

DIGITAL TECHNIQUES FOR MONITORING CHANGES IN WATER-BODY USING SATELLITE IMAGE

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Abstract

In this paper, two pairs of temporal TM, and ETM+ (28.5 spatial resolution) images have been used to detect the change in water body. The first study area was the (Mosul Aski Dam, 1984 to 2002) in the upper Jazirah (located approximately 60 km northwest of Mosul city), the geographic corners coordinates was (Lat. $36^{\circ} 37' 30''$ to $36^{\circ} 55' 00''$ N, Long. $42^{\circ} 30' 00''$ to $43^{\circ} 00' 00''$ E). The second was the area of remaining Marshland areas (Hawr Al-Hawizeh /Al-Azim, 2000 to 2002), the geographic corners coordinates was (Lat. $31^{\circ} 44' 13.62''$ to $31^{\circ} 26' 32.5''$ N, Long. $47^{\circ} 27' 0.32''$ to $47^{\circ} 50' 00''$ E), Southern East of Iraq. Image to map registration with first order polynomial has been adapted to correct images from geometric errors. An adaptive matching technique (depend upon the UTM coordinates projection) has been performed to match the two temporally images. Three digital algorithms have been utilized to detect the change between the two images; i.e. image differencing, image ratioing, and PCA methods. The total RMS error (registration & matching process) was less than 1 meter.

الخلاصة

في هذا البحث، تم استخدام زوجين من الصور الفضائية المتعددة الأطياف و الأوقات للمتحسسات (ETM+ & TM) بقدره تمييز 28.5 متر) لكشف التغيرات في المياه. منطقة الدراسة الأولى هي سد اسكي موصل للفترة (1984 إلى 2002) والواقع شمال مدينة الموصل بحوالي 60 كيلومتر، إحداثيات الأركان الجغرافية هي (خط عرض $36^{\circ} 37' 30''$ إلى $36^{\circ} 55' 00''$ شمالاً، خط طول $42^{\circ} 30' 00''$ إلى $43^{\circ} 00' 00''$ شرقاً). أما المنطقة الثانية فهي المساحة المتبقية من هور الحويزه للفترة (2000 إلى 2002) والذي يقع في الجزء الجنوبي الشرقي من العراق، إحداثيات الأركان الجغرافية هي (خط عرض $31^{\circ} 44' 13.62''$ إلى $31^{\circ} 26' 32.5''$ شمالاً، خط طول $47^{\circ} 27' 0.32''$ إلى $47^{\circ} 50' 00''$ شرقاً). تم تصحيح الصور من الأخطاء الهندسية باستخدام متعددة حدود من الدرجة الأولى وجعلها مطابقة للخرائط الطبوغرافية. استخدمت طريقة مطورة لمطابقة الصور (تعتمد على شبكة الإحداثيات UTM). استخدمت ثلاث طرق رقمية لكشف التغيرات في الغطاء الأرضي لمنطقتي الدراسة وهي: طريقة الفرق بين الصور، طريقة النسبة بين الصور و طريقة تحليل المركبات الأساسية (PCA). في عمليات التصحيحات الهندسية ومطابقة الصور فقد كان الخطأ الكلي بحدود أقل من متر.

Introduction

Monitoring *land-use* and *land-cover* changes has become one of the most important implementation for the remotely sensed purposes. Although the concept of change detection may be looked relatively simple, there are a number of important factors that must be considered to perform, correctly, the detection.

It is very important that the different dated images being viewed at the same seasonal calendar. Images obtained at different times of the year may appear dissimilar even if no changes have been occurred. Generally, variations in image brightness may not be caused by just the reflectance of the *Earth's*

surface, but also because of the different atmospheric components, [1].

In this research, the two studied areas have a dramatic change in landscape due to waterlogged in the first area and water-waterless in the second area. The United Nations Environmental Program UNEP was studying the two study areas. In the first region, a dramatic change in the landscape following the construction and of the Mosul Aski dam. Where, in the second region of interest, the study finds that rapid environmental change has taken place in the Iraqi marshlands. Indeed, after over a decade of precipitous decline – by 2003, [2]. Accordingly, three digital change detection algorithms have been utilized to evaluate the resulted change images such as, differencing, ratioing, and principal component analysis. The two pairs of temporary images were preprocessed for geometric correction using 1st order polynomial direct GCPs image to map registration. After that, each images pair was matched together according to map coordinates with the help of adaptive digital method.

