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REVIEW ARTICLE - ENGINEERING (MISCELLANEOUS)

Applications of Remote Sensing and GIS in Monitoring Surface Water of Al-Razzaza Lake: A Review

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Abstract

Al-Razzaza Lake, which was established in 1969 to protect the southern regions from heavy rains, is a part of the western plateau and is characterized by a semi-arid climate, hot in summer and cold in winter. The lake water level decreased in the past ten years due to the lack of rain and high temperatures, which affected the water quality and quantity so it was studied and monitored the decline of the water level and calculate the surface area of the lake by several researchers using remote sensing techniques integrated with the GIS environment. Several studies were reviewed in this study, which dealt with the use of satellite images taken at different periods with the help of Geographic Information Systems (GIS) to detect changes in the areas covered by Al-Razzaza Lake. Studies have shown that the area of the lake gradually decreased from 1990 to 2018 by about 1285 km^2, then recovered slightly since 2018 by about 118 km^2. The results of the studies also showed that there is a real threat to the environment of Al-Razzaza Lake as a result of the significant deterioration that affects the water quality and the environment in the region. Consequently, researchers are required to expand the study of this problem to provide recommendations and propose appropriate solutions to reduce the resulting risks.

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Keywords: Al-Razzaza Lake; Remote Sensing; GIS; Iraq.

1. Introduction

The main application of remote sensing data is the detection of seasonal changes in water bodies that determine changes in reflective properties, soil moisture, atmospheric conditions, illumination, and viewing angles, which influence spectral behavior [1-3]. Iraq is distinguished by the existence of various natural and artificial water reservoirs used to store water during the flood seasons for later use to compensate for the water shortage. There are three main natural lakes and four artificial water reservoirs distributed in different regions of Iraq (Table 1).

Table 1. Water bodies (Lakes and reservoirs) in Iraq

No.	Lake and reservoirs name	Area (Km^2)	Location
1	Tharthar	2710	Salah al-Din province and Anbar province
2	Habanyah	140	Anbar province
3	Razza	1810	Karbala province
4	Haditha Dam	500	Anbar province
5	Darbandikhan Dam	104	Sulaymaniyah province
6	Mosul Dam	385	Nineveh province
7	Dahuck Dam	270	Sulaymaniyah province
8	Hamrin	340	Diyala Province

Al-Razzaza Lake, which was chosen in this study as a case study, is the second biggest lake in Iraq and is one of the largest lowland lakes [4]. It has been described as the blue point in the desert, and it is an important source of fish wealth. The water level has decreased since the eighties of the last century, and then began to accelerate since the year 1990.

This is due to the lack of water entering the lake, climatic changes, the rise in atmospheric temperature, the increase in the evaporation process, and also due to the decrease in the water level in the Euphrates River.

It is the second largest lake after Tharthar, located about 15 km south of the city of Karbala, between latitude 33°53' to 32°26' N and longitude 43°53' to 43°22' E (Fig. 1). The total area of Al- Razzaza Lake is 1862 km^2 at the level of 40 m and a volume of 26 billion m^3 [1].

Nomenclature & Symbols			
GIS	Geographic Information system	TM	Thematic Mapper
DEM	Digital Elevation Model	OLI	Operational Land Imager
USGS	United States Geological Survey website	ETM +	Enhanced Thematic Mapper plus
NASA	National Aeronautics and Space Administration	NDVI	Normalized Difference Vegetation Index

