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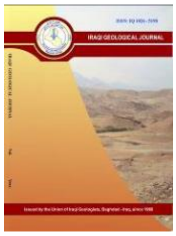

An Overview of the Remote Sensing and GIS Techniques Application to Detect Changes in the Surface Area of Water Bodies in Iraq

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Abstract

The use of Remote Sensing data in monitoring water bodies and reservoirs is a new and advanced approach that helps to study large areas covered by water in a short time and at a reasonable amount compared to traditional methods. Accordingly, the Remote Sensing technique integrated with Geographic Information Systems (GIS) has been used in several studies to monitor changes in water surface body area locally and regionally. In this study, several studies in Iraq were reviewed, using Remote Sensing techniques with the help of GIS to detect changes in the areas covered by the water bodies using satellite images captured in different periods. Natural and artificial lakes represent a large proportion of the water bodies in Iraq, including eight (8) lakes distributed in different regions of Iraq. An evaluation of the hydrological system of the studied water bodies showed that the changes in the area and size of natural and artificial lakes are affected by political, economic, and climatic conditions as the areas increase and decrease over years.

Keywords: Geographic Information Systems; Remote Sensing; Landsat satellite; Water bodies

1. Introduction

Water is one of the most important components of preserving the ecosystem as it plays an essential role in providing the necessary food supplies for humans, especially in countries with arid and semi-arid climates such as Iraq (Youssef, 2016; Al-hadithi, 2018; Al-Ansari, 2020). Most water bodies in Iraq, whether natural or artificial, are primarily used to maintain the water levels of the Tigris and Euphrates rivers and control water management for irrigation and electrical power generation, in addition to other economic uses of water such as tourism and fisheries development (Al-Ansari, 2020). Currently, an integrated approach of remote sensing and GIS techniques is widely used in the field of water resources management, especially in obtaining hydrological and morphological data for water bodies in a short period (Khasanov et al., 2019; Al-hadithi et al., 2019; Mahir et al., 2020; Alazawi et al., 2023).

These technologies are considered a modern and advanced method for monitoring all environmental phenomena and natural resources management that is involved in the process of sustainable development (Hassaan, 2009; Thomas et al., 2015; Hickmat and Abdelazim, 2016; Ahmed et al., 2018; Huang et al., 2018; Allawai and Ahmed, 2019).

The application of Geographic Information Systems (GIS) in the field of water study has acquired a strategic dimension, especially since water is one of the environmental elements that need management and rationalization (Husain, 2016; Jumaah et al., 2019; Kalantar et al., 2020; Hamed et al., 2021; Manal

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et al., 2023). Accordingly, it is the most controlling element in environmental management and the most obvious indicator in monitoring various environmental changes.

The link between GIS and spatial data analysis is critical in developing GIS in research, exploration, and analysis of spatial relationships (Michael and Pete, 2008). Several studies have been carried out to survey water bodies and continuously monitor rivers (Zaeen, 2012; El-Asmar et al., 2013; Al-Abudi and Kouder, 2016; Athraa et al., 2023). These studies have used various programs to classify multispectral images, as well as observation techniques by isolating land cover components from each other to obtain components of the land cover area (Mawahib et al., 2010; Abbas and Jaber, 2020; Titolo, 2021).

There is a real danger threatening the environment of these water bodies due to the significant deterioration that affects the quality of water and the environment in the region. Many researchers have conducted scientific studies in which modern technologies were used to monitor the changes occurring in the surface area of water bodies, provide recommendations, and propose appropriate solutions to reduce these risks. Consequently, this study was carried out to review research and studies that dealt with using Geographic Information Systems (GIS) techniques and Remote Sensing (RS) data for monitoring surface areas of natural and artificial water bodies in Iraq.

2. Water Bodies in Iraq

Three main natural lakes and five artificial water reservoirs are distributed in different parts of Iraq, as shown in (Fig.1) and (Fig.2).

Additional water bodies exist in various places, such as the marshes and seasonal lakes in Anbar and Salah al-Din and watersheds or water harvesting in Kut, Maysan, Anbar, and Diyala Governorates. This study's attention was on the main water bodies, which are considered among the primary water sources affecting water management in Iraq.