Study Areas and Available Data

The first studied area was the (Mosul Aski Dam, 1984 /2002) in the upper Jazirah (located approximately 60km northwest of Mosul city), the geographic corners coordinates was (Lat. 36° 37' 30" to 36° 55' 00" N, Long. 42° 30' 00" to 43° 00' 00" E). The average elevation is 280 meter, the area described as ragged terrain with much type of vegetation, and much rock erosion can be viewed. The second was the area of remaining Marshland areas (Hawr Al-Hawizeh /Al-Azim, 2000 & 2002), , the geographic corners coordinates was (Lat. 31° 44' 13.62" to 31° 26' 32.5" N, Long. 47° 27' 0.32" to 47° 50' 00" E), Southern East of Iraq. The average elevation is 12 meter, the area is a flat terrain, and the marsh plants is available in the region. The first image pair was Mosul Aski is multi-band Landsat TM (bands 2,4, and 7) exposed during October (1984 to 2002), see figure (1a). While, the second data sets are multi-band Landsat ETM+ images bands 2,4, and 7 exposed during May (2000 to 2002), shown in figure (1b). All images spatial ground resolution was 28.5m. The images of each set have been rectified and matched according to map coordinates system, the detail of rectification and matching process were out of scope of this paper. The geo-matched four real images will be illustrate in appendix A.



1984



2002

a- (Landsat -5 TM bands 2,4, and 7, Matched Image Area)



2000



2002

b- (Landsat-7 ETM+ bands 2,4, and 7, Matched Image Area)

Figure (1): Geo-Matched Available Data Pairs

Digital Change Detection Algorithms

At the first aerial photography, change detection can be evaluated by the visual comparison of photos. This process is slow, tiring, and is subjected to numerous errors of omission. Moreover the huge multi-band satellites images make the process more difficult. The world seeks for digital methods to solve the change between two set of imagery. The change detection methods should be included a sensor system with following conditions;

1. Systematic period between two or more images (repeatable capability).
2. Scan and see the same geographic site at the same time of day to minimized diurnal sun angle effect (sensor should be sun-synchronous).
3. Same geometric and radiometric parameters (the image ground resolution and extension).
4. Reduces relief

5. Recording of reflection or emitting radiant flux in consistent and useful spectral region, [3].

Change detection is an important application for remotely sensing of environmental areas, it may means different things to different user depending on the details of changes required. In general change detection is a process of identifying differences in the state of object or phenomena by observing them at different time. The fundamental assumption of digital change detection is that; there exit a difference in the spectral response of *Digit Number* (DN) of two images for the same considered area [4]. The reliability of the process may also strongly affected by multi environmental factors that might change between dates. Furthermore, there are many another factors influencing change

between two different data imagery; e.g. atmospheric, wind, soil moisture condition, and Lake Level. However, accurate change detection result depends on a variety factor associated with the data set and the adopted image processing technique. In the registration and matching process, errors within (0.25) or (0.5) pixel is generally required in all digital change detection methods, [5]. The following three methods have been considered to detect the changes in the water body.

1-Image Differencing

It is one of the simplest digital algorithms for detecting changes within an image. As it finds, image differencing means taking an image at one point in a time and subtracting it from another image at later time. Since each 8-bit band has digital values ranging from 0-255, the total potential range is -255 to +255. Usually, a constant is added to the resulting value so that the differences are all positive. Given perfectly normalized images, any existed variation in brightness would mean change in the land cover. Potential errors can be introduced via source noncontiguity's and poor registration. The procedure can be expressed as, [6];

$$\|CD_{ijk} = DN_{ijk}(t_2) - DN_{ijk}(t_1) + C\| \quad (1)$$

Where: CD_{ijk} is the produced differencing image, $DN_{ijk}(t_2)$ and $DN_{ijk}(t_1)$ are the second and first image values, respectively. While C is a positive constant added to produce positive differencing image values (e.g. 255 for 8-bit image). Figure (2a), show the result of differencing process for the two pairs. The second area was traced with red polygon, will the first was non, because it appear clearly.

