Monitoring of Water Surface Change of Haditha Dam's Lake Using Satellite Data Technique

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Abstract
Water bodies in Iraq and other countries are considered the essential key for human life as they play a large and influential role in the country's economy. Thus, the strategic plans of water management must be developed according to the need for future requirements. The current study aims to monitor the change in the water surface area of Haditha Dam Lake by calculating the surface area of the lake over a sequential time (1985-2019). GIS and Satellite imagery techniques were used to achieve the goal of the study. Landsat Space Archive was used with its fifth, seventh and eighth categories according to Path 170 / Row 36. The results showed that the lake generated from the dam was tested by three main stages. The first stage (1985-1988), the second stage (1988-2000) and third stage (2000-2019). The study presented that the average area of the Haditha dam Lake for the period 2001-2016 was 313 km², compared to the average area of 418 km² for the period 1988-2000, which means that the difference in the average surface area decreased by 25%. The Maximum and minimum water surface areas were about 427 km² and 148 km² for 2014 and 2015 respectively throughout the period time of 1988 to 2019. The declination behaviour of the surface area was observed from 1988 to 2019 for the general trend line with a slope of 11.8.

1 Introduction
Throughout history, the subject of water has been considered one of the most essential components of human life since it plays a major role in preserving the ecosystem. Climate change and global warming as well contributed to the drought aspect in the Middle East in general and Iraq in particular (1). Resulting in a significant decrease in rainfall and snow amounts leading to decreasing in water resources in Iraqi rivers and tributaries especially Tigris
and Euphrates Rivers. Rainfall rates declination in recent decades throughout the world, which affected Iraq particularly, causing water insufficiency in large parts of Iraq. Most of Iraq's areas suffer from rain falling to less than 50% except for very small areas in comparison with other places. Amount of rainfall in Iraq decreased from 310.6 mm to 242.6 mm for the period between (1941 – 1975) and (1990 – 2009) respectively with a rate of change 68 mm (2).

Water bodies and water reservoirs are of great significance in human life, especially in dry and semi-dry countries such as Iraq. It was, therefore, important to have an integrated knowledge of environmental and natural changes that occurred and damaged the water areas in the past decades. Currently, Iraq has several water control projects that are used to regulate the distribution of water for use in numerous other usages. Many dams have been constructed in Iraq such as Haditha Dam. These projects aimed to maintain the water level in rivers and to prevent seasonal floods as well as for irrigation and electricity production (3).

Haditha Dam considered as one of many major reservoirs distributed in Iraq, Syria, Turkey and Iran as shown in Figure 1. It was operated in 1988. The storage capacity, height, water surface area and hydropower of Hadith dam are about 8.2 m$^3$, 57m, 503 km$^2$ and 660 MW respectively (4).

![Figure 1: Main reservoirs along Tigris-Euphrates rivers (5)](image)

Four countries share the catchment area of the Euphrates River, which is about 444000 km$^2$. Each share is about 28.2%, 17.0%, 39.9%, and 14.9% for Turkey, Syria, Iraq and Saudi Arabia respectively (4, 6) as shown in Figure 2. Turkey controls 88% of its water, while Syria controls 18%. Accordingly, a series of strategic planning absence for water storage projects by the Iraqi government. This aspect has led to a significant influence on the deterioration of Iraq's water resources, which results have developed to the time of this research. This strategic ignorance is clearly can be seen when a comparison to be calculated about the number of constructed water projects and dams on Euphrates River, which is shared by three countries Turkey, Syria and Iraq. There are nine and three dams on Euphrates River on the Turkish and Syrian territories respectively. While just one dam has been constructed in Iraq. In other words, the ratio is about 9:3:1 for Turkey, Syria and Iraq consecutively.
Consequently, water resource in Iraq suffered a lot of damage and threats that led to a decline in water supplies and intensified these damage and threats in the end of the 19th century (7). The main reason for providing inadequate water amount for country requirements is the imbalance in Iraq's strategic policy regarding future water projects (3). Given this fact, there was a moderate decrease in the total revenues of Tigris and Euphrates rivers from about 68.16 billion m$^3$/year for the period (1930–2009) to about 47.6 billion m$^3$/year in 2011 (3). Besides, Negative impact on lakes and rivers in Iraq resulting from the construction of many dams and irrigation projects in the neighbouring countries which represent the sources of Tigris and Euphrates rivers such as Iran, Turkey and Syria (8).

One of the main difficult problems that Iraq and Syria are experiencing is the problem of water lacks and deteriorating quality. Therefore, to overcome these obstacles, there must be national, regional, and international cooperation between them. It was expected by the UN that several regions of the world will face a water matter especially Arab countries, Iran, Pakistan. To overcome this issue, many water resources such as water bodies of Haditha Dam should be monitored, evaluated and studied. This research focuses on detecting the variation in the water surface area of Haditha lake by combining GIS and remote sensing techniques. Haditha lake located on Euphrates River and controlled by neighbouring countries (Turkey and Syria). The period specified in this research is from 1985 to 2019.

