Evaluation water scarcity based on GIS estimation and climate-change effects: A case study of Thi-Qar Governorate, Iraq

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Abstract: This work aims to evaluate water scarcity in Thi-Qar governorate, Iraq, based on GIS estimation, environmental data, climate-change effects, and detection of the changes in marshes over the last three decades (1991–2021). The methodology process included collecting and analysing the related data sets such as water quality indicators, surface water quantity, climatic data, and Landsat’s images. GIS-based data and spatial data were acquired from the USGS website. Arc GIS 10.4.1 software was used to create a hydrological analysis. The results showed that generally, in Iraq, the annual volume of water available per person is 1,390.95 m³/cap/year, which is lower than the threshold for water scarcity (1700 m³/cap/year). The average daily potable water per person in Thi-Qar governorate was 284 L/cap/day, lower than the general average daily potable water per person of Iraq (340 L/cap/day). Meanwhile, 6% of the months along 1998–2018 did not meet the water demands. Water quality tests exhibited some high amounts of pollutants in drinking water, e.g., biological pollution was recorded in 55% of the total number of annual samples. Landsat’s images illustrated a high variation in water areas of marshes over the selected period, whereas the highest marsh area was 1548.21 km² in 1991 compared to the lowest area, 65.45 km² found in 1999. To sum up, the research outcomes revealed that the...
study area faced a serious water scarcity, which had a negative impact on the local people. Also, this research offered a scientific view for the decision-makers to mitigate and manage the water scarcity problem.

Subjects: Agriculture & Environmental Sciences; Environmental Studies; Environmental Management; Environment & the City; Environmental Policy

Keywords: Climate change; GIS; Landsat; water quality; water scarcity

1. Introduction
Continuous water availability is critical for daily life and sustainable communities. Economic growth, food security, poverty alleviation, energy security, conflict resolution, biodiversity loss, and climate change adaptation are all dependent on water. Increased global water resource exploitation results in considerable degradation of natural ecosystems (Liu et al., 2017). Moreover, climate change has increased water demand, shrunk water supplies (Zubaidi et al., 2020), and shifted the seasonal rivers flow in many countries (Ampadu & Aziz, 2021). Socioeconomic variables such as continuous population growth and urbanisation will expand freshwater demand problems. (Greve et al., 2018). Additionally, rapidly growing industrial activities increased freshwater pollution (Ethaib & Zubaidi, 2020). Setting global, regional, national, and local water policies is essential to controlling water demand which require understanding water shortage reasons. Hence, understanding and highlighting water scarcity directions are vital requirements for vulnerable communities to water security risks and fragile ecosystems. Therefore, water scarcity is one of the water resource risks, which is deemed a considerable challenge facing the world in the 21st century (Ikudayisi et al., 2018). Water scarcity is a broad term that may refer to a shortage in water availability due to physical shortage or lack in access due to the deficit of institutions to ensure a regular supply or a lack of adequate infrastructure. (Van Loon & Van Lonen, 2013). In this context, many countries are suffering from several challenges expected to amplify the already complex relationship between water development, water demand, and climate change. These challenges included rapidly and unplanning growing urban areas placing heavy pressure on water resources, and water pollution in watersheds that resulted in untreated wastewater sometimes being discharged directly into these watersheds (Al-Maliki et al., 2021; Erabee & Ethaib, 2018). Several studies have discussed various aspects of water scarcity in different countries, including risk assessment, scarcity impact, and possible solutions (Hess et al., 2015; Hoekstra, 2014; Tian et al., 2017). Zulfiqar et al. (2021) suggested a comanagement system against climate-induced water scarcity in Pakistan. It was reported that India and China have frequently had to choose between water-intensive agriculture and population growth (Bond et al., 2019). Meanwhile, Mekonnen and Hoekstra (2016) developed a global map to distribute regions affected by water scarcity. Therefore, identifying priority areas is essential to address and mitigate or reverse the effects of water scarcity.

