SURFACE AREA EVALUATION OF MOSUL DOM LAKE USING SATELLITE IMAGERY TECHNIQUE

Mahir Mahmod H.
Corresponding Author, Ministry of Science and Technology, Baghdad, Iraq
mahir.mahmod@gmail.com

Imad Shakir Abbood
Engineering Affairs Department, Sunni Endowment Diwan, Baghdad, Iraq
imadshakirabbood@gmail.com

Ammar Nasiri Hanoon
Department of Reconstruction and Projects, University of Baghdad, Iraq
civileng.ammar@gmail.com

Abstract

Due to water resources such as Tigris and Euphrates rivers, tributaries branches, marshlands and lakes, Iraq is considered, generally in the world and especially in Middle East, as one of the richest countries. These resources are already affected by the consequences of climate change increasingly. One of the most vital projects in Iraq is Mosul Dam (in the northern of Iraq), thus, Mosul Dam lake (MDL), in term of surface area, was observed and studied during the prior 35 years (1984-2019) to detect the effects of historical climate changes on surface area. Satellite data of Landsat has been used in this study based on route 170 and line 35. Best and cloud-free satellite images were downloaded from US Geological Survey. Eventually, ArcGIS technique was used to process and analyze the satellite images. The result displayed that average surface area and parameter of study area was about 242 km² and 432 km consecutively. Relationship between surface area (A) and parameter (P) of study area has been generated and formulated. Furthermore, the correlation coefficient between surface area and parameter was about 71%. Coefficient of variance (COV) was found also to be about
Minimum surface area and parameter of study area were recorded in Sep. 2018 of about 171 km$^2$ and 350 km respectively regardless the dates before the operating Mosul Dam, whereas, maximum $A$ and $P$ lake was found to be 337 km$^2$ and 664 km in April, 1994 respectively. The analysis showed that the exponential curve representing the best relationship between $P$ and $A$.

**Keywords**
Mosul Dam Lake, Landsat, GIS, Water Resources Monitoring

**1. Introduction**

In the second half of the last century, water resource in Iraq such as Mosul Dam Lake (MDL) suffered from a lot of damage and threats that drove to a incline in water supplies (Al-Mossawi, 2020). The main source for drinking water for Iraqi provinces like Mosul, Baghdad and other cities is supplied by MDL, which is located on the Tigris river. Climate change and global warming contributed to the drought aspect in the Middle East in general and Iraq in particular, resulting in a significant decrease in rainfall amounts leading to decreasing in water resources in Iraqi rivers and tributaries (Adamo et al., 2020; Al-Khalidi et al., 2020; Khayyat et al., 2020; Othman et al., 2020). Most of Iraq's areas suffer from lack of rainfall to less than 50% except for very small areas (Boryan et al., 2011).

Negative impact on MDL and rivers in Iraq resulting as well from construction of many dams and irrigation projects in the neighboring countries which represent the sources of Tigris and Euphrates rivers such as Iran, Turkey and Syria (Husain, 2016). Accordingly, MDL has shrunk 60% in surface area from the late of 1990s to 2018 based on a report from World Resources institute (WRI). Many researches have been done to study Mosul Dam and its reservoir in term of water quality, risk assessment, sedimentation and other characters but rare or no studies have been conducted in term of evaluating the surface area and parameter of MDL.

Remote sensing and satellite data have been widely used in the field of monitoring and classification of natural, flood control and water resources. Landsat provides reliable and accurate spectral data for identifying changes in surface area of water bodies. Landsat 5, 7 and 8 offer a good calibrated continuous data set of moderate spatial resolution (30 m). satellite images are significant for the researches of natural resources (M. F. Khattab & Merkel, 2014; Moran et al., 2001; Mustafa & Bayat, 2019; Rogan & Chen, 2004; Wu et al., 2009; Yaseen et al., 2018).

The target for current study is to show the temporal comparison of area changes in water surface of MDL throughout the chosen period of years (1985-2019) to give a clear idea of the deterioration of study area. Accordingly, highlighting risks and challenges facing Iraq in the near future. By combining the techniques of spatial image analysis and geographic information system
(GIS), it was possible to obtain a realistic, scientific and significant results for surface area changes of the lake generated by Mosul Dam over the period specified in this research.

2. Remote Sensing 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. Eventually, it helps in reaching the results that give a predictive view of resources status and possibility of building and adopting appropriate policies (Aljoborey & Abdulhay, 2019; Allawai & Ahmed, 2019; Lillesand et al., 2015).