2-Image Ratioing

In this method, a ratio of the first image with respect to the second is considered. For example, if a pixel has a value of 100 in the first image and 200 in the second image, the ratio is 1/2. Consequently, the final values can range again from 0 to 255. Because of the equal statistical value of getting a number between 1/255 to 1, and 1 to 255, the ratios must be normalized. The ratio values of 1/255 to 1 are reassigned values of 1 to 128, whereas, the values 1 to 255 are reassigned values of 128 to 255. In areas where there is no change in the land cover, we expect to have a normalized value of 128, while any deviations from that represent change. A threshold is often used to

help filter source variations, figure (2b). The Mathematical expression of the ratio function is given as;

$$CD_{ijk} = DN_{ijk}(t_2) / DN_{ijk}(t_1) \quad (2)$$

Note: the computation of CD_{ijk} is not always simple because if $DN_{ijk}(t_1)=0$ then not possible. The way to overcome this problem is to replace any zero $DN_{ijk}(t_1)$ value with a value of one. Alternatively, one like to add a smaller non-zero value to the denominator of eq. (2). To represent the range of the function in a standard 8-bit format, normalization operation may be applied, the ratio of 1.0 is assigned to the brightness value 128, while those have the range between 1/255 to < 1.0 are reassigned values between 1 to < 128.0, using:

$$(CD_{ijk})_n = Int (CD_{ijk} * 127) + 1 \quad (3)$$

Accordingly, the ratios from 1-to-255 are assigned values within the range 128- to-255, given by :

$$(CD_{ijk})_n = Int (128 + CD_{ijk} / 2) \quad (4)$$

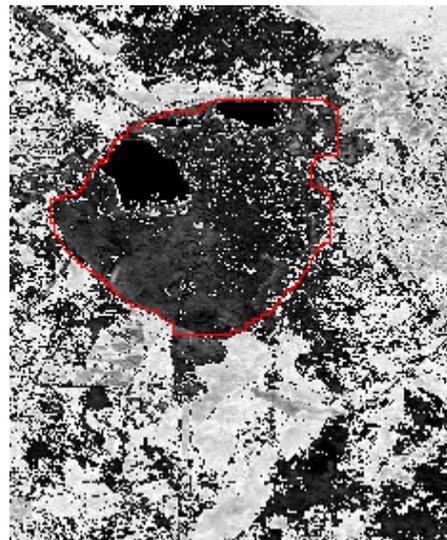
It should be noted that, all pixels having values 128 presenting the no-changed areas, others indicate changes. In fact, this result cannot be adopted because the ratio 0/0 goes to 0/1 and, thus, representing no-change areas. For this reason, the analyst must differentiate between change and no-change areas by utilizing threshold value, [3]. Figure (2b) demonstrates the image ratioing results for time 2 / time 1, (ETM+ & TM band -4). The rationing processing appear to be better than differencing for detection the water-body. The reason of band-4 selection was due to the wavelengths range which was suitable for identify the water-body.

3-Principal Components Analysis (PCA)

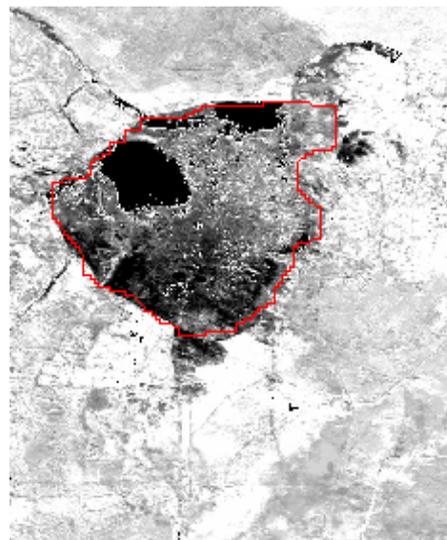
This algorithm is evaluated by mixed the spectral elements from all bands according to their statistical frequency among the image pixels. This technique does not reduce the search space, but rather reorganizes it resulting in a more manually intensive analysis. However, increasing use of PCA technique is being made in the remote sensing sciences, especially in reducing the dimensionality of the data sets, [7].