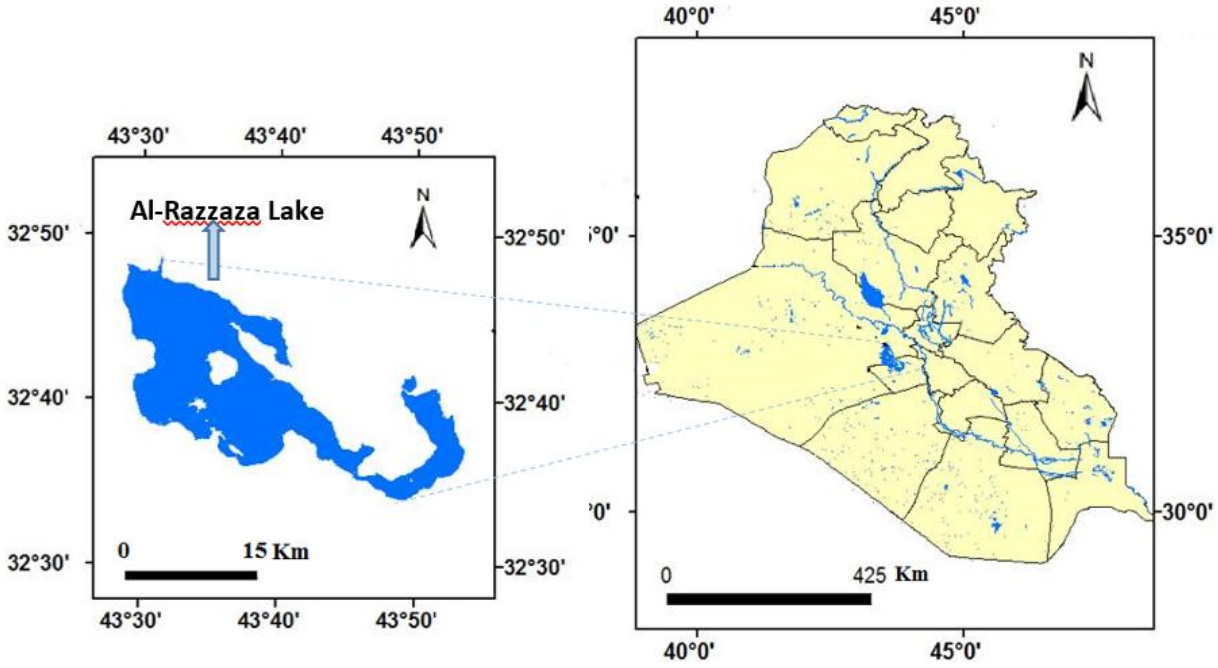

Fig. 1. Location map of study area

Al-Razzaza Lake is located at a short distance to the west of the Euphrates River, connected from the north to Al-Habbaniyah Lake by Nazim Al-Warar, and surrounded by the other three sides of the desert lands with some hills.

Al-Razzazah was a large and deep lake, but during the past ten years, the water level has decreased dramatically, with the depth of the lake reaching only 5-10 meters, and the salinity becoming very high due to the loss of nutrients from Habbaniya Lake [5]. In addition to climatic changes that led to an increase in evaporation during the extremely dry and hot summers, as well as the discharge of wastewater from the city of Karbala [5].

2. Geology and Hydrology of Al-Razzaza Lake

Tertiary sediments of different ages cover large areas surrounding Al-Razzaza Lake, located in the south and southwest directions.

It is also surrounded by plain terrain with heights ranging from 35 to 65 meters above sea level and a slope of less than one degree in the east-northeast direction of the lake [1]. Two types of aquifers have been identified in the area surrounding the lake, which are confined and unconfined aquifers. The Euphrates and Nafail are the main formations of unconfined aquifers, while the Dammam formation represents the confined aquifers, which is one of the most water-bearing layers in the western region of Iraq. These formations are characterized by cracks and joints in addition to cavities and channels that increase permeability. Accordingly, further details about the geology and hydrology of Al-Razzaza Lake can be obtained from many previous studies, such as [5-8].

3. Sources of Recharging Water for Al-Razzaza Lake

The main source of water for Al-Razzaza Lake is the surface water coming from the Euphrates River through the Al-Majarra channel linked to Lake Habbaniya [5]. Mixed agricultural, industrial, and domestic sewage also flows into Lake Razzaza, as well as from northern Karbala through the drainage channel [9]. In addition to precipitation and surface water flow of the valleys from north to south, its details are shown in Table 2 and Fig. 2.

