Using Remote Sensing Technology for Environmental Pollution Detection in Iraq

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Abstract: In this article, the Environmental pollution in Iraq was studied by using the remote sensing techniques for the period (2010-2014). In general, the environmental pollution can be divided into three major parts: Air, Water, and soil pollutions. To overcome the problem, multi-satellite images with different resolution and bands at different dates were used to detect and quantize the source of pollutions. Also, many adaptive digital image processing algorithms were used to evaluate the results. The digital processing was implemented using well-known package and written subroutine in Visual Basic and Matlab program. The results show that major Air pollution caused by dust and sand storms, sulphate dioxide, and some oil refinery gases. In addition, major water pollution caused from the urban the sewerage water pumped by the sewerage and water treatment stations and the low river levels that increased in the last few years. Finally, the agricultural degradation and desertification led to the soil pollution.

Keywords: Air pollution, Remote sensing, Soil pollution, Water pollution.
I. INTRODUCTION

The significant aim of this paper is to identify the main contaminated and polluted areas which may threaten the environment and human health, and to offer recommendations for risk remediation and reduction. The Iraqi environmental was polluted through multi-purpose and factors. Also, significant pollution phenomena arise in the last few years such as dust / sand storms, and increasing of weather temperature, [1, 2]. In this study, the remote sensing and image processing techniques were used to identify the pollution materials and quantity the amount of their effect on the environment. The MODIS satellite imagery was used to study and quantity the pollution amounts for each case and factors. Also, the Quick-Bird Panchromatic image was used to identify the pollution in the Tigris River. The research methodology starts from data gathering at the significant action such as dust / sand storms, sulfur dioxide, oil smoke, rivers sedimentation, and the urban activity and wastewater. The geometric correction process was performed using first order transform, image to image method; the reference images were set of LANDSAT ETM+14.25 m resolution, exposure at 2013. The digital remote sensing techniques were used to enhance and distinguish each pollution case. The ENVI, (Environmental Visualize Image) version 4.5 and Global Mapper version 9.1 were used to evaluate the geometric correction. The results show that the main pollution occurs in the air due to sulfurs dioxide, smoke of oil, fire smoke, and dust / sand storms.

The river pollution can be noticed clearly in the Southern part of Tigris River in southern part of Baghdad directly. Also, due to low water resources supply, the sedimentation can be detected in the Arabian Gulf caused by Tigris and Euphrates.

II. REGION OF INTEREST AND AVAILABLE DATA

A. Region of Interest

The region of interest is all Iraq area, coordinates, (upper left corner Lat. 36.5°, Long. 39.5° down right coroner Lat. 28°, long 48°) as shown in Figure 1. The fertile land Mesopotamia, which is now called Iraq, has been dominated over the centuries by a number of empires. Its capital city, Baghdad, located between the Tigris and Euphrates rivers, was the most important cultural and commercial center in the entire Muslim world. Iraq is in both the eastern and northern hemispheres. The country is located in the Middle East, a recognized geographical region of southwestern Asia. It is bordered by the Arabian Gulf, and by the countries of Kuwait, Iran, Turkey, Syria, Jordan and Saudi Arabia. (Land) 166,859 sq. miles (432,162 sq. km), (water) 1,895 sq. miles (4,910 sq. km), (TOTAL) 168,754 sq. miles (437,072sq km). Due to large region of interest, the MODIS (or Moderate Resolution Imaging Spectroradiometer) satellite imagery have been used to classify and extract the action such as dust / sand storms, sulfur dioxide, oil smoke, rivers sedimentation, and the urban activity and wastewater. The geometric correction
process was performed using first order transform, image to image method, the reference images were set of LANDSAT ETM+ 14.25 m resolution, exposure at 2013. The digital remote sensing techniques were used to enhance and distinguish each pollution case. The ENVI, (Environmental Visualize Image) version 4.5 and Global Mapper version 9.1 were used to evaluate the geometric correction. Figure 2 shows the processing of methods of this research. The results show that the main pollution occurs in the air due to sulfurs dioxide, smoke of oil, fire smoke, and dust / sand storms. The river pollution can be notice clearly in the Southern part of Tigris River in southern part of Baghdad directly. Also, due to low water resources supply, the sedimentation can be detected in the Arabian Gulf caused by Tigris and Euphrates. The MODIS is a key instrument aboard the Aqua (EOS PM) and Terra (EOS AM) satellites. Aqua passes south to north over the equator in the afternoon, while Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning. Aqua MODIS and Terra MODIS are viewing the entire Earth's surface every 1 to 2 days, obtaining data in 36 spectral bands, or groups of wavelengths, [3]. The selected data was downloaded from the NASA Visible Earth website at the significant pollution actions. All data ground spatial resolution is 250 m, the largest resolution. The spectral bands of each image were in the visible bands. The captions and date of each image will be summarized for each pollution categories. Also, the Quick-Bird panchromatic image 0.6 m spatial resolution was used to identify the pollution in the Tigris River. The used imager will be shown according to each caption and characteristics.