1.1 Remote Sensing and GIS Application

The use of remotely sensed data in Earth observation and all-natural resources applications is a modern and advanced approach that helps to monitor all the environmental phenomena involved in the agricultural development process, water bodies and reservoirs (8-10). Which eventually helps in reaching the results that give a predictive view of resources status and the possibility of building and adopting appropriate policies (10).
The RS/GIS technique are powerful tools to detect changes in natural resources. Landsat provides reliable and accurate spectral data to identify changes in the surface area of water bodies. Remote sensing and satellite data have been widely used in the field of monitoring and classification of natural, flood control and water resources (11-13). Many studies have conducted to survey water bodies and monitoring rivers periodically. These studies used different programs and multiple software technologies to classify the multi-spectral images, using monitoring techniques by isolating the components of earth cover from each other to get the components of the earth cover area (14, 15).

The current study aims to show the temporal comparison of area change in water surface of Haditha Dam Lake throughout a period of years (1985-2019) to give a clear idea of the deterioration of the study area. Accordingly, highlighting risks and challenges facing Iraq shortly.

2 Study Area

The territory of Iraq is located within the coordinates of longitude 45°38' to 45°48'E, and latitude 29°5' to 37°22'N., which covers a total area of 435,052 km2. It is bordered by Turkey to the north, to the east by Iran, to the southeast by the Arabian Gulf, and by the Saudi Arabia and Kuwait to the south, and Jordan and the Syrian to the west (5, 16).

Haditha lake is one of the largest and major water bodies on the Euphrates River. It is located in the western part of Iraq to the north of Haditha city at a distance of eight kilometres (Figure 3). It is formed as a result of Haditha dam construction, which was established in 1986. It has become a multi-purpose water tank. The study area lies between latitudes (34° 40´ and 34° 13´) North and between longitudes (42° 26´ and 41° 55´) East. The climate of the study area lies within the desert region, which is characterized by low rainfall rates ranging from 45 mm to 200 mm and the annual average is 127 mm.
3 Data Description

Satellite data of Landsat 5, 7 and were used in this study based on route 170 and line 36, as shown in Table 1. The number of satellite images was 18, which covered the study area for the period from 1985 to 2019. Data was downloaded from the US Geological Survey's website (www.earthexplorer.com). Eventually, the ArcMap software technique was used to process and analyse the imagery satellite data.

This research included the satellite images that covered the study area in April and its boundaries of each year, as this period is considered the peak time in Iraq in terms of the availability of water resources from its sources, as well as according to the availability of images in the space archive.

Table 1: Description of the satellite imagery in patch/row 169/36 used in this study

| No. | Satellite | Acquisition Date | No. | Satellite | Acquisition Date |
|-----|-----------|------------------|-----|-----------|------------------|
| 1   | Landsat 5 | 6 Apr. 1985      | 11  | Landsat 7 | 2 May. 2003      |
| 2   |           | 9 Jun. 1985      | 12  |           | 09-Apr-13        |
| 3   |           | 25 Apr. 1985     | 13  |           | 24 Apr. 2014     |
| 4   |           | 9 Jun. 1986      | 14  |           | 27 Apr. 2015     |
| 5   |           | 22 Apr. 1988     | 15  |           | 11 Apr. 2016     |
| 6   |           | 10 Apr. 1998     | 16  |           | 30 Apr. 2017     |
| 7   |           | 29 Apr. 1999     | 17  |           | 17 Apr. 2018     |
| 8   |           | 1 May. 2000      | 18  |           | 3 Mar. 2019      |
| 9   |           | 28 May. 2001     |     |           |                  |
| 10  |           | 29 Apr. 2002     |     |           |                  |

4 Methodology

Best satellite images were downloaded, which covered the Lake of Haditha Dam. The images had some cloud or devotion in their composition were omitted. Eventually, the total number of images comprised in this study was 18 satellite images. Figure 5 shows one of the geospatial classification map models for the study area.
The supervised classification technique was utilized to classify all the images to achieve the distribution of land cover variations, classified into three main categories: soil and water. In this paper, only the categorizing and studying were included and it was the location of the water surface of Haditha Dam Lake for all selected years that were presented in this study. The GIS/RS approach was used to perform all previous phases. Besides, the general direction of change in the water surface water area was determined and examined to draw the numerous graphs associated with the results (Figure 6).

Figure 5: Land cover classification model for the study area, April 2014

Figure 6: Flow chart steps followed in this study

5 Results and Discussions

The integration between the techniques of the GIS and satellite imagery data were combined to obtain realistic and scientific results of the change in the water surface area of the lake generated by Haditha Dam over the period specified in this study (1988-2019).
5.1 Water Surface Area

The variation in water surface area can be classified into three stages. The first stage (1985-1988), the period that included the history before the construction of Haditha Dam, and after its completion, construction, and operation. The first operation was on May 1, 1985, for the lowest storage level of 112 m above the sea level. In February of 1986, the first unit of the hydroelectric station accompanying with the Dam was put into operation, where the operational level of the Dam was 147 m above the sea level. The overall operation and the total completion of the Dam were in 1988.

