Sustainable Groundwater for Karbala Pilgrims: Assessing the Viability and Efficiency of Groundwater Wells along the Baghdad-Karbala Pilgrimage Route using Remote Sensing Techniques

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Abstract

In this study, remote sensing data and spatial analysis techniques were used to study the validity and efficiency of groundwater in 45 wells. The study area included the Baghdad-Karbala Road, passing through the Jurf al-Sakhar district, extending over a distance of more than 80 kilometres (50 miles). The road begins from the city of Latifiya, where it connects with al-Qamishli Street at the Jurf al-Sakhar bridge in the village of al-Fadhiliya, to cross the city of Jurf al-Sakhar longitudinally, passing through the villages. agricultural areas, reaching the Al-Khanafsa and Al-Jamaliyya area, then to Karbala Governorate. Well locations were determined using Global Positioning System (GPS) and this data was processed and georeferenced to represent actual locations on satellite images. The Sentinel-2 satellite was used to capture images and were processed using ArcMap 10.6 software. The depths of the wells were studied and spatial analysis maps were produced based on the spatial extrapolation technique provided by the program. The results showed that the depths of the selected wells were within international standards and Iraqi standards, as the depth in Karbala reached 280 meters, while in Baghdad it reached 84 meters. The wells in the Baghdad Governorate formation were more productive than the wells near the administrative borders of the Karbala Governorate, as the highest production value reached 864 m3/day in the city of Latifiyah, while the highest value in the wells of the Al-Fadhiliya village reached 432 m3/day. day. day. The concentrations of chemical elements and physical properties of well water in the study area (Mg, Na, Ca, Cl, Pb, pH, EC)

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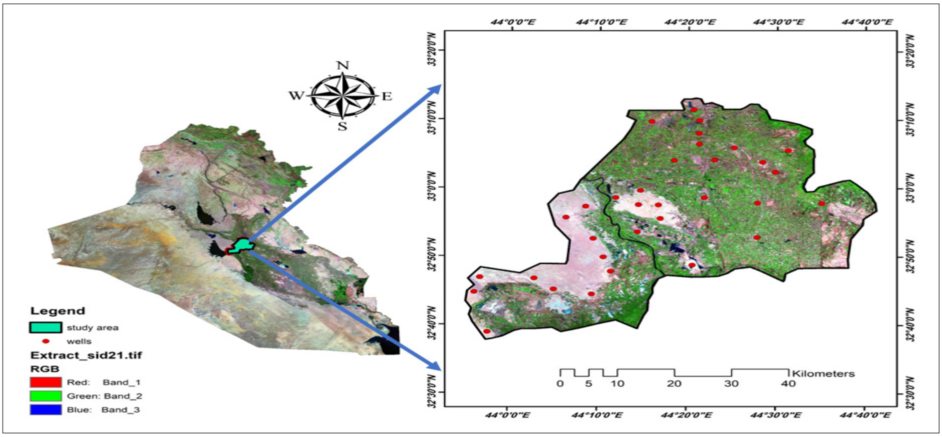
were also studied. The results, based on the electrical connection, showed that 53% of the wells in the city of Latifiya and 64% in the Al-Khanfasa and Al-Jamaliyah areas are very suitable for use in irrigating livestock and poultry, while the percentage reached 14%. In the wells of the village of Al-Fadhiliya. The maps were drawn using the IDW method. The results showed that about 55% of the wells of the city of Latifiya and 67% of the wells of the village of Al-Fadhiliya fall between 40-55, and these values show that the water used for irrigation and watering crops is subject to restrictions.

Keywords: Sustainable Groundwater, Pilgrimage Route, spatial analysis techniques and The Sentinel-2 satellite Images.

