

**Monitoring of Mosul Reservoir Using Remote Sensing Techniques For the Period After ISIS
Attack in 9 June 2014**

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1- Introduction

The Mosul Dam is the fourth largest dam in the Middle East, (1) established in 1986 to obstructing about 11 billion cubic meters of water from rushing down the Tigris River towards Mosul then to Baghdad. (2) Regarding to structural surveys from the Union of Iraqi Scholars and the US Army Corps of Engineers, the dam is threatening imminent collapse, which would affect the lives of millions of Iraqis living downstream of the dam – ultimately killing anywhere between 500,000 to 1.47 million people. (1) Therefore it takes the interesting of many researches and studies, this is one of them.

Many studies used remote sensing techniques to monitor water bodies. Coloring method used to recognize the details of Delta in the mouth of the Mackenzie River in Canada, with an area of about 12 000 km² and containing thousands of small lakes and hundreds of kilometers of river channels (3).

Optical and thermal bands of satellite images provide both spatial and temporal information used to understand changes in water quantity and quality in more than 20,000 water bodies across America (4). Reflectance in the range from 400 to 950 nm used to monitor water bodies to evaluate water quality and pollution (5), the same range of visible and near infrared used in this study.

2- Aims of Study

After the attack of ISIS to Mosul, it is difficult to reach and control the dam. The aim of the study is using Landsat satellite images to monitor the reservoir of Mosul dam to estimate the water level and use these information to reduce the dangerous of dam damage may happened.

3- Area of Interest

The area of interest selected to monitor the reservoir of Mosul dam and the surrounding area especially to the south near to Mosul City as shown in Map 1 bellow. This area match the aims of the study. The area of Interest about 95 x 65 km, in location between the coordinates bellow in Geographic coordinate system and UTM, WGS-84 Datum.

A- Geographic

Upper left corner : 36°57'04.34"N ; 42°16'13.58"E

Lower right corner: 36°22'21.38"N ;43°06'56.06"E

B- UTM zone 38

Upper leftcorner: 255630 E , 4089120 N

Lower right corner : 330120 E , 4028250 N

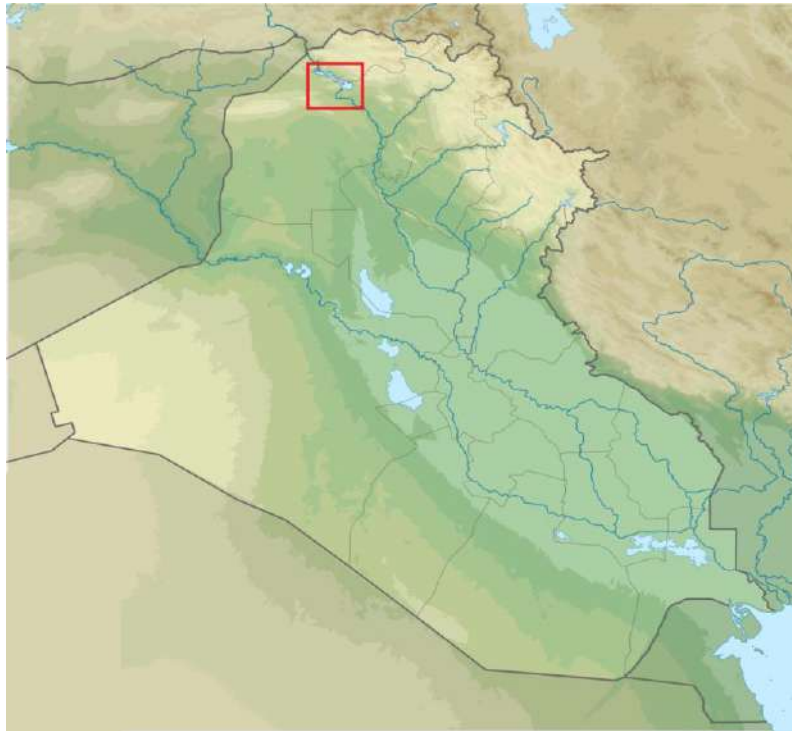


Figure (1) – Area of Interest

4- Data and Tools Used

The following data and tools were used in this case study,:-

- 1- 17 Scenes of Landsat -8, in different dates. From USGS.
- 2- Image Processing Software ERDAS Imagine V. 14.
- 3- GIS Software Geomedia Professional V.13.

4-

5- Methodology

Possibility of using image processing as a tool of monitoring of water bodies in both quantity and quality (6). The methodologies used in different researches are not standard, so the procedure used is specialist procedure for this case study.

