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Remote Sensing Model for Monitoring Trophic State of Al Huweizah Marsh

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Abstract

Remote sensing techniques were used to monitor the Trophic State Index (TSI) within Al Huweizah Marsh. The TSI is a function of Secchi depth (SD), which is a function of the spectral reflectance in Blue (TM1) and Red (TM3) spectrum bands. Satellite images of Landsat-7 ETM for February and March-2006 were selected and a series of remote sensing and digital image processing techniques and methods were applied on the selected images to extract the required data from these images. A set of measured SD and obtained spectrum reflectance from the Landsat ETM image of February-2006 were used to perform the calibration process by using the quasi-Newton optimization method. The calibrated model was applied on the marsh area by using the two selected images.

Results of applying this model show that the TSI values in most of the Iraqi parts of the marsh are between 40 and 50% and increased in the Iranian and the southern part of the marsh to about 70%. The developed model can be effectively used to estimate the TSI distribution pattern within the marsh.

Keywords: Remote Sensing Model, Trophic State Index, Al Huweizah Marsh.

نموذج تحسس نائي لمراقبة حالة الإثراء الغذائي في هور الحويزة

الخلاصة

تم إستخدام تقنيات التحسس النائي لمراقبة مؤشر حالة الإثراء الغذائي في هور الحويزة. إن مؤشر الإثراء الغذائي هو دالة لعمق ساكي وهو دالة لمقدار الطيف المنعكس ضمن الحزمتين الطيفيتين الزرقاء والخضراء. تم إختيار صورتين فضائيتين للقمر الصناعي / والمتحسس Landsat-7ETM لشهري شباط وأذار من عام 2006 وتم تطبيق سلسلة من تقنيات وطرق التحسس النائي ومعالجة الصور الرقمية على الصور المختارة لإستخلاص البيانات المطلوبة من هذهِ الصور. تم إستخدام مجموعة من أعماق ساكي المقاسة وقيم الإنعكاسية الطيفية المستخلصة من الصور الفضائية لشهر شباط لإجراء عملية المعايرة للنموذج بإستخدام تقنية كاوزي-نيوتن لإيجاد الحل الأمثل. تم تطبيق النموذج المعاير على مساحة الهور بإستخدام الصورتين الفضائيتين المختارتين.

بينت نتائج تطبيق النموذج إن قيم مؤشر حالة الإثراء الغذائي في معظم الجزء العراقي من الهور تتراوح بين 40% الى 50% وتزداد في الجزء الإيراني والجزء الجنوبي من الهور لتصل الى 70%. إن النموذج المطور يمكن إستخدامه بكفائة لتقدير انماط توزيع مؤشر الإثراء الغذائي في الهور.

Introduction

Al Huweizah Marsh is considered as the largest marsh at the southern part of Iraq. It is located at the east side of Tigris River at Maissan and Al Basrah

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Governorates. Protecting and monitoring marsh water quality is a major concern for many local and state agencies. Trophic state is useful in measuring water quality because it relates directly to both human-use perceptions of quality and to the abundance of algae. Thus, The three common water quality variables that indicate lake trophic state are total phosphorus (TP), chlorophyll a (chla), and Secchi depth (SD), (Kali, E. et al, 2003).

However, because of expense and time requirements for ground-based monitoring, it is impractical to monitor more than a small fraction of marsh by conventional field methods. Remote sensing techniques, Satellite images, are another tool that can potentially be applied to gather information needed for trophic state assessments.

Trophic State Estimation Model

Water clarity is an indirect measure of a marsh's trophic state, its status in terms of nutrient concentrations and biological productivity. Water clarity commonly is measured by the Secchi disk. The depth of disappearance is called the Secchi depth (SD).

Close correlations were found between water clarity, as measured by the Secchi disk, and light in the blue and red bands of the spectrum reflected from lake water surfaces and measured as "brightness" by satellite sensors. The general predictive equation that was found for water clarity estimation has the form, (Olmanson, L. G. et al, 2002):

$$\ln(SD)=a(TM1/TM3) + b(TM1) + c \quad \text{........(1)}$$

where a, b, and c are coefficients fit to the calibration data by the regression analysis, ln(SD) is the natural logarithm of the Secchi depth for a given water body, and TM1 and TM3 are the brightness values measured by the Landsat sensor in the blue and red bands, respectively.