1-Introduction

Groundwater occupies the forefront in areas where there are no sources of surface water from rivers and irrigation projects, where groundwater exists in the form of free ground water at depths of 1-5 meters below the surface of the earth in the plain parts and river valleys, and the depth of the groundwater surface increases to more than that in in the hills, groundwater moves towards rivers and streams to drain into them, while rainwater seeps in winter to replenish groundwater. In the summer, irrigation water seeps into it, and the level and concentration of groundwater changes depending on the withdrawal from it for irrigation and land use purposes, the availability of a drainage network, or the presence of a nearby river channel, as well as high temperatures, evaporation from the surface of the earth, wind movement, and the hydrological conditions of the region. The role and importance of groundwater in the region has increased with the population increase during religious visits to Karbala in general and the Arbaeen pilgrimage in particular, in addition to the recurrence of years of drought in the recent period, especially since large parts of the region depend mainly on groundwater wells for agricultural investment, so Determining the suitability of groundwater for the purposes of human and agricultural consumption, through the application of modern techniques represented by the use of (GIS), in the analysis and spatial distribution of the qualitative characteristics of groundwater in the study area, is of great importance. The evaluation of water quality depends on several criteria, the most important of which is the total salt content and its ionic composition, which results in variation in its quality, as it depends on the type and quantity of dissolved salts resulting from the dissolution or weathering of rocks, such as the dissolution of gypsum and lime, which in turn are transported with irrigation water. Water quality is the subject of research and study in many countries, and the most important qualitative specifications for irrigation water that must be studied are agreed upon by most classifications. The US Department of Agriculture (USDA) indicated in its 1954 guide (Richards, 1954) that the most important characteristics determining water quality are the electrical conductivity value, the sodium adsorption rate, and the concentration of boron and bicarbonate. As for the classification of the Food and Agriculture Organization of the United Nations (FAO) (Ayers and Westcot 1985), they adopted the value of electrical conductivity for its direct effect on plant growth and the rate of sodium adsorption for its effect on soil permeability, water sinkage, and the concentration of chlorine, boron, and sodium as harmful ionic concentrations, and they adopted other incidental effects such as the concentration of nitrates. And bicarbonate and the degree of water interaction. As for the classification of the same organization in 1992, they used salt concentration estimated by electrical conductivity to determine the type of salt water and came up with six types and types of salt water. As for the classification (Glim, 1997), it classified water into six types based on electrical conductivity and percentage Sodium adsorption, boron ion concentration, and chloride ion activity, which is a proposed guide for classifying irrigation water quality specific to Iraqi water. A study was conducted to evaluate the quality of groundwater in Karbala Governorate (Shukri, 2002). To evaluate the quality of groundwater for a poultry project, Karbala, the annual average electrical conductivity values varied. Between 2.06 - 6.48 dSm-1 and the values of the sodium adsorption rate ranged between 3.50 - 6.98 and it was classified under the C4-S2 category according to the American classification of 1954 (Richards, 1954) and under the acute problem according to the International Food and Agriculture Organization classification. The research aims to represent a set of qualitative characteristics of groundwater on the Baghdad-Karbala Road, passing through the Jurf al-Sakhar district, extending over a distance of more than 80 kilometres. The road begins from the city of Latifiya, where it connects with al-Qamishli Street at the Jurf al-Sakhar bridge in the village of al-Fadhiliya to cross The city of Jurf Al-Sakhar, passing through the agricultural villages, reaching the Al-Khanfasa and Al-Jamaliyya area, then to Karbala Governorate, using geographic information systems (GIS) and analyzing their spatial distribution, where each of the studied properties is represented by an independent map, and its categories are classified according to a set of criteria to provide See how valid this is Qualitative characteristics for purposes of drinking, irrigation, and watering animals over the area of the research area, and then performing a spatial matching process (overlay) on the maps of these properties to reach the final determination of the areas in which groundwater is suitable for the purposes of drinking, irrigation, and watering animals, over the area of the study area.

