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Physical and Chemical Properties of the Iraqi Marshes: A Cartographic Study

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Abstract:

The marshlands of southern Iraq are an ecological zone of major importance, hosting high levels of biodiversity besides supporting large sources for the sake of both agriculture and domestic consumption: the main basins, Basra, Maysan, Wasit, and Dhi Qar. Unfortunately, most wetlands on this earth are doomed by various reasons such as human activities, change in climatic conditions, diversion of water for other needs, increased salinization, and degradation in water quality, owing to meager river supply in the rivers of Tigris and Euphrates. This work tends to analyze the physical and chemical properties of wetland soils across these marshes, together with a detailed shape index evaluation. It reflects the complicated inter-relationships between water flow, soil minerals, and climate, manifested in the varied mineral composition of the four regions. The regional variation in sodium concentration was recorded as in Maysan, 0.21%, Basra, 0.27%, Dhi Qar, 0.24%, and Wasit, 0.195%. These regional shifts are principally due to the dissolution of halite during sodium chloride extraction. These activities significantly retarded the water permeability of the soils while increasing the concentration of salts within the soils - the outcomes that might seriously impact the flora and fauna. Other major nutrients of soil, which varied in the present study besides sodium, are calcium, phosphorus, potassium, and magnesium. The levels of calcium were 9.8% in Basra, 9.0% in Maysan, and 8.6% and 8.4% in Dhi Qar and Wasit, respectively. The levels of phosphorus are low, ranging between 0.011 and 0.020% across the governorates. The present paper has carried out a critical analysis of soil characteristics, such as texture, permeability, and pH. It pointed out that with lower permeability-0.5 cm hr^{-1} for Basra and 0.4 cm hr^{-1} for Dhi Qar-and more saline-12.5 dS m^{-1} in Basra and 13.1 dS/m in Dhi Qar-soil, both Basra and Dhi Qar may thus be rendered comparatively more vulnerable due to the enhanced risks of salt-induced contamination and eco-damage. On the other hand, Maysan and Wasit have more propitious conditions for soil. It was of a more permeable content with a high organic matter content. This paper has focused on the detailed mapping of physical and chemical features of marshland soil, which provides critical information that could be very useful for the development of water management, agricultural practices, and environmental conservation strategies within southern Iraq.

Keywords: salinity, biodiversity, agriculture, soil degradation, marshlands

Introduction

Marshlands and wetlands in southern Iraq, especially in Basra, Maysan, Wasit, and Dhi Qar Governorates, fall within this ecological unit. Besides being a a fundamental ecological niche, wetlands have great cultural and economic significance, with large biodiversity

as well asprovide agricultural and drinking water. However, in recent decades, these areas have been increasingly threatened by changes in water distribution, rising salinity, and environmental degradation, primarily driven by the reduction of water flow from the Tigris and Euphrates rivers, as well as human activities and climate change [1; 2].

These marshes fall into a geologically complicated area with the interaction between sedimentary deposits, hydrological systems, and saline groundwater. The physical and chemical properties of soil and water play a significant role in the balance of the ecosystem and its agricultural potential. But, high salinity with inefficient practices of water management and degradation in infrastructure, is gradually ruining the environment and hence threatening livelihoods for the populations who depend on it. Recent research by [3] and [4] has showen that water quality differs largely across the different marsh zones regarding its salinity and chemical composition of water. The variation depends upon the combination of natural groundwater salinity, agricultural runoff, and discharge of untreated wastewater into rivers. The land salinization due to rising salinity levels in the Tigris and Euphrates rivers, as the main feeders of the marshes, has resulted in the salinization of soils, which has been leading to negative effects on agriculture and biodiversity. [5], along with [6], adopted a cartographic approach to the study of the physical and chemical properties of marshes and wetlands within the four governorates would be able to provide detailed mapping that may allow the illustration of salinity, soil types, and water quality distributions. It will finally contribute to the sustainable management of such vital ecosystems through the integration of remote-sensing data and GIS in this study and by effectively implementing strategies to deal with the ongoing environmental challenges. This is accordance with the statements of Al-Khayat and [7] and [8]. This becomes important research in terms of educating the policy makers, local authorities, and communities regarding the status of marshes and wetlands for informed decision-making on water resource management, land use, and environmental conservation in southern Iraq. The research shall, therefore, undertake a more critical cartographic analysis of certain physical and chemical characteristics of the marsh and wetland areas for Basra, Maysan, Wasit, and Dhi Qar governorates of southern Iraq, with the help of remote sensing data and GIS mappings to delineate the spatial pattern of some very important environmental concerns: soil salinity, water quality, and soil types. This will contribute to the knowledge of increased salinity, change in water distribution, and degradation of the environment, affecting agriculture, biodiversity, and water resources. The ultimate aim is to contribute to informed decision-making on water resource management, land use, and environmental conservation that would support these vital ecosystems for the sustenance of local populations.