SD can be used for water clarity measurements, along with various transformations such as the trophic state indices (TSI). The estimated SD can be converted to Carlson's trophic state index based on (Carlson, R. E., 1977):

$$TSI(SD) = 60-14.41 \ln(SD)) \quad \text{.......(2)}$$

It is important to recognize that other factors besides algal turbidity, as indicated by chlorophyll levels, may affect SD in marshes. Most important of these, non-trophic-state, factors are humic color and non-algal turbidity, including soil-derived clays and suspended sediment. For this reason, the results were presented based on SD calibrations as satellite-estimated SD or TSI (SD), which clearly identifies the value as an index based on transparency, rather than the generic term, TSI.

Remote Sensing Works

Digital Image Processing (DPI) may involve numerous procedures including formatting and correcting of the data, digital enhancement to facilitate better visual interpretation, or even automated classification of targets and features entirely by computer. In order to process remote sensing imagery digitally, the data must be recorded and available in a digital form suitable for storage on a computer tape or disk. Obviously, the other requirement for digital image processing is a computer system, sometimes referred to as an image analysis system, with the appropriate hardware and software to process the data. ERDAS 8.4

package was used to process and analyze the satellite images.

Satellite Image Selection

Landsat, particularly the Landsat-7 Enhanced Thematic Mapper (ETM), offers global coverage of Al Huweizah Marsh, with a resolution of 14.25m and revisit period of 16 days, (CCRS, 2002). This type of satellite images can be effectively used for the marsh water monitoring. Accordingly, the Landsat-7 ETM images of February and March- 2006 were selected to use for estimating the water clarity within the marsh.

Layer Stack and Image Subset

The selected images, Landsat-7 ETM, were of eight bands. In this research, only the visible range of the spectrum was required. Therefore; Three bands of the selected Landsat-7 ETM, ETM1, ETM2 and ETM3 and, were used. The selected satellite images of Al Huweizah Marsh were very large and include area outside the study region, area of interest AOI, which is specified according to CRIM, 2007. From these points the layer stack and image subset operations were applied on each image using ERDAS 8.4 package to reduce the sizes of images files, **Figures (1)** and **(2)**.

Converting Digital Numbers to Radiance.

Conversion of a digital number to its corresponding radiance is necessary when comparing images from different satellite sensors or from different times. Each satellite sensor has its own calibration parameter, which is based on the use of linear equation that relates the minimum and maximum radiation brightness. Each spectrum band also has its own radiation minimum and maximum. Information pertaining to the minimum and maximum brightness (L_{min} and L_{max} , respectively) is usually found in the metadata or from ERDAS 8.4 software by using imageinfo command. The obtained L_{min} and L_{max} for the three bands of each one of the selected images were listed in **Table (1)**, (US Army Corps of Engineers, 2003).

The equation for determining radiance from the digital number is (US Army Corps of Engineers, 2003):

$$L=(L_{max} - L_{min})/225\times DN+L_{min} \quad ...(3)$$

Where

L= radiance expressed in $Wm^{2}sr^{-1}$

L_{min}= spectral radiance corresponding to the minimum digital number (DN).

L_{max}= spectral radiance corresponding to the maximum digital number (DN).

DN= digital number given a value based on the bit scale used.

Depending on Eq. (3) and **Table (1)**, a digital image processing model was developed by using the extension Imagine Spatial Modeler component of the ERDAS 8.4 package to perform this conversion, **Figure (3)**. The result of applying this model is an image of three layers, bands, with extension of (.img). This model was applied on the selected two images.