2-Study area



the Baghdad-Karbala Roads, passing through the Jurf al-Sakhr district, extending over a distance of more than 80 kilometres. The road begins from the city of Latifiya, where it connects with al-Qamishli Street at the Jurf al-Sakhr bridge in the village of al-Fadhiliya, to cross the city of Jurf al-Sakhr longitudinally, passing through the agricultural villages. Reaching the Al-Khanafsa and Al-Jamaliyya area, then to Karbala Governorate. The region is located within the desert climate zone, which is characterized by very hot summers and moderate to cold winters. Summer is long and dry, with temperatures rising to more than 40 C during the day, while falling at night but remaining high. Winters are relatively short, with little rain and temperatures sometimes falling below zero at night on the coldest days. Monsoons are common and can stir up dust and sand, affecting visibility and agricultural activities.

The road represents great geostrategic and economic importance as it connects Baghdad and Karbala, making it a major hub for commercial and religious movement, especially during the Hajj seasons and the large religious visits that Karbala witnesses. The city witnesses religious visits throughout the year, and perhaps one of the most important visits that the city witnesses is the Arba'een visit, which is considered one of the religious social and human occasions and rituals that are practiced on the twentieth of the month of Safar every year according to the Hijri date, and millions of delegation's head towards the city. Figure 1 shows the location of the study area in Iraq

Figure (1): RGB image with bands (MID IR, NER-IR, GREEN) of the study area taken from the Sentinel-2 Satellite, showing the boundaries of the study area and the wells used.

3-Data Sources and Programs used:

The study relied on a variety of data, mainly represented by the following data:

Data on well water distributed over the research area extending on the Baghdad-Karbala Road, passing through the Jurf al-Sakhar district, extending over a distance of more than 80 kilometers (50 miles). The road begins from the city of Latifiya, where it connects with al-Qamishli Street at the Jurf al-Sakhar bridge in the village of al-Fadhiliya, to cross the city of Jurf al-Sakhr is located longitudinally, passing through the agricultural villages, reaching the area of Al-Khanfasa and Al-Jamaliyya, then to Karbala

Governorate, which has a number of (145) groundwater wells. For each of these wells, a set of spatial data is available that was obtained from (GPS) readings, represented by the coordinates of the geographic location (X., Y), and the other part of the data was represented by the descriptive data (Attributes Data) for these wells, which was represented by the qualitative analyses of the groundwater, which included the following characteristics (EC, TDS, Ca, Mg, SO4, CL, Na, Ca, HCO3).

Radar data and digital elevation models (DEM) were also adopted to identify the nature of the terrain surface of the area (elevation and slope).

Giovanni data was used to obtain climate data for the study area and is a web platform of NASA Goddard Geoscience Data and Information Services Centre (GES DISC) and Distributed Active Archive Centre (DAAC) developed by Goddard Geoscience Data and Information Services Centre (GES DISC). It provides a simple and intuitive way to visualize, analyse and access massive amounts of Earth science remote sensing data.

4-Study Methodology

4-1Spatial Analysis of Physical and Chemical Properties

The study relied on the descriptive analytical approach and the quantitative approach to identify the qualitative characteristics of groundwater in the study area. Data related to the subject of the study was collected from the water of some wells approved by the Groundwater Directorate and the Environment Directorate in Muthanna Governorate, as well as from other selected wells distributed throughout the study area. The results were analysed laboratory-wise and modelled map-wise using the ArcGIS 10.6 geographic information system program, which is one of the most modern and efficient programs in this field. Spatial interpolation tools, represented by the inverse distance weighted (IDW) method, were used for the purpose of derivation, digital processing, and cartographic output of the selected water sampling points. The concentrations of each element were represented by an independent map that was classified into three categories according to the approved planning standards, and then a spatial matching process (overlay) was performed on the maps of these elements after giving them assumed weights to reach the final determination of the wells whose groundwater is suitable for use.

The qualitative variables studied: The quality of groundwater is no less important than its quantity, and the desired quality of the existing groundwater depends on the use of that water. The qualitative variables of groundwater mean the sum of the dissolved salts it contains, and are expressed in terms of weight in parts per million A set of basic determinants were adopted in evaluating the validity Groundwater for drinking and irrigation purposes. In light of this, the decision was made to determine the areas in which groundwater well water is suitable for drinking and irrigation purposes. These determinants included the following variables:

1. Electrical Conductivity (EC): The electrical conductivity of water is its ability to carry electrical current, and its high value indicates the presence of a large percentage of salts, bases, and acids. The reason is either natural or human.