Remote sensing and GIS technique are powerful tools to detect changes in natural resources in comparison with conventional methods (Al-Quraishi & Negm, 2020; Kaoje & Ishiaku, 2017; Mohamad et al., 2016; Mustafa & Bayat, 2019; Sameen et al., 2014).

Many studies have been conducted for the purpose of surveying 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 (Robertson, 2009; Shehab et al., 2010). In this study, different Landsat satellite was used as shown in Table 1.

| Satellite   | Sensor                        | Spectral Resolution (Wave length in um) | Spatial Resolution | Temporal Resolution |
|-------------|-------------------------------|----------------------------------------|--------------------|---------------------|
| Landsat 1-5 | Multispectral Scanner (MSS)  | 1: 0.5 – 0.6 (B)                      | 60 m; 185 km      | 16 days             |
|             |                               | 2: 0.6 – 0.7 (G)                      |                    |                     |
|             |                               | 3: 0.7 – 0.8 (R)                      |                    |                     |
|             |                               | 4: 0.8 – 1.1 (NIR)                    |                    |                     |
| Landsat 4-5 | Thematic Mapper (TM)         | 1: 0.45 – 0.515 (B)                   | 30 m (visible, near | 16 days             |
|             |                               | 2: 0.52 – 0.60 (G)                    | and mid-IR):       |                     |
|             |                               | 3: 0.63 – 0.69 (R)                    | 120 m (thermal IR);|                     |
|             |                               | 4: 0.75 – 0.90 (NIR)                  | 185 km             |                     |
|             |                               | 5: 1.55 – 1.75 (Mid-IR)               | Swaths width       |                     |
|             |                               | 6: (thermal): 10.40 – 12.5            |                    |                     |
|             |                               | 7: 2.09 – 2.35 (Mid-IR)               |                    |                     |
| Landsat 8   | Operational                   | 1: 0.43-0.45 (CA)                     | 30 m               | 16 days             |
Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

| Number | Wavelength (μm)               |
|--------|------------------------------|
| 2      | 0.45 – 0.51 (B)              |
| 3      | 0.53 – 0.59 (G)              |
| 4      | 0.64 – 0.67 (R)              |
| 5      | 0.85 – 0.88 (NIR)            |
| 6      | 1.57 – 1.55 (SWIR 1)         |
| 7      | 2.11 – 2.29 (SWIR 2)         |
| 8      | 10.40 – 12.5 (Panchromatic)  |
| 9      | 1.36-1.38 (Cirrus)           |
| 10     | 10.6-11.19 (TIRS) 1          |
| 11     | 11.50-12.51 (TIRS) 2         |

(visible, near and mid-IR): 120 m (thermal IR); 185 km swaths width

3. Study Area

Mosul Dam Lake (MDL) was constructed in 1985 at Tigris River approximately 60 km north of Mosul city and 80 km from Syria and Turkey borders at latitude 36°37'44"N and longitude 42°49'23"E (Issa et al., 2015; M. Khattab & Merkel, 2012; M. F. Khattab & Merkel, 2014), as shown in Figure 1. Mosul Dam was operating officially on 24 July 1986 (Issa, Al-Ansari, & Knutsson, 2013). It is the second largest dam in the Middle East (Adamo & Al-Ansari, 2016). Accordingly, MDL is considered as one of the biggest artificial reservoir in Iraq (M. Khattab & Merkel, 2012). The total storage volume of the lake is about 13.13 billion m³ with maximum operation level of 330 m above sea level and maximum water depth of 80 m leading to drainage basin of about 4,200 km² inside Iraq (Al-Taiee & Sulaiman, 1990; Kelley et al., 2007; M. F. Khattab & Merkel, 2014). MDL received of about (60-5000) m³/sec of discharge from Tigris River. Outflow amount varies from 100 to 1000 m³ since the manufacture of Mosul Dam in 1985 (M. Khattab & Merkel, 2012). According to (Issa, Al-Ansari, Sherwany, et al., 2013), the useful life of Mosul dam reservoir, by using bathymetric survey and algebraic formula, is approximately 125 years.

Arid to semi-arid is the ambient climate in the study area with temperature reaches to more than 55°C in July and drops to 12°C in winter, while average amount of rainfall is about 300 mm/yr. Surface area of the lake is about 385 km² and total storage volume 11.13×10⁹ m³ at max. operation level (M. Khattab & Merkel, 2012).
4. Data Description

According to (Bureau, 2010; Issa, Al-Ansari, & Knutsson, 2013), the highest and driest mean monthly discharge occurs usually during April and September respectively (Figure 2). The max. and min. monthly discharge of Tigris, observed since 1931, was 3514 m³/s and 87.7 m³/s during April 1954 and September 1986 consecutively.

