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Soil Texture Characteristics in Iraq: A Key to Optimizing Agricultural Sustainability and Land Productivity

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خصائص نسجة التربة في العراق: مفتاح تحسين الاستدامة الزراعية وإنتاجية الأراضي

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ABSTRACT

Background

It's been documented that Iraq houses numerous soil types that exist as an expression of varied climates, landscapes, and land-use patterns. This study focuses on the physical and chemical soil characteristics existing within five of Iraq's major geographical regions: Al-Anbar, Baghdad, Basrah, Erbil, and Diyala.

Materials and Methods

Analysis showed significant variation in salinity, organic matter content, bulk density, and soil texture from one region to another. For example, Al-Anbar soils are predominantly sandy (82%), with a high bulk density (1.60 g/cm³) and low organic matter (0.6%). On the other hand, clay-rich soils found in Basrah are extremely saline (EC = 8.0 dS/m, ESP = 45%), although bulk density is much lower (1.25 g/cm³).

Results

Baghdad and Diyala were loamier with more balanced textures and moderate fertility, as well as organic matter of between 1.8 and 1.9%. The hilly soils of Erbil, being of moderate permeability and low salinity (EC = 1.9 dS/m), were suitable for crop rotation and orchards.

Conclusion:

The findings clearly indicate that soil management practices are region-specific, calling for organic amendment applications to sandy soils, improved drainage in saline clay soils, and conservation methods in loamy areas.

Key words

Texture of soils, Iraq, salinity, soil fertility, sustainable agriculture, soil improvement, precision farming.

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INTRODUCTION

Having had fertile land throughout antiquity, Iraq is endowed with such land mostly in the Mesopotamian plain, a region mostly referred to as the cradle of civilization. However, in the last few decades, this priceless resource has undergone serious degradation. Environmental degradation due to soil erosion, soil infertility, pollution, and water mismanagement has also risen to further concern. This has been under investigation in the most recent studies. **[1]** reported on soil degradation and erosion in some important agricultural areas. [**2]** investigated the interaction of some land-use practices on soil organic carbon, an important soil health determinant. Their findings, based on infrared spectroscopy, indicated a potential role for carbon management across diverse farming systems. Another study by [**3]** showed that untreated wastewater contributes to soil degradation. Meanwhile**,** [**4]** applied spatial assessments in identifying regions of northern Iraq vulnerable to erosion due to changes in rainfall patterns and land use. The river system, such as the Tigris, has also greatly affected soil situations, mainly around the region of Baghdad. Work by [**5, 6]** discussed the instability of the riverbanks and their influence on the ecosystems and agriculture there. Moreover, the presence of several heavy metals, including lead, would fast-track soil degradation [**7]**. while the remediation of these soils with locally available materials is ongoing. Transportation of sediments naturally by such anthropogenic activities as dam construction has been disrupted. For instance, the Ilisu Dam has obstructed sediment transport downstream in northern Iraq, particularly around Mosul, causing enormous land degradation. [**8]** also spoke of deterioration in the irrigation water quality from the Tigris River, while [9] pointed an accusing finger at the exploitation of groundwater in Kirkuk. It is through this interlinkage of soil health degradation in Iraq that the studies compel an immediate need for the adoption of integrated and sustainable management strategies.

MATERIALS AND METHODS

1. Selection of Sites

A total of five distinct areas had been chosen depending on their climate, landscape, and geography with the goal to gather information on the diversity of varieties of soil through Iraq's major agroecological zones:

- Western The desert (Al-Anbar Governorate): Describes arid regions alongside soils that have a sandy the texture.
- Loamy soils utilised in agriculture with irrigation are the defining characteristic of the Central Alluvial The Plain (Baghdad Governorate).
- Southern The floodplain (Basra Governorate): characterised by high levels of salt and clay-based soils.

• Erbil Governorate is the northern region. A mountainous region: The region has loamy soils that drain well and moderately sloped terrain.

• Loamy the Plains (Diyala Governorate): Those regions have silty clay and combined loam soils that have varying salinities.

In order to guarantee wide coverage of the environment and soil illnesses, picking the location was informed by the International Reference Base for Soil. The resources [9] and Iraqi agroclimatic zoning information [**10]**.

