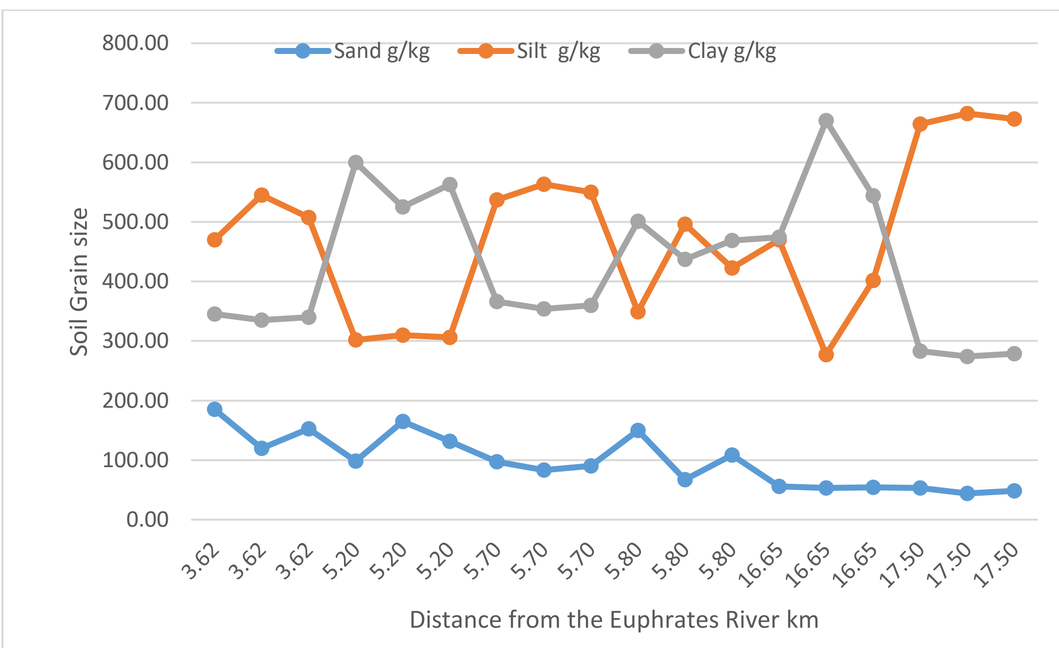

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Fig. 3: Effect of distance from the Euphrates River on soil particle fractions.

Distance from the Shatt al-Arab River

Fig. 4 illustrates the relationship between soil fractions (sand, silt, clay) and the distance from the Shatt al-Arab River. It shows that sand tends to increase gradually with distance from the Shatt al-Arab after the initial few kilometers, reaching higher values at approximately 5–10 km, and then fluctuating with further distance, though remaining relatively higher than values near the riverbanks. This trend corresponds to the limited capacity of the Shatt al-Arab to transport coarse particles over long distances due to the reduction in hydrodynamic energy caused by the influence of seawater intrusion and tidal effects, which allows fine particles (silt and clay) to settle near the main channel. Silt exhibits a strong positive correlation with distance from the Shatt al-Arab, as confirmed statistically by a significant correlation ($r = 0.729$, $p = 0.001$), with its proportion gradually increasing and reaching a marked peak at farther distances (around 28–32 km). This indicates that relatively distant areas receive silt transported by the complex hydrological system of the Shatt al-Arab, influenced by long term tidal effects. In contrast, clay shows the opposite behavior, decreasing clearly with increasing distance from the Shatt al-Arab, as confirmed by a very strong negative correlation ($r = –0.840$, $p = 0.000$). This can be explained by the rapid deposition of ultrafine clay particles near the riverbanks due to slow settling and prolonged residence time, while their proportion gradually diminishes in more distant areas, allowing silt to dominate in those locations (Raml and Kadhim, 2024). These patterns highlight the dual role of the Shatt al-Arab in shaping soil properties along its gradient. Near the river, soils are clay rich with low silt and sand content due to the rapid deposition of fine particles in a relatively calm aquatic environment. At intermediate and greater distances, silt content increases along with a gradual rise in sand and a decrease in clay, reflecting changes in the transporting energy that redistribute sediments. This results in a clear depositional trend from clayey soils near the river toward silty–mixed soils with increasing sand content, a pattern that fully aligns with the statistical correlation results presented in Table 2.