Satellite data of Landsat have been used in this study based on route 170 and line 35 to determine and analyze the coverage area of each classified class, as shown in Table 2. Number of satellite images was 33, which covered the study area for the period from 1984 to 2019. Most of acquisition Dates were selected in April and September since the peak mean monthly discharge happens in April and the driest month is in September (Issa, Al-Ansari, & Knutsson, 2013). Data was downloaded from US Geological Survey's website (earthexplorer.usgs.gov) as can be seen in Table 2. Eventually, ArcGIS technique was used to process and analyze satellite images.
Figure 2: Monthly Inflows Received by Reservoir from Tigris River throughout the Years 1931–2011

Table 2: Description of the Satellite Imagery with Patch/Row 170/35, (earthexplorer.usgs.gov)

| Landsat Type | Acquisition Date       | Landsat Type | Acquisition Date       |
|--------------|------------------------|--------------|------------------------|
| Landsat 5    | 1984 June 6, 1984      | 2013         | September 10, 2013     |
|              | September 26, 1984     | 2014         | April 22, 2014         |
|              | 1985 July 27, 1985     | 2015         | September 13, 2014     |
|              | April 25, 1986         | 2016         | April 25, 2015         |
|              | August 15, 1986        | 2017         | October 2, 2015        |
|              | 1987 September 3, 1987 | 2018         | May 13, 2016           |
|              | 1989 April 1, 1989     | 2019         | September 18, 2016     |
|              | 1991 September 30, 1991| 2017         | March 29, 2017         |
|              | 1994 April 15, 1994    | 2018         | September 21, 2017     |
|              | 1996 September 27, 1996| 2018         | April 17, 2018         |
|              | 1998 April 10, 1998    | 2019         | September 24, 2018     |
|              | 2000 April 22, 2000    |              | May 22, 2019           |
|              | 2004 April 26, 2004    |              | September 11, 2019     |
|              | 2006 September 23, 2006|             |                        |
|              | 2008 April 23, 2008    |              |                        |
|              | 2009 September 15, 2009|             |                        |
|              | 2010 May 29, 2010      |              |                        |
|              | October 20, 2010       |              |                        |
|              | 2011 April 14, 2011    |              |                        |
|              | September 21, 2011     |              |                        |

5. Methodology

Best and cloud-free satellite images, which covered the entire study area, were collected, bad images or containing some defects in their composition were excluded. Eventually, the total number of images included in this study was 33 satellite images.
The classification technique was used to categorize all images to obtain the distribution of land cover varieties, classified into three main categories: soil, plant and water as displayed in Figure 3. In this research, only water category has been studied and classified and it was the location of water surface (study area) for all selected years that were introduced in this study. GIS was used to perform all previous steps. In addition, water surface area and general direction of change in surface water area were calculated and analyzed to draw the various graphs related to the results.

![Image of Land Cover Classification Model](image)

**Figure 3: Land Cover Classification Model for Study Area, Sep. 2019**

6. Results and Discussion

The remote sensing method offers a suitable technique in integrating water quality information composed from conventional measurements. Satellite images are also being commonly utilized for observing numerous quintessences in water bodies. Thirty-three satellite images, which covered the whole study area, were selected for detecting the variations in water surface of MDL throughout years (1984-2019). Landsat 5 and Landsat 8 have been used to collect the needed data. In addition, ArcGIS used to process and categorize the geometry analysis.

This study has potential limitation

6.1 Water Surface Area of Study Area

The classification maps have been conducted for the study area according to the chosen years (1984-2019). The results indicated that the water layer suffered a pattern of changes concerning the water of surface area. Most of image dates were chosen in April and September since the peak average monthly discharge happens throughout April and the driest month is mostly during Sept. (Issa, Al-Ansari, & Knutsson, 2013). Impounding of MDL began in June (1984), with incipient basin fill throughout spring (1985), whereas the actual operating of the dam began in 1986 (Issa, Al-Ansari, & Knutsson, 2013), as shown in Figures4 and 5.
It can be clearly seen, from Table 3 and Figure 5, that A and P are about 242 km² and 43 km respectively. As expected, the maximum A and P were calculated to be about 337 km² and 664 km in April 15, 1994. While the minimum A and P were about 171 km² and 350 km consecutively in September 24, 2018.