The collection of soil

The upper 0–30 cm of the rooted zone, considered to be the region with the greatest biologically active layer for impacting the growth of plants, is where soil samples were taken. Three replicates were taken at each point so as to ensure both spatial reliability and statistical reliability. Before being submitted to laboratory evaluation, examinations were stored in determined polyethylene bags, allowed to air dry, and then sieved by means of a 2 mm screen for removing larger particles [**11].**

3. ANALYSIS IN THE LAB

3.1 Texture of Soil

The hydrometer's technique, which determines the ratios of sand, silt, and clay depending on the rates of sedimentation in a hexametaphosphate sodium remedy, has been applied for determining the grain structure of the soil [**12].** The USDA soil condition triangle was used to categorise the outcome.

3.2 Physical The characteristics

• Bulk density: determined through establishing the number of pounds of soil per volumetric unit using the core density process [**13].**

• Total porosity: determined by utilising the subsequent calculation using the bulk density and a given particle amount of 2.65 g/cm³:

$$\text{Porosity (\%)} = \left(1 - \frac{\text{Bulk Density}}{2.65}\right) \times 100$$

• Water-Holding Capacity: Estimated by the gravimetric techniques obeying water drainage and saturation level by employing an elevated pressure plate device [**14]**

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3.3 The Attributes of Chemicals

A calibrated EC meter is employed to gauge the conductivity of electricity (EC), which can be expressed in dS/m, in a 1:1 soil-to-water extract.

• Soil pH: measurements are provided via a computerised pH meter in a 1:1 soil-water suspension.

• Exchangeable The exchangeable sodium percentage (ESP) was established by following standard protocols with sodium retrieved via 1N ammonium acetate (pH 7.0) **[15]** according to the equation below **(15)** :

$$ESP\ \% = (Na^+ / CEC) \times 100$$

3.4 Organic Substances

Ten grams of soil that had been air-dried have been burned for four hours at 550°C in a muffle furnace to determine the level of organic matter using the one that powers the loss-on-ignition method [16].

4. ANALYSIS OF STATISTICS

Microsoft Excel and SPSS version 25.0 were used to process the data. To check for significant differences between the sites, a one-way ANOVA was employed. Relationships between soil texture and other physical and chemical parameters were investigated using Pearson correlation analysis $p < 0.05$ was adopted for all tests.

RESULTS AND DISCUSSION

Analysis of soil physicochemical characteristics through correlation

Soil texture, climatic gradients, and land use intensity have been among the primary variables affecting the significant variability in the chemical and physical properties of soils throughout Iraq's many reasons agroecological zones. Crop efficiency, soil health, and environmentally friendly land use are all significantly influenced by these features (Figure 1; Table 1). Soil texture had a significant impact on bulk density. The biggest bulk densities, with an average about 1.6 gcm^{-3}, were found in sandy soils, especially in the Western Desert region (Al-Anbar). This tighter consolidation of particles is ascribed for their coarse texture, inadequate organic matter material, and the minimum aggregation. On the other hand, because of their increased porosity and capacity to retain fluids, their clay-laden soils of the Southern The floodplain (Basrah) showed significantly reduced bulk density values, averaging about 1.2 $g\ cm^{-3}$.

The southern areas had greater electrically conductive (EC) amounts, especially around Basrah, in which these values were close to 8 dS m⁻¹. This shows serious agronomic difficulties and demonstrates severe stress from salinity. The actual existence of sodic conditions on the soil was proven by the associated exchangeable sodium percentages (ESP), which shifted from 40 to fifty percent. Targeted irrigation oversight and soil rehabilitation strategies must be implemented because these environmental limitations can significantly affect the growth of plants and the composition of the soil.