Therefore, this study aims to do a cartographic analysis of marsh and wetland areas in the Basra, Maysan, Wasit, and Dhi Qar governorates for their physical and chemical characteristics. In this context, detailed maps will be drawn that will show the spatial distribution of the features of the soil and water in the areas under investigation, emphasizing salinity levels and the quality of groundwater, among other important environmental parameters. The study also seeks to explore the implications of these characteristics on agricultural practices, biodiversity, and water resource management .

Material and methods

Study Area and Soil Sampling

Soil samples were collected from agricultural areas located in the provinces of Basra, Maysan, Wasit, and Dhi Qar. Areas with different soil types and environmental conditions were randomly selected. A stratified random sampling technique that takes into consideration land use and topography was used. Soil samples were taken from the topsoil at a depth of 0– Physicochemical Analysis

Soil Texture Determination

The distribution of particle size of the soil samples was analysed by the hydrometer method of [9]. Consequently, the percentage of sand, silt, and clay was determined, and soil texture was classified according to the USDA classification of soil.

Measurement of Soil Permeability

The permeability was measured using a constant head permeameter for sandy soils and by a falling head permeameter for finer-textured soils, as described by [10]. The permeability values are expressed in cm hr^{-1} to represent the transmitting capability of water by the soil under saturated conditions**.**

Soil pH and Electrical Conductivity (EC)

The pH of the soil was determined in a 1:2.5 (soil: water) suspension using a digital pH meter (Hanna HI 2211). Electrical conductivity (EC) was measured with an EC meter (Jenway 4510) in a 1:5 (soil: water) extract to determine salinity levels.

Organic Matter Content

The OM content was determined by [11], which consists of the oxidation of organic carbon by potassium dichromate ($K_2Cr_2O_7$) and subsequent titration with ferrous sulfate.

Macronutrient Analysis

- Sodium (Na) and Potassium (K) were measured by flame photometry (JENWAY PFP7).

- Calcium (Ca) and Magnesium (Mg) concentrations were determined by complexometric titration using EDTA.

- P was analyzed by the Olsen method, where phosphate was extracted with sodium bicarbonate ($NaHCO_3$) and colorimetrically determined at 882 nm using a UV-1800 Shimadzu spectrophotometer.

- S content was determined through the turbidimetric method [12], consisting of the precipitation of sulfate ions as $BaSO_4$ and subsequent determination by spectrophotometry at 420 nm.

These methods provided complete information about the physical and chemical features of the soil for deeper analysis of soil fertility and the possibility to use it for cultivation in the studied regions.

Data collected through analysis of soil-water with the help of remote sensing and field survey data integrated into GIS for comprehensive cartographic analysis. The maps of the soil texture, salinity levels, quality of groundwater, and nutrients distribution were further developed in relation to the regional agricultural practices and biodiversity implications brought about by each soil property; this will make it easier for the land-use management strategies for sustainability.

Statics analysis

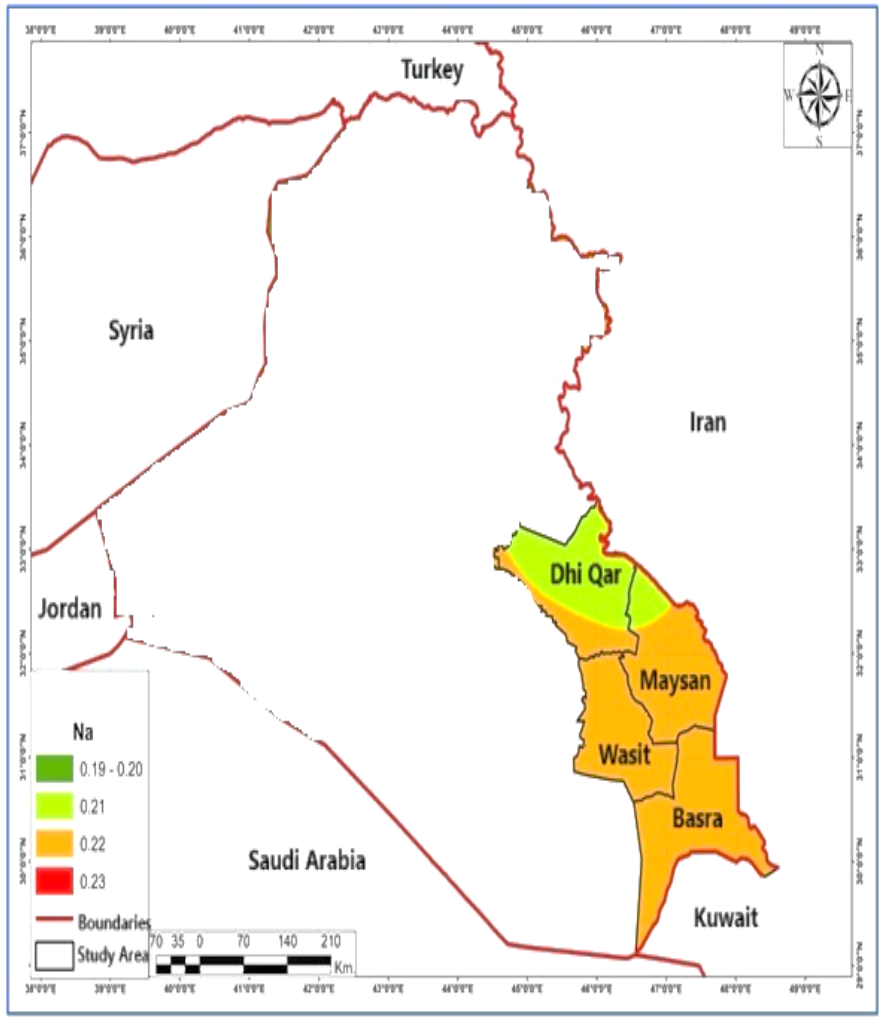
In this study, descriptive statistics means values and standard deviations were calculated using SPSS software, version 26.0. Testing for significant variance among governorates was done with one-way ANOVA analysis.