2. Dissolved Solids (T.D.S): This variable reflects some of the physical

and chemical characteristics of water, such as salinity and water quality. The movement of groundwater affects the effectiveness of water in dissolving limestone rocks and evaporates, thus raising the concentration of dissolved salts. This changing acquires a great importance in the process of classifying the qualitative of the underground water in terms of its suitability for the purposes of drinking and irrigation as well as watering the tales, which is the basic standard in determining or evaluating the validity of the water to water the animals in the first place.

3. Sodium (Na): The sodium ion is produced from the dissolution of minerals that make up salt rocks, such as halite, as well as from the weathering of clay minerals.

4. Calcium (Ca): The high percentage of calcium ions is due to the predominance of gypsum and limestone rocks, whether they are passing rocks or containing it, where calcium reacts quickly and combines with bicarbonate to form calcium bicarbonate.

5. Magnesium (Mg): Dolomite rocks, limestone, and clay minerals are the main sources of magnesium ion, which is formed as a result of the process of decomposition and dissolution in groundwater.

6. Bicarbonate (HCO3): The source of this ion is water reacting with carbon dioxide, forming carbonic acid. This water, in turn, reacts with carbonate rocks exposed in the study area, especially limestone, forming a calcium bicarbonate solution.

7. Chlorides Cl: The reason for its presence in the study area is due to the lamellar clay that prevails in rock formations such as the Injana and Fatha formations.

8. Sulphur, SO4: The reason for its presence is due to the predominance of gypsum formations (gypsum and anhydrite) due to the formation of the hole, which have a high ability to dissolve and decompose in water. Table 1 shows the official measurements of the Iraqi specifications adopted in

evaluating the suitability of groundwater for drinking and irrigation.

Table (1): The official measurements of the Iraqi specifications adopted in evaluating the suitability of groundwater for drinking and irrigation.

Concentrations (mg/L)	Acceptable Upper Limits	Maximum Allowed Limits
Ca	75	200
Mg	50	150
Cl	250	600
SO4	200	400
TDS	500	1500
Na	250	-
HCO3	-	250
EC	750	1500

42- Natural and Geological Characteristics of the Study Area

The natural characteristics of the study area, represented by the geological formation, surface, climate, and water resources, are effective controls because of their influence in determining the quantity and quality of groundwater, because the possibility of managing the environment according to what man wants is still limited, as its effects appear in surface water resources, such as rivers, for example. However, they Directly responsible for determining the quantity and quality of groundwater under the surface of the Earth, which varies from one region to another. The geological structure also has an influential role in determining the locations of the areal extent of water by studying the effect of rock properties on the quantity and movement of groundwater. Climate elements also participate in determining the amount of groundwater, which is Rain and heat, the effects of which vary seasonally between summer and winter, and their role in the formation of groundwater, as well as the role of surface water resources in enhancing the amount of water recharge to that water. Geological construction plays an essential role in the availability of groundwater in terms of determining the locations of groundwater reservoirs and their extensions, as well as distinguishing their qualitative characteristics. The geological structure of the research area dates back to the Cretaceous period of the second geological time and the Holocene of the fourth geological time. The rock characteristics of these formations were reflected in the qualitative characteristics of groundwater in the region. The plain land formed an important range in the development of groundwater reservoirs. Climate plays a fundamental role in the availability of groundwater and its variation from one season to another and from year to year. The effect of this factor depends directly on the amount of rainfall and the distribution of temperatures, which directly affects the effectiveness of rain. Table (3) shows the climatic characteristics of the study area.

