MONITORING DEGRADATION OF WETLAND AREAS USING SATELLITE IMAGERY AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES

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ABSTRACT

In order to conserve the ecosystems and biodiversity of wetland areas, it is necessary to monitor the degradation of these areas. Currently, Al Razzazah lake and its surrounding areas have degradation significantly due to its low water level, which has negatively affected its biodiversity. Hence, this research aims to propose a method to model the monitoring of spatio-temporal changes in that lake and its surrounding areas with an area estimated at 4660 km² between (1998 – 2018) using Remote Sensing and Geographic Information System (GIS) techniques. After conducting the supervised classification by the method of Support Vector Machine (SVM) for all satellite images, we extracted thematic maps, which contain five classes. The results showed the overall accuracy was 90.11%, 91.60% and 90.57% while the Kappa coefficient were 0.8764, 0.8950 and 0.8821 for 1998, 2008 and 2018 respectively. Results showed that the lake area decreased by 86.21% in the study area in 2018.

Keywords: wetland degradation; GIS; supervised classification; (SVM); thematic maps.

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INTRODUCTION

Wetland, including lakes, rivers, swamps, rice fields, and marshes, is one of the most fertile ecosystems of biological production, providing food for fish, birds and animals as well as contribute to the provision of many services that increase human well-being and reduce poverty, particularly those living near these wetlands and are affected by the degradation of those areas (23). There are several reasons that led to the degradation of wetlands, which caused the reduction of its areas or areas of their existence, including natural and other man-made causes (14). Previous studies have shown that the area of wetlands has decreased significantly in the past 50 years due to the reclamation of wetlands, population pressure, water diversion, dam construction, pollution, over-resources, biological invasion, desertification, climate change and Global warming as well as misguided policies (6,16).

As referred by Tian et al. (24) it's necessary to strive to preserve those environments for the sustainability of life. On his part, (9), confirmed that studying deterioration and/or drought in water resources contributes greatly to exploring and analyzing the universal change of these wetlands in any part of the world. A study conducted by the United Nations (UN) in Iraq at 2013 has shown that many rivers and lakes in some countries have been heavily affected by dams and irrigation projects built in the headwaters of adjacent countries such as Turkey, Iran and Syria, particularly in Iraq (13), these study also noted, the continuous decline in water resources in Iraq is one of the major problems affecting the Iraqi ecosystem. Indeed, we have seen a decline in the last 10 years of water resources within our country, especially in the Tigris and Euphrates rivers, and its impact on the water reserves in the lakes, especially "Al Razazah lake, as well as, the marshlands. Al Razazah lake is a second largest lake in Iraq in terms of water storage, with a surface area of 1810 km² and a depth of about 30 m and a reservoir capacity of 26 billion m³ and its one of the main sources of fish wealth, a main source of irrigation for agricultural areas, and a "tourist attraction" (11). More recently, this lake is in a critical situation because of the reduce of water coming from Euphrates river through Habbaniyah lake because of the apprehensive fall of the water level in the Euphrates river due to the external water policies of the sources of rivers and non-compliance with the water shares of riparian countries (1,27). Meanwhile, climate changes, higher temperatures and higher levels of evaporation have resulted in a decrease in the water level and surface area and an increase in salinity (9). Furthermore, an area of 4,660 km² including Al Razazah lake and its surrounding areas (case study) was selected to study and estimate the magnitude of those degradations.

MATERIALS AND METHODS

Study area and data used

The study area involves al Razazah lake and its adjacent areas and covers an area of 4,660 km², the smallest part of which is located in the north-west side of Karbala province, while the largest part is located in al Anbar governorate and limited by longitudes 43 ° 19 '34"E to 43 ° 55' 31"E and latitudes 32 ° 23'18"N to 33 ° 8'41"N. As shown in Figure 1.

![Figure 1 Study area map](image_url)

The region has a dry climate in hot summers and its cold and dry in winter, resulting in a clearly reduced annual rainfall rate in the past three decades and an increase in average maximum and minimum temperatures, as shown in table 1, fulfilling in a significant increase in annual evaporation rate since 1970 (9).
The geology of study area contains of several sorts of soils as a result of a different geologic environment and fluvial processes. Includes gypsiferous gravel, sand dunes, tertiary sediments and rock units and the barren land, which is dry salt flats, Razzaazah beaches, additionally, the water body includes shallow and deep water (19). Three satellite images were utilized to conduct this study for the period (1998 - 2018), as showing in Figures 2, 3&4. Two images obtained from the Landsat 5 TM in 9 August 1998 and 4 August 2008, and the third image downloaded from the Landsat 8 OLI in 16 August 2018, were gathered from the path 169 and row 37. As well as Quickbird satellite image for supporting the geometric correction process and increased visual ability in the interpretation of visual phenomena. It is worth mentioning, it can be obtained freely after registering at the USGS official website at https://earthexplorer.usgs.gov/.

