Research Article

Assessment of Fertility Status of Soils Under Wheat Cultivation in Dhi Qar Governorate, Iraq Using Geographic Information Systems

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Abstract | The fertility of agricultural soils plays a crucial role in sustainable crop production. Agricultural soils in different areas of Iraq exhibit a differential nutrient status. This study was conducted in the areas of Qalat Sukkar and Al-Rifai situated in the northern Dhi Qar Governorate of Iraq. Study areas of Qalat Sukkar and Al-Rifai districts lie between longitudes of 46˚ 13' 45" - 46˚ 12' 55" E and 46˚ 17 25- 46˚ 18' 50" E and latitudes of 31˚ 56' 25" - 31˚ 55' 50"N and 31˚ 45' 10" - 31˚ 44' 25" N, respectively. Soil fertility ratings were predicted by the standard multiplication method, and NPK distribution maps were generated by Geographic Information Systems (GIS) technology. Results showed that the soils under wheat cultivation in both study areas varied in most of their physical and chemical properties. Overall study results indicated a higher percentage of NPK in the Al-Rifai area than in the Qalat Sukkar area, which is consistent with the findings of the fertility assessment. Moreover, study results validate the importance of GIS-based soil fertility assessment for accurate fertilization and for precision agriculture.

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Keywords | Soil fertility status, Wheat production, Fertility assessment, North dhi qar, GIS, NPK.

Introduction

Wheat (*Triticum aestivum* L.) ranks as a major cereal crop and is considered a strategic crop globally, including Iraq. Owing a rich nutritional value, this staple crop plays a crucial role in achieving food security (Al Zubaidi and Kubba, 2016). The indigenous fertility of agricultural soils is always of prime importance in sustainable wheat production. Particularly, major edaphic nutrients such as potassium, nitrogen, and phosphorus are of prime significance because plants usually need them in large quantities to regulate their metabolic and physiological processes and to grow optimally (Rawal *et al*., 2022). These macronutrients must be available in appropriate quantities in the soil profiles to achieve optimal wheat productivity in terms of quantity and quality (Pandey *et al*., 2020). These elements are essential for achieving a nutritional balance between different phyto-nutrients and preventing any deficiency, as their lack negatively impacts the production of cultivated crops (Al-Marjani, 2005; Sun *et al*., 2024).

Availability of macronutrients (NPK) at various crop growth stages is very crucial, and optimum administration of fertilizers plays an important role as these provide essential nutrients to the crop plants. One of the most important of these fertilizers is urea fertilizer, as it contains a high percentage of nitrogen, which is essential for the biosynthesis of chlorophyll and amino acids and ultimately plant proteins (Abdel-Ati *et al*., 2023; Al Barakat *et al*., 2023; Kareem *et al*., 2024). Similarly, potassium is important for crops as it stimulates and activates about 80% or more of the phyto-enzymes (Cui and Tcherkez, 2021). These enzymes are involved in a number of vital processes that occur within the plant. It is an important regulator of the plant responses to environmental stimuli and plant tolerance to abiotic stresses and (Wang *et al*., 2013; Hasanuzzaman *et al*., 2018). It helps the crop plants to resist and tolerate drought and also withstand extreme cold without affecting plant production (Wang *et al*., 2013). Moreover, phosphorus is an important macronutrient for wheat crop as it plays a major role in plant cellular respiration (governing ATP and ADP synthesis) and in fatty acids and starch metabolism (Adnan *et al*., 2020). Balla *et al*. (2021) indicated that bioavailability of phosphorus depends on the soil phosphorus concentration and the ability to maintain it because there should be a balance between soil phosphorus and adsorbed phosphorus (Mwende Muindi, 2019; Yan *et al*., 2020; Al-Toki *et al*., 2021).