Table 2. Annual discharge rate and basin area of the seasonal valleys (runoff) of Al- Razzaza Lake from the western side

No.	Desert valley	Annual discharge rate (m)	Basin area $(Km)^2$
1	Wadi Al -Arjawi	3 million	3665
2	Wadi Fuwad	4 million	655
3	Wadi Al Ubaid	150 million	16170

An additional very important source indication is the groundwater flow towards Lake [9]. In general, feeding water to the lake, whether from surface water or groundwater, depends on the amount of precipitation in the region.

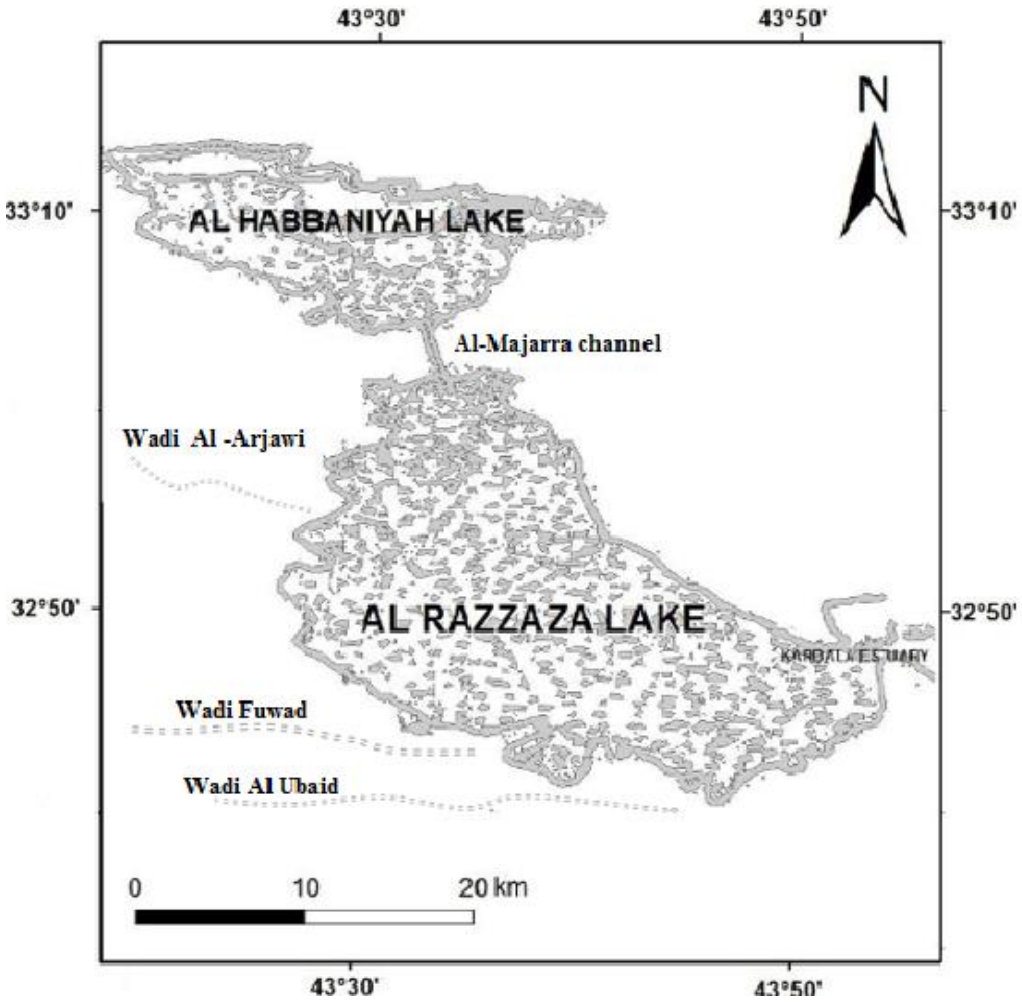

Fig. 2. Sources of recharging water for Al-Razzaza Lake

4. Literature Review

Hayder Dibs, 2018 [10] used Landsat satellite images for 1992, 2001, 2010, and 2018 to derive indices and perform unsupervised classification to monitor the extent of aridity of Lake Razzaza. The study showed that there were two outstanding results, which are the rapid decrease in the lake area by 81.17%. The decrease was measured using NDWIs, with a percentage of 79.69% using NDVIs, and the area was about 1187.40 km^2 and 1189.24 km^2, respectively.