### Table 1. Climate data of the study area for years 1998, 2008 & 2018

| Climate data     | Year | Annual rate |
|------------------|------|-------------|
| Rainfall         | 1998 | 0.14 mm     |
| Rainfall         | 2008 | 0.27 mm     |
| Rainfall         | 2018 | 0.10 mm     |
| Max temperature | 1998 | 31.09 C˚    |
| Max temperature | 2008 | 30.50 C˚    |
| Max temperature | 2018 | 31.22 C˚    |
| Min temperature | 1998 | 17.40 C˚    |
| Min temperature | 2008 | 16.87 C˚    |
| Min temperature | 2018 | 16.62 C˚    |

**Methodology**

The methodology followed in this study consists of several steps. The first step is very important of which are pre-processing raw data, including radiometric, geometric correction, as well as the co-registration process. The second step includes layer stacking and sub-setting, moreover, data are ready to be classified in the third step. After determining the elected classification categories and studying the case study well, the supervised classification of these corrected images was carried out by Support Vector Machine (SVM) algorithm using Environment for Visualizing Images (ENVI) 5.3v software.
The most prominent steps in the methodology can be summarized in the flowchart shown in Figure 5. After obtaining the thematic maps of all the images classified by Arc GIS 10.2v software in the fourth step, accuracy assessment was confirmed and compared to the global parameters as a fifth step, followed by the change detection process and statistical analysis as a final step in order to obtain the objectives and results of this research.

![Flowchart](image)

**Figure 5. Flowchart of the all steps adopted in methodology of the research**

It can be explained above steps as following:

**Image pre-processing**

These processes aim to correct distorted remote sensing data in order to obtain a more truthful representation of the real reality and to improve images for later use (12). As reported by (22), that several significant reasons lead to the calibration of satellite images, since raw sensor digital numbers (DNs) are just numbers without physical units and that each sensor has its own acquisitions and entitlements applied to registered signals to configure band names. Preprocessing is imperative, and includes a sequential operation such as radiometric, atmospheric and geometric corrections by achieving these operations, it is possible to correct image distortion and improve image quality and thus rise the feasibility of interpretation (22). We know that the solar radiation falling on the earth, part of it that is reflected and received by satellites in the layers of the atmosphere due to the presence of some particles (water vapor and dust, as well as some gases) and the other is penetrate the atmosphere to reach the surface of the globe to reflect a section of it once again the first type is called Path radiance (Lp) and the other type is outgoing radiance. As a result, satellite sensors record both types of light emission (12).

Measure Radiance \( L_{tot} = \text{Path Radiance} + \text{Outgoing Radiance} \)

\[ L_{tot} = \frac{(P - T)}{2\pi} + L_p \]

Where:
- \( L_{tot} \) = total spectral radiance measured by sensor
- \( P \) = reflectance of object
- \( E \) = irradiance on object
- \( T \) = transmission of atmosphere
- \( L \) = Outgoing Radiance
- \( L_p \) = path radiance

From eq. 1

Outgoing Radiance = Measure Radiance - Path Radiance

\[ L = L_{tot} - L_p \]

The path radiance (Lp) can be calculated from satellite bands by assuming that the darkest pixel represents the lowest recorded value and then subtracting that value from all pixel values in the image, this method is called Dark Object Subtraction (DOS) (18).

Since our research requires comparison of satellite images for different time periods, it has become necessary to correct the Sun's distance to Earth as well as to correct the Sun's altitude. To estimate correct reflectance of any material on the surface of the earth, we need to the following:

Convert DNs to Outgoing radiance utilizing radiometric calibration

Estimate incident irradiance (E)

Reflectance \( (P) = \frac{L}{E} \)

To convert any digital values (DN) to outgoing Radiance, we use the following equation

\[ L = (\text{DN} - B) / G \]

Where:
- \( L \) = Spectral radiance
- \( G \) = Slope of calibration function (Channel Gain) of metadata
- \( \text{DN} \) = Digital Number (value recorded)
B = intercept of calibration function (Channel Offset) of metadata.