Iraq is one developing country located in an arid to semi-arid region, and this country is one of the Middle East's most vulnerable countries to climate change (Shareef & Abdulrazzaq, 2021). In general, this area faces water lack that is likely to grow in the future resulting from the influence of several reasons including climate change, oil industry, urbanisation, and the high rate of population growth (Al-Maliki et al., 2021). The Euphrates and Tigris Rivers are the primary freshwater resources in Iraq, and several storage dams in Iraq were constructed on the path of these rivers (Karim et al., 2021). Both of these rivers faced significant water lack from 2009 to 2014, and the water shortage is expected to rise due to climate change, increasing water consumption upstream (Turkey, Iran, and Syria; Aljanabi, Mays, Fox et al., 2018a, 2018b). Additionally, Ewaid et al. (2018) mentioned that several studies had been conducted to evaluate the freshwater quality in Iraq, revealing an increase in the incidence of different contaminants. Also, Salman et al. (2018) concluded that the temperature is anticipated to increase in Iraq based on different techniques and scenarios. Moreover, the pattern and amount of rainfall are likely to be adversely affected in the future in Iraq (Osman et al., 2017). Furthermore, after 2003, in Iraq, terrorism attacked many barrages and dams, adversely impacting the rivers’ water control. After decades
of wars and struggle, Iraq’s water resources and infrastructure are under stress (Swedish International Development Cooperation Agency (Sida), 2014). Iraq is administratively divided into eighteen governorates. Thi-Qar governorate (alternatively spelled Dhi-Qar) is an Iraqi governorate located in the south. This governorate was divided into 20 administrative units. Al-Nassiya city is the capital of Thi-Qar governorate, which lies on the Euphrates River about 370 km southeast of Baghdad (Ethaib, 2019). Euphrates River passes through southern cities of Thi-Qar governorate. Meanwhile steams of the Tigris River the pass through northern cities of this governorate and supply them by water. Thus, this governorate takes advantage of these two rivers; both rivers contribute for creating marshes. This governorate includes considerable parts of Iraqi Marshes (Mesopotamian Marshes). The marshlands of Iraq are considered the largest wetland ecosystem in the Middle East. Unfortunately, the former regime led a drainage campaign in 1991 to dry these marshes. Since 2003, many attempts have been carried out to recover these wetland areas. However, the fluctuation in feeder rivers’ water quantities has negatively affected the effort for recovery and environmental restoration of the marshes (Asa, 2011; Guarasci, 2015). Therefore, highlighting the water shortage drivers over the last decades is essential for sustainable development in Thi-Qar governorate and will help the decision-makers to enhance water strategies.

A geographic information system (GIS) is a conceptualised framework that can capture and analyse spatial and geographic data. In this way, various studies have adopted different methodologies and approaches utilising GIS to study multiple case studies on worldwide water crises (Changwony et al., 2017; Cordão et al., 2020; Farajzadeh et al., 2007). Besides GIS, Landsat offers the critical and irreplaceable capability to observe and monitor surface water bodies at global and regional scales (Chattaraj et al., 2021). The combination of GIS and these technologies allows for faster, more accurate, and real-time geographic data mapping than traditional geographic information systems (Habeeb & Weli, 2021). Therefore, these tools can be utilised to monitor water surface changes and address water resource risks such as scarcity. Also, analysing the climatic and qualitative environmental data can be highlighted the water problems. Thus, this work aims to evaluate the water scarcity in Thi-Qar governorate based on GIS estimation, climate change effects, water quantitative and qualitative data, and detect marshes changes over the last 30 years (1991–2021). This paper has the following structure: Section 2 provides the following methods, including the study area and data collection. While section 3, results and discussion that contains data analysis and GIS technique. Finally, in section 4, the concluding remarks and some possible future recommendations are reported.