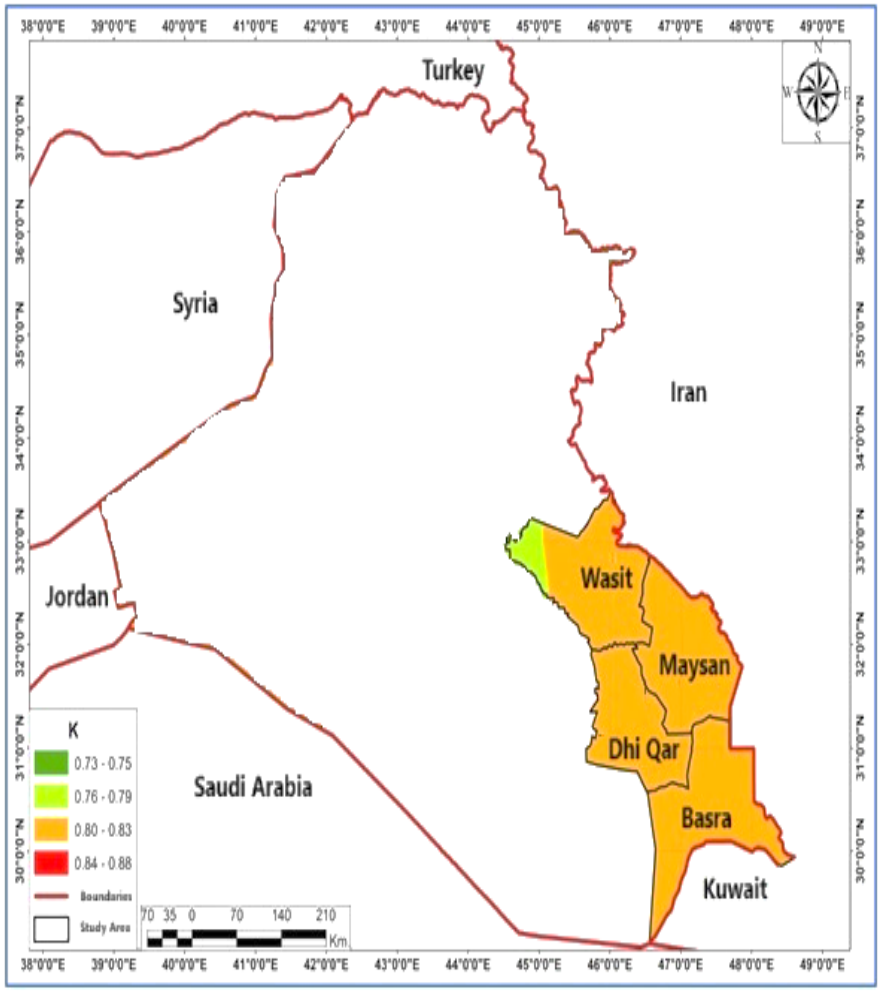
Results and Discussion

Soil Properties and Physical Characteristics of Marshlands

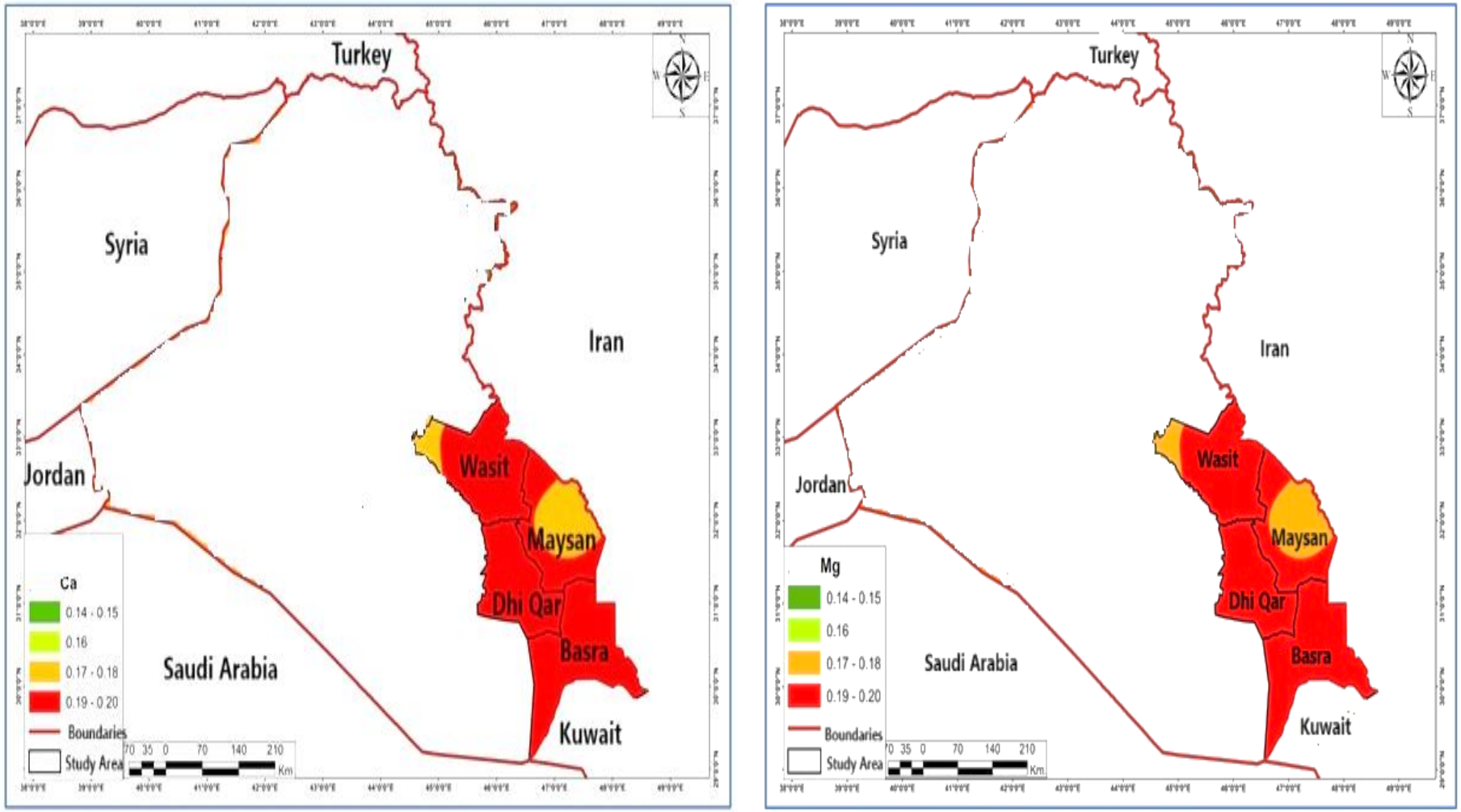
The studies of chemical composition in the marshland soils of Basra, Maysan, Wasit, and Dhi Qar showed significant differences in critical mineral concentrations of these wetland ecosystems, pointing out the complicated interactions between hydrology, soil composition, and climate. Sodium (Na) values are different in every governorate: 0.21% in Maysan, 0.27% in Basra, 0.24% in Dhi Qar, and 0.195% in