For the second step, the estimation of radiation falling on the surface of the globe is three steps:

1- Sun elevation correction

Equation 5 is used to complete Sun elevation correction

\[ E = E_\circ \cos \theta \] .......................... 5

2- Earth -Sun distance correction

\[ E = \frac{E_\circ}{d^2} \] .......................... 6

Where:

\( E \) = Normalized solar irradiance

\( E_\circ \) = Solar irradiance at mean earth–sun distance

\( \theta \) = Sun’s angle from the zenith

\( d \) = Earth–sun distance in astronomical units

3- Combined irradiance correction

\[ E = \frac{E_\circ \cos \theta}{d^2} \] .......................... 7

Finally, by compensation for equations 5 & 8 in equation 4, It can have the reflectance corrected for any object on Earth's surface.

Regarding the implementation of atmospheric correction, Dark Object Subtract (DOS) technique has been chosen to implement these corrections by using ENVI 5.3v. software. So to convert digital number values DNs ranging from 0-256 to reflectance values ranging from 0-1 (17).

The following equation can be used:

\[ L_s = L_t + L_h \] .......................... 8

Where:

\( L_s \) = energy reflected

\( L_t \) = energy emitted from the ground

\( L_h \) = energy from scattering

The purpose of the geometric correction is to correct the position of each pixels and thus to put the ground target in its correct geometric position in the image(25). Remote sensing techniques are often based on ground control points (GCPs) in geometric correction. GCPs are fixed points on Earth's surface, provided they are visible in the image, or can represent features in the image, such as intersections of roads, building corners, airport runways and other stable phenomena. Geometric correction can be done in several methods such as (From

\[ \text{Table 2. Coordinates of GPS navigator} \]

| No. | East GPS m | North GPS m |
|-----|------------|-------------|
| 1   | 397629     | 3619217     |
| 2   | 394185     | 3604198     |
| 3   | 387553     | 3630593     |
| 4   | 383076     | 3594452     |
| 5   | 380630     | 3644071     |
| 6   | 361468     | 3603471     |

The RMSE is the standard for accuracy of geometric corrections and co-registrations between images in the next steps. it confirmed by (4) that RMSE is usually equal to half pixel size in the modified satellite model. Figure 7 below shows the value of the RMAE which is equal to 0.47 m from the geometric correction of the satellite image 2018 in the Arc GIS 10.2v software. In order to correct all satellite images which used in this research, the image of Landsat OLI 2018 was corrected by the corrected Quickbird image as applied (image to corrected image technique). Eight common points were identified between the two images for the implementation of this process that conducted by utilizing Arc GIS 10.2v software. The results showed that RMSE is equal to 0.40 m as shown in Figures 6, 7, 8 & 9, which enhances confidence of the previous geometric correction by GPS.
Figure 6. Showing the geometric correction by using Arc GIS 10.2v software

Figure 7. RMSE of geometric correction processes

Figure 8. Geometric correction process between satellite image 2018 of Landsat 8 OLI and corrected satellite image 2007 of Quickbird for the study area
After the geometric correction, Registration or Co-registration is the process of alignment of any image to another image of the same region (8). As reported (5) by utilizing this approach leads to gaining of the second image a same geometric error from the first basic image. However, this approach is more appropriate when using multiple-date images to monitor changes on Earth. Accordingly, the registration process for both images (1998 and 2008) to base image 2018 was conducted individually using the ENVI 5.3v software.

Image processing

The second stage of the data processing include Image layers stacking and Sub setting. Layer stacking, that means collecting all bands in a single file for easy opening the image in the program and accelerate the processing (9). The sub setting is defined as the process of take out part of a large file to form one or more small files to simplify and accelerate the analysis in order to obtain the results required as soon as possible. (10). After determining the area of study covering lake Al-Razazzah and its surrounding areas, the steps of images Sub-setting and Resizing were applied by ENVI 5.3v software by select spatial subset by map coordinates shown in the Table 3.