The water resources in Iraq are mainly the water of the Tigris and Euphrates rivers, which were the main source of drinking water for the Iraqi governorates. The annual flow of the Euphrates River amounted to about 15.15 billion cubic meters (bcm), representing 7.27% of the total annual flow of the Tigris and Euphrates Rivers, as estimated by the Iraqi Ministry of Planning (Al-Ansari, 2020). However, the annual flow of the Tigris River reached about 15.37 bcm, and the total flow of its tributaries is estimated at 24.23 bcm (Al-Ansari, 2020). Thus, the total flow of the Tigris River reaches 39.60 bcm, representing 72.3% of the total flow of all rivers combined (Al-Ansari, 2020; Ala et al., 2020).

River water sources are affected by neighboring countries, where the Tigris and Euphrates river basins flow, covering a total area of 705,500 km^2. The flow of water has recorded an apparent decline over the past years, reaching 7.660 bcm, compared to 20.930 bcm per second, which was pumped to Iraq annually until the beginning of the nineties (Al-Ansari and Knutson, 2011; Al-Ansari et al., 2012; Al-Ansari, 2013 and 2016; Ala et al., 2020).

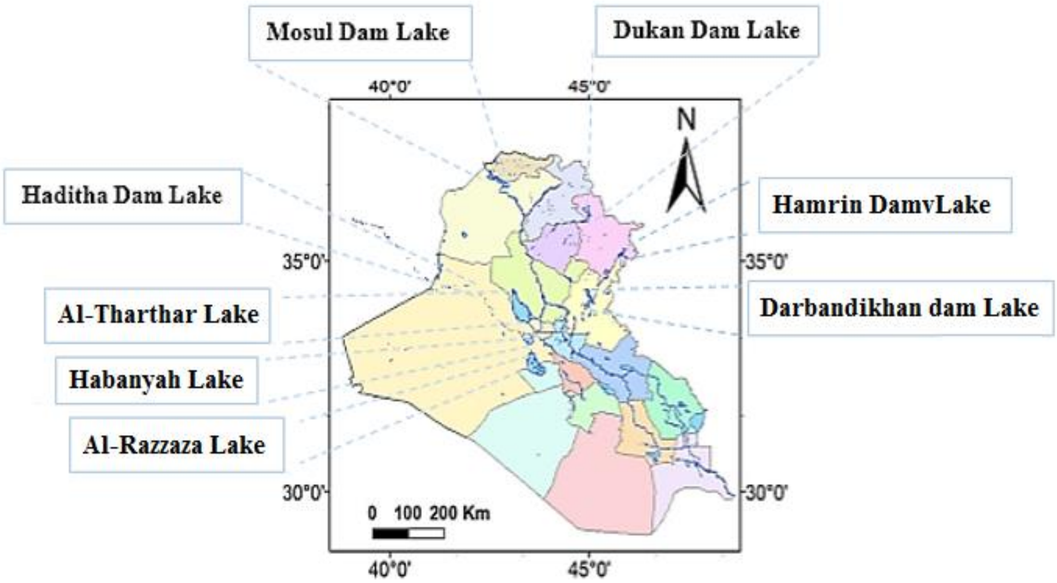

Fig.1. Location map of artificial and natural water bodies in Iraq

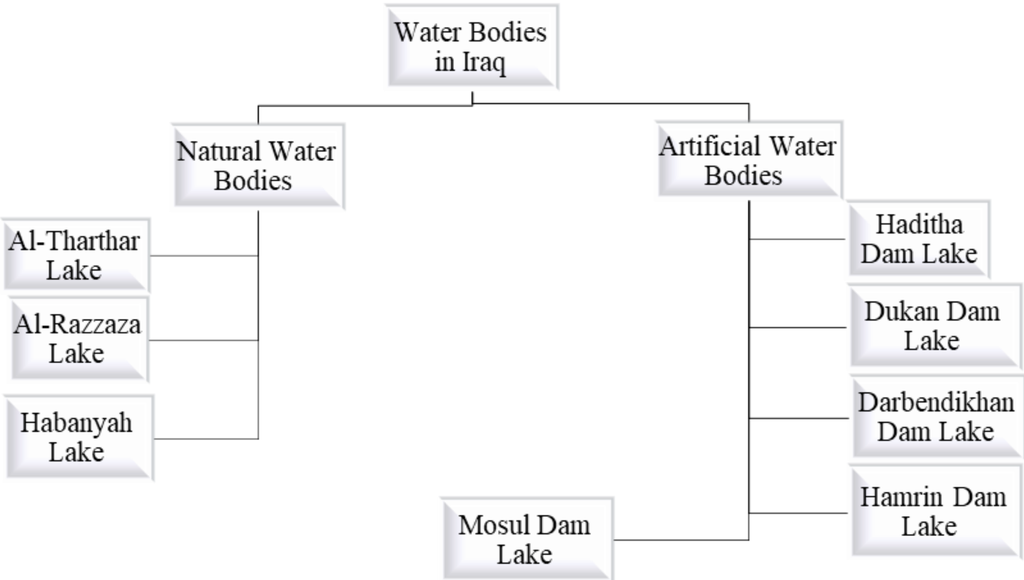

Fig.2. Diagram showing natural and artificial lakes in Iraq

2.1 Natural Water Bodies

2.1.1. Al-Tharthar Lake

Al-Tharthar Lake is the largest natural lake in Iraq, representing one of the most important lakes, bounded between latitude 33˚39' 00"- 34˚36' 00" N and longitudes 43˚42' 00"- 42˚59' 00" E and 120 km northwestern Baghdad between Tigris and Euphrates revisers. The main goal of Tharthar Lake is to control the waters of the Tigris River during flood seasons, collecting water reaching the Tigris River and recharging water to the Tigris and Euphrates rivers during dry seasons (Sissakian, 2011). The highest level of lake storage is 65 m (AMSL), and the area at this level is 2679.53 km^2, with a maximum water capacity of up to 85 bcm (Mukhalad et al., 2019; Sissakian, 2011). In 2016, the surface water area of the lake and the volume of water stored at the lake water level were 45 m, about 1715.9382 km^2 and

42.32 bcm, respectively, compared to 1733.1678 km^2 and 44.05 bcm at the water level of 46 m for the year 2021 (Ruaa, 2022).

2.1.2. Al-Razzaza Lake