Wasit (Map1). High sodium content, from the dissolution of halite and irrigation water, is the major contributor to soil salinity and low permeability that has significantly impacted vegetation cover in the marshlands and aquatic life [13]. The concentration of Mg is highest in Basra and Dhi Qar at 0.25 and 0.22%, respectively, with Wasit and Maysan having a fairly low quantity of 0.182 and 0.19%, respectively. The presence of dolomite and variations in groundwater composition influence these differences, impacting plant nutrient uptake and soil stability [14;15]. Calcium (Ca) levels, crucial for soil structure and plant growth, are highest in Basra (9.8%) and gradually decrease in Maysan (9.0%), Dhi Qar (8.6%), and Wasit (8.4%). Regional variation also relies on the abundance of calcite and limestone minerals through seasonal flooding along with evaporation. According to [16; 17] the potassium range in Wasit falls within 0.763-0.872% (nearly similar to what was indicated for Maysan: 0.841%; Basra: 0.810%; and Dhi Qar: 0.832%). High temperatures, evaporation, and the presence of orthoclase and mica minerals regulate potassium availability, which plays a crucial role in maintaining plant resilience under saline conditions [18; 19]. Phosphorus (P) levels are relatively low across all regions, with concentrations between 0.011% and 0.020%, influenced by phosphate fixation with calcium and clay minerals, limiting its bioavailability in marsh soils [20; 21]. These values are variable in the marshlands, with 3% for Wasit and 2% for Dhi Qar. Basra and Maysan have no data recorded. This may be because of variability in the dissolution of gypsum and anhydrite, along with anthropogenic inputs from agricultural runoff. High sulfate concentrations may also increase the salinity stress and, in anaerobic conditions, contribute to the reduction of sulfate into hydrogen sulfide (H_2S), toxic to aquatic organisms. Interactions among these main soil elements-primarily sodium, calcium, and sulfates-affect the aggregation of soil, water retention, and the dynamics of plant nutrients. High evaporation rates, seasonal floods, and fluctuating groundwater further develop the chemical properties of marshland soils through climatic contribution, thereby affecting their long-term ecological stability and agricultural productivity.

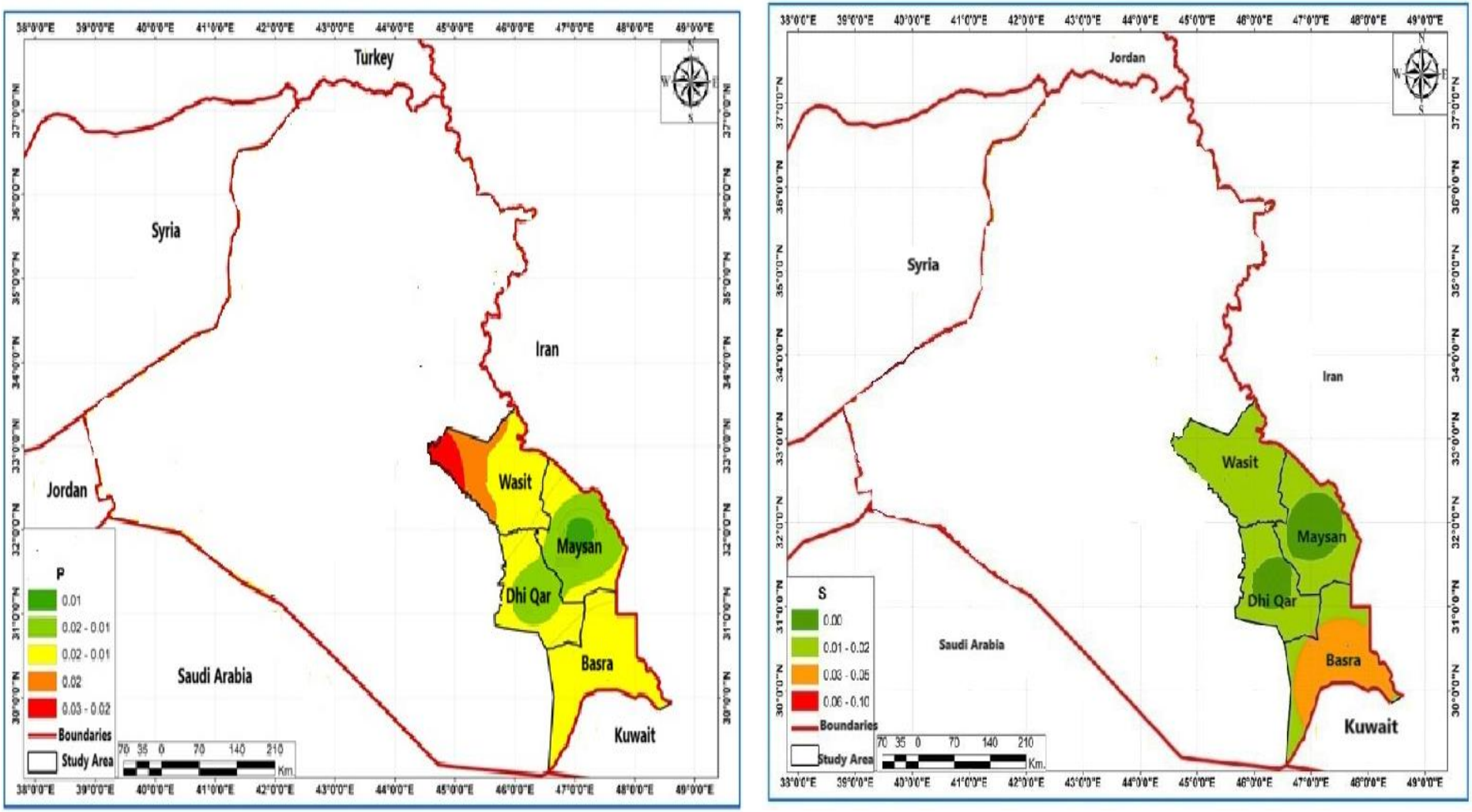




Map (1) Chemical Modeling of the Sodium and Potassium in the Study Area.