The PCA transform is used to overcome the problems arises from the environmental variations associated with different time imagery (i.e. As Enhancement Operator). In this paper, the PCA transformation is utilized to expanding bands numbers by newly band's images, (merge two image for each pair to extract 6-bands new image). The six images, acquired in different times, have been grouped and used to create six PC's that represent newly 6-bands. Uncorrelated principal components, in general, are presenting the changed areas. The shortcoming of this process is; the difficulties in

interpreting and identifying the specific nature of the involved changes or variations. However, the first PC, normally, represents the unchanged land-covers. Where, the 2nd and 3rd PC's include some changed information, while the last PC's contained uncorrelated information, such as random noise or changing patches [8]. Figure (3- a, & b) illustrates the results of change detection using image composite principal components. The Eigen values of this transformation are listed in table 1. Appendix (B), show the flowchart of the above three digital methods.



a- Image Differencing of Two Pairs



b- Image Ratioing of Two Pairs

Figure (2): Image Differencing and Ratioing Procedures, (ETM+, & TM, band-4)

Table (1): The Eigen Values of Principal Components Change Detection

<i>First Studied Area Analysis</i>					
<i>PC₁</i>	<i>PC₂</i>	<i>PC₃</i>	<i>PC₄</i>	<i>PC₅</i>	<i>PC₆</i>
0.086991	0.055558	0.045617	0.014337	0.011046	0.003523
<i>Second Studied Area Analysis</i>					
<i>PC₁</i>	<i>PC₂</i>	<i>PC₃</i>	<i>PC₄</i>	<i>PC₅</i>	<i>PC₆</i>
0.647563	0.304527	0.027470	0.012455	0.005848	0.002134