It is considered the second-largest lake after Al-Tharthar and is located about 15 km south of Karbala. It is bounded by latitude 43°53' -43° 22' N and longitude 33° 53'- 32° 26' E. Al-Razzaza Lake is connected from the north with Habbaniyah Lake by Nazim Al-Warwar and is surrounded by the other three sides of the desert land interspersed with some hills. There were significant fluctuations in the lake level and water surface area, with a sharp change in water levels for the years 1990, 2000, and 2016, as the lake area decreased from 1.621 km^2 in 1990 to 270 km^2 in 2012, and the lake's shoreline decreased by 63.4 percent from 1989 to 2019 (Haider, 2018; Al-Qaraghuli et al., 2021).

2.1.3. Habanyah Lake

It is a shallow lake located south of Ramadi and is bounded by latitudes 33˚10' 71''-33˚22' 20'' N and longitudes 43˚19' 40''-. 43˚36' 34'' E (Al-Kubaisi et al., 2021) (Aws et al., 2020). The lake is located on an almost flat terrain, with heights ranging from 43.3 to 45.2 meters above sea level, and the area of the lake is estimated at 365.2 km^2 (Al-Kubaisi et al., 2022). The importance of the lake is controlling the floodwaters of the Euphrates River, in addition to agricultural and tourism purposes. It has faced many changes in recent years, as the total area of the lake reached 193.11 km^2 in 1972, increasing to 292.16 km^2 in 2012, with an increase of 1.28% annually, along with increasing the storage capacity to 40 bcm (Youssef, 2016). The water level of the lake decreased during the period from October 2016 to September 2017 from 230.39 km^2 at the level of 44.85 to 76,177.76 km^2 at the level of 43.41, as estimates by the National Center/ the Ministry of Water Resources (Khalid and Ali, 2022).

2.2 Artificial Water Bodies

2.2.1 Haditha Dam Lake

It is one of the largest and most important lakes on the Euphrates River, located between latitudes 34° 40' - 34° 13' N and longitudes 42° 26'- 41° 55' E. The lake's maximum and minimum surface area changed from 1988 to 2019, reaching approximately 427 km^2 in 2014 and 148 km^2 in 2015 (Mahir et al., 2020).

2.2.2. Dukan Dam Lake

It is the oldest lake located south of Rania in northern Iraq, about 60 km northwest of Sulaymaniyah province. It is bounded by latitude 35º 57′- 36º 14′ North and longitude 44º 45′- 45º 03′ East (Haveen, 2023). The lake's drainage area is about 11.690 km^2, and the storage capacity is 6.87 x 109 m^3 (Rebwar et al., 2016). Also, the overall average area of Dukan Lake was about 168.86 km^2 (Aiman et al., 2018).