Map (2) Chemical Modeling of the Calcium and Magnesium in the Study Area



Map (3) Chemical Modeling of the Phosphorus and Sulfur in the Study Area

Soil Properties and Chemical Characteristics of Marshlands

The soil characteristics of the marshlands in Basra, Maysan, Wasit, and Dhi Qar show notable variations (Figures 1 and 2), influencing water retention, permeability, and fertility. From the soil texture analysis, it is observed that the soils of Basra constitute 30% sand, 35% silt, and 35% clay; Maysan, 40% sand, 40% silt, and 20% clay; Wasit, 55% sand, 30% silt, and 15% clay; and Dhi Qar, 25% sand, 35% silt, and 40% clay. This variation in texture plays a key role in the overall soil behavior and plant growth potential in each region. Basra and Dhi Qar (Figure 3) have the lowest permeability rates, 0.5 cm hr^{-1} and 0.4 cm hr^{-1}, respectively, and high clay content, which contributes to poor drainage and increased waterlogging risk. The high salinity levels of 12.5 dS m^{-1} and 13.1 dS m^{-1} further complicate the soil conditions, reducing oxygen availability and increasing salinity stress. Organic matter is also low which was 0.8% in Basra and 0.7% in Dhi Qar, which promotes compaction and restricts root development. The alkaline pH values of 8.1 in Basra and 8.2 in Dhi Qar further reduce nutrient availability, hence restricting plant growth. These findings are quite in agreement with the observations made by [23; 24]. The Maysan soil profile showed a more balanced distribution, with moderate permeability of about 1.2 cm hr^{-1}, better organic matter content of 1.5%, and moderate salinity at 8.4 dS m^{-1}. It provides optimum conditions for soil aeration, fertility, and plant growth. On the other hand, Wasit has the highest permeability value of 1.5 cm hr-1 and the lowest salinity of 5.2 dS m^{-1} and thus provides well-drained conditions, which are favorable for healthy root development and restrict salt accumulation (Figure 3). With a higher organic matter content of 2.3%, it contributes to an increase in soil structure and water retention, hence enhancing the sustainability of wetland ecosystems [6; 20; 21]. The soil characteristics of these regions are different, and it is for this reason that region-specific management practices become quite important. Amendment with organic materials and gypsum can enhance the permeability of Basra and Dhi Qar and reduce salinity adversities, whereas for Wasit, strategies like mulching or cover cropping that may help retain soil moisture can balance the rapid drainage. The soil properties and nutrient availability of marshlands in Iraq are also further affected by high evaporation, fluctuating groundwater, and seasonal flooding that may be related to climatic factors.

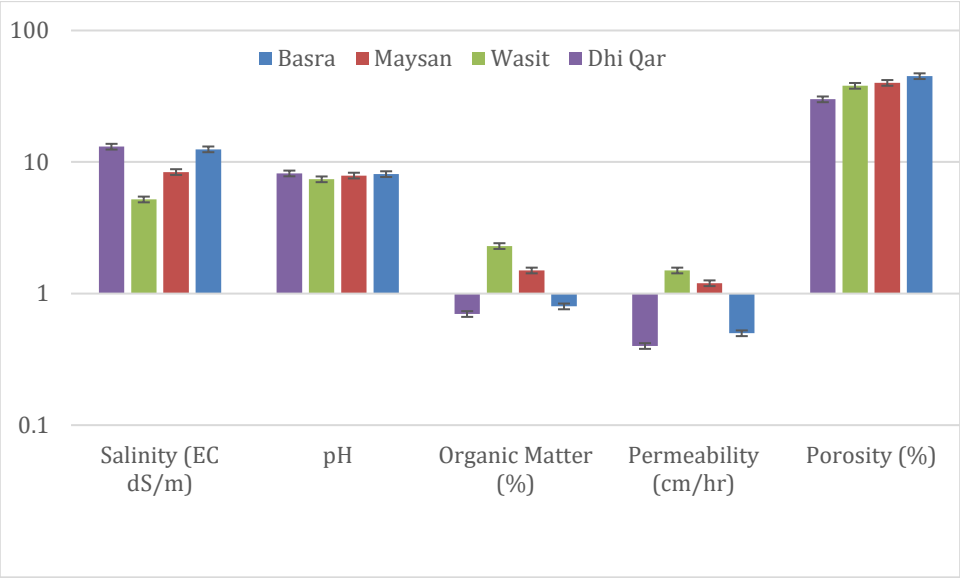


Figure 1. Soil Properties and Chemical Characteristics of Marshlands in Different Governorates of Iraq