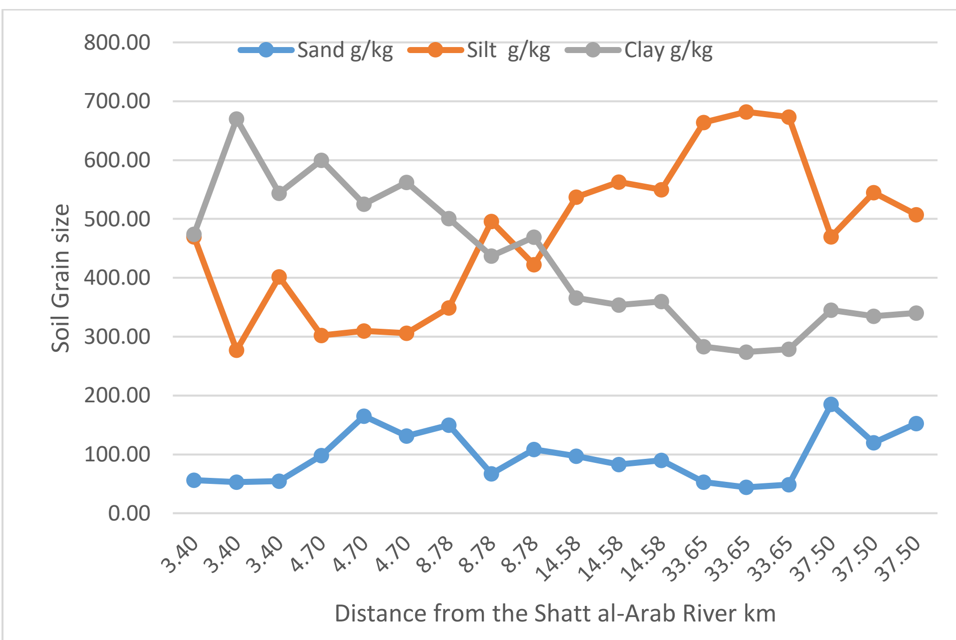

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Fig. 4: Effect of distance from the Shatt al-Arab River on soil particle fractions.

Effect of the Euphrates and Shatt al-Arab rivers of Soil Physical properties

Fig. 5 illustrates the variation in soil particle density and bulk density (A) and total porosity (B) at the study sites for 18 soil samples from northern Basra in southern Iraq. Particle density values ranged from approximately 2.55 to 2.75 g/cm³, with an average of about 2.65 g/cm³. These values fall well within the natural range for mineral soils in the region, indicating a relatively consistent composition of primary minerals such as quartz and clay minerals across the sites, which constitute the main components of the Basra alluvial soils (Al-Khalf and Al-Saad, 2016). In contrast, bulk density values ranged between roughly 1.25 and 1.55 g/cm³, with a mean of approximately 1.35 g/cm³. These values are typical for well aerated clayey or silty soils, which generally range from 1.1 to 1.6 g/cm³. Relatively low bulk density values suggest well-structured soils with high porosity, facilitating water and air movement as well as root penetration. Some variation in bulk density is observed, particularly in samples from S5 onwards, which may be attributed to local differences in soil texture (sand, silt, and clay content), organic matter content, or agricultural practices (Al-Daraji et al., 2023). It is natural for particle density to be significantly higher and relatively stable compared to bulk density, as the former accounts only for the volume of solid particles, while the latter includes pores and voids. It should also be noted that soils in the area may contain elevated calcium carbonate content and be affected by salinity due to proximity to the Shatt al-Arab and tidal influences (Al-Kawam and Mahmood, 2022). Regarding soil porosity, Fig. 5 shows that total porosity ranges from 40% to 55% across the studied sites. This behavior is consistent with the geological and environmental characteristics of the alluvial plain, which is dominated by fine clayey deposits transported by the tributaries of the Tigris, Euphrates, and Shatt al-Arab through successive depositional cycles. These fine sediments typically exhibit high porosity due to the small particle size and large specific surface area, allowing for a greater number of interparticle voids compared to sandy soils. This pattern also indicates that the area has not experienced significant compaction or sediment lithification, consistent with its nature as a relatively recent alluvial landscape that was previously submerged and subsequently covered by seasonal flood deposits. Additionally, the hydrodynamic characteristics of the Shatt al-Arab, fluctuations in groundwater levels, and salinity transported with the water contribute to modifying particle structure and aggregation, leading to slight but logical variations within the 40–55% range. This reflects the soil's response to an active sedimentary–environmental system, combining fine material deposition, moderate natural compaction, and the interplay of hydrological and saline influences characteristic of the geomorphological environment of northern Basra (Al-Hasab et al., 2025).