Table 3. Coordinates of sub setting the study area from satellite images

| Corner                  | Longitude       | Latitude       |
|-------------------------|-----------------|----------------|
| Upper left coordinate   | 43° 19΄ 33.50” E| 33° 08΄ 40.68” N|
| Lower right coordinate  | 43° 55΄ 31.02” E| 32° 23΄ 17.42” N|

SUPERVISED CLASSIFICATION: After completing the radiometric and geometric corrections of the satellite images, the analyst or interpreter can identify homogeneous sets of pixels of similar digital values and divide it into separate sets such as vegetation, water, barren land, etc. (15). One of the supervised classification methods, was chosen as the Support Vector Machine (SVM) to obtain the most accurate results. SVM is one of the most important algorithms used in supervised classification, where nonlinear improvement plays an "effective" role in its methodology (20). It was invented by Vladimir Fabnik and the current version has been updated by Corina Curtis and Vladimir Fabnik (26). The general idea is based on the creation of a hyperplane between datasets to collect data similar to a category indicated by the user. The challenge is to train the machine to understand the structure of the data and plan using the appropriate label for the category for best results (26). Figure 10 identifies the ideal location of the hyperplane which based on the margin value (W).
To calculate a training set (T) as defined as follows:

\[ T = \{(p_i, q_i) \mid p_i \in \mathbb{R}^n, q_i \in \{-1, 1\}, i = 1, \ldots, m\} \]  

Where:

- \( p_i \) = vector of input values
- \( q_i \) = vector of output values

To produce hyperplane H, that separates positive and negative values as:

\[ W = \sum_{i=0}^{m} m_i \cdot q_i \cdot p_i \]  

Where:

- \( m_i \) = a multiplier
- \( W \) = normal hyperplane.

Can compensate for any point on the hyperplane as

\[ w \cdot x + b = 0 \]

Where

- \( b \) = bias function

As a final result, if any points have \( n_i > 0 \), are called support vectors.

All stages of the classification were done employing by ENVI 5.3v, after we determine the types of classes within the study area according to "international standards used in land use - land cover (LU/LC)" classification. Five major classes were selected: Deep water, Shallow water, Agricultural land, Saline Soil and Barren land. In short, shallow water can be described as less than 2 meters deep, while the water more than 2 meters deep is considered a deep water. Then gathered training sites for each selected class by drawing polygons around areas of interest by 30,000 pixels for samples used in the classification process and 10,000 pixels for samples which utilizing, subsequent, in accuracy assessment, according to the limits used to determine the size of the selected samples, it is 70% for the classification process and 30% for the evaluation of accuracy (7). The program performs the direct classification of the corrected satellite image by applying the SVM algorithm using "training sites which entered into the program by the user, where the algorithm matches the spectral signature of each pixel in the image with the sample values of the training to form separate groups that are very similar in order to obtain a classified image (5).
Accuracy Assessment of Classification Results

The accuracy assessment is the last step in analyzing the satellite images through which the accuracy of the results obtained can be verified (7). (5, 12) Confirmed that the value of the Kappa coefficient is between 0 - 1, if it is equal to 0. This indicates that there is a strong disagreement between the outputs of the classification and the reference data. In contrast, there is a strong agreement if the value is equal to 1, while if the value ranged from 0.4 - 0.8 the accuracy is medium, and the low value refers to the randomized classification. After the classification process has been completed using the ENVI 5.3v software, the results of accuracy of those classifier images has been assessed and validated and showed it are accepted because of Kappa coefficient is more than 0.80. Confusion matrix for five different classes for the study area is shown in Tables 4, 5, & 6 below:

| Land Cover Class | Producer’s | User’s |
|------------------|------------|--------|
| Deep Water       | 90.14%     | 95.13% |
| Shallow Water    | 90.39%     | 83.91% |
| Agricultural Land| 91.77%     | 94.42% |
| Saline Soil      | 85.16%     | 92.32% |
| Barren Land      | 93.04%     | 86.13% |
| Overall Accuracy | 90.11 %    |        |
| Kappa Coefficient| 0.8764     |        |

| Land Cover Class | Producer’s | User’s |
|------------------|------------|--------|
| Deep Water       | 87.04%     | 93.72% |
| Shallow Water    | 88.34%     | 83.72% |
| Agricultural Land| 93.64%     | 92.40% |
| Saline Soil      | 92.34%     | 90.17% |
| Barren Land      | 91.49%     | 93.50% |
| Overall Accuracy | 90.57 %    |        |
| Kappa Coefficient| 0.8821     |        |

| Land Cover Class | Producer’s | User’s |
|------------------|------------|--------|
| Deep Water       | 96.26%     | 94.45% |
| Shallow Water    | 84.75%     | 90.87% |
| Agricultural Land| 90.16%     | 90.30% |
| Saline Soil      | 91.53%     | 94.03% |
| Barren Land      | 95.46%     | 86.31% |
| Overall Accuracy | 91.60 %    |        |
| Kappa Coefficient| 0.8950     |        |