Figure 1 Map of Iraq
B. Data Used

Figure 3 shows the available data that used in this research as following:

(1) Toxic sulfur smoke across Iraq, Sensor Aqua / MODIS, Visualization Date 2013-07-07, spatial resolution 250m.

(2) Oil smoke in Southern Iraq (afternoon overpass), Sensor Aqua / MODIS, Visualization Date 2014-03-24, spatial resolution 250 m.

(3) Smoke plume from oil fire near Baghdad, Iraq, Sensor Aqua / MODIS, Visualization Date 2013-07-02, spatial resolution 250 m.

(4) Dust Storm over Iraq, Sensor Aqua / MODIS, Visualization Date 07/30/2014, spatial resolution 250 m.
(5) Sediment from the Tigris and Euphrates Rivers, Sensor Terra/ MODIS, Visualization Date 2011-11-29, spatial resolution 250 m.

(6) Urban Activity, Baghdad, Sensor Quick-Bird panchromatic, Visualization Date February 2012, spatial resolution 0.6 m, Geo-referencing, UTM projection, WGS-84 Datum.

Figure 3 Available Data Used
III. GEOMETRIC CORRECTION PROCESS

In all remote sensing applications, the geometric correction is essential and important process. It involves, image rotation, re-coordinate with map projection and datum, and scaling. These steps can be automatically preformed through the process. The output geo-images are holds the map coordinates, directed with the true north of map, and with new convenient scale, [2, 4]. The geometric process was performed using image to image, 1st order transform, according to LANDAT ETM+ mosaic scenes of IRAQ (2010-2011) as reference images. 3-band synthetic natural colours were produced from the 32 ortho- rectified scenes. The 3-band images with a spatial resolution of 14.25 meters. Many of the 32 scenes were originally UTM, zone 38, WGS84. Some western Iraq scenes were originally UTM, zone 37, WGS84, and had to be re-projected to zone 38 prior to mosaicing. The mosaic products are in UTM, zone 38, WGS84. The mosaic was created by histogram matching the images and feathering along cut lines. The full tiled mosaic file size is approximately 16 GBs, [5]. The large image size (for reference image) cased to un-display it in this paper. The direct GCPs fitting was used in each image correction, (6-points were used in direct fit between input images and reference). The GCPs tables dose not display in this paper because they out of scope. The 1st order transform is the simple and best in many geometric process, [6]. Twice number of GCPs required from the min. number of GCPs (3 points). The total RMSE, (Total Mean Square Error) was (3- 5) meter for MODIS, Aqua / and Terra sensors (250 m) in spatial resolution. The process was evaluated using the Global Mapper version 9.1 package, the output images format were (tif) format. Al geometric process include two processes in the same time, first, transformation, second, Resampling, [7]. For first order transform, the transformation equations can be given as following:

\[
\begin{align*}
X_0 &= a_0 + a_1 x_m + a_2 y_m \\
Y_0 &= b_0 + b_1 x_m + b_2 y_m
\end{align*}
\]

Where \( X_0, Y_0 \) are map coordinates ( meter) \\
\( x_m, y_m \) are input image coordinates ( pixel )

\[
\begin{bmatrix}
a_0 & a_1 & a_2 \\
b_0 & b_1 & b_2
\end{bmatrix}
\] : are transformation coefficients. In order to evaluate all GCPs values, Least Square criteria was used through matrix notation such as;
Where:

\[
Q = \begin{bmatrix}
a_0 \\ a_1 \\ a_2
\end{bmatrix}
\]

\[
K = \begin{bmatrix}
X_{o1} \\ X_{o2} \\ X_{o3} \\ \vdots \\ X_{on}
\end{bmatrix}
\]

\[
M = \begin{bmatrix}
1 & x_{m1} & y_{m1} \\ 1 & x_{m2} & y_{m2} \\ 1 & x_{m3} & y_{m3} \\ \vdots & \vdots & \vdots \\ 1 & x_{mn} & y_{mn}
\end{bmatrix}
\]

\[
R = \begin{bmatrix}
b_0 \\ b_1 \\ b_2
\end{bmatrix}
\]

\[
L = \begin{bmatrix}
Y_{o1} \\ Y_{o2} \\ Y_{o3} \\ \vdots \\ Y_{on}
\end{bmatrix}
\]