Water Clarity Model Calibration

The variables a, b, and c of Eq. (1) are coefficients fit to the calibration data by the regression analysis. A set of measured SD at 20 points, (USAID, 2006), and the obtained spectral reflectance at these points from the selected Landsat-7 ETM of February- 2006, **Table (2)**, by using ERDAS 8.4 software, was used to perform the calibration process. This process was performed to obtain the variables of a, b and c by using the quasi-Newton optimization method. The results of the calibration process, **Figure (4)**, show that the values of the variable a, b and c are 2.309, -0.094 and -0.199, respectively.

Water Clarity Model Application

To estimate the TSI pattern within Al Huweizah marsh by using Eq. (1) and (2), an image processing model was developed by using Imagine Spatial Modeler component of the ERDAS 8.4 software to estimate the value of TSI in each pixel of the used image, **Figure (5)**. The output of this model is an image with pixel values equal to the estimated value of TSI in the corresponding positions of these pixels in the source image, input image.

The developed model was applied on the marsh area by using the selected Landsat ETM images of February and March-2006. The results of applying this model on the marsh area by using these two satellite images are shown in **Figures (6)** and **(7)**. These figures show that the TSI values in the water part of the marsh, where there is no vegetation, are fluctuated between 40 and 60%. These values increased in the vegetation part of the marsh to be between 60 and 70% because of the vegetation effect on the trophic state and on the obtained spectral reflectance in the red band, ETM3, from this part. At the soil part of the marsh, where it is not expected that true results can be obtained from Eq. (1), the TSI values are fluctuated between 90% and to greater than 100%.

Conclusions

Results of water clarity model application show that the developed model, Trophic State Index (TSI), an be effectively used to estimate the TSI distribution pattern within the marsh. In most of the Iraqi parts of the marsh, especially these named Al Adham, AsSodda and Um Alnaaj, the TSI values are between 40 and 50%. This indicates that these parts are trophicly poor. The values increased in the Iranian and the southern part of the marsh to about 70%. The TSI values within Al Adham, AsSodda and Um Anaaj parts of the marsh increased at March-2006 to about 60%. While at the southern part of the marsh it increased to about 80%.

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Table (1). Obtained L_{min} and L_{max} for the four bands of each one of the selected images (after US Army Corps of Engineers, 2003).

Image	Band	L_{min} $(Wm^{-2}sr^{-1})$	L_{max} $(Wm^{-2}sr^{-1})$
February-2006	ETM1	34	92
	ETM2	22	78
	ETM3	17	90
March-2006	ETM1	29	95
	ETM2	5	94
	ETM3	18	125

Table (2). Measured SD and obtained spectral reflectance.

Point no.	Location		Secchi disk (SD), (m) (After USAID, 2006)	Spectral reflectance	
	Easting	Northing		ETM1	ETM3
1	758522	3509844	2.64	42	19
2	759928	3510417	2.46	39	20
3	760813	3510261	2.83	36	18
4	762220	3510365	1.87	37	19
5	750396	3507657	1.63	38	23
6	750292	3507292	2.30	37	19
7	753365	3508126	0.76	41	29
8	745968	3503750	1.41	40	22
9	748781	3504323	0.47	41	28
10	744093	3501042	0.38	44	29
11	754615	3499739	0.29	41	31
12	753834	3504584	0.35	42	30
13	754927	3504896	0.62	39	26
14	740655	3486301	1.07	38	23
15	743052	3484842	0.09	43	37
16	745343	3483957	2.64	36	19
17	747114	3482707	0.27	40	26
18	754146	3473487	1.07	39	25
19	748885	3473904	0.47	40	28
20	743052	3449944	0.62	42	27