Table (2): Monthly climate data in the study area

Month	Rainfall rates/mm	Average Temperature/°C	Monthly Evaporation/mm
Jan	67.1	7.8	53.78
Feb	64.1	8.5	71.91
Mar	77.2	15.5	116.81
Apr	19.9	18.6	179.89
May	12.2	29.6	294.48
Jun	0.0	33.4	415.72
Jul	0.0	35.1	513.62
Aug	0.0	37.4	493.93
Sep	0.2	29.3	387.43
Oct	15.8	23	265.46
Nov	41.6	15.3	163.46
Dec	44.0	9.1	62.79
Average	32.65	23.74	3096.21

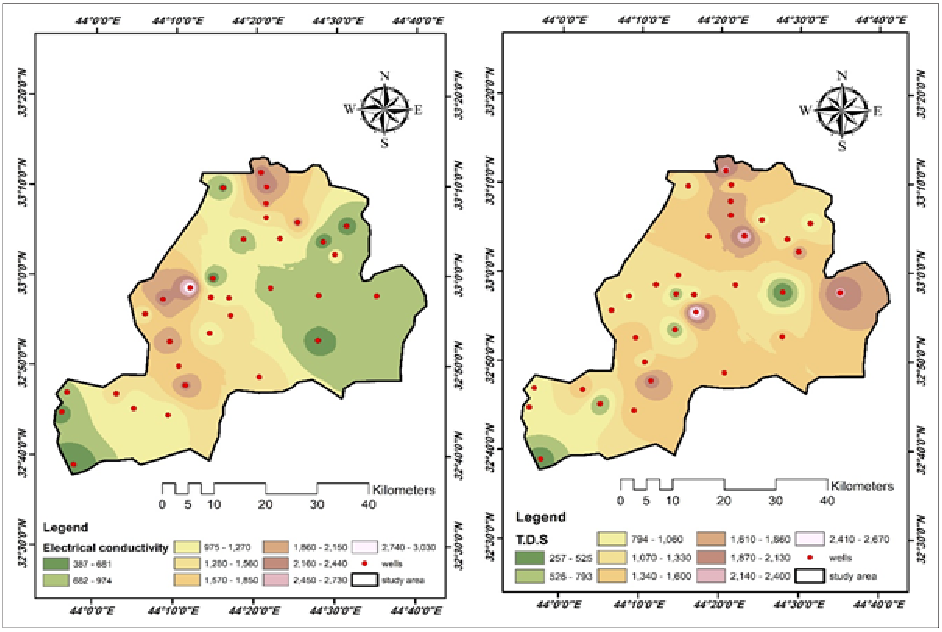
5- Results and Discussion

5-1 Spatial Analysis of the Qualitative Characteristics:

Spatial analysis of the qualitative characteristics of groundwater in the study area was conducted using spatial interpolation tools, represented by the inverse distance weighted (IDW) method, for the purpose of derivation, digital processing, and cartographic output of the selected groundwater sampling points, as the concentrations of each element were represented by an independent map that was classified into categories according to The approved planning standards and according to the Iraqi standard specifications, where the electrical conductivity value ranged between 387 and 3030, and as shown in Figure (2), it was classified into three groups, according to the specifications of the Iraqi standards table, as the first and second groups were within the permissible limits for drinking and irrigation and accounted for (44.14% of the area of the study area, while the third group was classified within the impermissible boundaries for irrigation and drinking purposes and occupied 55.86% of the area of the area.

The 57 and 2re (2), and the shape categories were classified according to the specifications of Iraqi standard standards (Table 2), into three groups, as the first and second groups fall within the permissible limits Drinking purposes Irrigation and occupied a percentage of (63.65)% of the area of the research area, while the last group was classified within the impermissible boundaries for irrigation and drinking purposes and occupied a percentage of (36.35)% of the area of the area, which constitutes a positive element in investing in groundwater in this area.