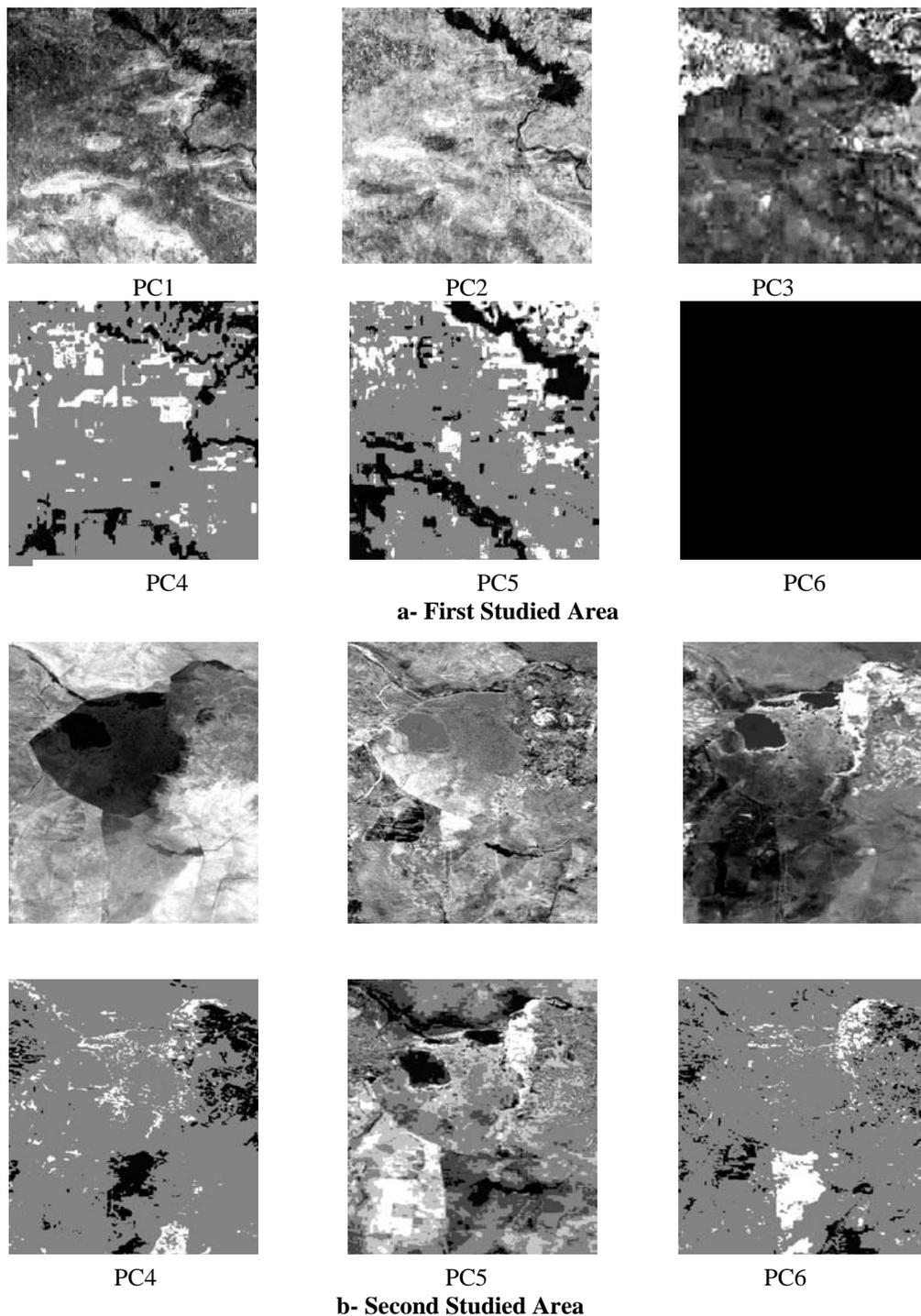


Figure (3): PCA as Change Detector for Composite Images

Results and Conclusions

1. Image differencing result showed the location of water reservoir of the Aski dam (lighter tone area), while the others brightness referring to the mainly fallow lands.
2. The ratioing result illustrates the location of water reservoir of the Aski dam only. Accordingly, *the ratioing detector may be considered as to be performed better than the differencing process.*
3. The principal components analysis yields six-components, first one indicate the no change image, where, the second showed the change in water area, figure (3) dark tone area. The other components represent uncorrelated data. The water supply from the new dam reservoir has enabled the implementation of modern irrigated agriculture.
4. The second considered area showed an opposite action; i.e. the marshland was declined due to drying process among the last few years. The differencing and ratioing results showed that the water area had been vanished, while the deeper area (i.e. still filled) appeared black. At this rate of loss, the marshes are likely to totally vanish within the next five years.
5. The Aski reservoir area can be estimate from the change second PC image, figure (3-a), approximately 348.192081km^2 . Where, in the marshes, the affected area can be calculated from the 2nd & 3rd PC's figure (3-b) approximately $971.3114960625\text{ km}^2$

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References

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Appendix A, The Geo-Matched Real Images