2. Methods

2.1. Study area
Thi-Qar governorate is located in the south of Iraq (Figure 1) and has an area of about 13841.65 Km². This governorate has borders with five governorates: Wasit governorate to the north, Basra Governorate to the south and south-east, Maysan Governorate to the east, Muthanna governorate to the west, and Qadissiya governorate to the north-west. Thi-Qar governorate is separated into five administrative districts (i.e., Nasiriyah, Suq al-Shuyukh, Chibayish, Shatrah, and Rafei) and nineteen sub-districts; The population of Thi-Qar is around 2 million capita live in urban and rural areas. Climatically, Thi-Qar governorate is located in the arid zone. It has hot summers and moderate winters. The sunny weather prevails in this region. This area recorded high-temperature degrees and, in some cases, reached 51°C (123°F) during July and August. The temperature can occasionally decline until zero in January during winter. Most rain occurs between December and April, and it averages between 100 and 180 mm (3.9 and 7.1 in) per year (Al-Ansari et al., 2021). There are two primary freshwater resources in Thi-Qar governorate (Figure 1). Euphrates River and Al-Gharraf stream (branch of the Tigris River) supply Thi-Qar cities and marshes (Erbabee & Ethaib, 2018). By the same token, a downstream public project (Al Massab Al-Am) passes through this governorate. This project considers the main drainage project in Iraq for saline water.
2.2. Data collection and processing

2.2.1. Climatic and water quality data collection
The climatic variables and water data were collected based on published materials, surveys, and interviews with local authorities and officials. The climatic data were collected from the Iraqi Meteorological Organization and Seismology (http://meteoseism.gov.iq). The quantitative and qualitative water data were collected from Iraq Environment Ministry, Iraqi Water resource Ministry, Ministry of Health and Environment of Iraq (Ministry of Health and Environment of Iraq (MHEI), 2017), and Central Statistical Organisation of Iraq (Central Statistical Organization Iraq (CSO), 2020).

2.2.2. Satellite data acquisition and processing
Remote sensing technology and GIS-based data from the U.S. Geological Survey (USGS, earthexplorer.usgs.gov) were utilised to collect spatial data. The general steps of the processing methodology are shown in Figure 2. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) was used to extract the digital elevation model (DEM), which was employed to determine the Earth's surface elevation relative to sea level in Thi-Qar governorate and create a hydrological analysis by applying Arc GIS 10.4.1 software. Also, imagery from Landsat satellites 7 and 8 were considered. Table 1 shows some characteristics of each satellite. The process included the acquisition of raw data for satellites. Landsat images of the U.S. Geological Survey website (USGS) were captured by Landsat 7 ETM C1 level 1 on 23 March 1991, Landsat 7 ETM+ C1 level 2 on 15 March 1999, Landsat 8 OLI/ TRIS C1 level 1 on 22 April 2013 and on 4 April 2021. Merging the spectral bands of images was carried out to obtain composite images for the study area. Also, a mosaic for the images of each satellite separately was performed to get one large image while keeping all the data in it. Then, cutting the study area (Clip) from the resulting image of the mosaic was accomplished. The calculation process included determining the Normalised Difference Water Index (NDWI) separately for each satellite image. This index is used to monitor changes related to water content in water bodies, using the green band and
near-infrared radiation (NIR) as defined by McFeeters (1996). It depends on the relationship between the spectral bands' NIR and the green band. Visual or digital interpretation of the output image/raster created is similar to Normalised Difference Vegetation Index (NDVI). The index results can range from −1 to +1, whereas water features vary less than 0 to −1, the bare soil may have zero, and vegetated