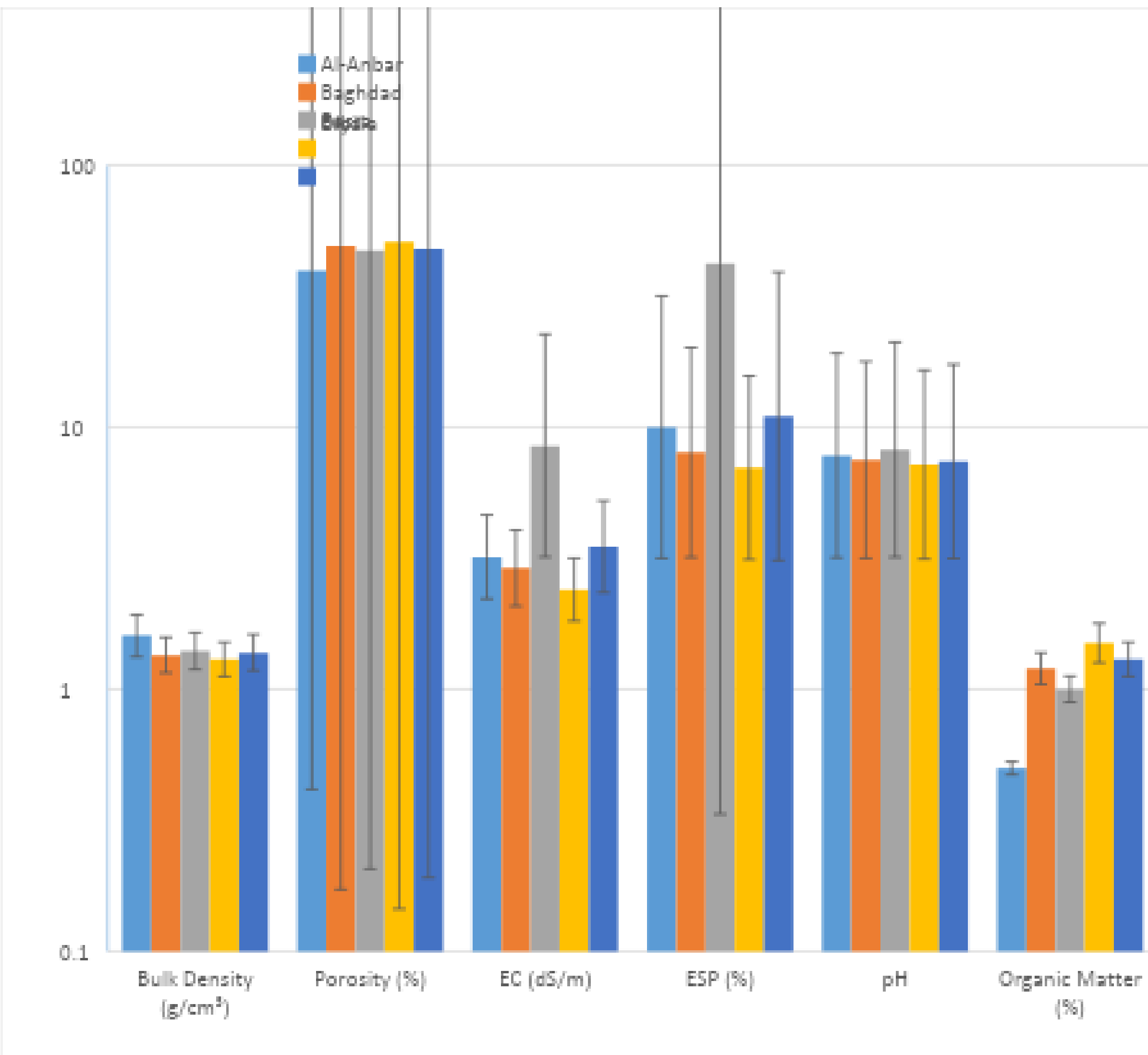

Figure 1. Soil Physicochemical The characteristics

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For the reason of its harsh environment as well as small biomass inputs, the semi-arid Western Desert had the least amount of organic matter (<1%). Fortunately, owing to comparatively greater moisture the availability, lush vegetation cover, as well a history of agricultural activity, soils from the central and southern floodplain regions (such as Baghdad and Basrah) showed somewhat higher OM levels (2–3%).

A Pearson regression matrix has been developed for BD, porosity, EC, ESP, pH, and OM content with the goal to explore the connections among all of these variables (Table 1). The findings of the examination showed statistically significant associations with embraced pedagogical concepts. The basic opposite causality between compaction and pore space was highlighted by the nearly perfect and adverse correlation across bulk density and porosity (r = -0.9999). For the reason of the capacity of this substance to improve soil structure and lessen compactness, organic matter content showed a strong positive correlation with permeability. (r = 0.9662) and a significant negative correlation with BD (r = -0.9665).

In addition, EC and ESP had a very significant positive correlation (r = 0.9979), suggesting that elevated sodicity and higher salinity frequently occur together.