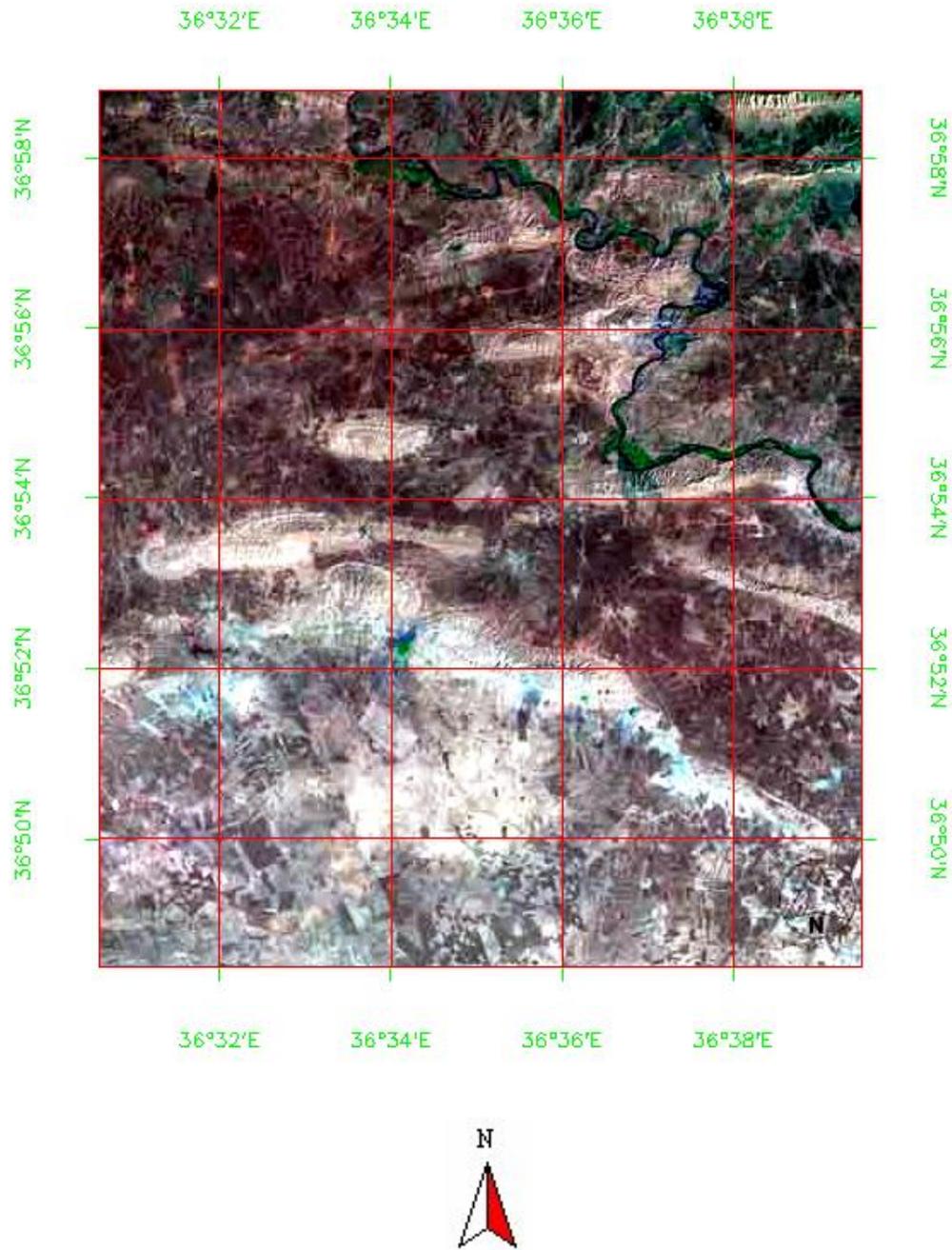


Plate (1): TM bands 2,4,and 7, October 1984, 28.5 meter Resolution

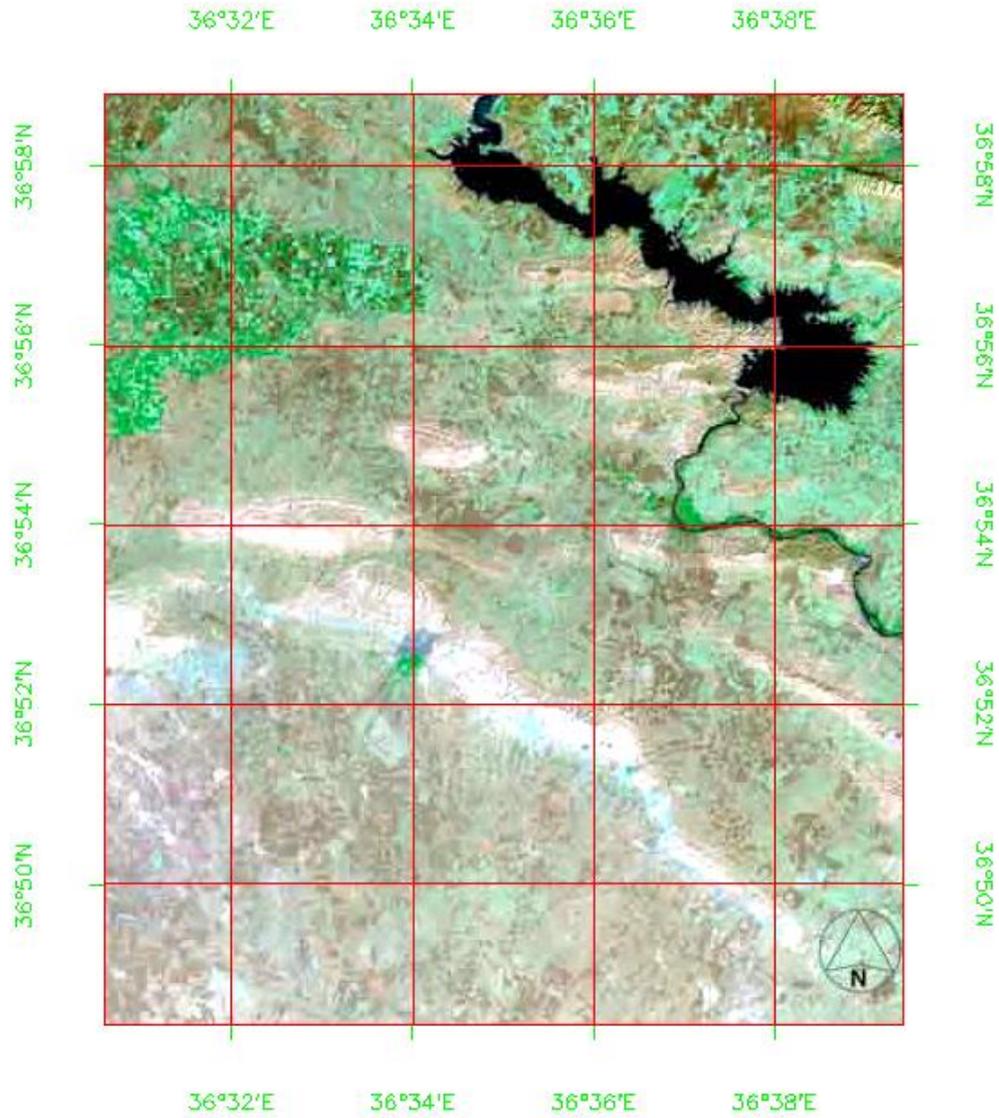