Table 1. Some features of Landsat satellites

| Satellite  | Sensor | Band Number and Spectral Bands*(µm) | Spatial Resolution(m) | Quick Facts |
|------------|--------|-------------------------------------|------------------------|-------------|
| Land Sat 8 | OLI    | 1 (0.433–0.453)                     | 30                     | Launch Date: 2 November 2013; Status: continuous; Sensors: Operational Land Imager (OLI); Thermal Infrared Sensor (TIRS); Altitude: 705 km; Repeat Coverage: 16 days |
|            |        | 2 (0.450–0.515)                     |                        |             |
|            |        | 3 (0.525–0.600)                     |                        |             |
|            |        | 4 (0.630–0.680)                     |                        |             |
|            |        | 5 (0.845–0.885)                     |                        |             |
|            |        | 6 (1.560–1.660)                     |                        |             |
|            |        | 7 (2.100–2.300)                     |                        |             |
|            |        | 8 (0.500–0.680)                     | 15                     |             |
|            |        | 9 (1.360–1.390)                     | 30                     |             |
|            | TIRS   | 10 (10.6–11.2)                      | 100                    |             |
|            |        | 11 (11.5–12.5)                      | 100                    |             |
| Land Sat 7 | ETM+   | 1 (0.45–0.515)                      | 30                     | Launch Date: 15 April 1990; Status: continuous; Sensors: Enhanced Thematic Mapper Plus (ETM+); Altitude: 705 km; Repeat Coverage: 16 days |
|            |        | 2 (0.525–0.605)                     | 30                     |             |
|            |        | 3 (0.63–0.69)                       | 30                     |             |
|            |        | 4 (0.775–0.90)                      | 30                     |             |
|            |        | 5 (1.55–1.75)                       | 30                     |             |
|            |        | 6 (10.4–12.5)                       | 60                     |             |
|            |        | 7 (2.08–2.35)                       | 30                     |             |
|            |        | 8 (0.52–0.9)                        | 15                     |             |

* Only very shortest wavelengths of the spectrum, bands 1–4 and 8, are visible light while other bands cannot be seen. However, Landsat's true-colour view is around one-half of what it sees.
surfaces range above 0 to +1. This index is designed to (1) green wavelengths enhance the reflectivity of water, (2) reduce low-NIR reflectance with water features, and (3) utilise the high reflectance of NIR by soil and vegetation features. Consequently, vegetation and soil usually have zero or negative values, while water features have positive values and thus are enhanced. Equation (1) was adopted to calculate the value NDWI as below:

$$NDWI = \frac{B3 - B5}{B3 + B5}$$  \hspace{1cm} (1)

B3- GREEN

B5- NIR

Based on soil moisture, a prediction map based on GIS was developed for water scarcity in Thi-Qar governorate, considering bands 6 and 7 of Landsat. These bands cover different slices of the shortwave infrared (SWIR), and this technique is beneficial for sorting moist land from dry land.

3. Result and discussion

3.1. Water scarcity indicators

Water scarcity indicators include the volume of water available per person (calculated in m³/cap/year) and the water use to availability ratio. The indicators depend on the Water Crowding Index (WCI), which measures the number of people per unit of available water, e.g., persons/million m³/year (Liu et al., 2017). Generally, in Iraq, the annual volume of water available per person is 1,390.95 m³/cap/year, calculated based on water income to Euphrates and Tigris Rivers for the period 2009–2019 can be seen in Figure 3. Based on the WCI, Iraq can be considered one of the countries threatened by water scarcity. Falkenmark et al. (1989) suggested that the threshold for water scarcity is 1700 m³/cap/year. The same study proposed that the area has high water scarcity when water availability is less than 1,000 m³/cap/year and absolute water scarcity for quantities below 500 m³/cap/year. Around 69% of the total freshwater is used for domestic purposes (Hussain et al., 2020), and the average daily potable water per person in Iraq was 340 L/cap/day based on 2019 treated water. However, in Thi-Qar governorate, the average daily potable water per person was equal to 284 L/cap/day. It is assumed that the public water supply is prioritised over other uses in Iraq. The general percentages of serviced people by water networks in urban and rural areas of Iraq are 93% and 63%, respectively. Comparatively, urban and rural regions of Thi-Qar are supplied with water networks by 83% and 23%, respectively, which means many people do not get drinking water regularly. By the same token, in Thi-Qar governorate, it was recorded that 6% of the months during the period 1998–2018 did not meet the water demands. The calculation
was carried out depending on the failure to supply adequate demand when the total monthly water demand exceeded the total monthly water supply. In the production case, the average of monthly water was less than the demand. This situation occurred through 12 of the 21 years from 1998 to 2018 (IOM IRAQ, 2020). This situation almost happened when water levels in rivers were less than the water treatment plants’ level of intake pipe suction, as revealed by water treatment authorities. Therefore, the authorities tried to change water intakes positions inside the rivers for easy access to water. On the other hand, demand reduction can be achieved by enforcing water conservation measures and influencing user-responsible higher water fares and other billing routes. It can increase freshwater resources by using water reclamation methods and rain harvesting (Gude, 2017).