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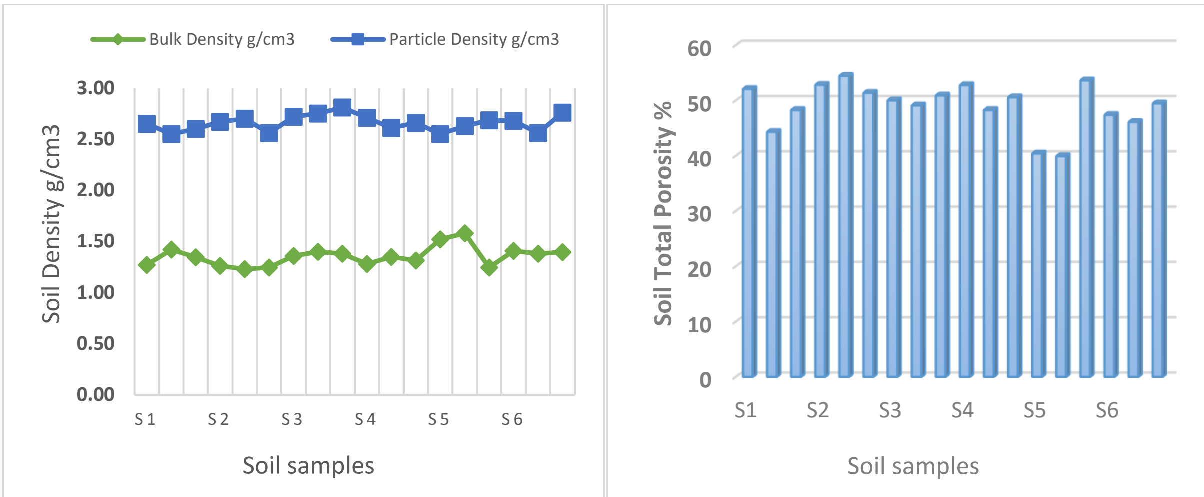

Fig. 5: Variation of soil density and total porosity at the study sites.