The bar chart in Figure 5 illustrates the amount of A and P during 35 years along the period 1984-2019. For the first three years, it was recorded very low average value for A and P of about 37 km² and 252 km respectively in comparison with average value 242 km² and 432 km respectively of the later 32 years (1987-2019), see Figure 7. Overall, the values of A and P fluctuated over the period given. increasing and decreasing in water surface probably due to the monthly inflows received by Mosul reservoir from Tigris River and because of the controlling of water imports by neighboring countries and in addition the territorial policy.

| Landsat Type | Acquisition Date       | Area (A), km² | Parameter (P), km | A/P |
|--------------|------------------------|---------------|------------------|-----|
| Landsat 5    |                        |               |                  |     |
| 1984         | June 6, 1984           | 30            | 285              | 0.11|
|              | September 26, 1984     | 34            | 249              | 0.14|
| 1985         | July 27, 1985          | 46            | 222              | 0.21|
| 1986         | April 25, 1986         | 244           | 327              | 0.75|
|              | August 15, 1986        | 221           | 299              | 0.74|
| 1987         | September 3, 1987      | 239           | 384              | 0.62|
| 1989         | April 1, 1989          | 201           | 363              | 0.55|
| 1991         | September 30, 1991     | 252           | 420              | 0.60|
| 1994         | April 15, 1994         | 337           | 529              | 0.64|
| 1996         | September 27, 1996     | 242           | 432              | 0.56|
| 1998         | April 10, 1998         | 260           | 464              | 0.56|
| 2000         | April 22, 2000         | 264           | 503              | 0.52|
| 2004         | April 26, 2004         | 311           | 664              | 0.47|
| 2006         | September 23, 2006     | 250           | 415              | 0.60|
| 2008         | April 23, 2008         | 274           | 441              | 0.62|
| 2009         | September 15, 2009     | 223           | 368              | 0.61|
| 2010         | May 29, 2010           | 280           | 361              | 0.78|
|              | October 20, 2010       | 200           | 360              | 0.56|
| 2011         | April 14, 2011         | 229           | 389              | 0.59|
|              | September 21, 2011     | 223           | 354              | 0.63|
| Landsat 8    |                        |               |                  |     |
| 2013         | September 10, 2013     | 249           | 531              | 0.47|
| 2014         | April 22, 2014         | 235           | 486              | 0.48|
|              | September 13, 2014     | 194           | 365              | 0.53|
| 2015         | April 25, 2015         | 294           | 524              | 0.56|
|              | October 2, 2015        | 190           | 362              | 0.52|
| Year   | Date           | A (km²) | P (km) | COV  |
|-------|----------------|---------|--------|------|
| 2016  | May 13, 2016   | 258     | 501    | 0.51 |
|       | September 18, 2016 | 201   | 399    | 0.50 |
| 2017  | March 29, 2017 | 207     | 350    | 0.59 |
|       | September 21, 2017 | 215   | 473    | 0.45 |
| 2018  | April 17, 2018 | 190     | 358    | 0.51 |
|       | September 24, 2018 | 171   | 352    | 0.49 |
| 2019  | May 22, 2019   | 323     | 553    | 0.58 |
|       | September 11, 2019 | 265   | 420    | 0.63 |
| Mean  |                | 242     | 432    | 0.56 |
| SD    |                |         |        | 0.10 |
| COV   |                |         |        | 0.183 |

**Figure 4:** Variations in Surface Area and Parameter of Study Area, 1987-2019
Figure 5: Water Surface Area Variations of Mosul Reservoir during the Years during 1984-1986
Figure 6: Water Surface Area Variations of Mosul Reservoir during the years 1987-2019
6.2 Statistical Analysis

Standard deviation (SD) has been found since it calculates the variation in the data. Lower the SD leads to lower variation in data and vice versa. In addition, coefficient of variation (COV) measures the true value of relative variance (Moksony, 1990). Table 3 expresses the statistical analysis of the surface area and parameter predicted by the proposed study. The mean value of the prediction is 0.54 with a standard deviation of 0.15 and coefficient of variation of 0.271. COV displayed good accuracy and consistency for the values obtained. This was enough to consider the suggested Equation model proper for evaluation the relation between surface area and parameter.