Irrigation often consumes the most amount of freshwater. It may quickly run into supply shortages during the dry years, partly because it is a lower priority than public water supply (IOM IRAQ, 2020). The agricultural sector loses the most freshwater, followed by power generation. Irrigation practices that conserve water can significantly improve this aspect. About 30–75% of water withdrawals are lost in power generation, particularly cooling. Other novel approaches, such as dry cooling, can help reduce evaporation losses (Gude, 2015). Thi-Qar governorate had practically continual irrigation problems, and the demand was not adequate due to the shortages, especially in relatively dry years: 1999, 2000, 2001, 2008, 2009, 2012, 2014, 2017, and 2018 in the period 1998–2018. The government must adopt efficient policies to enhance the irrigation sector to stimulate economic growth. Therefore, it is essential to perform some measures to improve the irrigation network’s efficiency. These measures include but are not limited to decreasing water losses via paving the irrigation channels with concrete and using drip irrigation systems. In addition, reducing illegal excesses of irrigation networks will help the farms located at the stems of these channels. Also, optimising water distribution for agricultural production enables attaining the best crop output under shortage irrigation (Jamshidpey & Shourian, 2021).

The water quality of south Iraq’s surface water is generally poor due to high suspended and dissolved solids and sewage contamination. This issue is related to the long path of rivers subjected to nonpoint and point sources of pollution, especially in some areas that do not have/ or not efficient wastewater treatment plants that drain directly into the rivers. The water quality indicators included physical and chemical measures to monitor water quality for Thi-Qar governorate in 2019 are illustrated in Table 2. These indicators are compared with the Iraqi drinking-water standard (Drinking-Water Standard IQS: 417,2001, 2001). The comparison showed that there is a failure in some indicators, such as the average annual turbidity of treated water (35.2 NTU) was much higher than the allowed limit (5 NTU) of IQS: 417/2001 (World Health Organization, 2006). Moreover, the tests showed the presence of some heavy metals like Mg in drinking water that had an annual average equal to 41 mg/L, which exceeded the World Health Organisation (WHO) criteria that suggest 5 mg/L (WHO, 2017). By the same token, the bacteriological tests also revealed a high level of biological pollution, whereas 3380 tests were carried out for Thi-Qar during the same year. The tests showed that 1870 tests (55%) are inadequate for drinking-water standard IQS: 417/2001, which suggests 5 mg/L as biological oxygen demand at 5 days (BOD5). Accordingly, this governorate has low water quality in terms of spreading the physical, chemical, and biological pollutants in supplied water. Urban water shortages and deteriorating water quality led to adverse socioeconomic changes in some areas in this governorate. IOM stated that 1,553 families displaced from Thi-Qar during 2019 were induced by water scarcity (IOM IRAQ, 2020).

3.2. Evaluation of the change in surface water
It is well known that Thi-Qar governorate area was covered by large areas of surface water and wetlands that were called marches until 1992, when the past regime of Iraq started a regular campaign to dry these marches. Thi-Qar governorate area is 13841.65 km². The marshes areas were 1581.16 km² in 1991, equivalent to 11.4 % of the governorate area, as illustrated in Figure 4. In 1999, the marshes area reached the lower value, 65.45 km² (0.47%), as shown in Figure 5. A considerable decrease in marshes areas can be recognised due to the
Table 2. The annual physical and chemical indicators for raw and drinking water in 2019