Effect of distance from the Euphrates River of soil properties The results shown in Fig. 6 illustrate the variation of soil density (A) and total porosity (B) with distance from the Euphrates River. Statistical analysis (Table 2) indicates no significant relationship between distance from the Euphrates and soil particle density, with a correlation coefficient of –0.126 and a non-significant p-value of 0.618. This aligns perfectly with the geological characteristics of the soil composition in the region. Particle density exhibited limited variation, ranging from 2.55 to 2.75 g/cm³, with an average of approximately 2.65 g/cm³. These values fall within the natural range for mineral soils dominated by quartz and clay minerals, reflecting a consistent primary mineral composition of soil particles across the different sites. It is noted that depositional factors, such as proximity or distance from the river, influence particle size distribution and soil structure but do not alter the fundamental mineral composition, which explains the relative stability of particle density. The region may also contain variable concentrations of calcium carbonate and degrees of salinity due to the hydrodynamic effects of the Shatt al-Arab; however, these factors typically do not affect particle density unless present in very high concentrations, which is not reflected in the data. Consequently, the stability and uniformity of particle density represent a geological behavior consistent with the environment of modern floodplain deposits, dominated by primary clay minerals such as smectite, illite, kaolinite, and chlorite, with variations depending on the depositional environment. These minerals are influenced by moisture, paleoclimate, and parent material, and the clay mineral composition affects soil texture in different fluvial settings, while arid and saline environments also play a role (Al-Dabbas et al., 2012).The study also revealed a significant positive relationship between distance from the Euphrates and soil bulk density, with a correlation coefficient of +0.513 at a significance level of 0.029, indicating that bulk density gradually increases with distance from the river. This is consistent with the geological and environmental behavior of floodplain sediments in northern Basra. Bulk density values ranged between 1.25 and 1.55 g/cm³, with a mean of approximately 1.35 g/cm³, falling within the ideal range for well aerated clayey and silty soils. Relatively low bulk density values near the river indicate well-structured soils with high porosity, promoting water and air movement, a property directly associated with the deposition of fine sediments during flood seasons. Higher bulk density values at more distant sites, particularly in samples S5 and beyond, are attributed to the reduced influence of floodplain deposition and the predominance of more compact particles, in addition to possible decreases in organic matter content, differences in soil texture, or increased effects of soil compaction and tillage (Nedawi, 2022). This trend reflects the natural gradient of floodplain deposits, where

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soils near the river are looser and less compacted, while soils farther away tend to exhibit greater relative compaction, fully consistent with the observed statistical correlation.

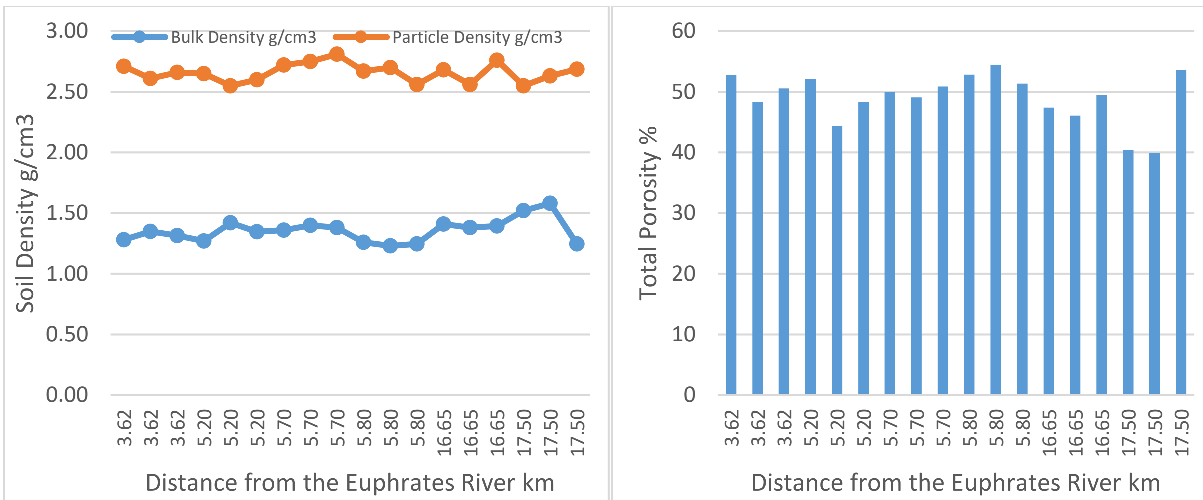

Fig. 6: Variation of soil density and total porosity with distance from the Euphrates River.