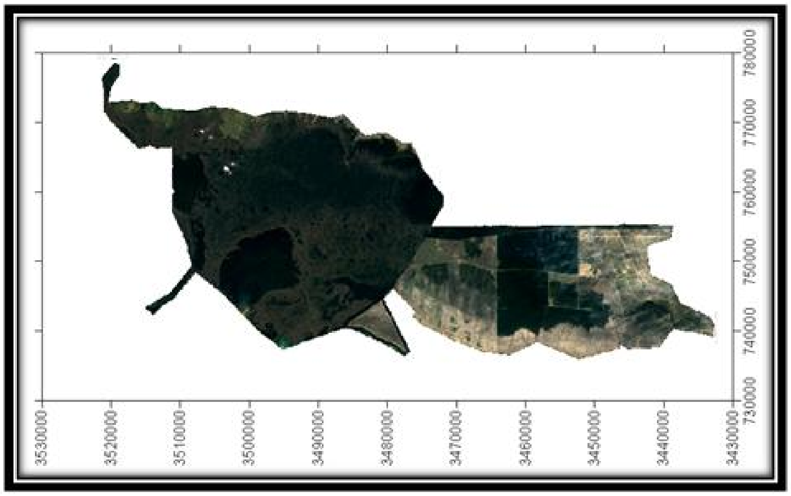

Figure (1). Landsat-7 ETM, 2/2/2006, 3-bands stack and subset

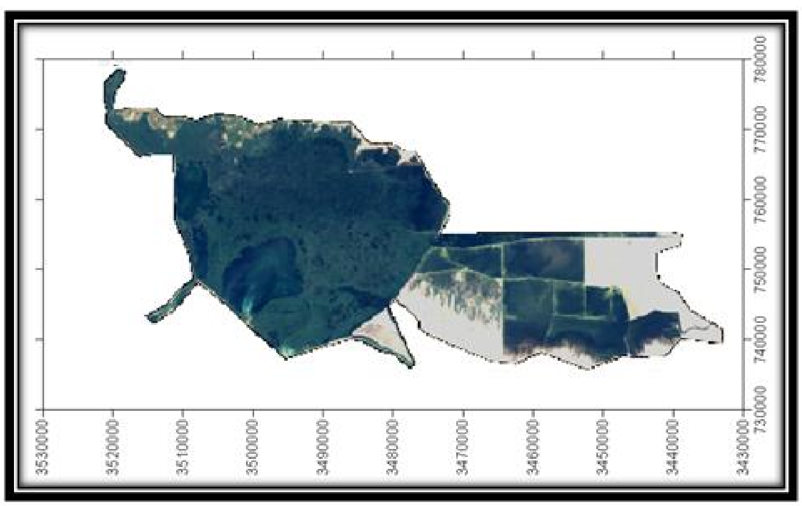

Figure (2). Landsat-7 ETM, 6/3/2006, 3-bands stack and subset.

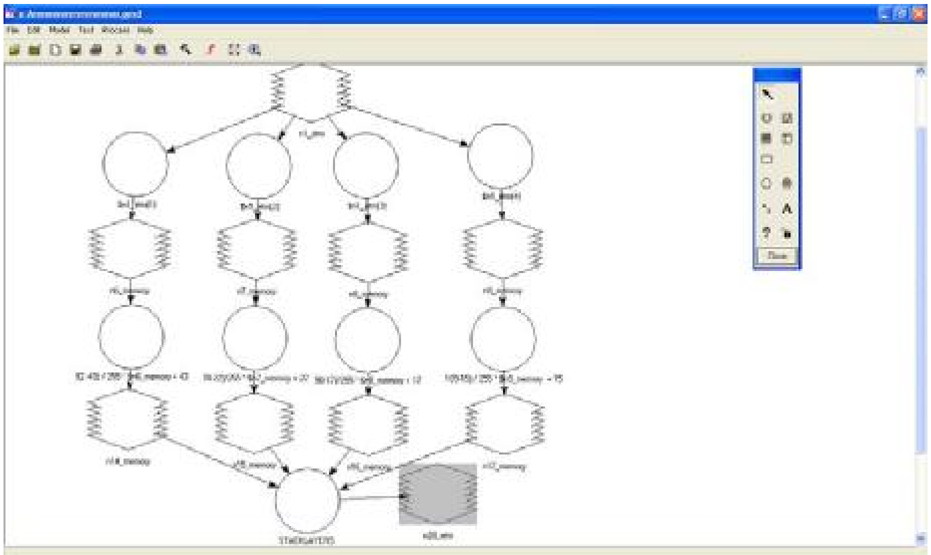

Figure (3) Convert Digital Numbers to Radiance Digital Image Processing Model.