Resampling is the second important process, it is the process of output image file creation, [8]. Three famous interpolation methods can used in resampling such as; nearest neighbor, Bilinear, and cubic convolution. The resampling involves image data interpolation pixels value. In all correction process, the output images are often low sharpness, i.e. low contrast, this is due to the resampling interpolation of image data. The Quick-Bird image was already georeferencing into the same above projection and datum. Each image hold two projection systems, UTM, (Red) grid line & geographic, (Green) grid line in same scale for first five images.

**IV. POLLUTION EXTRACTION TECHNIQUES**

For pollution extraction, many remote sensing and image processing techniques have been used to identify each pollution case. Our task is quantity each pollution feature from the satellite imagery. This can be accomplished through the spatial pixel resolution and each class area.

Ratio Image Transform; The first method was image ratio transform, this algorithm consists of computing the ratio of the values of corresponding bands; if no changes, (the changes may be between two images or between the same image bands) are occurred, the result is unity, while if changes were existed in a particular pixel, the ratio will
be either considerably more or less than unity (depending on the “direction” of the change), [9]. The Mathematical expression of the ratio function is;

\[ B.R = \frac{Band(1)}{Band(2)} \]  

The computation of B.R is not always simple since B.R = 0 is possible. The way to overcome this problem is to replace any zero B.R value with a value of one. Alternatively, some like to add a small non-zero value to the denominator of equation (3) if it equals zero. To represent the range of the function in a standard 8-bit image format, normalization function can be applied. Using this normalization function, the ratio of 1 is assigned the brightness value 128, while those have the range between 1/255 to 1 are reassigned values between 1 to 128, using;

\[ B.R = \text{int}(B.R \times 127) + 1 \]  

(4)

The ratio values between 1 and 255 are assigned values between the range 128 and 255, given by;

\[ B.R = \frac{\text{int}(128 + B.R)}{2} \]  

(5)

Figure 4 represent the sulfur smoke pollution extracted by the band ration transform. The figure shows a massive sulfur dioxide plume from the fire eruption at the Al-Mishraq State Company. The result show that the sulfur smoke cross Iraq to Iran and if cover approximately 1/3 from image area where total sulfur smoke are nearly equal to 21000 square km. The UNEP, (United Nations Environment Program) report revealed that the leaves of more than 40% of trees in a radius of 100 km from the sulfur plant have already dropped. There is a serious need to expansively assess the environmental and health impacts of this incident, [1, 2]. The result was obtained using blue band (1st) as numerator, and the green band (2nd) as denominator. The class of sulfur smoke appears in gray tone, where other images features, such as soil, water appear bright or dark tone respectively. The smoke can be identifying clearly because there was exiting change between the two bands in the same image. This was due the spectral characteristics of each bands detector that construct the image. The result of this pollution case was evaluated through written subroutine in visual basic 6.0 facility with help of above equations and thresholds value.
A. Supervised Classification

The second method was minimum distance supervised classification used to extract the oil smoke in the southern of Iraq. The Supervised classification is the more popular technique used in remotely sensed classification [10]. In this technique the signature spectra are typically identified by a remote sensing analyst from a set of image pixels of known land cover / use classes. A sample of the pixels in each known cover type is selected as “Region of Interest (ROI)” or training set. By applying these signatures to images, they would detect those pixels which contain the ROI using some decision rule, such as maximum likelihood, spectral distance or other techniques. The Minimum-Distance-Mean Classifier has been used to determine the mean value in band 2 for every category at first. The pixel values include the mean vector for every category, and the pixel of unknown identify might be classified via computing the distance between the value of the unknown pixel and of the category mean. After the distance is computed, the unknown pixel is assigned to the “closest” category. If the pixel is farther then an analyst- defined distance from any category mean, it would be categorized as “unknown”, [11]. Three (ROI) have been sued as well as the unknown pixels, oil smoke, (red), water, (blue), soil & sand (yellow), and the unclassified pixels (black). Therefore, the oil smoke pixel was extract using zeros matrix, shown in Figure 5. The total area that affected by the smoke was approximatlyl11000 square km.
B. Image Slicing

The (GIS) Geographic Information System facility was used to extract the pollution of fire smoke near Baghdad using the image slicing method. The total polluted area was about 9500 square km affected by the fire smoke as shown in Figure (6).