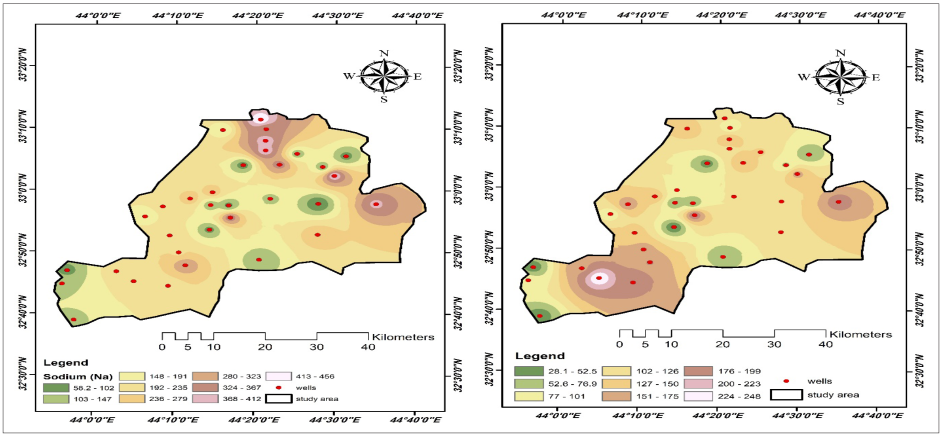
Figure (2): Spatial analysis of the physical and chemical properties of the wells of the study area. On the right the electrical conductivity (EC), and on the left is T.D.S.



The sodium (Na) concentration values varied between 58 and 456 mg/L, as shown in Figure (3). The map categories were classified according to the Iraqi standard specifications (Table 2) into two groups. The first group was within the permissible limits and accounted for 79.24%, while the first group The second rate was 20.76% and was within the permissible limits for drinking purposes.

The percentage of calcium (Ca) concentration varied between 28 and 248 mg/L, as shown in Figure (3), and according to Iraqi standard specifications (Table 2), the categories of the map can be classified into three groups. The first two groups belong within the permissible limits for drinking purposes and occupied 85.02%. From the area of the area While the third group belongs within the limits permitted for drinking purposes, and it occupied 14.98% of the area of the region.

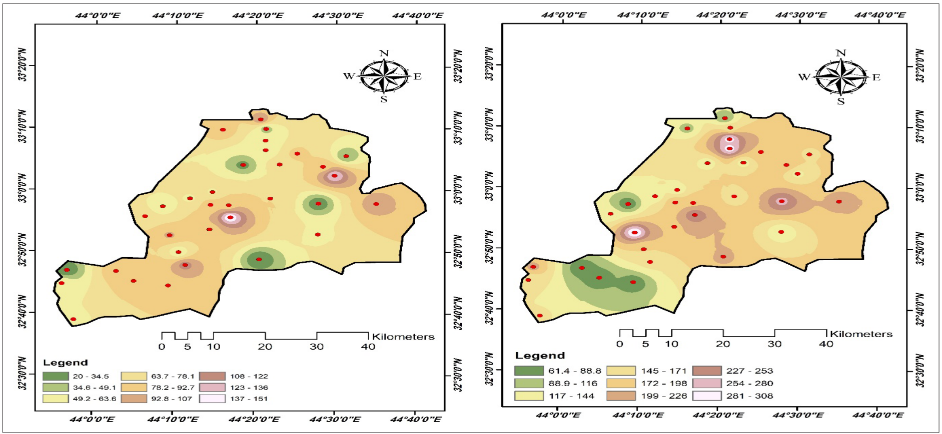
Figure (3): Spatial analysis of the physical and chemical properties of the wells of the study area. On the right sodium (Na) concentration, and on the left the calcium (Ca) concentration.



The concentration of magnesium varied between 20.1 and 151 mg/L, as shown in Figure (4), and based on (Table 2), According to the specifications of the Iraqi standard standards (Table 2), it was divided into three groups. The first and second groups were within the permissible limits for drinking and irrigation purposes and accounted for (65.49) % of the area of the research area, while the last group was classified within the permissible limits for irrigation purposes. And drinking, and it occupied 41.35% of the area of the region

The concentration of bicarbonate varied between 61 and 308 mg/L as shown in Figure (4), and based on (Table 2) it is clear that the distribution of the concentration of this element over the research area falls within the permissible limits for drinking purposes. The map categories were also classified into three groups. The first two groups belonged within the limits permitted for drinking purposes and occupied 81.02% of the area of the region, while the third group belonged within the limits permitted for drinking purposes and occupied 19.98% of the area of the region.