Previous research has shown that wetlands, like marshes in Iraq, are considered a special kind of ecosystem because of their distinguished features in soil, water, and plant interactions. In this context, the study by [26; 25] on the effect of salinity stress on urease activity in calcareous soils in semi-arid regions of Iraq provides a deeper understanding of how salinity impacts soil in the semi-arid regions, extending to the marshlands in southern Iraq. Salinity in both water and soil has been on the increase in such environments; hence, the study of how such factors influence soil biological activity is very important in marshes. On the other hand [28; 27] conducted research on the decomposition of organic matter in different-texture soils to show how soil texture affects decomposition. In marsh environments, for example, where the soil is waterlogged, this can impact organic matter decomposition, influencing nutrient availability for plants in that region. This idea is in agreement with our findings on the importance of comprehending environmental changes being faced in marshlands. Besides, the study by [26] on the behavior of potassium in soil suggests that marsh soils may interact differently with nutrients compared to calcareous soils in semi-arid regions. This therefore calls for the assessment of nutrient availability in wetland soils for the improvement of agricultural sustainability to support the local vegetation in marsh ecosystems. [29; 30] discuss bioaccumulation in plants from the Al-Chibayish marsh of southern Iraq, while noting the effects that contaminants such as heavy metals may have on marsh organisms. This is in agreement with our findings, where studying bioaccumulation is of immense importance in wetland ecosystems where marshlands act as habitats for so many plant and animal species, which are generally thought of as facing endangerment. Besides, [31] demonstrated in their work how different organic matter additions affect CO_2 emission in calcareous soil and that soils in wetland environments could have a different response to organic matter addition. Organic amendments may be able to increase CO_2 emissions, which affects the chemical interaction within the soil and marsh environment. These studies all point to one conclusion: Marshes in Iraq

are very vital ecosystems that need the adaptation of sustainable management practices, owing to the occurrence of chemical and environmental changes within the soil and plant life found in these wetlands. Grateful for unending research into the integrated practices of agriculture concerning marsh ecosystems, contributing to the sustenance of such an environment by protecting it against ecological degradation.

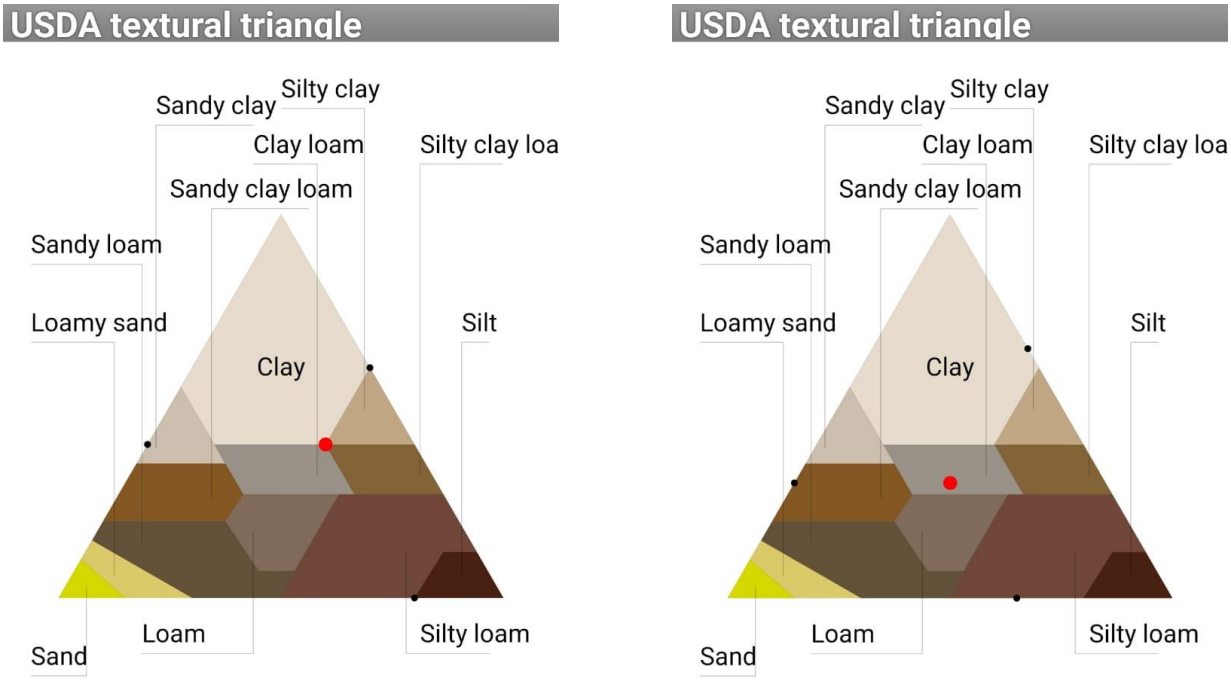


Figure 2. USDA Textural Triangle: Soil Texture Classification Based on Sand, Silt, and Clay Percentages for Maysan, Basra.