Recent research works have demonstrated that the balanced use of NPK fertilizers enhances the productivity of the wheat crop. Research conducted in South Asia has also shown that adding about 120 kg of nitrogen per hectare, 26 kg of phosphorus per hectare, and 50 kg of potassium enhances the efficiency of utilization and exploitation of nutrients up to 58%, leading to a significant increase in crop productivity (Godebo *et al*., 2021; Rawal *et al*., 2022). Moreover, it has been found that nature and conditions of the agricultural field soil affect the bioavailability and absorption of nutrients by the crop plants, particularly in case of macronutrients (Comerford, 2005; Ali *et al*., 2014; Dhaliwal *et al*., 2024). Keeping in view the aforementioned information, this field study was planned to assess the prevailing fertility status of soils under wheat cultivation in different areas of Dhi Qar Governorate of Iraq and to create spatial distribution maps using GIS for the traits included in the fertility assessment.

Materials and Methods

Study sites

For this study, two sites were selected in the northern part of the Dhi Qar Governorate, Iraq. One was Qalat Sukkar district, and other was Al-Rifai district. Studied areas of Qalat Sukkar and Al-Rifai districts lie between longitudes of 46° 13` 45`` - 46° 12` 55`` E and 46° 17 25- 46° 18' 50" E and latitudes of 31° 56' 25" - 31° 55' 50"N and 31° 45' 10" - 31° 44' 25" N, respectively. The study areas covered an area of 15 and 21 hectares, respectively. The locations in each field were identified using Geographic Information Systems (GIS). Samples were taken before wheat planting at 0–30 cm depth. These soil samples were identified using a Garmen™ GPS with a UTM coordinate system (GARMIN 72 equipped with coordinates system WGS_1984_UTM_Zone_38N).

Soil sampling protocol

These samples were spatially mapped using a ArcGIS™ Pro 3.4.0 software to meet the requirements of spatial analysis. The soil samples were shade-dried, grounded into fine particles, and then were sifted through a sieve/sifter (2 mm mesh size) to be ready for the determination of soil chemical and physical properties as brief below.

Determination of available nitrogen (N)

Soil nitrogen was determined by Kjeldahl extraction method using magnesium oxide (MgO) and potassium chloride solution (2M KCl), followed by the reduction of the nitrate ion to ammonium (NH_4) using Devarda alloy. After evaporation, the nitrogen was distilled using a micro-Kjeldahl and titrated with sulfuric acid (0.005N H_2SO_4) as per the method of Keeney and Nelson detailed in Emmerich *et al*. (1982).

Measurement of available potassium (K) and phosphorus (P)

Soil potassium was extracted with 1N NH_4OAc (ammonium acetate) with a pH of 7 and was determined by a flame photometer as per protocol detailed in Emmerich *et al*. (1982). While the available soil phosphorus was extracted using sodium bicarbonate (0.5N $NaHCO_3$) with a pH of 8.5, and was determined by a flame photometer as per protocol detailed in Emmerich *et al*. (1982).

Results and Discussion

The current research work was planned to assess the prevailing fertility evaluation of soils under wheat cultivation in areas of Qalat Sukkar and Al-Rifai in the Dhi Qar Governorate of northern Iraq. Results of the study showed varied status of N, P, and K (macronutrients) in soil samples of both areas.

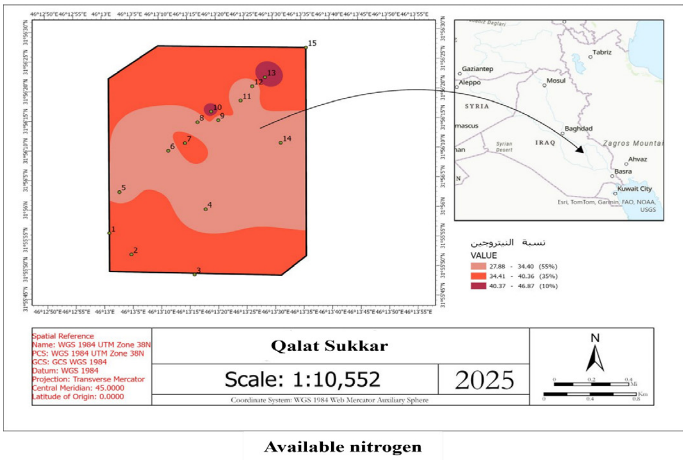

Figure 1: *Geographic distribution map of available nitrogen in the area of qalat sukkar, dhi qar governorate, southern iraq.*