EC and ESP additionally showed a rising association with the pH (r = 0.8694 as well as r = 0.8571, correspondingly), which corresponds to the scenario that outlines saline soils. Furthermore, a slight upward correlation (r = 0.4938) within BD along with pH was detected, indicating that compressing may be affecting the salinity of the soil. Fortunately, there were also inadequate adverse correlations with EC (r = -0.2159) and OM while ESP (r = -0.1946) suggested a negligible instead of a potentially beneficial impact in minimising salinity.

The results above demonstrate the significance of location-specific approaches to soil management and the complex relationships between the soil's chemical and physical aspects, particularly during arid times in salt-affected domains like the Western Desert alongside southern Iraq. The main objectives for enhancing soil health and ensuring long-term agricultural production remain increasing the amount of organic matter in the environment, addressing the limitations brought about by salinity, and resolving these issues.

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Table 1. Interactions between Soil Physicochemical Parameters

	Bulk Density (g/cm³)	Porosity (%)	EC (dS/m)	ESP (%)	pH	Organic Matter (%)
Bulk Density (g/cm³)	1					
Porosity (%)	-0.99994	1				
EC (dS/m)	0.054157	-0.05104	1			
ESP (%)	0.031104	-0.02863	0.997913	1		
pH	0.493756	-0.49119	0.869389	0.857142	1	
Organic Matter (%)	-0.96646	0.966199	-0.21595	-0.19463	-0.65675	1

Soil Quality and Texture Characteristics Across Selected Iraqi Governorates

The spatial heterogeneity in soil quality indices and physical properties across the selected Iraqi governorates reflects the diverse pedo-climatic conditions shaping each region. The integration of texture classifications with derived indices—SRI, SQI, hydraulic conductivity, and water retention—provides insight into the functional performance and limitations of these soils (Figures 2 and 3).

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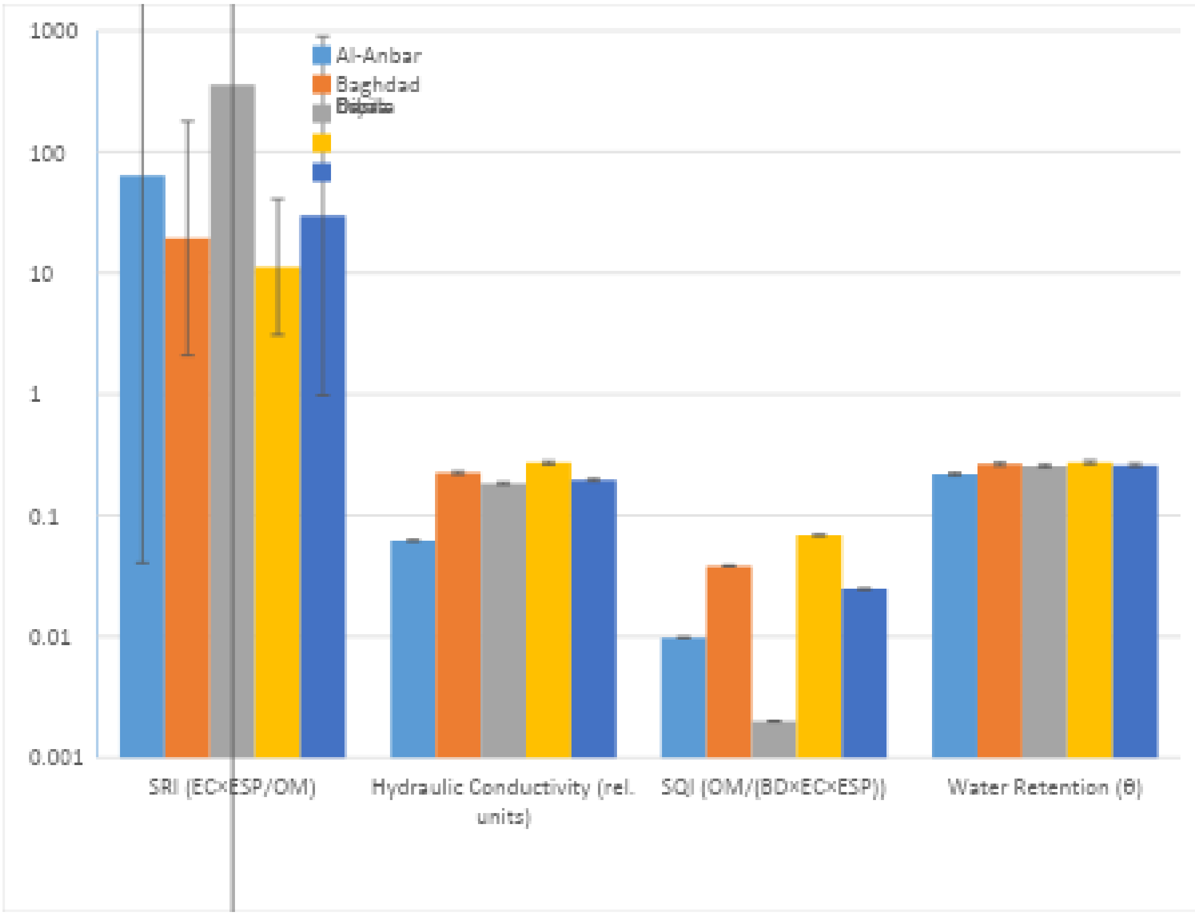