Sabah et al., 2021 [11] used Landsat TM and ETM + data for the years 1987, 2000, and 2015 to monitor the land cover around Lake Al-Razzaza in Iraq based on the multiple temporal analysis technique. The results showed that the water level in the lake fluctuated according to the different seasons during the period from 2000 to 2015, as the surface area of the lake decreased by about 320 km^2, and climatic changes led to an increase in dry areas and a significant increase in the amount of salty water. The 2015 study showed a significant decrease in the depth and area of the lake as a result of the substantial decrease in the saline areas.

Al-Qarqouli et al., 2021 [5] used an archived series of multispectral satellite images from Landsat for the years 1990, 2000, and 2016 to study changes in the temporal and spatial characteristics of water levels in Al-Razzaza Lake. An indexing technique such as (NDWI) was adopted to extract the lake borders and map its water surface area by analyzing data and climatic elements for the period from 1990 to 2016. The results show that there is a particularly sharp rate of change in the water level and large fluctuations in lake level and water surface area over time.

Huda et al., 2022 [3] monitored and evaluated changes in the coastline and surface water area of Al-Razzaza Lake in Iraq from 1989 to 2020 using six Landsat satellite images and with the help of GIS. In this study, the Support Vector Machine (SVM) and International Organization for Standardization (ISO) cluster classifier methods were used to classify and extract surface water areas. The results showed that the shoreline of Al-Razzaza Lake witnessed a decline of 63.4 percent from 1989 to 2019.

Al-Lami et al. 2023 [1] applied remote sensing technology and geographic information systems (Geo-informatics tools) that incorporate an extensive range of technologies to provide a solution for managing water resources in the future and provide an excellent way to improve knowledge of sustainable planning. The study aims to reveal the spatiotemporal changes of the lake from 1988 to 2018. The results showed that there was a decrease in the size of the lake by about 30% from 1990 to 2002, while between 1999 and 2014 it was about 70%. The results showed that compared to 2014, there was a slight increase in the area of the lake in 2016 by about 40%.

Table 3 shows a summary of all discussed studies in which remote sensing techniques and geographic information systems were used to detect changes that occurred in Al-Razzaza Lake and most importantly they obtained results.

Table 3. Studies that used GIS and remote sensing techniques in monitoring changes in water bodies in Iraq

Author	Techniques and data used	Results and conclusion
Al-Qaraghuli et al. 2021 [5]	Landsat. TM, ETM+ and OLI for 1990, 2000 and of 2016	There is a particularly sharp change in the water levels of Lake Razzaza and there are large fluctuations in the lake level and water surface area over time.
Hayder Dibs, 2018[10]	Landsat satellite images	The rapid decrease in the lake area by 81.17%. Using NDWIs with a percentage of 79.69% using NDVIs and an area of about 1187.40 km^2 and 1189.24 km^2, respectively.
Sabah et al, 2021[11]	Landsat TM, ETM+. Arc GIS 9.3 و ERDAS 14 Microsoft Excel 2010	The water level in the lake was fluctuating with different seasons. During the period 2000 and 2015 the area of the lake was height decreased to around 320 Km^2.
Al-Obaidi and Al-Tamimi 2022 [12]	Landsat series images data ArcGIS 10.3	The minimum water surface area in 2010 was about 225 km^2, while the maximum area of the lake in 2005 was 320 km^2.
Al-Lami et al. 2023 [1]	Landsat TM, ETM+ Geo-informatics tools ArcGIS 10.3	There was a decrease in the size of the lake by about 30% from 1990 to 2002, while between 1999 and 2014, it was about 70%, and a slight increase in the area of the lake in 2016 by about 40%.