The storage capacity decreased by 28% due to sediment accumulation inside the reservoir, with an annual average of (7) million cubic meters (mcm), which was demonstrated by calculating the volume of the reservoir before the construction of the dam and from the bathymetric survey conducted in 2014 (Youssef, 2016; Rebwar et al., 2016). Also, the overall average area of Dokan Lake was about 168.86 km^2

2.2.3. Darbendikhan Dam Lake

It is located between latitudes 35° 06' - 35° 21' N and longitudes 45° 40' - 45° 44' E, about 230 km northeast of the city of Baghdad and 65 km southeast of Sulaymaniyah city. The dam's catchment area is approximately 17.850 km^2 (Dalshad et al., 2020). The surface area of the lake reservoir was 110.79

km^2, and the volume of the reservoir was 2.567 km^3, at the highest level of 485 m above sea level. At a level of 471 m, the lake's surface area and volume were 60.0104 km^2 and 1.427 km^3, respectively (Aljoborey and Abdulhay, 2019; Alazawi et al., 2023).

2.2.4. Hamrin Dam Lake

It is an artificial lake on the Diyala Dam constructed in 1981 and extends along the Diyala River, a tributary of the Tigris River. It is located in Diyala province, about 50 km northeast of Baqubah (Husain, 2016). It is extending between latitudes 34° 22′ - 34° 20′ N and longitudes 44° 49′ - 45°12' E (Huda et al., 2023). The storage capacity of Hamrin Lake is about 3.95 bcm, with an area of 445 km^2 (Abdulrazzaq et al., 2022). The lake's surface area was about 358.38 km2, decreasing successively by 80% in 2008. The largest area of the lake reached 264.617 km^2 in October 2022, while the smallest area reached 140.202 km^2 in September 2022 (Ahmed, 2022). Huda et al. (2023) confirmed a sharp change in the lake's surface water area due to the dam's construction on the Lund River, which affected its original shape.

2.2.5. Mosul Dam Lake

It is located 60 km north of the city of Mosul and 80 km from the borders of Syria and Turkey at latitude 36˚36' - 36˚50' N and longitude 42˚27' - 42˚58' E (Khattab and Merkel, 2014; Issa et al., 2015). The water surface area of the Mosul Dam Lake fluctuated (increased and decreased) during the years 2000, 2005, 2015, and 2020 (Al-Obaidi and Al-Timimi, 2022). There is an increase in the area of the Mosul Dam Lake from its original area in 1986, which amounted to 244 km^2 by (15.1, 31.14, 13.11, 20.9) % for the given periods and decreased by 7.78% for the period 2010. It has been registered that the minimum water surface area of Mosul Lake in 2010 was about 225 km^2, while the maximum area of the lake was found to be 320 km^2 in 2005. The overall average of increasing and decreasing change detection was 25.4550174 and 19.7851824 km^2, respectively (Al-Obaidi and Al-Timimi, 2022).

3. Previous studies related to the application of remote sensing and GIS on water bodies in Iraq

The integrated approach of Remote Sensing and GIS techniques is a modern and advanced method for monitoring the earth's surface and all-natural resource applications. It helps to monitor water bodies, reservoirs, and all environmental phenomena that are involved in the process of sustainable development, thus helping to reach results that give a predictive view of the state of resources and the possibility of building and adopting appropriate policies (Allawai and Ahmed, 2019; Aljoborey and Abdulhay, 2019). Several studies used Remote Sensing and GIS techniques to monitor the natural and artificial water bodies in Iraq.

Abdulwahhab et al. (2012) used remote sensing and Geographic Information Systems (GIS) techniques to estimate surface ratio changes in the Al-Razzaza Lake area from 1990 to 2012. The study showed a significant receding of water in Al-Razaza Lake due to the scarcity of water resources, where the surface water area decreased from 1.621 Km^2 in 1990 to 270 km^2 in 2012.

Using various satellite images, Abed-Al-Razaq et al. (2015) monitored the changes in the prominent features of the Hamar Marsh area, including water, vegetation, and soil. Different satellite sensors such as Multispectral System (MSS) 1973, Thematic Mapper (TM) 1990, Enhanced Thematic Mapper Plus (ETM+) 2000, and MODIS 2010 were used to perform the classification in this study. The study showed that the supervised classification results gave a better and more accurate description of the study area than the unsupervised.