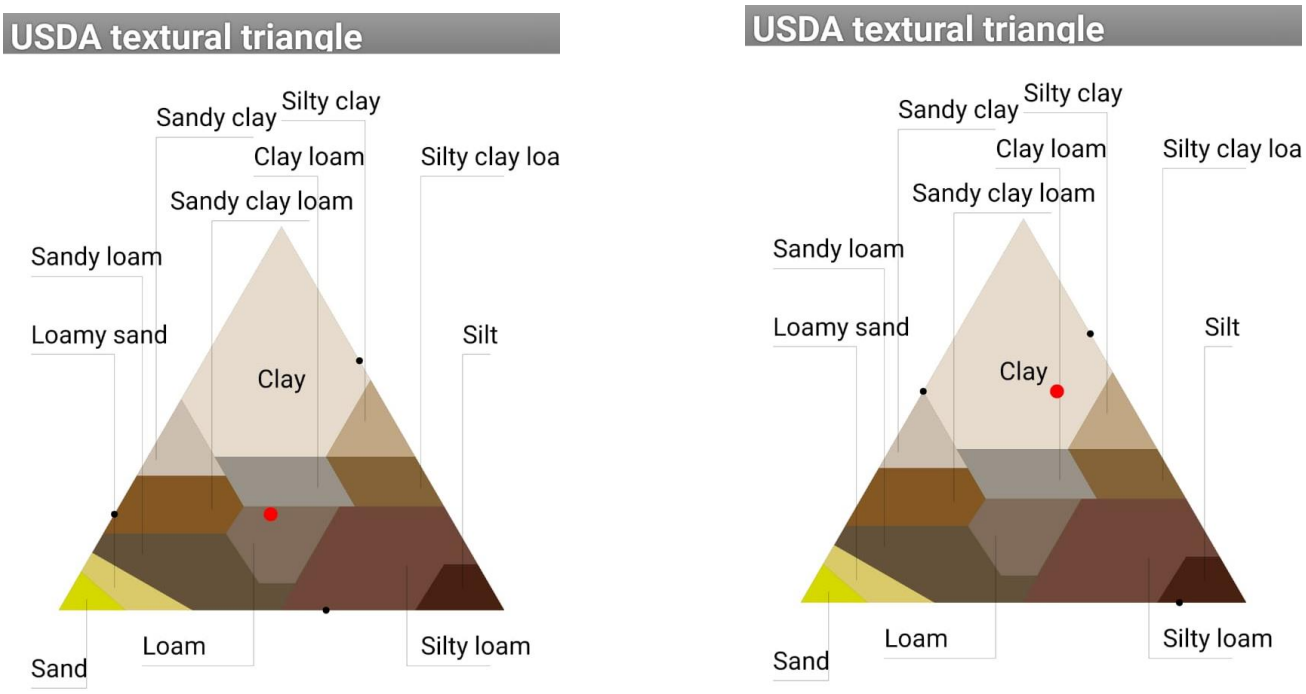


Figure 3. USDA Textural Triangle: Soil Texture Classification Based on Sand, Silt, and Clay Percentages for Dhi Qar, Wasit.

Conclusion

These findings give reason for local management strategies to be put into place in every marshland area since there is great variability in soil characteristics among the governorates. While Basra and Dhi Qar have some problems related to soil drainage, salinity, and low organic matter, Wasit presents more favorable conditions of higher soil permeability and lower salinity values, hence, it is in better shape for sustainable agriculture. The cartographic results of the research provide substantial inputs on the conditions of such marshes to policymakers and local authorities' intervention against environmental degradation. The high salinity and nutrient imbalance across the marshlands indicate target soil amendments-such as gypsum and organic matter, to improve the structure and fertility of the high salinity areas found in Basra and Dhi Qar. Furthermore, methods involving mulching and cover cropping can be advantageous in regions with good permeability, like Wasit, for retaining moisture. The study concludes by highlighting the importance of these wetlands in the ecological and socio-economic landscape of southern Iraq and lays a scientific basis for the sustainable management of this invaluable resource against growing environmental pressures. Integration of GIS and remote sensing with field data holds promise for environmental monitoring and informed decision-making in support of the region.

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