The study results revealed a significant inverse relationship between distance from the Euphrates River and total soil porosity, with a correlation coefficient of –0.495 and a significance level of 0.037. This indicates that porosity decreases as distance from the river increases, a trend consistent with the measured values, which ranged from 40% to 55%, reflecting the young depositional structure of the floodplain in northern Basra. Soils near the Euphrates are richer in silty and clayey deposits accumulated through successive depositional cycles of the Tigris–Euphrates–Shatt al-Arab system. These fine sediments exhibit high porosity due to their small particle size and large specific surface area, allowing for a higher proportion of interparticle voids. The reduced porosity at more distant sites is attributed to increased natural compaction and diminished influence of recent flooding, in addition to salinity effects and fluctuations in the groundwater table, which may reorganize particle aggregates and reduce void space. The absence of significant geological compaction or sediment lithification explains why porosity remains within the 40–55% range, representing an active depositional structure continuously influenced by hydrodynamic factors. Therefore, the observed decreasing trend of porosity with increasing distance from the Euphrates is both geologically and statistically consistent, reflecting the natural response of a relatively recent alluvial soil whose properties gradually vary according to the extent of floodplain processes (Menshed et al., 2021).

Effect of distance from the Shatt al-Arab River of soil properties

The results presented in Fig. 7 illustrate the variation of soil density (A) and total porosity (B) with distance from the Shatt al-Arab River. Statistical analysis (Table 2) indicates no significant relationship between distance from the

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Shatt al-Arab and soil particle density. Particle density remained relatively constant across all sites, ranging from 2.55 to 2.75 g/cm³, with an average of approximately 2.65 g/cm³, and showed a non-significant correlation with distance from the river ($r = –0.016$, $p = 0.951$). This stability is attributed to the fact that particle density primarily depends on the fundamental mineral composition of the soil, such as quartz, clay minerals, and calcium carbonate, which remain consistent across different sites, whether near or far from the river. Minor variations in particle density reflect small relative differences in fine minerals or carbonate accumulations rather than the effect of distance from the river (Al-Hasab et al., 2025). In contrast, the correlation analysis showed that soil bulk density did not exhibit a significant relationship with distance from the Shatt al-Arab, with a correlation coefficient of +0.154 and a p-value of 0.542. This indicates that variations in bulk density across the sites were not directly related to river distance. This behavior is geologically reasonable, as bulk density values ranged from 1.25 to 1.55 g/cm³, with an average of approximately 1.35 g/cm³, within the ideal range for young clayey–silty soils. Slight variations observed in some samples, such as S5 and beyond, are attributed to local differences in soil texture (proportions of sand, silt, and clay), organic matter content, or the effects of compaction and tillage, rather than a gradient based on distance from the river. Soils near the Shatt al-Arab contain higher proportions of clay and silt, giving them a more porous structure and relatively lower bulk density, whereas more distant soils tend to be slightly more compacted without forming a significant pattern across all sites, consistent with the statistical results (Saleh, 2023).