Yousif (2016) monitored and calculated the surface area of Habbaniya, Tharthar, Hamrin Kan, and Darbandikhan Lakes using satellite images over 40 years (1972-2012). The results showed that the total surface area decreased by 17.646% in 2012 from the total surface area in 1972 for the five lakes. It has also been shown that the lakes were at their highest levels in 1988, while the minimum surface area was recorded in 2008, as the area of these lakes reached only 1.795.1567 km^2.

Dawood et al. (2018) used different satellite sensors such as Multispectral System (MSS) 1973, Thematic Mapper (TM) 1990, and Enhanced Thematic Mapper Plus (ETM+) 2000 for the period extent from 2005 to 2012 integrated with GIS technology in the period from 2005 to 2012 to investigate the surface area of five lakes (Habbaniyah, Tharthar Lakes. Hamrin, Dokan Darbandikhan) and two marshes (Al-Hammar and Al-Hawizeh). The results showed that the total area of marshes increased by 85% while the total area of selected lakes decreased by 15.5% in 2012.

Rebwar et al. (2019) studied the storage capacity reduction of the Dukan Dam reservoir by conducting a bathymetric survey using a single-beam echo sounder in November 2014. The output of the echo sounder was converted to determine the water depth points, and then the points were converted into height points for the bottom of the reservoir. Two sets of storage height curves were prepared based on the reservoir digital elevation model (DEM) layer created using ArcGIS software.

The first group relates to the topography of the reservoir in 1952 before the dam's construction, while the second group relates to the beginning of the dam operation in 1959, where the size of the reservoir was calculated using topographic maps at a scale of 1: 20,000. The result was compared to the calculated volume of the same reservoir using bathymetric data collected in 2014. A comparison of the results indicates that the reservoir's storage capacity decreased by 28% due to sedimentation, estimated at 7 mcm annually.

Al-Qargouli et al. (2021) also investigated changes in the temporal and spatial characteristics of water levels in Al-Razzaza Lake using an archived series of multispectral Landsat satellite images for the years 1990, 2000, and 2016. The Natural Difference Water Index (NDWI) technique was adopted to extract and map the water surface area of a lake with analysis of climatic data and elements for the period (1990-2016). The results show a particularly sharp rate of change in the water level and significant fluctuations in the lake level and water surface area over time.

Huda et al. (2022) monitored and evaluated the changes in the shoreline and surface water area of Al-Razzaza Lake from 1989 to 2020 using six Landsat satellite images and GIS. This study used the Support Vector Machine (SVM) and ISO cluster classifier methods to classify and extract surface water area .The results showed that in 2019, the lake suffered a heavy loss in water level, where the surface water area decreased by 84.1% percent from 1.631.72 km^2 in 1989 to 259.65 km^2 in 2019.

Al-Obaidi and Al-Tamimi (2022) used Landsat series image data obtained during April 2000, 2005, 2010, 2015, and 2020 with the help of ArcGIS 10.3 software to study spatial changes in Mosul Dam Lake. Spectral water indices, including normalized difference water index (NDWI) and unsupervised classification, were used to extract water bodies and calculate surface water area to detect changes for 20 years. The results showed that the minimum water surface area in 2010 was about 225 km^2, while the maximum lake area in 2005 was 320 km^2.

Ruaa (2022) used an integrated approach of remote sensing, topographic maps, and GIS to calculate the storage volume of Tharthar Lake. The results showed that at the water level of 45 m, the lake surface area and stored water volume for 2016 were 1715.9382 km^2 and 42.32 bcm, respectively, compared to 1733.1678 km^2 and 44.05 bcm at the level of 46 m for 2021. The difference in the surface area of the lake water and the volume of stored water between 2016 and 2021 is estimated to be 17.2296 km^2 and 1.73 bcm, respectively.

Huda et al. (2023) used Sentinel-2 images and GIS to investigate the surface water changes in Hamrin Lake in eastern Iraq. A severe change in the surface water area of the lake has been observed during the past ten years, as the surface water area reached 144 km2 in 2018 and decreased to 39 km^2 in 2022. The decrease is due to changing the course of the water, cutting off some rivers and building dams by neighboring countries, and the lack of rain, making water flows into the lake less than coming out.

Table 1 shows a summary of the selected studies discussed above that use an integrated approach of remote sensing and geographic information systems (GIS) techniques in Iraq to monitor water level fluctuations of water bodies.

Table 1. Studies that used GIS and remote sensing techniques to monitor changes in Iraq's water bodies.