5. Methodology

There is a wide range of technologies to provide solutions for managing water resources in the future and provide an excellent way to improve knowledge of sustainable planning, the most important of which are remote sensing techniques and geographic information systems (Geo-informatics tools) [1]. Remote satellite images are the most reliable data types in the world for monitoring the Earth's surface [12], and the main advantage of applying remote sensing techniques and geographic information systems (GIS) is the possibility of accessing, collecting, analyzing, and mapping data. Thus, it enables geospatial information, such as water basins, to be correlated with descriptive information, such as rain and water level. Several satellite sensors have been launched since the 1960s into orbit to follow and monitor the Earth's surface and its environment [13]. These satellite sensors are widely used in monitoring water level fluctuations in lakes, rivers, reservoirs, and water bodies [14]. Most of the satellite image data used to monitor bodies of water is from the Landsat satellite, which is a group of satellites launched consecutively by NASA from 1972 to date and is freely available on the USGS website. NASA has given sequential designations to the satellites, including Landsat 1, Landsat 2, and the latest version, "Landsat 9". Landsat satellite details of the most frequently used sensors, bands, and wavelengths for detecting water body change are listed in Table 4.

Table 4. Main characteristics of the Landsat satellite images [15]

BAND	TM Spectrum	ETM+ Spectrum	OLI Spectrum
1	0.45-052 µ m Blue	0.45-052 µm Blue	0.433-0.453 µm Coastal/ Aerosol
2	0.52-0.6 µ m Green	0.52-0.6 µm Green	0.450 – 0.515 µm Blue
3	0.63-0.69 µ Red	0.63-0.69 µm Red	0.525-0.600 µm Green
4	0.76-0.9 µ m NIR	0.77-0.9 µm NIR	0.630 – 0.680 µm Red
5	1.55-1.75 µ m SWIR	1.55-1.75 µm SWIR	0.845-0.885 µm NIR
6	10.4-12.5 µ m TIR	10.4-12.5 µm TIR	1.560 – 1.660 µm SWIR-1
7	2.08-2.35µ m SWIR	2.09 -2.35 µm SWIR	2.100-2.300 µm SWIR-2
8	-------	0.52-0.9 µm Panchromatic	0.500 – 0.680 µm Panchromatic
9	-------	---------	1.360-1.390 µmCirrus
Spatial Resolution	30m (b1- 5,7) 120m (b6)	30m (b1-5,7) 60m (b6) 15m (b8)	30m(b1- 7,9) 15m(b8)

The main approach of using remote sensing and GIS to monitor changes and estimate storage volume in a reservoir can be illustrated in Fig. 3.

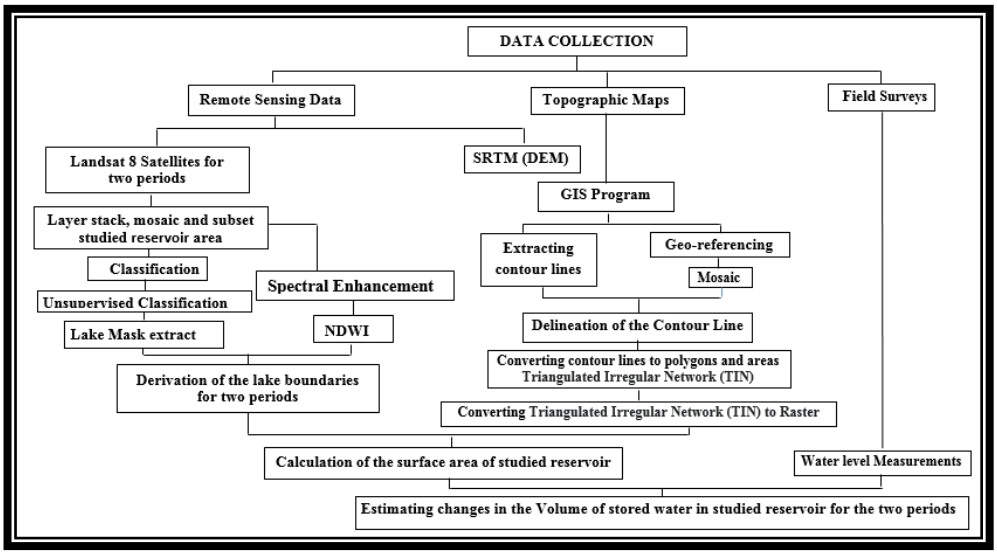

Fig. 3. Schematic flow chart of remote sensing and GIS for monitoring changes and calculating the storage volume in reservoir

6. Result and Discussion

Change detection of the Al-Razzaza Lake surface area in many studies has been widely used to assess the shifting of the shoreline of the lake using satellite images from 1988 to 2018.