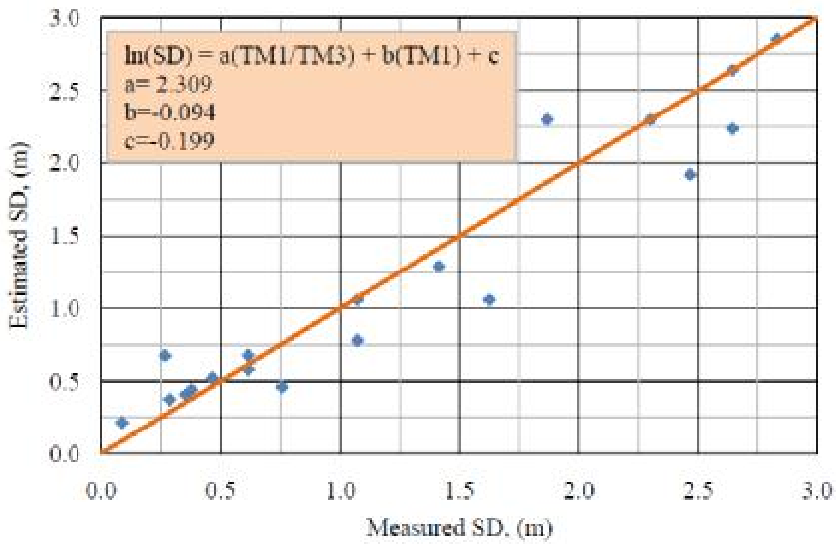

Figure (4) Results of the water clarity model calibration process.