To indicate the change in the water surface area that stored by Haditha Dam via classification maps of satellite images, Figure 4 represents the variation in the water body during the three stages. The date of April 6, 1985, is to indicate the status of the water body before the construction of Haditha Dam, and the date of June 9, 1985, shows the water body after the first operation of the dam. Whereas, the date of the twenty-fifth of April to the ninth of June 1986 is to show the water body variation after the first operation of the hydroelectric unit, which requires a higher level of the Dam's water.

The second stage of the period covered by this study includes the years extending from 1988 (the year in which the dam was completely built and operated) until the year 2000, wherein this period there was relative stability in the surface area of the reservoir (see Figure 7). The results indicated that the average surface area of the lake within this period was 418 km² and this area can be considered as a reliable reference for comparing the change in the surface area of the lake in subsequent years owed to the relative stability in the amounts of annual water revenues and other secondary factors.

The third stage includes the years from 2000 to 2019. It is clearly noticed, from Figure 4, that there was a significant change in the water surface area in 2001, where the decline in the surface area was about 64% of the average area relative to the previous period. After that, a fluctuate inclination and declination for the later period except for the sudden sharp reflection decrease point in 2015. where the area decreased from 427 km² in 2014 to 148 km² in 2015 of about 65%. The reduction was due to two main reasons. Firstly, the disturbance of the water resources of the Euphrates from Turkey from February to September of 2015. Secondly, the control of armed groups of Tabqa Dam in Syria and the closing of its gates.
The average surface area of Haditha Dam Lake for the period 2001-2019 was 313 km², compared to the average surface area of 418 km² for the period 1988-2000. Which means that the difference in the average surface area decreased by 25% as presented in Figure 8. As a result, the second stage can be considered as the reference average surface area of the reservoir in the case of the relative stability in terms of water revenues of the Euphrates River without the presence of problems and exotic variables. While the third stage can be considered as the average surface area in case of conflicts and lack of water revenues.

Figure 8: Percentage of average water surface area for stage two and stage three

5.2 Classification Maps

The techniques of analysing and processing the satellite images and GIS provides a great power to determine the challenges and degradation that may affect water bodies. Besides, the ability to study the water bodies throughout the year, which helps to obtain an integrated database for all details of the water surface.
To give a fully comprehensive comparison of the water surface area of the Haditha reservoir, various classification maps of water surface area were recorded and drawn. The supervised classification technique was used to categorize 15 images of Landsat TM, ETM and Landsat 8 for the period 1985-2019. Figures 9, 10 and 11 show the change in the water surface area of Haditha lake according to the conducted years in this study.

Figure 9: Comparative change of water surface area of Haditha Dam Lake, 1985-1988

Figure 10: Comparative change of water surface area of Haditha Lake, 2001-2016
5.3 Correlation Analysis

To visualize the type of variation in the surface area of Haditha Dam Lake throughout the study years, the general trend line was calculated from 1988 to 2019. This is because 1988 was the real completion and operation year of Haditha Dam. Figure 12 shows the general trend line, where it is noted that the surface area of the lake gradually decreases with time by a slope of 11.8 based on the results and data of this study.

Figure 11: Comparative change of water surface area of Haditha Lake, 2016-2019

Figure 12: General trend line of the water surface area change of Haditha Dam Lake, 1988-2019.
6 Conclusion

This study was divided into three main phases according to the data available in this research. The first phase included the construction and storage of the reservoir (1988-1985), where the surface area of the lake began to expand until it reached the beginning of the second stage in 1988 which continued until the year 2000. This stage can be described as the relative stability in the surface area of the lake. The third stage was confined to the period from 2000 until 2016. The following conclusion can describe the general behaviour of this study:

- The GIS/RS approach gives the possibility of dividing and describing the stages of change in the surface area of the water body into time numerous periods depending on the influencing factors that involving the water surface, such as water revenues and management of the use of this water.
- It was found that the water surface in 2001 decreased to 64% relative to the average surface area of the previous. As well as, the surface area in 2015 decreased by 65% in comparison to the surface area in 2014. This is due to the regional politics and political influence of the water policy.
- The Maximum and minimum water surface areas were about 427 km$^2$ and 148 km$^2$ for 2014 and 2015 respectively throughout the period time of 1988 to 2019.
- The difference between the average water surface area between stage two and stage three was 25%.
- The general trend line of the surface area variation was investigated from 1988 to 2019. The declination of the surface area by a slope of 11.8 was the behaviour of the trend line based on the results and data conducted in this study.

The integration process between the techniques of analysing and processing the satellite images and GIS provides a great power to determine the challenges and degradation that may affect water bodies. Besides, the ability to study the water bodies throughout the year, which helps to obtain an integrated database for all details of the water surface.

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