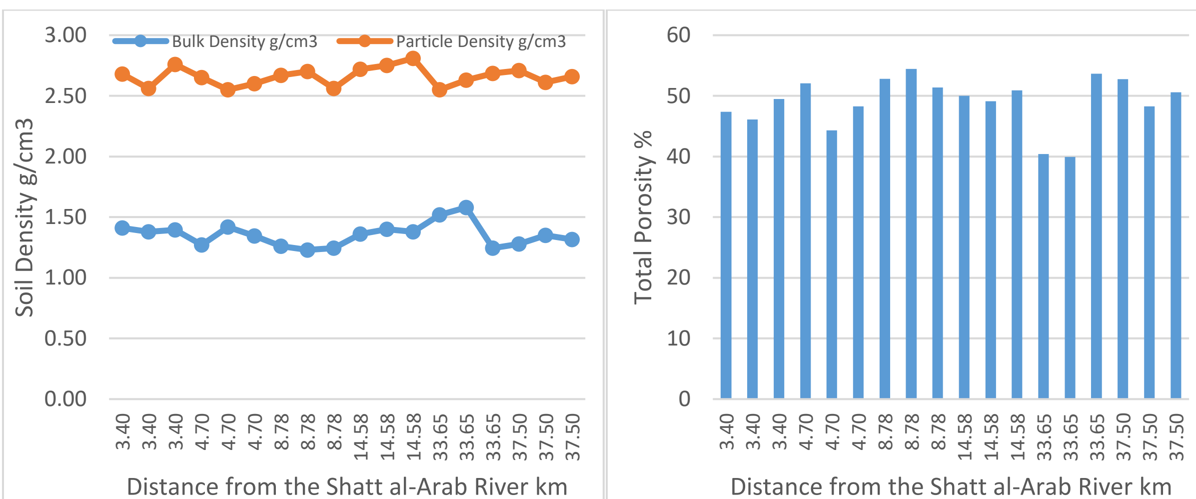

Fig. 7: Variation of soil density and total porosity with distance from the Shatt al-Arab River.

Total soil porosity also showed no significant relationship with distance from the Shatt al-Arab, with a correlation coefficient of –0.144 and a p-value of 0.570. Nonetheless, measured values ranged from 40% to 55%, reflecting the young alluvial nature of the floodplain and the silty–clayey depositional system shaped by successive riverine flood cycles. Soils near the river exhibit higher porosity due to the small particle size and large specific surface area, while porosity decreases at relatively distant sites because of increased sand content and the reduced influence of flooding. However, this gradient does not produce a statistically significant pattern across the eighteen samples. Additionally, salinity effects and fluctuations in the groundwater table in the Shatt al-Arab region contribute to modifying particle aggregates, resulting in slight variations in porosity within this range, which explains the non-significant correlation with distance according to statistical analysis. Overall, the variability in these three properties reflects the natural

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https://iasj.rdd.edu.iq/journals/journal/issue/18682 https://doi.org/10.54174/ktf0b953

response of soils to a dynamic sedimentary–environmental system. Soils near the Shatt al-Arab maintain a young structure with high porosity and stable particle density, while some local changes in bulk density and porosity occur at greater distances from the river, though these do not reach statistical significance. This pattern highlights the complex interaction among fluvial deposition, mineral composition, salinity, and groundwater fluctuations in shaping the physical properties of northern Basra soils (Al-Yasiry et al., 2023).

V. Conclusions

- **Dominance and variability of fine sediments:** Fine fractions (silt and clay) dominate all study sites, indicating a calm, low energy depositional environment within the floodplain. However, there is a clear spatial variation in soil texture classification, with clay predominating at some sites and silt at others, reflecting differences in sub environmental depositional conditions.
- **River influence on particle distribution:** The impact of each river on soil texture differs significantly. The Euphrates primarily and strongly affects sand distribution, with sand content decreasing with distance from the river, while it does not significantly control silt or clay distribution. In contrast, the Shatt al-Arab exhibits a more complex pattern: sand increases after a certain distance, silt rises with increasing distance, and clay decreases markedly due to tidal influence and variable hydrodynamic energy.
- **Stability of soil mineral composition:** Soil particle density remained relatively constant across all sites and was unaffected by distance from either river, confirming the homogeneity of the primary mineral composition (e.g., quartz and clay minerals) in the region's soils, a characteristic feature of the uniform alluvial depositional environment.
- **Euphrates' impact on soil physical structure:** Soil structural properties showed a clear response to distance from the Euphrates, with bulk density increasing and total porosity decreasing with distance, indicating a structural gradient from loose, porous soils near the river to more compacted soils at more distant locations.
- **Weak structural pattern near the Shatt al-Arab:** Unlike the Euphrates, neither bulk density nor total porosity showed a significant relationship with distance from the Shatt al-Arab, suggesting that local factors such as salinity, groundwater fluctuations, and soil texture predominantly control the soil's physical structure near the river rather than linear distance from the channel.

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