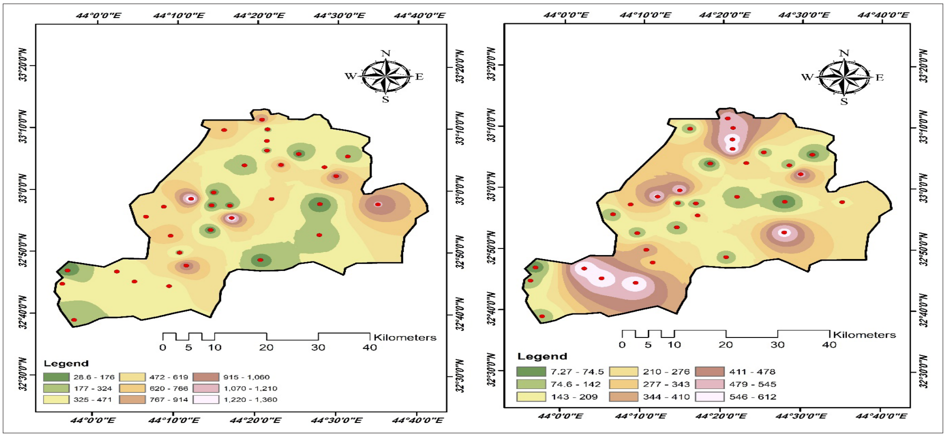
Figure (4):Spatial analysis of the physical and chemical properties of the wells of the study area. On the right magnesium (Ma) concentration, and on the left the bicarbonate (HCO3) concentration.



concentrations varied between 28.6 and 1360 mg/L and was classified into three groups, according to the Iraqi standard specifications (Table 2), where the first two groups belong within the permissible limits for drinking purposes 34.4% of the area of the area, while the third group occupied 65.6% of the area of the area, and this group wasn't within the limits permitted for drinking purposes.

The concentration of chlorides (CI) varied between 7.25 and 612 mg/L, as shown in Figure (5). Based on the Iraqi standard specifications (Table 2), the map categories can be classified into two groups. The first group was within the permissible limits for drinking purposes, as it accounted for 98% of the concentration Area square While the second group occupied 2% of the area, which was outside the permissible limits for drinking purposes.

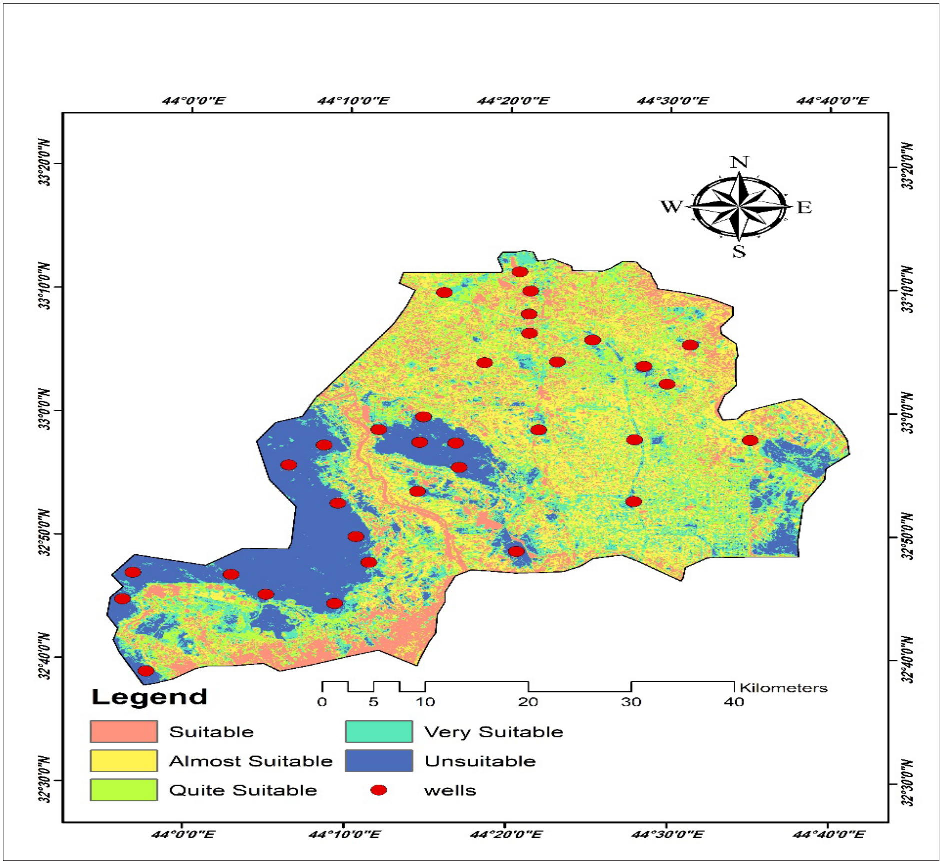
Figure (5): Spatial analysis of the physical and chemical properties of the wells of the study area. On the right sulfate (SO4) concentration, and on the left the chlorides (CI) concentration.