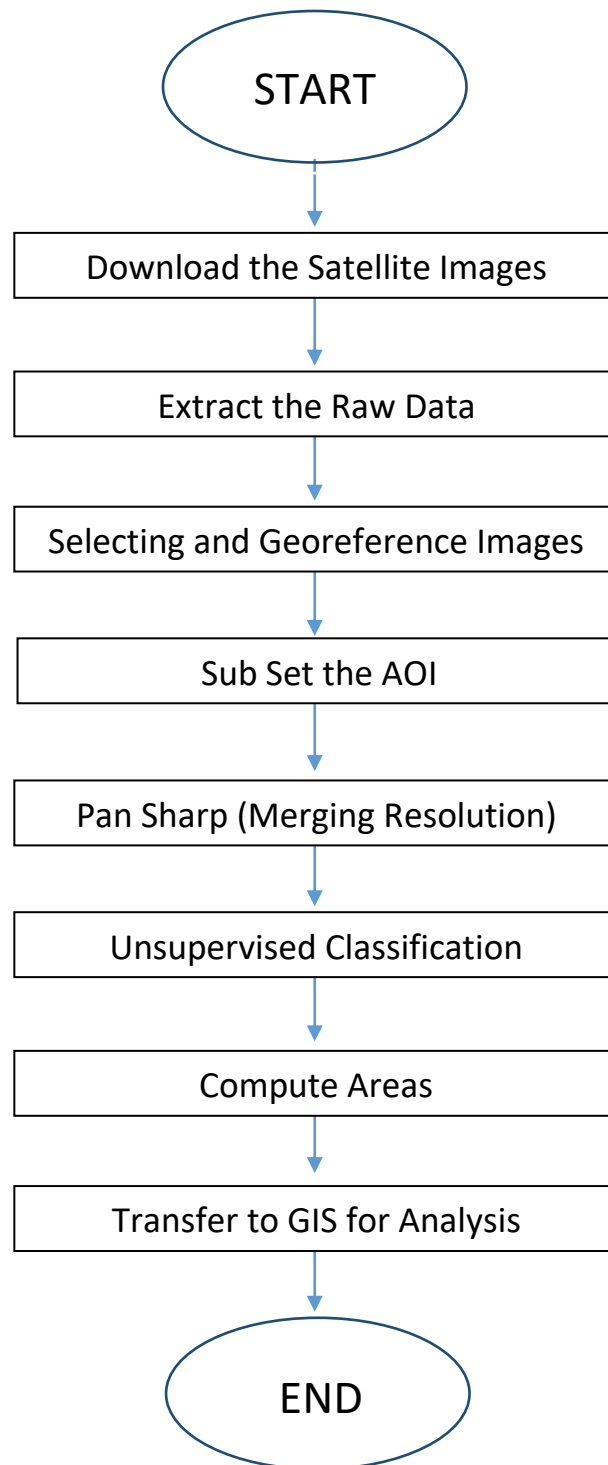


Fig (2) bellow mention to flow chart of methodology.

5.1 Download Satellite Images

The website of United State Geological Survey USGS provided satellite images and many types of maps for free, LANDSAT Images one of the data provided there. Account was created, area of interest was defined before and download 17 images available in period between June 2014 and February 2016.

5.2 Extract the Raw Data by ERDAS and Selecting Images

USGS provided data in compressed form to make the download easier, ERDAS Imagine software has a tool designed specially to extract this form to get the raw bands. After the extraction all images reviewed to check the capability of process and analysis. 10 scenes from 17 collected were selected for process and 7 neglected because of the cloud or snow that cover the main target in the study (Reservoir). Table 1 illustrate these scenes and mention the selected ones, the field of image number refers to the image date in the system of LANDSAT where typing the year and the number of the day in the year.

Table (1) Images used in the study

No.	Image Number	Image Date	Selection
1	2014_160	09 Jun 2014	Y
2	2015_019	19 Jan 2015	Y
3	2015_051	20 Feb 2015	N
4	2015_067	08 Mar 2015	N
5	2015_099	09 Apr 2015	Y
6	2015_131	11 May 2015	Y
7	2015_163	12 Jun 2015	Y
8	2015_179	29 Jun 2015	Y
9	2015_195	14 Jul 2015	Y
10	2015_227	15 Aug 2015	Y
11	2015_259	16 Sep 2015	N
12	2015_291	18 Oct 2015	Y
13	2015_323	19 Nov 2015	N
14	2015_355	21 Dec 2015	Y
15	2016_022	22 Jan 2016	N
16	2016_038	07 Feb 2016	N
17	2016_070	11 Mar 2016	N

5.3 Geo reference all Images

Regarding to the time between the sequence of images, features may shifted from a scene to the next scene. So geometric correction is required to geo reference all images together before making change detection or classification. The correction used here not by ground control points, where the target not to produce a map, the old image assumed as a reference image and all other images registered to that image. Fig (3) explain the situation of images before and after geo referencing.