Authors	Techniques and data used	Results and conclusion
Abdulwahhab et. al., (2012)	Remote sensing and GIS	Al-Razaza Lake decreased in area from 1.621 km^2 in 1990 to 270 km^2 in 2012.
Abed- Al-Razaq, et al., (2015)	MSS 1973, TM 1990, ETM+ 2000 and MODIS 2010	The supervised classification gave a good and accurate description of the Hamar Marsh area, better than the unsupervised classification.
Yousif, (2016)	Landsat Satellite images	The total surface area decreased by 17.646% in 2012 from the total surface area in 1972 for the five lakes, which include Habbaniya, Tharthar, Hamrin, and Darbandikhan Lake.
Dawood et al., (2018)	Landsat MSS, TM & ETM+ Arc GIS 9.3	The total area of Al-Hammar and Al-Hawizeh marshes increased by 85% in 2012, while the total area of Habbaniyah, Tharthar, Hamrin, Dokan, and Darbandikhan Lakes decreased by 15.5% in 2012.
Rebwar et al., (2019)	A single-beam echo sounder ArcGIS software Topographic maps	The storage capacity of the Dukan Dam reservoir decreased by 28% due to sedimentation, estimated at 7 mcm annually.
Huda et al., (2022)	Landsat satellite images and with the help of GIS	The shoreline of Al-Razzaza Lake witnessed a decline of 63.4 percent from 1989 to 2019.
Al-Obaidi and Al-Tamimi, 2022	Landsat series images data ArcGIS 10.3	The minimum water surface area in 2010 of Mosul Dam Lake was about 225 km^2, while the maximum area of the lake was in 2005 to be 320 km^2.
Ruaa, (2022)	Landsat series image data, topographic maps, and ArcGIS 10.3	The surface area of the Tharthar Lake and the volume of storage for the year 2016 amounted to 1715.9382 km^2 and 42.32 (bcm) at level 45 m, respectively, compared to 1733.1678 km^2 and 44.05 (bcm) at level 46m for the year 2021.
Huda et al., (2023)	Sentinel-2 images and ArcGIS 10.3	The surface water area of Hamrin Lake reached 144 km^2 in 2018 and decreased to 39 km^2 in 2022

4. Remote sensing and GIS technique approach

The integrated approach of remote sensing and GIS technology is widely used in water resources management, especially in detecting changes in the water area of lakes, rivers, reservoirs, and other water bodies, thus calculating the area and volume of stored water. The significant advantage of applying remote sensing and geographic information systems (GIS) techniques in water is the ease of updating and developing databases associated with those water bodies. Thus, it enables workers in the water field to link geographic information, such as water basins, with graphic information, such as rain and water level, where it can be used.

The most remote sensing data used in monitoring water bodies' is the Landsat satellite, a group of satellites launched by NASA successively since 1972 and is available on the United States Geological Survey (USGS) website. NASA has given serial designations: Landsat 1, Landsat 2, and the last is Landsat 9 (Fig. 3).

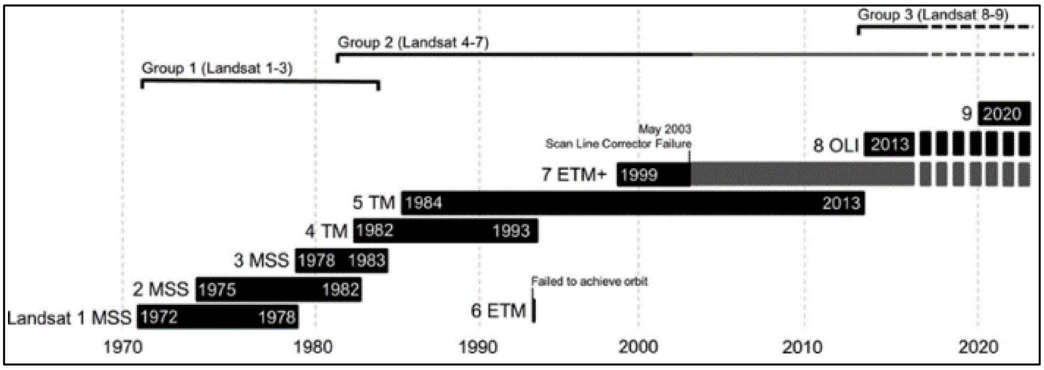

Fig. 3. Timeline of satellite launches and associated sensor data availability (Wulder et al., 2016).