Four important aspects of change detection when monitoring natural resources are detecting changes that have occurred, determining the nature of change, measuring the extent of the change area, and evaluating the spatial pattern of change [16]. The most important current technology for detecting changes is an integrated approach of remote sensing data with Geographic Information System (GIS). It has been widely used in recent years for automatic or semi-automatic extraction and mapping of water bodies by many researchers, such as [17-20]. It is clear from the available previous studies that examined the spatiotemporal changes of Lake Razzaza that the surface area of the lake was about 1450 km^2, and it increased by about 74 km^2 during the two years up to 1990, then it gradually decreased to 239 km^2 in 2012, a total decrease of about 1285 km^2. Then, it increased slightly to 370 km^2 in 2018 at a rate of 118 km^2, as shown in (Fig. 4) [1].

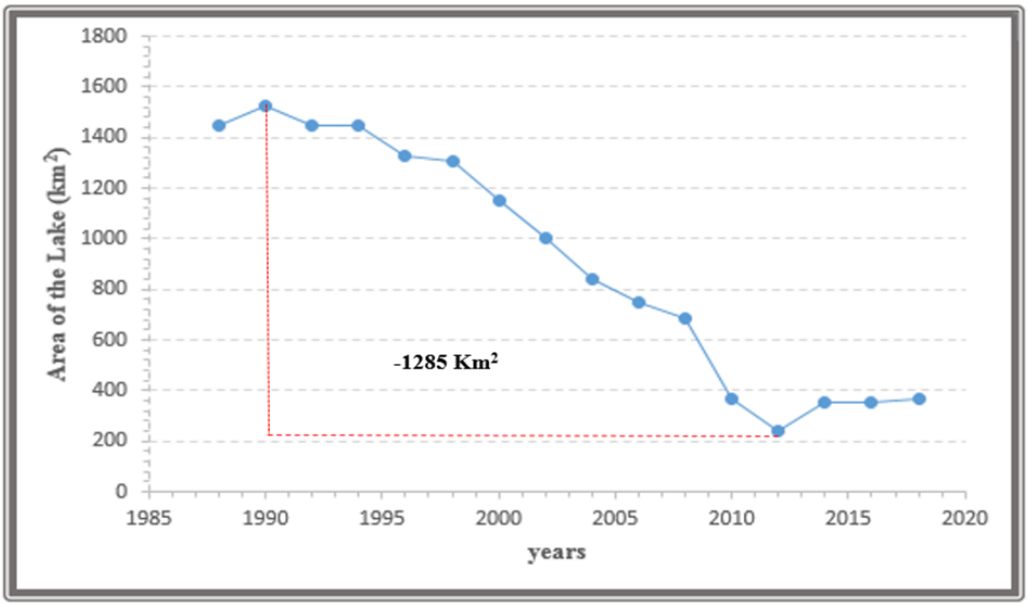

Fig. 4. Surface area changes in the Al-Razzaza lake during the years of 1988 and 2018 [1]

5. Conclusion

According to the studies that have been reviewed and evaluated for the surface, environmental, and hydrological changes of Al-Razzaza lakes using an integrated approach of GIS and remote sensing, it has been concluded the following:

- The sources of the lake vary, and its key characteristics are fluctuation and irregularity.
- The surface area of the lake decreased gradually from 1990 to 2018 by about 1285 km^2, then it recovered slightly, increasing by 118 km^2 by 2018.
- The existence of a real danger threatening the environment of Al-Razzaza Lake as a result of the great deterioration that affects the water quality and the environment in the region. Therefore, researchers must expand the study of this problem to make recommendations and propose appropriate solutions to reduce these risks.

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