Figure 2: Soil Quality Indices and Physical Properties Across the Selected Iraqi Governorates

Al-Anbar, with a dominant sandy texture (85% sand), exhibits the lowest water retention (0.2186) and hydraulic conductivity (0.062), despite its coarse nature, which typically enhances infiltration. The extremely high SRI value (64) and the lowest SQI (0.0098) among moderate performers reflect significant vulnerability to degradation due to poor structure and minimal organic matter input. Baghdad, characterized by a balanced loam texture (40% sand, 30% silt, 30% clay), demonstrates moderate performance across all indicators. Its SQI (0.0383) and hydraulic conductivity (0.224) suggest improved biological and physical function relative to the more extreme environments, supported by favorable organic matter levels and porosity.

Basrah presents a clay soil profile (50% clay) with high porosity and water retention (0.2557), yet suffers from the highest SRI (357) and lowest SQI (0.002). This paradox reflects a critical deterioration in soil quality driven by severe salinity (EC) and sodicity (ESP), overwhelming the otherwise beneficial structural characteristics of the soil. Erbil, with a clay loam texture (35% sand, 35% clay), registers the highest SQI (0.0685) and hydraulic conductivity (0.271), indicating a well-balanced physical environment with moderate organic inputs and reduced salinity stress. These conditions support enhanced soil biological function and resilience. Diyala, with a silty loam

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texture (45% silt), shows intermediate performance across all indices. Its moderate SRI (29.6) and SQI (0.0246) suggest a soil environment with better buffering capacity against salinity and erosion but still susceptible to degradation under poor management. The observed trends underscore the strong correlation between soil texture, organic matter, and chemical stressors (EC and ESP) in determining soil quality and hydrological function. Notably, fine-textured soils (e.g., Basrah) may retain more water but are at higher risk of structural collapse and salinization under mismanagement, while coarse soils (e.g., Al-Anbar) suffer from low fertility and moisture retention. Erbil and Baghdad emerge as more resilient zones, where soil physical balance supports sustainable land use with appropriate conservation strategies. These findings advocate for region-specific management tailored to both the inherent textural properties and external degradation pressures of each zone, particularly for restoring functionality in highly saline or structurally weak soils such as those in Basrah and Al-Anbar. The findings from this study align with and extend prior research on Iraq's soil systems. The spatial variation in physical properties such as soil texture and bulk density corroborates the patterns reported by [**17**], who observed that soil type distribution across agroecological zones is highly dependent on climatic and geological conditions. For example, the high sand content and bulk density in Al-Anbar resemble characteristics typical of Aridisols in arid ecosystems, confirming earlier observations that these soils are structurally weak, poor in nutrients, and require external inputs for sustainable agriculture. The high salinity and sodicity levels recorded in Basrah echo the results of [18], who noted that salt accumulation in southern floodplain soils leads to restricted root development and crop yield decline. **[19]** similarly reported that soils with ESP above 40% show a significant decline in permeability and biological activity, highlighting the urgency of implementing drainage and leaching techniques. Loamy soils in Baghdad and Diyala demonstrated moderate salinity and higher organic matter, supporting the assertion by FAO [8] that these areas offer relatively favorable conditions for intensive agriculture. Their balanced texture allows for better water retention and root aeration, consistent with global findings on loam's agronomic potential [**20**]. In Erbil, the sandy loam soils with moderate porosity and low salinity suggest a higher potential for horticulture and rainfed crops. This supports [21], who identified northern regions as having a comparative advantage for diversified agriculture due to their cooler temperatures and moderate rainfall. Overall, the comparison of these zones underscores the importance of tailored soil management strategies that account for local constraints such as salinity, poor structure, or low fertility**. [22]** Integrating these practices with climate-resilient approaches is vital for improving productivity and mitigating soil degradation in Iraq (20; 21; 22; 23).