5-2 Spatial Correspondence of Maps of Physical and Chemical Variables:

Spatial matching of maps of physical and chemical variables is the process of integrating a set of different maps within a unified coordinate frame. This process is done by overlaying several layers of data, with each layer containing a specific characteristic. These data are processed digitally using computational capabilities, which facilitates their analysis by merging and unifying the various data to produce a new map that includes comprehensive descriptive information for all the phenomena to be analyzed. This process is one of the main functions of geographic information systems. After performing spatial matching of the maps that include the physical and chemical variables specified for the study, the areas or polygons whose water appears suitable for drinking and irrigation are identified, The results of spatial matching, according to Iraqi standard specifications (Table 2), showed that the wells in the city of Latifiya and in the areas of Al-Khanafa and Al-Jamaliyah are very suitable for use in irrigating livestock and poultry at a rate of 66%, while the percentage reached 14%. In the wells of the village of Al-Fadhiliya. The results showed that about 55% of the wells of the city of Latifiya and 67% of the wells of the village of Al-Fadhiliya fall between 40-55%, and these values show that the water used for irrigation and watering crops is subject to restrictions. High in order to become highly efficient and practical in using it for drinking. While the wells near the city of Karbala were classified into three groups, according to the Iraqi standard specifications (Table 2), where the first two groups belonged within the permissible limits for drinking purposes and accounted for 34.4% of the area's square footage, while the third group occupied 65.6%. % of the area of the area. This group falls within the limits unpermitted for drinking purposes. as shown in Figure (6).

Figure (6): The final output of the matching process based on the results of the spatial analysis of physical and chemical properties (The area isolating whose wateris suitable for drinking and irrigation).



Conclusions

1. The spatial analysis of data on the qualitative characteristics of groundwater using modern techniques

2. It enabled the researcher to move from the descriptive analysis stage to the decision-making stage.

3. The presence of a strong spatial relationship between environmental conditions, which are mainly represented by the geological formations of the region, which is reflected in the qualitative characteristics of groundwater.

4. The values of the qualitative characteristics of groundwater varied between

5. Acceptance is 100% for the distribution of the element (Mg), and acceptance is 34% for the element (So4) based on the area of the study area.

6. The values of the qualitative characteristics of groundwater varied in terms of its suitability for irrigation purposes, between a percentage of (46%) for the element (EC) and a percentage of (60%) for the element (TDS).

7. The results of the spatial correspondence of the distribution of suitability values of the qualitative characteristics of groundwater for drinking purposes showed that (37%) of the area of the study area was water suitable for drinking purposes, while it was (55%) for irrigation purposes.

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