Change detection analysis and results

One of the most important advantages of remote sensing is its ability to capture, record and store a large amount of information about phenomena on Earth’s surface at different conditions and for different periods to benefit
from them in determining and knowing the changes that have taken place, this is called “Change Detection process”, this applies several digital algorithms that calculate the detection of numerical differences in the corresponding pixel values with different dates (12). The same source added that the reliability of the change detection process is affected by several factors, including the different environmental factors that change between the acquisition dates, weather requirements, wind, and soil moisture. The Post Classification Change Detection technique was used to obtain desired results due to the smoothness and accuracy of this method, it naturally requires pre-classified satellite images, where its algorithm compares the corresponding (thematic) pixel labels to detect and identify changes between existing classes. One of the most important features of this method is that it reduces search area and the effects of seasonal variations and atmospheric differences between scenes, in contrast to its most prominent disadvantages, is that classification errors that may exist during classification lead to the discovery of the wrong change (Jensen, 2015).. From Table 7 and Figure 14 changes can be observed in the study area for the period from 1998 to 2008. It can conclude the area of deep water of al Razazah Lake in 2008 decreased by 786.85520 km², or 57.89% compared to 1998, as well as the shallow water area reduced by 38.69% or 56.386197 km², which in turn clearly affected on the neighboring areas, which led to a minimize in the area of vegetation in all its varieties by 81.5693 km², or 44.55% than in 1998. Accompanied by a clear increase in saline soil, especially in the land that was covered with water where it increased by 86.544896 km², or 23.29%. In addition to the rise of arid land by 32.09%, an increase of 836.57455 km².

| Classes         | (1998) Area km² | (2008) Area km² | Differen t km² | Ratio % |
|-----------------|-----------------|-----------------|----------------|--------|
| Deep Water      | 1359.15         | 572.29          | -786.85        | -57.89 |
| Shallow Water   | 145.71          | 89.33           | -56.386        | -38.69 |
| Saline Soil     | 371.47          | 458.01          | +86.544        | 23.29  |
| Agricultural Land | 183.09       | 101.52          | -81.569        | -44.55 |
| Barren Land     | 2606.53         | 3443.10         | +836.57        | +32.09 |
| **Total Area km²** | **4665.96**     | **4664.27**     |                |        |

As for the results of the second stage of the change detection for the period 2008–2018, Table 8 and Figure 13 show that the area of deep water also minimized by 384.932621 km² or 67.26% of its area in 2008 accompanied by a reduction in the area of shallow water by 40.400923 km², or 45.23%, which in turn led to a significant increment in saline soil by 154.82203 km², which means by 33.80%. In addition to a slight increase in the barren lands by 2.31% or 79.576781 km² as a result of the growing in agricultural land, which raised significantly despite the continuous decline in the level of the lake water to reach the increase to 189.74%, or 192.625931 km². This can be explained by that a some of agricultural land owners have followed modern irrigation methods such sprinkler irrigation, as well as increase of areas covered by the cane, shumbolan vegetation and algae, which
usually grow in shallow water and in river stream water. From these result in this research, the large reduction in the surface area of the lake can also be seen by the Figure 16 below.

**Table 8. Results of Change Detection (2008 - 2018)**

| Classes            | (2008) Area km² | (2018) Area km² | Different km² | Ratio % |
|--------------------|-----------------|-----------------|---------------|---------|
| Deep Water         | 572.29          | 187.36          | -384.932      | -67.26  |
| Shallow Water      | 89.33           | 48.93           | -40.40        | -45.23  |
| Saline Soil        | 458.02          | 612.84          | +154.82       | +33.80  |
| Agricultural Land  | 101.52          | 294.14          | +192.62       | +189.74 |
| Barren Land        | 3443.11         | 3522.68         | +79.57        | +2.31   |
| **Total Area km²** | **4664.27**     | **4665.96**     |               |         |

**Figure 16. The change in the surface area of the lake for years (1998, 2008 & 2018)**

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