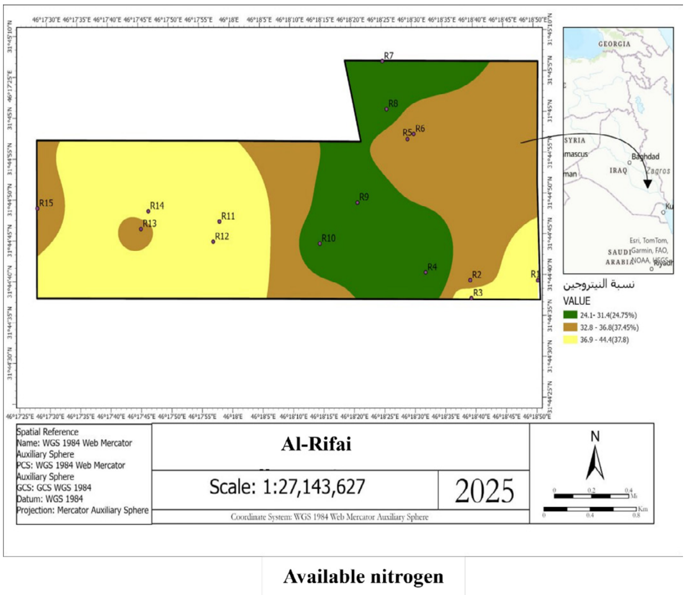

Figure 2: *Geographic distribution map of available nitrogen in the area of al-rifai, dhi qar governorate, southern iraq.*

Status of soil nitrogen (N)

Overall, the study results indicated variations in the nitrogen levels of soil in Qalat Sukkar area. According to Figure 1, the soil nitrogen levels were 38.39, 38.7, 39.01, 32.34, 33.71, 31.26, 37.5, 27.87, 31.24, 45.62, 32.52, 30.6, 46.88, 28.12, and 35.44 mg kg^{-1}. The values that ranged between 27.87–34.4 mg kg^{-1} represented 55% of the total area, while the values that ranged between 34.42–40.36 mg kg^{-1} covered 35% of the total area, and the values that ranged between 40.37–46.37 mg kg^{-1} represented 10% of the total area. In case of Al-Rifai area, the soil nitrogen concentrations were 40.2, 32.8, 41.2, 25.8, 35.5, 34.2, 24.1, 30.6, 29.7, 31.4, 39.2, 44.4, 35.4, 36.9, and 36.0 mg kg^{-1} (Figure 2), where the values between 24.1–31.4 mg kg^{-1} represented 24.7% of the total area, and the values between 32.8–36.8 mg kg^{-1} represented 37.4% of the total area, while the values between 36.9–44.4 mg kg^{-1} covered 37.8% of the total area of the studied area in Al-Rifai.

Nitrogen (N) is considered a determining factor for optimum plant growth and for soil fertility because it directly affects crops in terms of their growth and effectiveness. Available nitrogen content is considered as a most important factor for plant growth and soil fertility, because it directly affects the crop plants in terms of their growth and activity (Ali *et al*., 2012; Mălinaş *et al*., 2022). Nitrogen varies from one soil to another according to the prevailing conditions in addition to the leaching and loss processes, which in turn lead to the loss of nitrogen from the soil and thus affect its fertility (Barłóg *et al*., 2022; Grzebisz *et al*., 2022).