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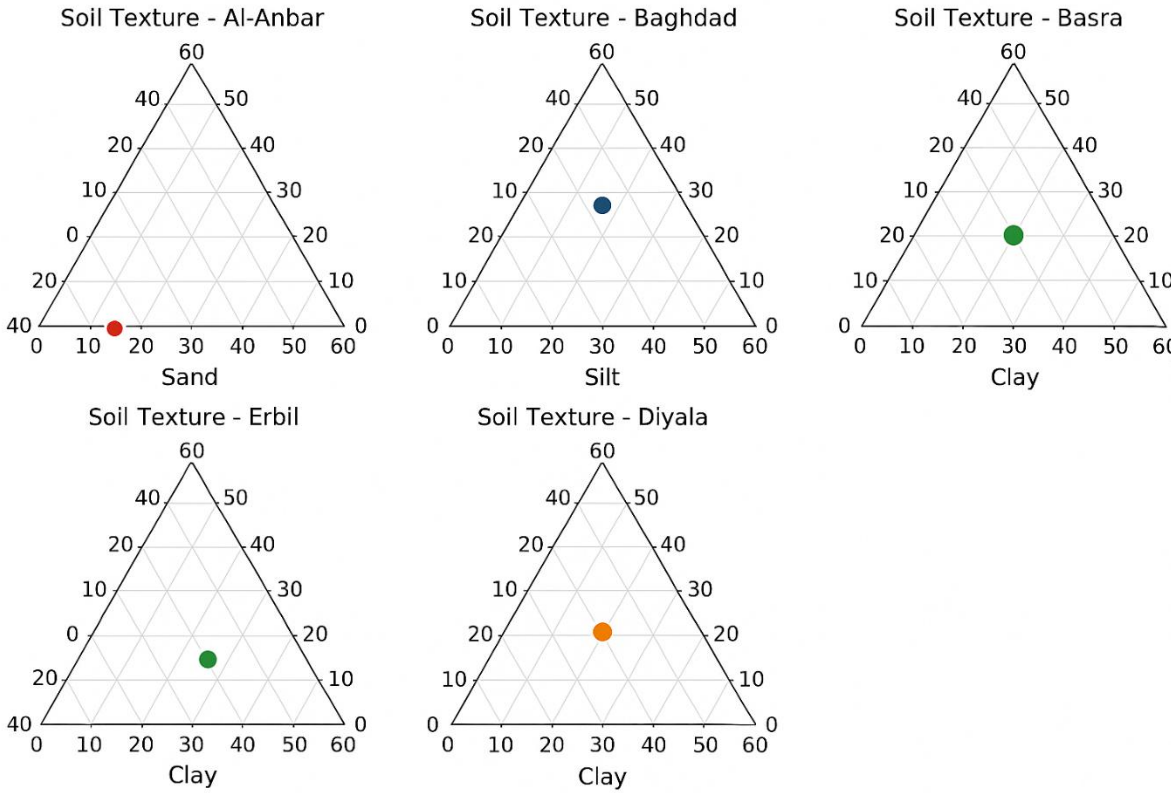

Figure 3: Soil Profile for Across the Selected Iraqi Governorates Conclusion

This study demonstrates that soil characteristics in Iraq exhibit significant spatial heterogeneity, influenced by climatic gradients, topography, and land use. The dominant soil types—ranging from sandy Aridisols in Al-Anbar to clayey Vertisols in Basrah—present distinct challenges such as low fertility, poor drainage, and high salinity. Nevertheless, the presence of productive loamy soils in Baghdad and Diyala indicates strong potential for sustainable agriculture when supported by proper management. The results highlight the critical role of soil texture and chemistry in shaping agricultural viability. To ensure long-term productivity and environmental stability, region-specific interventions such as organic amendments, improved drainage systems, and conservation farming must be prioritized in national agricultural policy [23].

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Conflict of interests.

There are non-conflicts of interest.

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