6.3 Regression Analysis

Regression and correlation were joined together to determine the relationship between A and P of MDL (Figure 7) to calculate out the magnitude of determination variable ($R^2$) since it represents the mostlsignificantindicators of quality of a study (Moksony, 1990). $R^2$ of maximum 0.71 shows a good exponential relationship with positive sign, which means that the relationship is proportional and the two variables move in the same direction. In other words, it can be said that 71% of the variation of P are accounted for by the relationship with A.

The analysis show that the exponential curve representing the best relationship between P and A as observed in Figure 4 and the best equation assumed to be:

$$P = 217.1335e^{0.0027A}(1)$$

where P and A are parameter and surface area respectively of MDL.

![Figure 7: Relationship between Surface Area and Parameter of Study Area](image_url)
7. Conclusion

This research is limited to the collected data from the resources and software mentioned previously for the determination of surface area and parameter. Some data is impossible to perform because not all images captured in a GIS system can be available completely in the required date. However, the factors performance to be investigated in this study includes surface area, parameter and correlation equation of Mosul lake using Landsat satellite images to detect the changes occurred since 1984. Extensive future studies should be provided on all characteristics of Mosul dam Lake.

Thirty-three maps were created and compound for MDL using ArcGIS 10.2 technique. First stage was in 1984 (before and after impounding the reservoir), The second stage represented the initial filling of the reservoir in 1985 while the third was before and after operating Mosul Dam in 1986. Eventually, the period of 1987-2019 was studied to compare the overall changes in the surface area and parameter of MDL. It was found that the minimum surface area and parameter of study area was recorded in Sep. 2018 of about 171 km<sup>2</sup> and 350 km respectively, whereas, the maximum A and P of the studied lake were found to be 337 km<sup>2</sup> and 664 km in April, 1994 respectively. Correlation coefficient analysis has been formulated between A and P and it was found to be 71%. Inclination in correlation coefficient possibly because of the controlling of water imports by neighboring countries and in addition the territorial policy. The exponential curve representing the best relationship between P and A displayed by the regression analysis. COV displayed a good accuracy and consistency for the values obtained.

References
Adamo, N., & Al-Ansari, N. (2016). Mosul dam full story: Safety evaluations of mosul dam. Journal of Earth Sciences and Geotechnical Engineering, 6(3), 185-212.
Adamo, N., Al-Ansari, N., & Sissakian, V. K. (2020). Global Climate Change Impacts on Tigris-Euphrates Rivers Basins. Journal of Earth Sciences and Geotechnical Engineering, 10(1), 49-98.
Al-Khalidi, J., Bakr, D., Hadi, A., & Omar, M. (2020). Investigating the linkage between precipitation and temperature changes in Iraq and greenhouse gas variability. فیزیک زمین و فضا.
Al-Mossawi, M. A. (2020). Biological Approach for Recycling Waste Water in Iraq. Air, Soil and Water Research, 7(1).
Al-Quraishi, A. M. F., & Negm, A. M. (2020). Updates, Conclusions, and Recommendations for Environmental Remote Sensing and GIS in Iraq. *Environmental Remote Sensing and GIS in Iraq* (pp. 517-529): Springer.

Al-Taiee, T., & Sulaiman, Y. (1990). *Preliminary Water Balance of Saddam Dam Lake*. Paper presented at the The Second Scientific Conference of SDRC.

Aljoborey, A. D. A., & Abdulhay, H. S. (2019). Estimating total dissolved solids and total suspended solids in Mosul dam lake in situ and using remote sensing technique. *Periodicals of Engineering and Natural Sciences*, 7(4), 1755-1767.

Allawai, M. F., & Ahmed, B. A. (2019). Using GIS and Remote Sensing Techniques to Study Water Quality Changes and Spectral Analysis of Tigris River within Mosul City, North of Iraq. *Iraqi Journal of Science*, 2300-2307.

Boryan, C., Yang, Z., Mueller, R., & Craig, M. (2011). Monitoring US agriculture: the US department of agriculture, national agricultural statistics service, cropland data layer program. *Geocarto International*, 26(5), 341-358.

Bureau, E. C. (2010). Sedimentation study at the intake of North Al-Jazira Irrigation Project (Final Report ed.). Mosul: Mosul University, College of Engineering.

Husain, Y. (2016). Monitoring and calculating the surface area of lakes in northern Iraq using satellite images. *Applied Research Journal*, 2(2), 54-62.

Issa, I. E., Al-Ansari, N., & Knutsson, S. (2013). Sedimentation and new operational curves for Mosul Dam, Iraq. *Hydrological Sciences Journal*, 58(7), 1456-1466.