Landsat satellite details for the most used sensor, bands, and wavelength for the change detection of water bodies are listed in Table 2.

Table 2. Bands wavelengths of the Landsat satellite images (Acharya and Yang, 2015).

BANDs	**Landsat satellite**		
	TM Spectrum	**ETM+ Spectrum**	**OLI Spectrum**
1	0.45-052 µ m Blue	0.45-052µm Blue	0.433-0.453 µm Coastal/ Aerosol
2	0.52-0.6 µ m Green	0.52-0.6µm Green	0.450 – 0.515 µm Blue
3	0.63-0.69 µ Red	0.63-0.69µm Red	0.525-0.600 µm Green
4	0.76-0.9 µ m NIR	0.77-0.9µm NIR	0.630 – 0.680 µm Red
5	1.55-1.75 µ m SWIR	1.55-1.75µm SWIR	0.845-0.885 µm NIR
6	10.4-12.5 µ m TIR	10.4-12.5µm TIR	1.560 – 1.660 µm SWIR-1
7	2.08-2.35µ m SWIR	2.09 -2.35µm SWIR	2.100-2.300 µm SWIR-2
8	-------	0.52-0.9µm Panchromatic	0.500 – 0.680 µm Panchromatic
9	-------	---------	1.360-1.390 µm Cirrus
Spatial Resolution	30m (B1- 5,7) 120 m (B6)	30m (b1-5,7) 60m (B6) 15m (B8)	30m (b1- 7,9) 15m (B8)

The main approach of using remote sensing and GIS for monitoring changes and calculating the storage volume in lakes can be summarized as follows:

- Download the satellite image, particularly Landsat of water bodies, from the USGS website to prepare maps for the study area, which includes Layer stack, Mosaic, and Subset study area.
- Conducting a satellite image classification process (Unsupervised type classification) to extract the boundaries of the lake (lake mask extract**)**
- Derive the surface area of the lake.
- Measuring water body levels.
- Transfer all data, including areas and levels, to the GIS program and thus calculate the water storage volumes of the water body.

5. Conclusions

Reviewing the articles showed that the number of studies related to monitoring changes in the areas and volume of storage of water bodies in Iraq using remote sensing techniques and geographic information systems has increased significantly over the past period, and the results of the studies can be summarized as follows.

1. The most remote sensing data used in most studies to monitor changes in water bodies is the Landsat satellite group that NASA launched successively from 1972 until now.

2. Al-Tharthar Lake area and the volume of storage for 2016 amounted to 1715.9 km^2 and 42.32 bcm at level 45 m, respectively, compared to 1733.17 km^2 and 44.05 bcm at level 46 m for the year 2021.
3. Habbaniya Lake faced many changes in recent years, as the total area of the lake reached (193.11) km^2 in 1972 and became 292.16 km^2 in 2012, an increase of 1.28% annually, and the storage capacity increased to 40 bcm. It decreased from October 2016 to September 2017 from 230.39 km^2 at the level of 44.85 to 76.177.76 km^2 at the level of 43.41m.
4. Al-Razzaza Lake's water area decreased from 1.621 km2 in 1990 to 270 km2 in 2012 and continued to decline, as the lake shoreline decreased 63.4 percent until 2019.
5. Haditha Dam Lake's average area amounted to 313 km^2, compared to an average area of 418 km^2 for 1988-2000. The maximum and minimum water surface area decreased to 427 km^2 and 148 km^2 in 2014 and 2015, respectively.
6. Dukan Dam Lake's storage capacity decreased by 28% due to sediment accumulation inside the reservoir, with an annual average of 7 bcm.
7. Darbandikhan Dam Lake reservoir was 110.79 km^2, and the reservoir volume was 2.567 km^3 at the highest 485 m above sea level.
8. Hamrin Dam Lake area was about 358.38 km^2, which decreased successively by 80% in 2008. It underwent significant changes in 2022, as the largest area of the lake reached 264.617 km2 in October, while the smallest area reached 140.202 km^2 in September.
9. Mosul Dam Lake's minimum water surface area in 2010 was about 225 km^2, while the maximum area of the lake was found to be 320 km^2 in 2005.

6. Recommendations

A real danger threatens these water bodies' environment due to the significant deterioration that affects the water quality and the environment in the region. Therefore, researchers must expand the study of this problem to provide recommendations and propose appropriate solutions to reduce these risks.

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