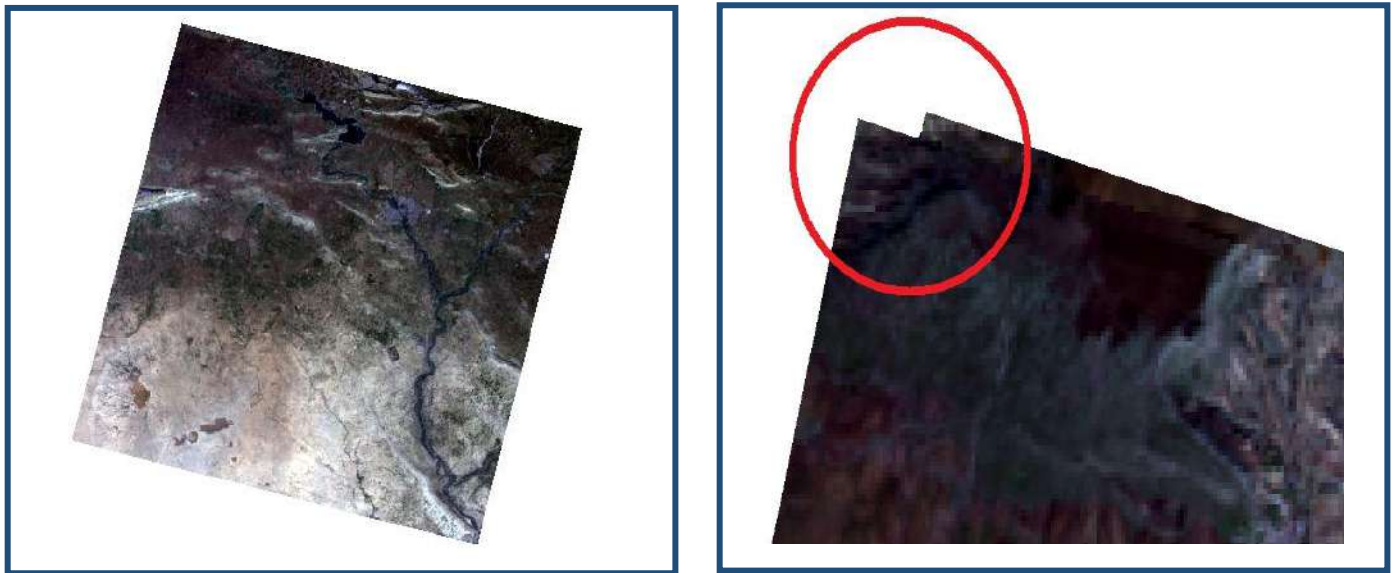


Figure (3), Image Geo referencing

5.4 Sub Set the AOI

It is known that Landsat image has a size of 185 x 185 Km, while area of interest about 95 x 65 km, so all images cropped to match the area of interest. The sub setting images reduced processing time where the area of interest is about 18% of the scene area. Fig (4) bellow includes sample of sub setting process, annex(1) includes all application.