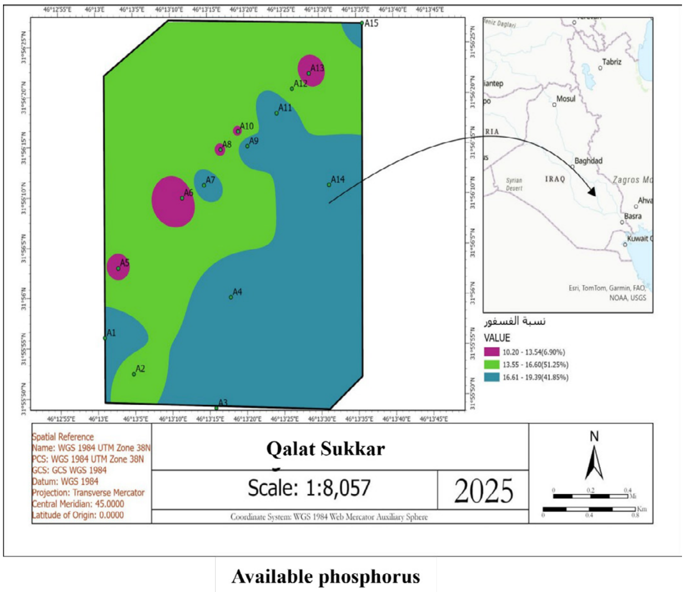

Figure 3: *Geographic distribution map of available phosphorus in the area of qalat sukkar, dhi qar governorate, southern iraq.*

Available phosphorus (P)

The results analysis showed variations in the quantity of available phosphorus within the soil profiles of Qalat Sukkar area as shown in Figure 3. The available phosphorus values of soil samples were 19.0, 16.0, 18.02, 18.3, 13.2, 10.2, 19.0, 13.2, 18.6, 13.1, 19.4, 15.3, 12.12, 19.1, and 17.3 mg kg^{-1}. The values ranging between 10.20–13.54 mg kg^{-1} representing 6.9% of the total area, and the soil phosphorus values ranging between 13.55–16.60 mg kg^{-1} represented 51.2% of the total area, while the values ranging between 16.61–19.39 mg kg^{-1} represented 41.8% of the total area. For Al-Rafai area, the amounts of phosphorus in the studied soil samples were 18.1, 15.6, 19.2, 18.0, 13.01, 12.0, 10.9, 19.3, 18.3, 17.1, 20.5, 14.01, 19.15, 13.1, and 19.2 mg kg^{-1} (Figure 4). The phosphorous values ranging between 10.9–14.5 mg kg^{-1} showed a percentage of 8.5 of the total area, and the values 14.55–16.85 mg kg^{-1} covered a percentage of 42.9% of the total area, and the values 16.9–20.5 mg kg^{-1} represented about 48.56% of the total area.

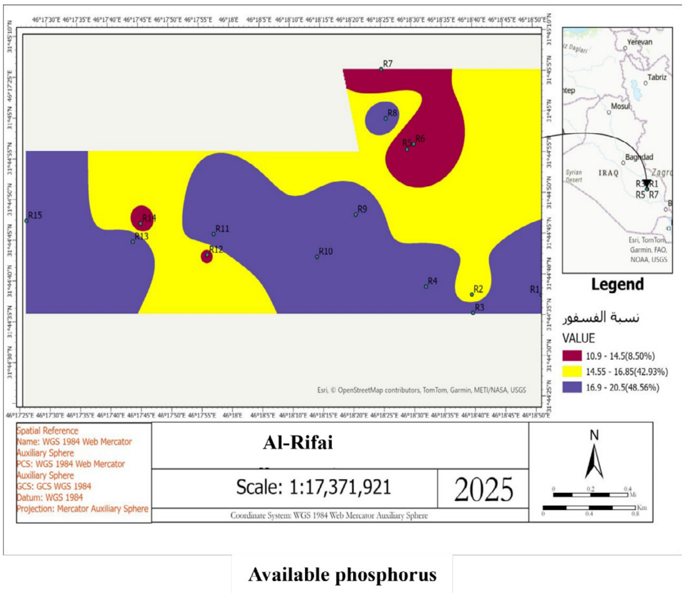

Figure 4: *Geographic distribution map of available phosphorus in the area of al-rifai, dhi qar governorate, southern iraq.*