| Test    | Unit | Raw water |   | Drinking water |   | Iraqi Drinking-water Standard IQS: 417/2001 |
|---------|------|-----------|---|----------------|---|---------------------------------------------|
|         |      | Min       | Max | Ava.           | Min | Max | Ava.                      |                             |
| Turbidity | NTU  | 7.16      | 285 | 64             | 1.04 | 107 | 35.2 | 5                         |
| pH      | -    | 7         | 8.95 | 7.9            | 6.73 | 8.51 | 7.8  | 6.5–8.5                   |
| EC      | μS/cm | 543       | 8340 | 934            | 531  | 7450 | 745  | 250                       |
| TH      | mg/L | 226       | 2,966 | 373           | 222  | 2,860 | 357  | 500                       |
| ALK     | mg/L | 128       | 260  | 158           | 108  | 230  | 150  | 100                       |
| TDS     | mg/L | 412       | 4,890 | 638           | 400  | 4,500 | 630  | 1000                      |
| Na      | mg/L | 42        | 568  | 76            | 41  | 527  | 74  | 200                       |
| Cl      | mg/L | 46        | 765  | 109           | 43  | 750  | 109  | 250                       |
| K       | mg/L | 1.6       | 45   | 3.2           | 1.5  | 32   | 2.98 | -                         |
| Ca      | mg/L | 48        | 660  | 82            | 45  | 636  | 80  | 50                        |
| Mg      | mg/L | 21        | 317  | 41            | 20  | 300  | 40  | -                         |
| SO4     | mg/L | 123       | 2,741 | 224          | 120  | 2,600 | 215  | 250                       |

intentional drying process of the marshes areas during the nineties of the last century. This reduction in marshes areas led to a humanitarian crisis; tens of thousands of people were displaced to other governorates due to losing their livelihood. At the same time, most of the people of the marshlands work as fishermen and buffalo breeders. Additionally, the decrease in the marshland areas led to drastic changes in the ecosystems, such as the loss of the natural breeding habitat for different immigrant birds. Also, it caused environmental problems such as the area's increasing temperature and the number of dusty days.

After 2003, a series of efforts were accomplished to recover the marshes areas. It can be noticed that after ten years, these efforts partially succeeded in recovering some of the marches areas and supporting the environmental restoration and resettlement of the people of these areas, as can be seen in Figure 6. The marshes areas reached 1330.57 km² (9.7 %) in 2013.

However, these efforts still struggle with fluctuation of water source income, as previously shown in Figure 3, due to the policy of water source countries (i.e., Turkey and Iran) that were building and operating new dams on the path Euphrates and Tigris rivers. Additionally, the climate change effects on water resources represent a vital challenge that may increase water scarcity and decrease the annual water volume income, which will be discussed in the following section. These challenges decreased the areas of marshes to be 1148.21 km² (8.29%) in 2021, as can be observed in Figure 7.

3.3. Climate change effects on water resources
Climate change causes touchable consequences on water resources worldwide and Iraq in particular. The United Nations reports warned of the effects of climate change on Iraq, which directly adversely affects Iraq's food and freshwater resources (Elasha, 2010). The report classified Iraq as one of the fragile countries regarding water and food scarcity. The reports stated that water resources management in the country is vulnerable to climate change and storage projects in neighbouring countries. Rising temperatures are one of the most critical indicators of climate change. Statistical analyses indicate increasing trends in the average temperature in all stations belonging to the General Authority for Meteorology and Seismic
Monitoring. The annual increase in the temperature reached 0.032°C since 1941 (Ministry of Health and Environment of Iraq (MHEI), 2017). The increment led to an increase in the evaporation rates, which are considered initially one of the higher rates in the world. For instance, approximately 10% of storage water in Iraqi reservoirs was evaporated; the evaporated water quantity was 5005.19 million m$^3$ of the total storage, which was 50.47 billion m$^3$ in 2019.