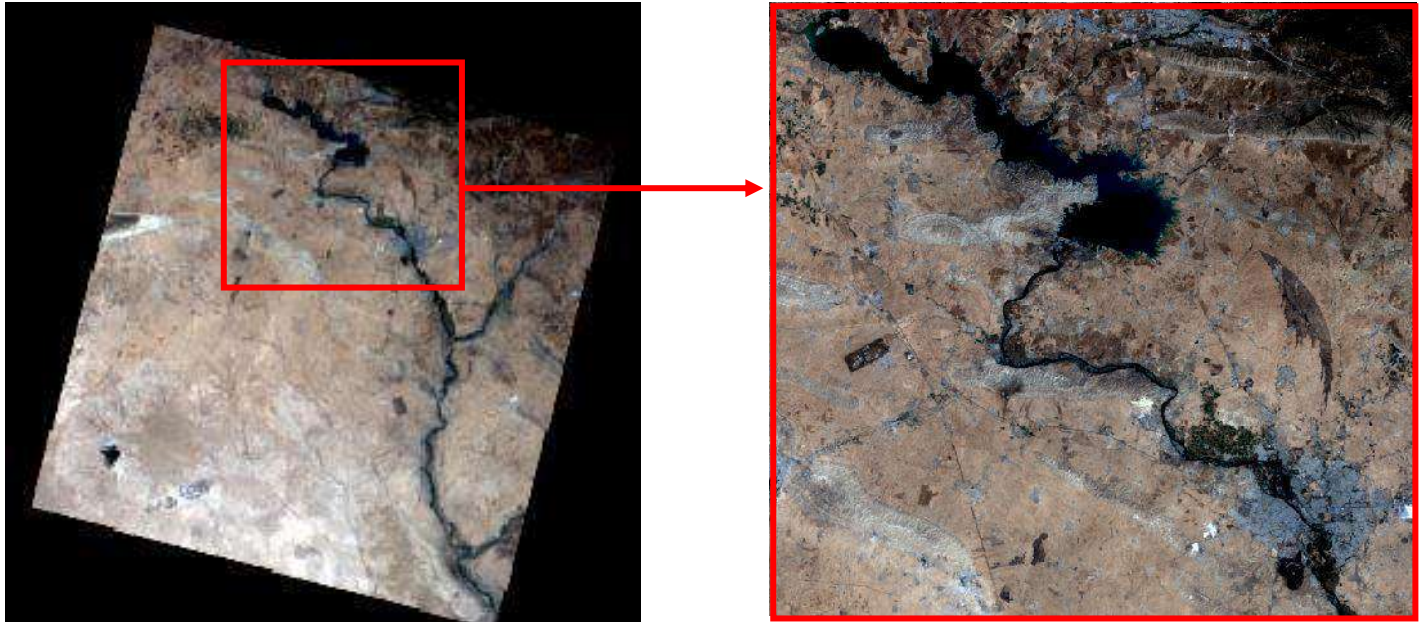
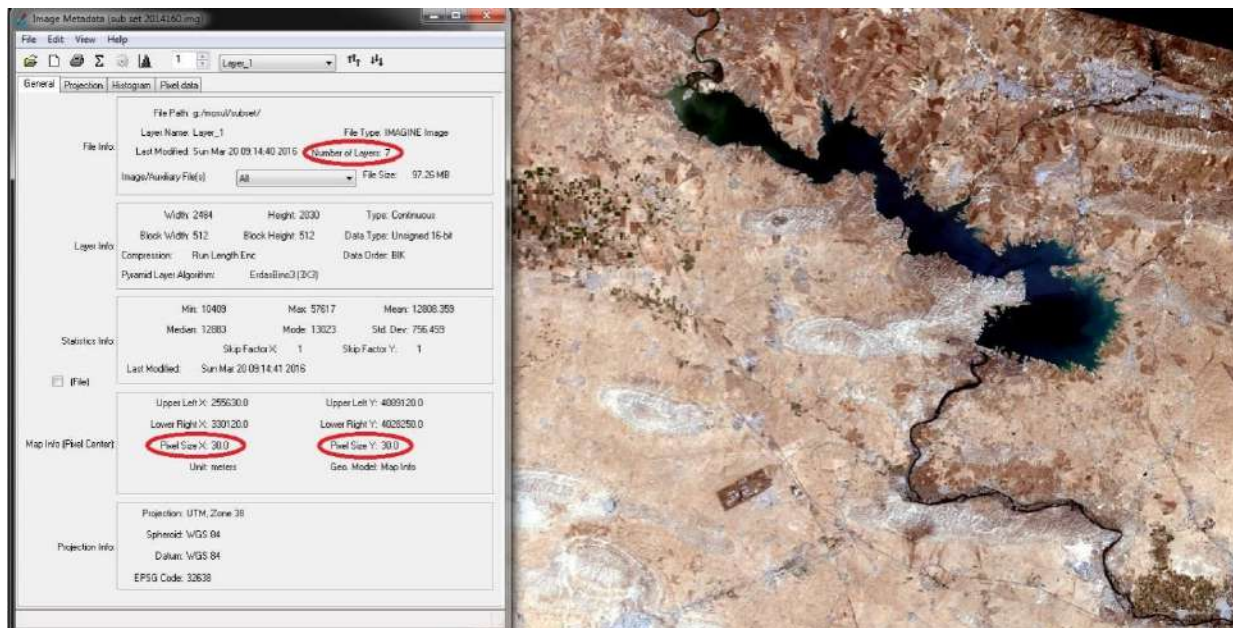


Figure (4), Image Sub setting

Landsat-8 images has 9 bands, 7 of them with 30m resolution, the panchromatic band with 15m resolution and the thermal band with 60m resolution. Pan sharpened is the process of merging the 7 bands of 30m resolution with the panchromatic band of 15m resolution to obtain 15m resolution image with 8 bands, Fig (5) explain image sample before and after pan sharpened. Thermal band not used in this study.