Available phosphorus within agricultural soils is an essential element for crop cultivation and soil fertility due to its importance for plant growth. Phosphorus undergoes many processes that lead to its adsorption and deposition, reducing its availability to plants (Malhotra *et al*., 2018; Ibrahim *et al*., 2024). The soils in the study areas are calcareous, so phosphorus deposits are found in the form of calcium phosphate. Higher amounts of calcium carbonate in the soils of the studied areas also lead to phosphorus deposition (Tunesi *et al*., 1999). The presence of organic matter reduces phosphorus adsorption, increasing its availability to plants. This is the reason for its high concentration in the soil solutions (Barker and Pilbeam, 2007; Mabagala, 2022).

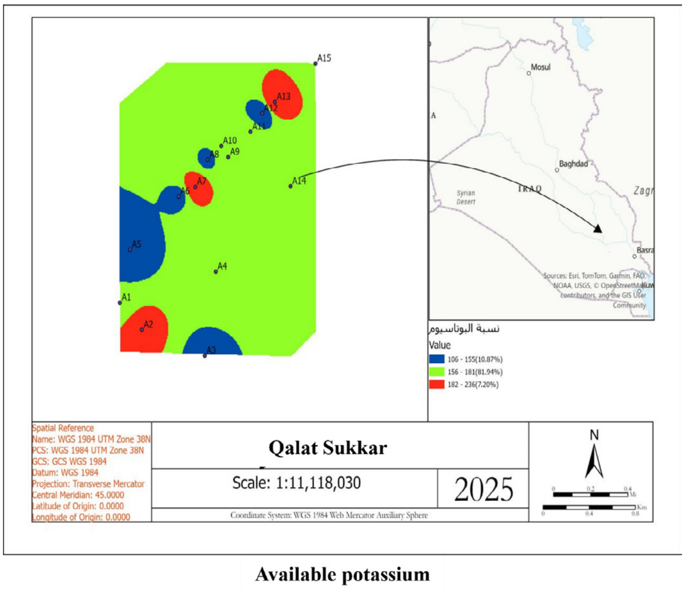

Figure 5: *Geographic distribution map of available potassium in the area of qalat sukkar, dhi qar governorate, southern iraq.*

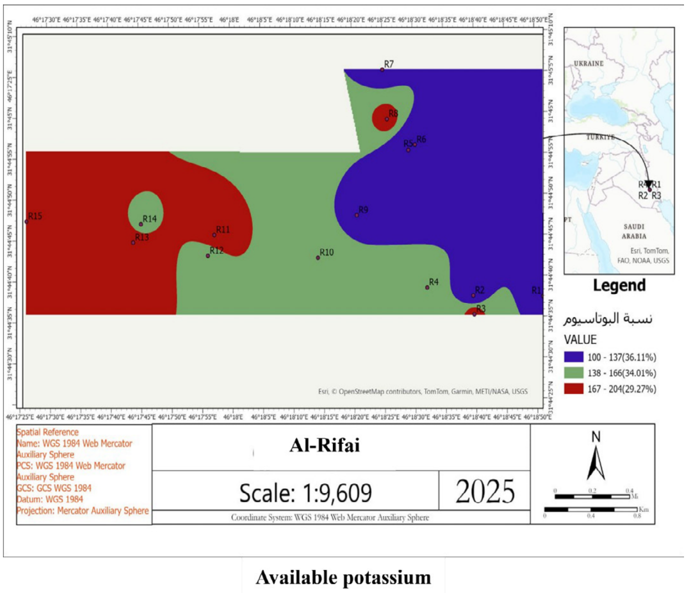

Figure 6: *Geographic distribution map of available potassium in the area of al-rifai, dhi qar governorate, southern iraq.*