Another aspect of climate change is the low rainfall rates. Iraq has an arid to semi-arid climate, which limits rainfall and other precipitations in most country areas. The rainy season start in late October until the beginning of April, and the snow sometimes falls in the northern parts during winter. The hills of the north and mountains have a higher level of annual precipitation that generally ranges from 300–1000 mm, while the rainfall in the extreme south and west area varies between 100–300 mm. For instance, the recorded rate of rainfall level in Thi-Qar governorate during the last decade is shown in Figure 8. The general perception is the low rainfall rate in this area. Moreover, it was evident that there is an allocation rainfall level and a dry year, and the lower level was recorded during 2017 with 27 mm of rainfall. These facts revealed that climate change could magnify the water scarcity in this governorate.

3.4. Management of water scarcity
A prediction map was developed based on soil moisture to expect water scarcity in the Thi-Qar governorate. This model reveals that water scarcity represents a significant threat that may arise in Thi-Qar governorate, as shown in Figure 9. This map suggested two classes of water scarcity that may find in the Thi-Qar governorate. Water scarcity-class one represents the areas (337.6 km$^2$, 2.43%) that have severe water scarcity, which is less than areas of water scarcity-class two that may affect about 6076.8 km$^2$ (i.e., 43.9 % of Thi-Qar regions). Water scarcity risk can vary over time and from place to place. As a result, there is no single solution to manage this risk. However,
Figure 5. Water surface map in 1999.

Figure 6. Water surface map in 2013.
according to the World Wildlife Fund, four fundamental principles should be followed to determine successful management and mitigation of water scarcity concerns (Orr et al., 2009):

- Encouraging the interventions that aim to reduce long-term scarcity, such as protecting environmental flows for rivers.
- Prioritising water allocations for those people and ecosystems least suited to cope with water scarcity will lower overall risk.
• Flexibility to adjust includes using water more efficiently and lessening the water scarcity-related risks and climate change-induced uncertainties.
• A wide range of stakeholders must be actively included in the policymaking process to improve allocation and avoid shared risk.

4. Conclusion
Water scarcity is one of the considerable challenges that need to be highlighted for proper management. Analysing GIS, climatic data, and qualitative and quantitative water data showed that Thi-Qar governorate suffers from water shortage. Based on the research outcomes, a GIS-based prediction map for water scarcity in the Thi-Qar governorate presented severe water scarcity that caused water shortage for different purposes like drinking and irrigation. Accordingly, the water shortage decreased the areas of marshes and negatively affected the environmental restoration in these areas. In addition, climate change worsens the freshwater problems.

Over the last three decades, the hydrological maps showed that the marshes areas witnessed a continued fluctuation in water areas which caused socioeconomic effects and led to internal displacement crises for local society. Therefore, this area needs urgent short-term activities to mitigate and manage water scarcity. The decision-makers should set immediate and strategic plans to solve water scarcity by improving water resource management. Additionally, implementing a comprehensive study on the effect of water scarcity on the agriculture sector is recommended as further study because agriculture is vital to Iraq’s economic growth. Moreover, this research recommends the official authorities enhance the water resource infrastructure by expanding the drinking water networks, using smart irrigation techniques, and encouraging local people to use the groundwater.
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Nomenclature

| Acronym | Definition |
|---------|------------|
| ASTER | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| ALK | Alkalinity |
| DEM | Digital Elevation Model |
| EC | Electrical Conductivity |
| ETM+ | Enhanced Thematic Mapper Plus |
| GIS | Geographic Information System |
| PH | Hydrogen Ion Concentration |
| IOM | International Organization for Migration |
| NIR | Near-Infrared Radiation |
| NDVI | Normalised Difference Vegetation Index |
| NDWI | Normalized Difference Water Index |
| OLI | Operational Land Imager |
| TIRS | Thermal Infrared Sensor |
| TDS | Total Dissolved Solids |
| TH | Total Hardness |
| USGS | United State Geological Survey |
| WCI | Water Crowding Index |
| WHO | World Health Organization |

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