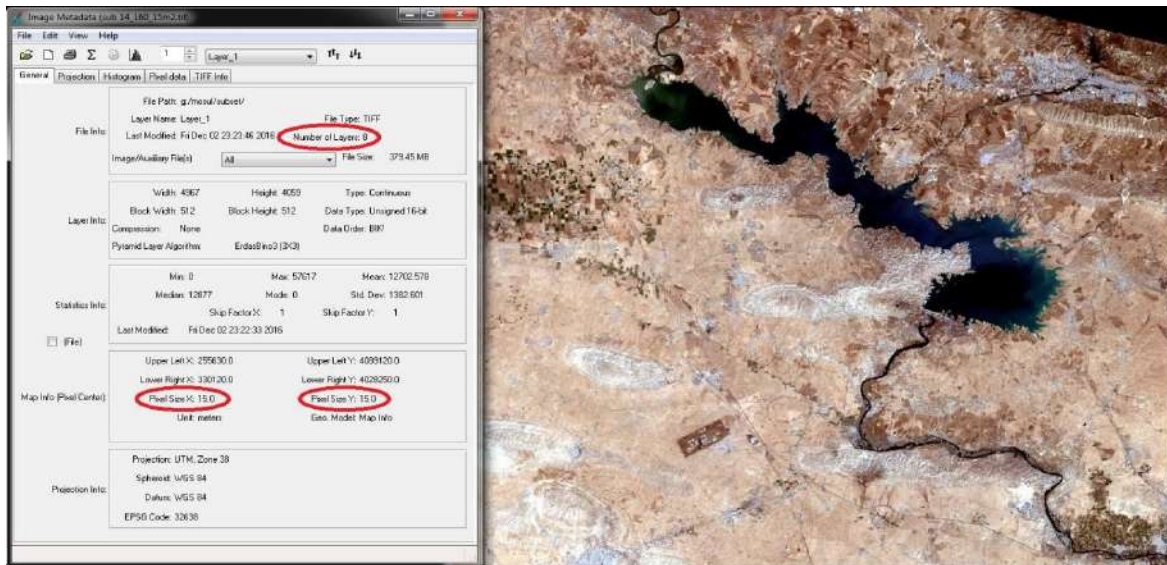


Figure (5), Image pan sharpening with meta data

5.6 Classification

While the field survey is impossible in area of interest because of the dangerous. Unsupervised classification may be the most suitable process can achieve the aims of the study. The main target of the study is to calculate the area of Mosul Reservoir in each scene to make the comparison, but by the way we made 4 classes. The areas calculation is a normal and easy process by adding area field to the table of classification result directly in ERDAS Imagine. Fig (6) below includes sample of unsupervised classification process, annex (2) includes all application.

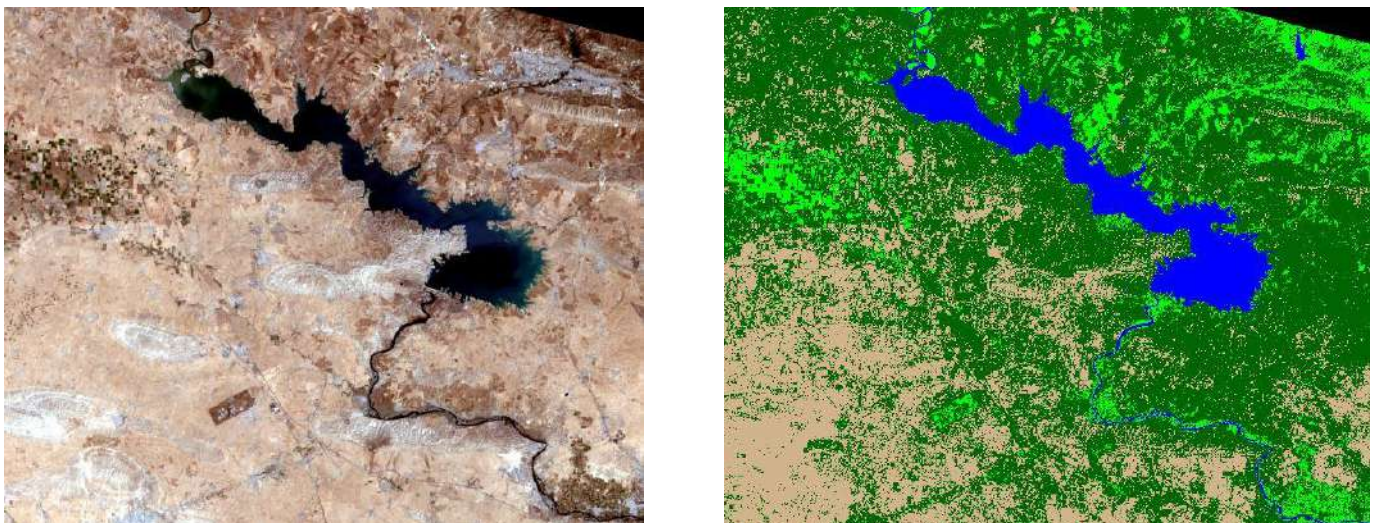


Figure (6), Image unsupervised classification

5.7 Convert Data to GIS

ERDAS Imagine software used for image processing is produced by Hexagon which produced GIS software called Geomedia Professional, by using the link in ERDAS to convert the data directly to Geomedia. after the unsupervised classification. Geomedia Professional V.13 used to produce histograms and bar charts.