Available potassium (K)

Similar trend was found in case of available soil potassium of the study areas. There was a variation in the potassium concentrations in the soil profiles of Qalat Sukkar area as shown in Figure 5. The potassium concentrations were as follows: 160, 212, 140, 180, 118, 140, 220, 142, 178, 164, 182, 106, 236, 160, and 160 mg kg^{-1}. The potassium values of soils ranging between 106–155 mg kg^{-1} and 156–181 mg kg^{-1} and 182–236 mg kg^{-1} represented an area of 10.8, 81.9, and 7.2% of the total area, respectively. In case of Al-Rafai area, Figure 6 showed that the potassium concentrations were as follows: 128, 110, 185, 142, 100, 102, 124, 186, 130, 160, 192, 146, 204, 152, and 198 mg kg^{-1}, where the soil potassium values ranging between 100–137 mg kg^{-1} occupied 36.1% of the total area and the values 138–166 mg kg^{-1}mg kg^{-1} represented 34.01% of the total area, while the potassium values of 167–204 mg kg^{-1} represented about 29.2% of the total area.

The study results showed that the soil's ability to absorb potassium increases with the quantity of potassium supplemented to the equilibrium solution, as the potassium contents in the solution directly affects the concentration of ions absorbed (Maathuis and Sanders, 1996; Sardans and Peñuelas, 2021). It was also found that this amount varies depending on the soil characteristics and the soil locations. Some factors such as texture, organic matter level, and cation exchange capacity (CEC), play a major role in determining the soil's ability to absorb and store potassium (Caravaca *et al*., 1999; Bedeeh *et al*, 2024).

The variations in potassium levels among the studied areas and within the site itself, might be due to the poor management through irrational fertilization and irrigation processes (Ruan *et al*., 2014; Al-Shahmani, 2015; Wang *et al*., 2023). The quantities of potassium in the study areas are considered acceptable, because the indigenous soils in both of the study sites are loamy silt, which means that the proportions of soil particles, particularly the proportion of clay, which contains high quantities of potassium sufficient for wheat plant growth (Chen *et al*., 2023; Abdel-Ati*et al*., 2023; Abdalkadhum *et al*., 2024; Nigon and Kaiser, 2025).

Conclusions and Recommendations

Based on overall fertility assessment, soils of the study sites can be categorized into four different classes, as follows: I) rich fertility class: this class covered 13% of the total area of the Qalat Sukkar area, while it covered 15% of Al-Rifai total area. This class is characterized from the other classes by its considerably higher NPK content. II) medium fertility class: this class covered 27 and 45% of the total area of Qalat Sukkar and Al-Rifai area, respectively, and is characterized by its moderately high NPK content. III) low fertility class: this class covered 53 and 40% of the total area of Qalat Sukkar and Al-Rifai total area, respectively, and is characterized by its adequate NPK content. IV) non-fertile class: this class appeared in the Qalat Sukkar area only, where it occupied an area of 7% of the Qalat Sukkar area, while this class did not appear in Al-Rifai area. This fourth-class soil is characterized by a small percentage of macronutrient (NPK) content.

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Novelty Statement

The soils under wheat cultivation in both study areas varied in most of their physical and chemical properties. Overall study results indicated a higher percentage of NPK in the Al-Rifai area than in the Qalat Sukkar area, which is consistent with the findings of the fertility assessment.

Author's Contribution

Talib Shamkhy Jaber AL-Humaydawi: Prepared the first drift and data analysis
Kahraman Hussein Habib Al-Khazaei: Supervised the project.

Generative AI or AI assisted technology statement

The authors declare that no generative artificial intelligence (AI) tools or AI assisted technologies were used in the preparation, writing, data analysis or editing of this manuscript.

Conflict of interest

The authors have no conflict of interest.

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