Plate (2): TM bands 2,4,and 7, October 2002, 28.5 meter Resolution

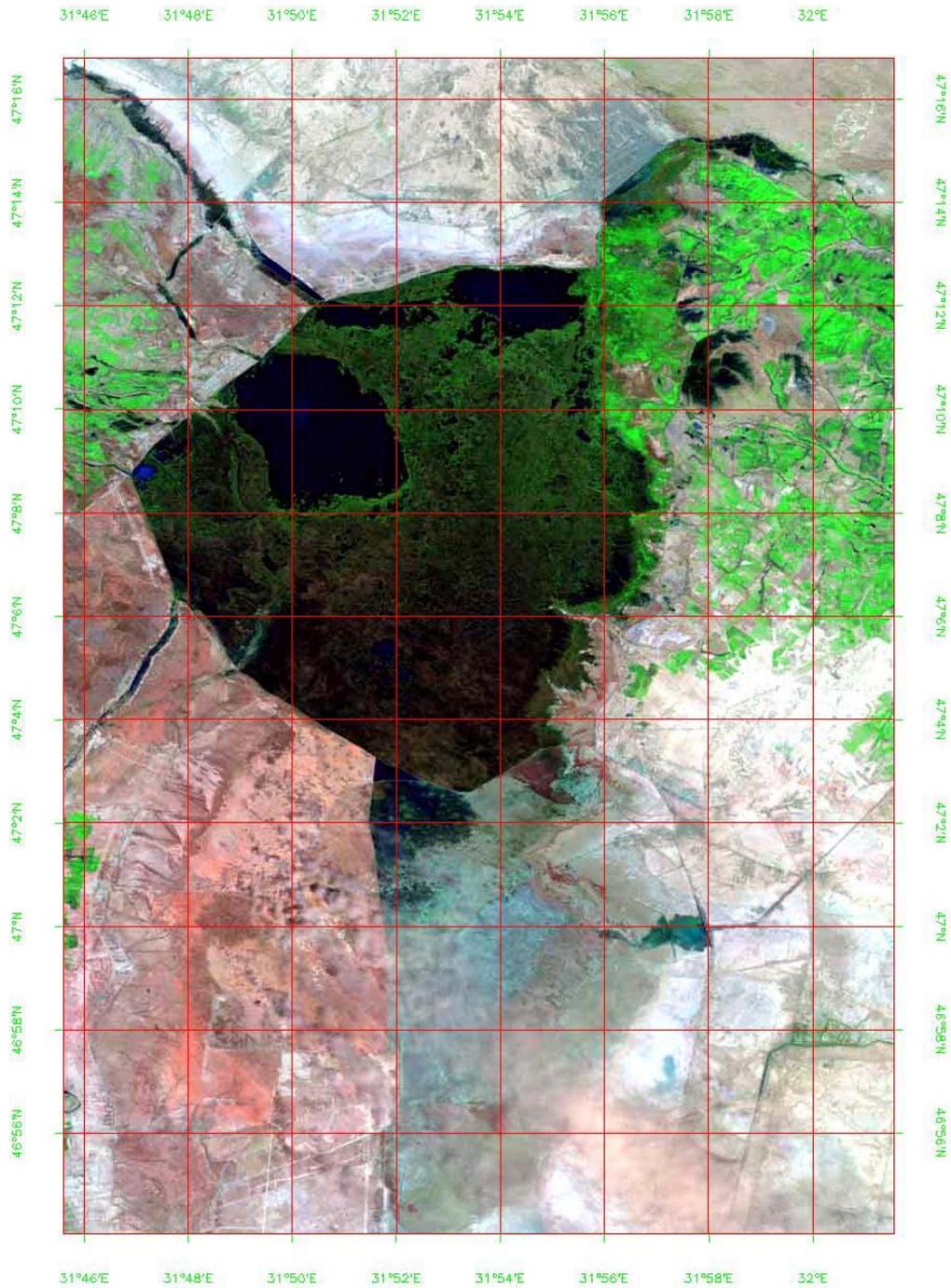


Plate (3): ETM+ bands 2,4,and 7, May 2000, 28.5 meter Resolution