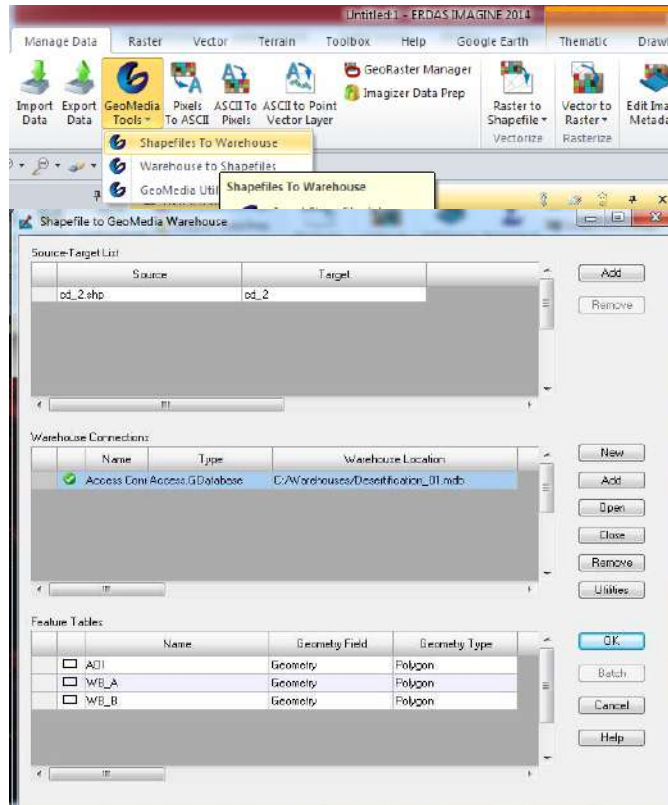


Figure (7) – Data Transform From ERDAS to Geomedia

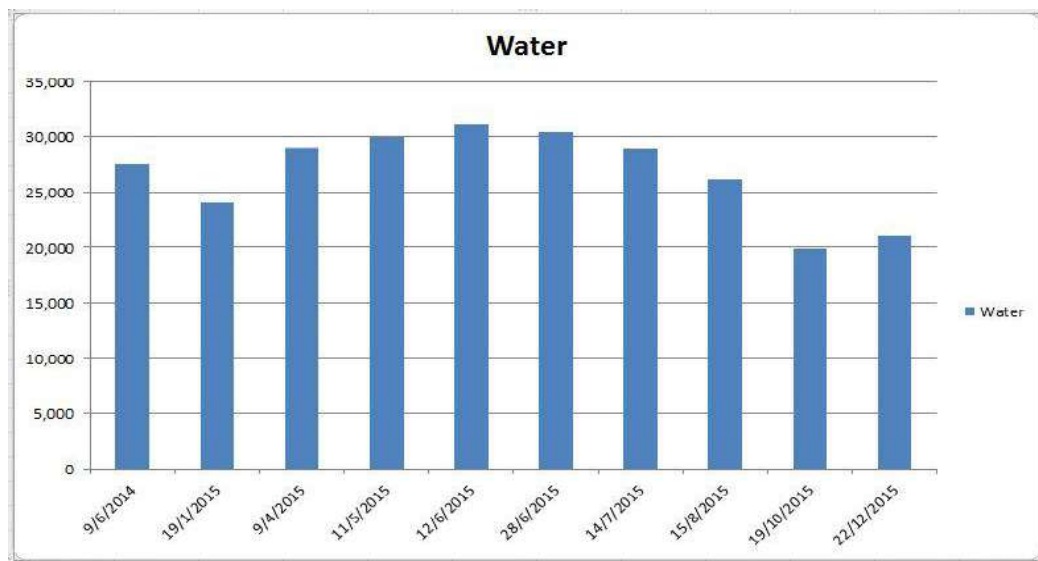
6- Results

The results collected in table (2) below which explain the summary of the processes done before. And the chart focuses on water body area only where it is the target of the study. While the area reflects the water level where any increasing in the water level will expand the area of the water body, figure (8) is the chart of water level in the periods studied.