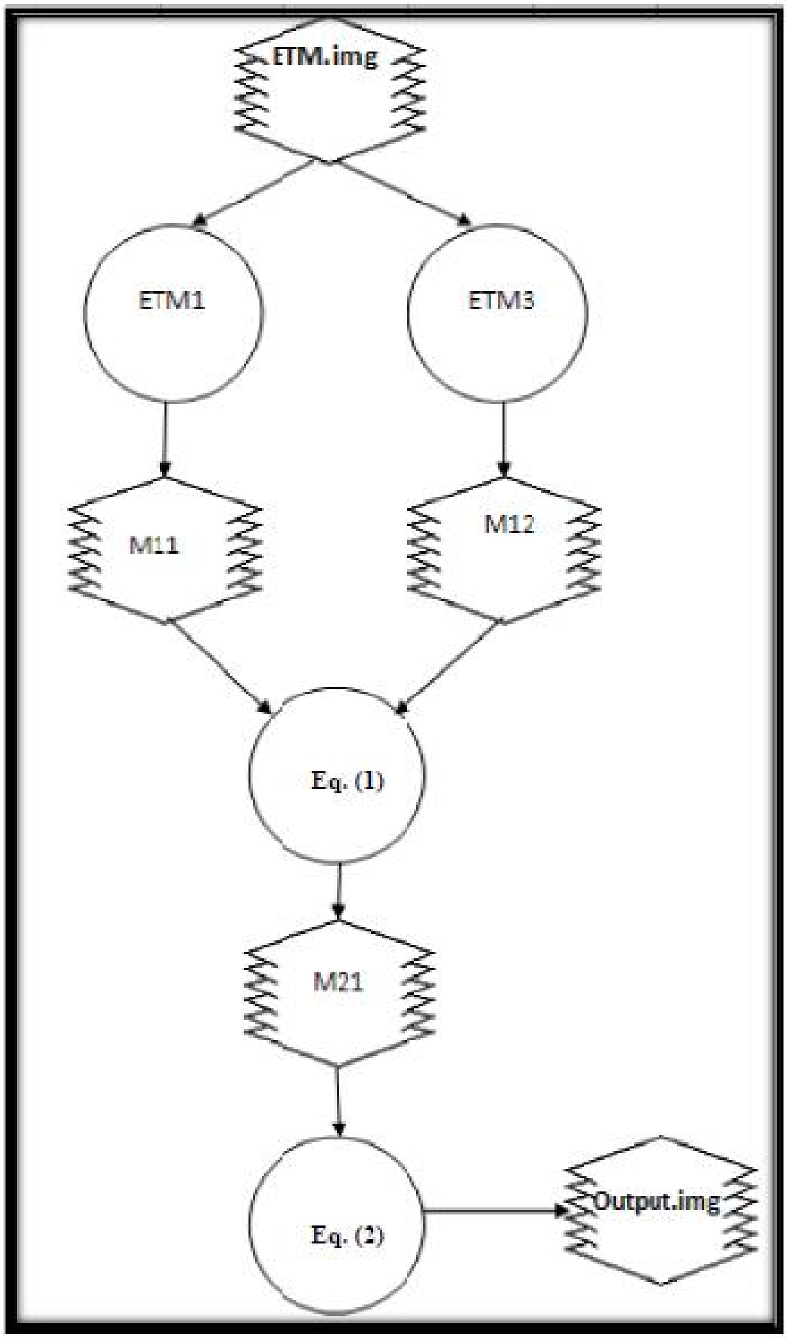

Figure (5) Trophic state index, TSI, Digital Image Processing Model.

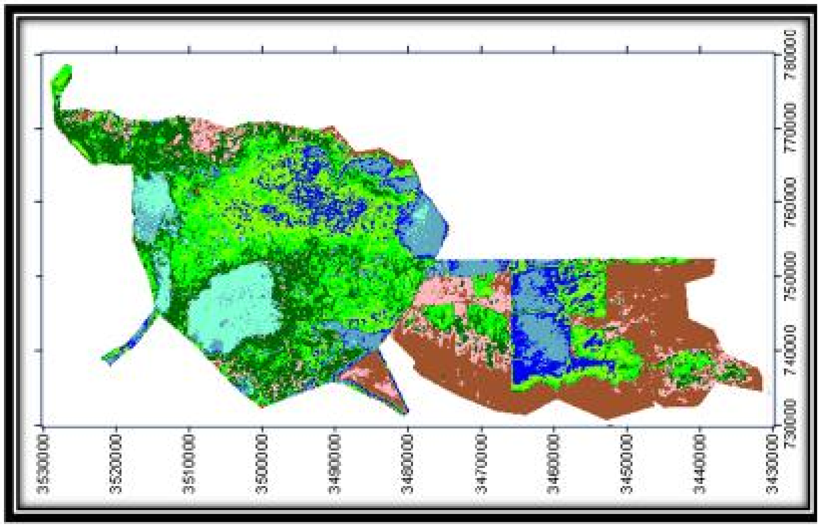

Figure (6). TSI distribution within the marsh area at February-2006.

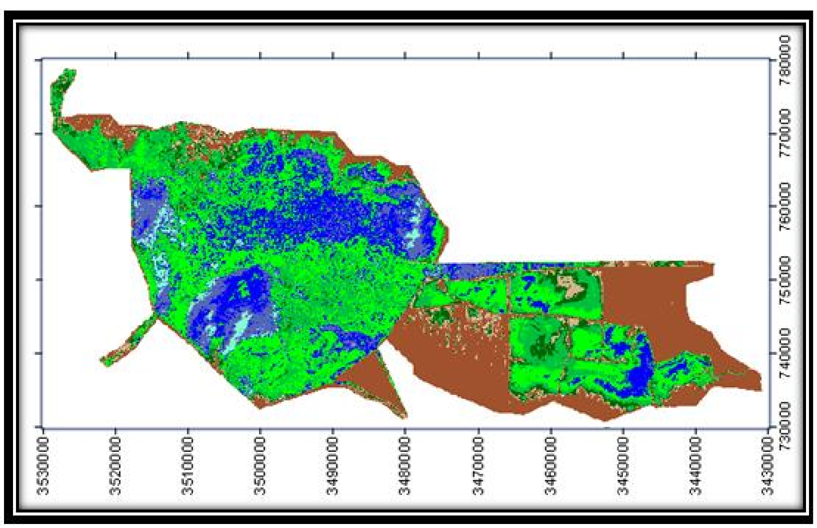

Figure (7). TSI distribution within the marsh area at March-2006.