C. Vegetation Indices

The new method was the (NDVI) Normalized Difference Vegetation Index transform. This was a widely used vegetation index in which multi-spectral data transformed into a single image band representing vegetation distribution. The NDVI values indicate the amount of green vegetation present in the pixel, where more green vegetation indicated by higher NDVI values [12]. This method was used to detect the dust storm over Iraq at 30-7-2009. The image bands were 1, 4, 3 respectively. In this transform, multi-bands divisions were used to extract many
vegetation indices. This method, the division of band 2 (NIR), to Band 3, (Red) was used to extract the NDVI transform. The low vegetation amount yield the soil (dust & sand) represent. Therefore, figure (7) show the dust storm (dark tone) which represent the low amount of vegetation. That was a new method in dust detection. According to NOAA Air Resources Laboratory, there are small, yet distinct differences between sand and dust storms. A “sandstorm” is mostly a wind storm that carries sand through the air, and form a fairly low cloud near the ground. Usual sandstorms contain particles of sand with sizes between 0.15 to 0.30 millimetres in average, reach up to 15 m (49 feet) heights, with wind speeds more than 16 Km per hour and last as long as wind speeds continue. "Dust storms" are similar phenomena but have distinctly different characteristics. Stronger storms have dust to 2650 -3300m, while it may reach 900-1800m as an average height. Dissimilar in pure sand storms, dust particles are very small that can be lifted in the air by currents of turbulent air and carried into suspension. Haze and dust with extreme storms were recognized as high as 11500-13250 m, [7]. From figure (7), the dust cover 70% from country area, therefore, from above information, the user can estimate the amount of dust and sand in the air using simple calculation.

Figure 7. The Dust Storm Cross Iraq, 2014

D. Image Differencing

The direct approach to change detection is an image differencing. Image pixels of the earlier image are subtracted from those of a co-registered more recent one [13]. The subtraction results in negative and positive values in areas of radiance changes, and zero values in areas were no changes occurred. Mathematically, the procedure can be expressed as:

\[ I \cdot D. = \text{band1} - \text{band2} + c \]  \hspace{1cm} (6)

Where; I. D. is the new image resulting from differencing. C, is regulating value.
In this method, the change was calculated between band 1, (Blue) and band2, (Green), this was true result due to the pixel value changes in the individual bands in the same image. The multi-bands remote sensing system record the multi-spectral images with high bands correlation, but, the pixel values for the same feature are different from band to the another[10]. Figure 8 shows the sedimentation in grey tone in the Arabian Gulf, the area affected by sedimentation was approximately 35000 square km.

![Sedimentation in Arabian Gulf from the Tigris and Euphrates Rivers](image)

**Figure 8 Sedimentation in Arabian Gulf from the Tigris and Euphrates Rivers**

**E. River Pollution**

Also, the minimum distance, supervised classification method was used to extract the pollution in the Tigris River in the southern part of Baghdad. Due to sewerage water pumped by the sewerage and water treatment station, the waste water was drained directly to the river. Two selected regions of interest have been used to extract the drained waste water. The first ROI was clear water, (Blue), where, the second was waste water, (Yellow) and the unclassified class, (Black). Figure 9 represent the classification results that appear clearly the waste water distributed in the river basin near the station.
The polluted area is approximately 0.15 square km. Also, the results show that not only the pollution drained with the river flow direction, but it distributed in the opposite direction. Table I concludes each pollution type area in square km.

**TABLE I: THE POLLUTION FOR EACH TYPE**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>33% scene</td>
<td>11000</td>
<td>9500</td>
<td>70% scene</td>
<td>35000</td>
<td>0.15</td>
</tr>
</tbody>
</table>
V. CONCLUSION

The remote sensing techniques were used to detect and quantity the multi-pollution types in the Iraq Environmental. The available data was 5 MODIS Aqua / Terra images and Quick-Bird image. The pre-processing was performed to rectify and enhance each image. A 6 pollution event have been detected through different remote sensing methods. The first technique was image rationing used to detect the pollution from the sulphur smoke from Al-Mishraq State Company. The minimum distance supervised classification method was used to extract the oil smoke in the southern of Iraq and the pollution in the Tigris River in the southern part of Baghdad, Al-Dora wastewater treatment plant. The (GIS) image slicing facility was investigated to identify the fire smoke pollution near Baghdad. The NDVI recognitions method has been used to extract the dust storms over Iraq. Finally, the image differencing transform was used to detect the pollution of sedimentation in the Arabian Gulf caused from the Tigris and Euphrates Rivers. In all above techniques, user can calculate and quantity the amount of each pollution case.

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REFERENCES