By following the results, we find that the Ministry of Water Resources manages the reservoir normally similar to the previous years by collecting water in winter and spring to compensate the shortage in summer.

Table (2) Mosul Reservoir Area (Hectare) per date

No.	Date	Mosul Reservoir Area (Hectare)
1	9/6/2014	27,599
2	19/1/2015	24,055
3	9/4/2015	29,001
4	11/5/2015	29,968
5	12/6/2015	31,170
6	28/6/2015	30,417
7	14/7/2015	28,853
8	15/8/2015	26,132
9	19/10/2015	19,859
10	22/12/2015	21,036



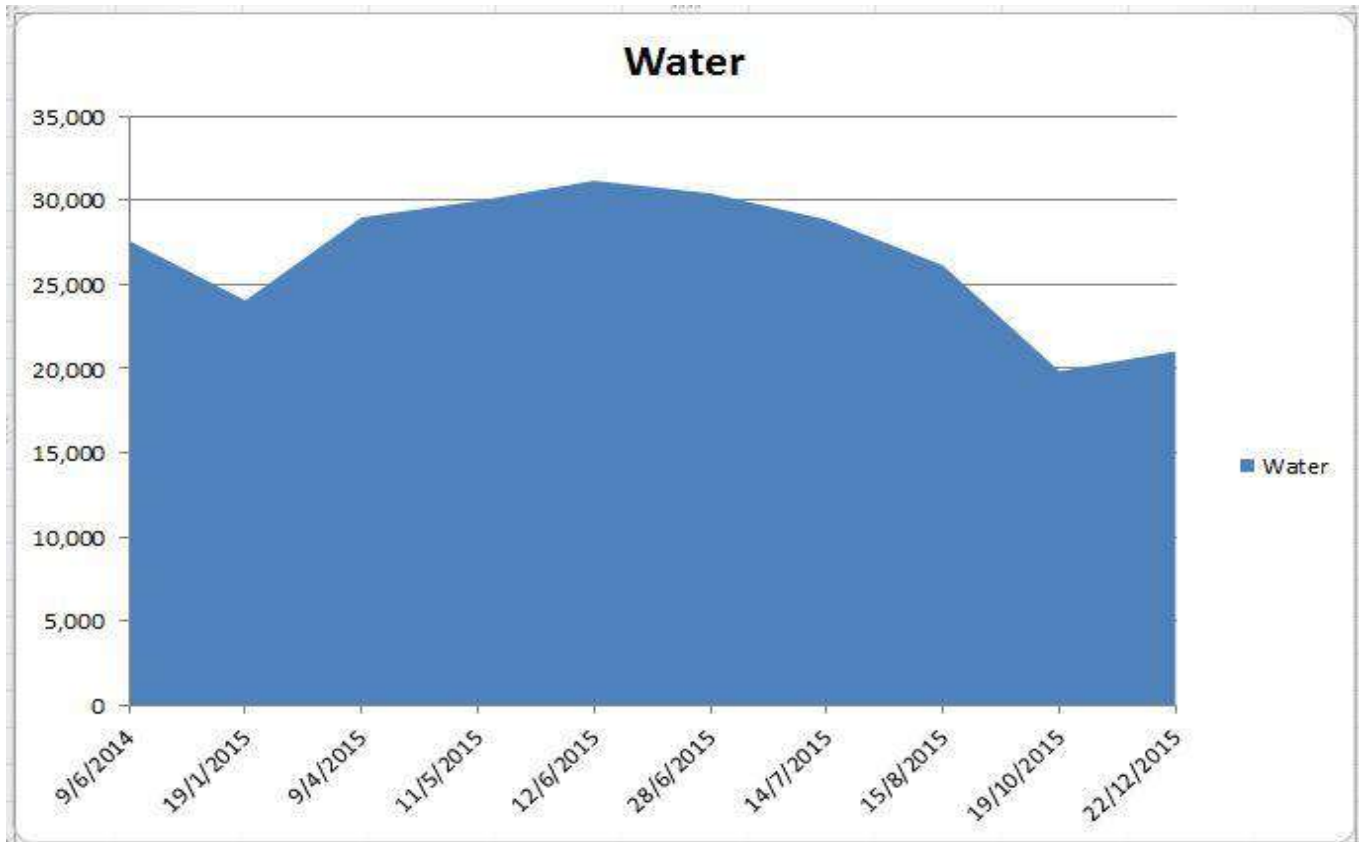


Figure (8) – Histogram and Bar Chart for Reservoir Area with date

7- Conclusion

After the classification process, the area of water body calculated for each image, data base for the 4 classes created using Geomedia Professional GIS software, then table, histogram and bar chart produce to illustrate the water level movement per time.