Issa, I. E., Al-Ansari, N., Knutsson, S., & Sherwany, G. (2015). Monitoring and evaluating the sedimentation process in Mosul Dam Reservoir using trap efficiency approaches. *Engineering*, 7(4), 190-202.

Issa, I. E., Al-Ansari, N., Sherwany, G., & Knutsson, S. (2013). Sedimentation processes and useful life of Mosul Dam Reservoir, Iraq. *Engineering*, 5(10), 779-784.

Kaoje, I. U., & Ishiaku, I. (2017). Urban Flood Vulnerability Mapping of Lagos, Nigeria. *MATTER: International Journal of Science and Technology*, 3(1).

Kelley, J. R., Wakeley, L. D., Broadfoot, S. W., Pearson, M. L., McGrath, C. A., McGill, T. E., . . ., Talbot, C. A. (2007). Geologic setting of Mosul Dam and its engineering implications: Engineer Research and Development Center Vicksburg Ms.
Khattab, M., & Merkel, B. (2012). Distribution of heterotrophic bacteria and water quality parameters of Mosul Dam Lake, Northern Iraq. *WIT Transactions on Ecology and the Environment, 164*, 195-207.

Khattab, M. F., & Merkel, B. J. (2014). Application of Landsat 5 and Landsat 7 images data for water quality mapping in Mosul Dam Lake, Northern Iraq. *Arabian Journal of Geosciences, 7*(9), 3557-3573.

Khayyat, H. A. K. A., Sharif, A. J. M., & Crespi, M. (2020). Assessing the Impacts of Climate Change on Natural Resources in Erbil Area, the Iraqi Kurdistan Using Geo-Information and Landsat Data *Environmental Remote Sensing and GIS in Iraq* (pp. 463-498): Springer.

Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). *Remote sensing and image interpretation*: John Wiley & Sons.

Mohamad, A. A., Pugi, N. A., & Zainol, H. (2016). The GIS Application in Smartphone for Tourism. *MATTER: International Journal of Science and Technology, 2*(1).

Moksony, F. (1990). Small is beautiful. The use and interpretation of R2 in social research. *Szociológiai Szemle, Special issue*, 130-138.

Moran, M. S., Bryant, R., Thome, K., Ni, W., Nouvellon, Y., Gonzalez-Dugo, M., . . . Clarke, T. (2001). A refined empirical line approach for reflectance factor retrieval from Landsat-5 TM and Landsat-7 ETM+. *Remote Sensing of Environment, 78*(1-2), 71-82.

Mustafa, F. A., & Bayat, O. (2019). Water surface area detection using remote sensing temporal data processed using MATLAB. *The International Journal of Electrical Engineering & Education, 0020720919851500*.

Othman, A. A., Shihab, A. T., Al-Maamar, A. F., & Al-Saady, Y. I. (2020). Monitoring of the Land Cover Changes in Iraq *Environmental Remote Sensing and GIS in Iraq* (pp. 181-203): Springer.

Robertson, C. (2009). Iraq suffers as the Euphrates river dwindles. *The New York Times, 13*.

Rogan, J., & Chen, D. (2004). Remote sensing technology for mapping and monitoring land-cover and land-use change. *Progress in planning, 61*(4), 301-325.

Sameen, M. I., Al Kubaisy, M. A., Nahhas, F. H., Ali, A. A., Othman, N., & Hason, M. M. (2014). Sulfur Dioxide (SO^ sub 2^) Monitoring Over Kirkuk City Using Remote Sensing Data. *Journal of Civil & Environmental Engineering, 4*(5), 1.
Shehab, A. T., Al-Ma'amir, A. F., & Jabbar, M. F. A. (2010). Change detections in marsh areas, south Iraq, using remote sensing and GIS applications. *Iraqi Bulletin of Geology and Mining, 6*(2), 17-39.

Wu, M., Zhang, W., Wang, X., & Luo, D. (2009). Application of MODIS satellite data in monitoring water quality parameters of Chaohu Lake in China. *Environmental monitoring and assessment, 148*(1-4), 255-264.

Yaseen, A. k., Mahmood, M. I., Yaseen, G. k., Ali, A. A., Mahmod, M., & Mustafa, A. H. (2018). Area Change Monitoring of Dokan & Darbandikhan Iraqi Lakes Using Satellite Data. *Sustainable Resources Management Journal, 3*(2), 25-41. doi: [http://doi.org/10.5281/zenodo.1284844](http://doi.org/10.5281/zenodo.1284844)