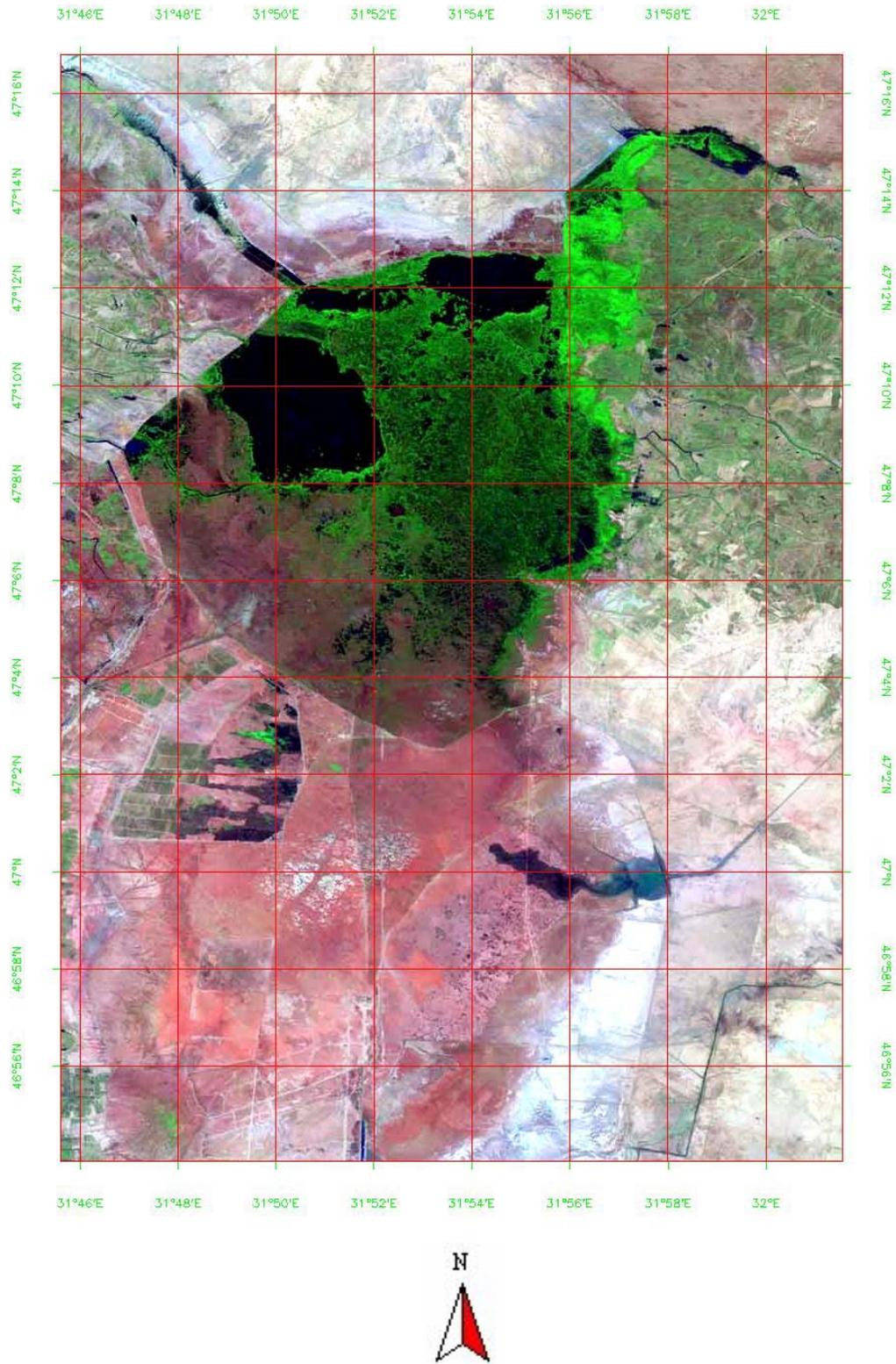


Plate (4): ETM+ bands 2,4,and 7, May 2002, 28.5 meter Resolution

Appendix B, The Digital Methods Flowchart Representation