We confirm that:-

- 1- We can monitor water bodies by using satellite images.
- 2- We can study water level expansion and reduction by Remote Sensing techniques.
- 3- We can got good results and fast estimation.
- 4- The link between ERDAS and Geomedia very important for feeding data base more details from the Image processing to use the capabilities of GIS analysis.

8- References



1. Mosul Dam Crisis, by: International Foundation Peace Ambassadors for Iraq
2. Mosul Dam Issue File, by: The Middle East Seismological Forum Special Reporting.
3. Monitoring the Water Bodies of the Mackenzie Delta by Remote Sensing Methods, by: MARIE-CATHERINE MOUCHOT, THOMAS ALFOLDI, DANIEL DE LISLE and GREG McCULLOUGH
4. Remote Sensing Techniques for Determining Water Quality, by: Jerry C. Ritchie and Charles M. Cooper
5. Monitoring of Polluted Water Bodies by Remote Sensing, by: Anatoly A. Gitelson, Robert Stark, Gideon Oron, and InkaDor
6. Monitoring of Polluted Water Bodies by Remote Sensing, By: Anatoly A. Gitelson /University of Nebraska - Lincoln, and Robert Stark / Ben-Gurion University of the Negev


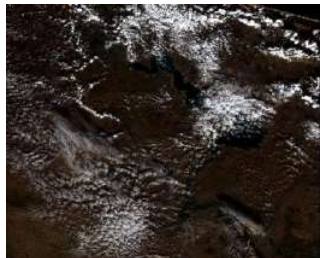


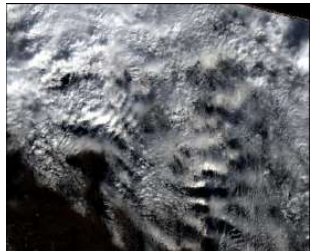
Annex (1)


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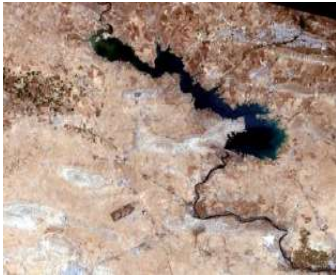


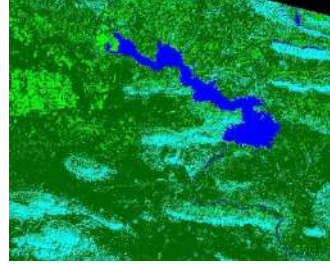


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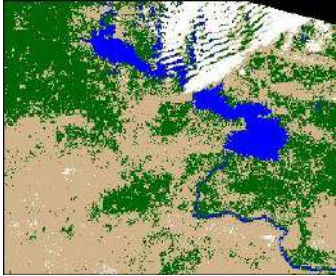

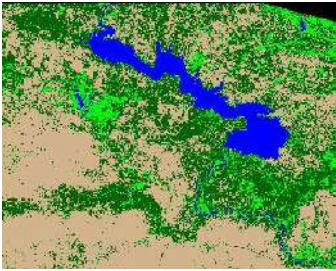

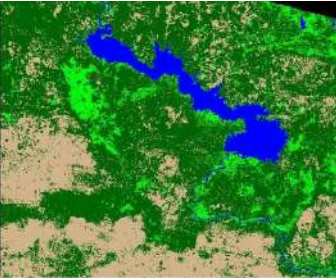



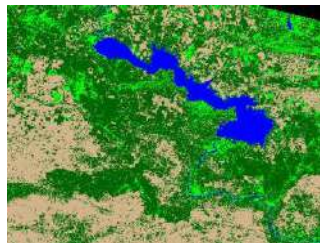
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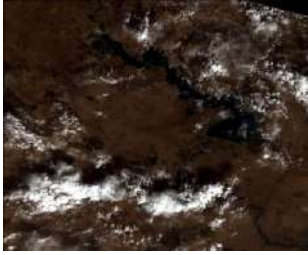

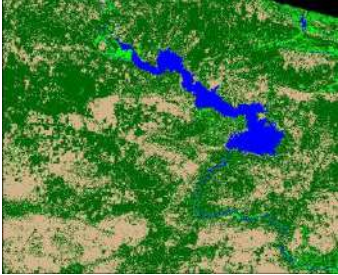




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Annex (2)

No.	Image Number	Preview	Classification
1	2014_160		
2	2015_019		
3	2015_051		
4	2015_067		
5	2015_099		

			
6	2015_131		
7	2015_163		
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