PREDICTION OF TOTAL SUSPENDED SOLIDS FOR LAKE NASSER FROM REMOTE SENSING DATA USING OLD ALGORITHMS

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ABSTRACT:

Suspended sediment represents a big problem that is facing development in aquatic ecosystems around the world. Since the past two decades, remote sensing data are playing an important role to monitor water quality parameters in the surface of lakes and reservoirs. This research is aiming to present an attempt to estimate total suspended sediments of Lake Nasser in Upper Egypt using Landsat TM data. In this paper, a multi regression model that is correlating surface suspended sediment with reflectance from remote sensing satellite data is used to estimate suspended surface sediment in Lake Nasser during highest as well as lowest water levels of the flood.

The results are presented in the form of maps of total suspended sediments of Lake Nasser. They show areas, where suspended sediments are mostly dominating the water surface. The results also show that any new development at Nasser Lake area should be followed by a monitoring remote sensing program in order to ensure a synoptic view and wide coverage for the Lake environment and to control erosion and sediment yield in their watershed.

INTRODUCTION:

Lake Nasser has been created between Egypt and Sudan after the establishment of the High Aswan Dam in 1964. The existence of Lake (Fig.1) added a lot of opportunities to the Egyptian economy as well as the improvement of water resources management in Egypt. It is very important to make an environmental monitoring program for the lake so as to follow up the status of the water for all activities. Several countries are giving a great attention to monitor the environment of their water resources, in this regard; they are aiming to develop monitoring programs that are using up to date technologies and to ensure efficiency and economy at the same time.

The Nile Research Institute is organising an annual monitoring field trip for the Lake. Since normal field monitoring programs are very expensive and time consuming and do not allow the required spatial coverage of reservoirs, especially for lakes of large surface areas like lake Nasser, it will be more sensible to search for better methods, which can give a synoptic view for large areas and to be cost effective at the same time. Remote sensing data in general and Landsat data in particular have been used since more than two decades in order to monitor water quality parameters for fresh water lakes.

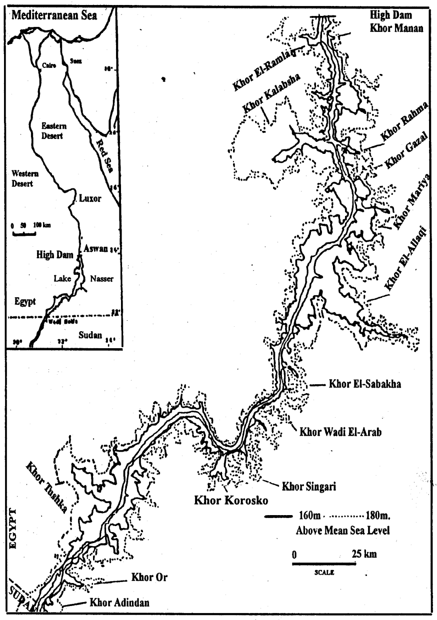

Fig. 1 Lake Nasser and Important Khors.

With recent and planned launches of satellites with improved spectral and spatial resolution sensors, greater application of remote sensing techniques to assess and monitor water quality parameters will be possible (Ritchie et al, 2000). The large aerial coverage of remotely sensed satellite images makes them useful for mapping and monitoring large regions and studying entire ecosystems. This can be important in helping understand how various parts of an ecosystem are reacting to environmental stress introduced at different locations and/or to climate differences that occur temporally and spatially (Chavez et. al, 1997).

In this research, an algorithm was used to predict suspended sediments in Lake Nasser. The main idea of the algorithm is to correlate suspended sediments reflectance from the visible bands of Landsat TM data with the true in situ measured values of suspended sediments using a multiple regression analysis of the data. Table 1 shows the spectral characteristics of Landsat TM Sensor, where bands 1-3 are the visible bands of the electromagnetic spectrum. The algorithm was tested in several areas of the world for ecosystems with problems of suspended sediments and it showed good and precise results for monitoring and finding solution for the problem.

Table 1 Landsat Thematic Mapper ™ Radiometric Characteristics

Characteristic of Landsat TM	μM
Band 1	0.45-0.52
Band 2	0.52-0.60
Band 3	0.63-0.69
Band 4	0.76-0.90
Band 5	1.55-1.75
Band 7	10.4-12.5
Repeated Cycle	16 days

Digital Image Processing:

Two Landsat TM 5 scenes of the lake from 1998 and 1987 were chosen to carry out this research. Landsat scenes from 1987 were covering Lake Nasser during the lowest water level, while in 1998, the scenes were covering the lake during the flood at its highest level. The area of Lake Nasser is covered by three Landsat scenes, which are as given in Table 2 at the dates of acquiring. The scenes were geometrically and radiometrically corrected using ERDAS remote sensing software.

Table 2 Landsat Thematic Mapper ™ Scene Information

Path/Row	Date	Solar Elevation in Degrees	Satellite
174/44	10/31/1987	37.00	Landsat 5
175/44	11/17/1987	37.5	Landsat 5
175/45	11/17/1987	37.7	Landsat 5
174/44	11/16/1998	31.6	Landsat 5
175/44	11/23/1998	32.2	Landsat 5
175/45	11/23/1998	32.5	Landsat 5

Fixed geodetic points taken from 1:50,000 topographic maps were chosen to geometrically rectify the images according to the national projection system of Egypt. The images were then radiometrically corrected using Cosine Theta (COST) model developed by Chavez in 1996. This model uses information provided by the image header and the image itself as model inputs to correct for the additive effect of atmospheric scattering as well as for the multiplicative effect of atmospheric transmittance (Tagestad, J., 2000). The model is namely specialized for correcting infrared and near infrared bands of Landsat data from atmospheric influences.

In ERDAS software, there is a modeling module. This module was used to create a model which corrects the pixel values of Landsat data for different radiometric corrections based on the COST model as mentioned before. This model can be used for any other Landsat data to correct scenes radiometrically. Before using it, the sun elevation angle should be set up because the transmittance term of the COST model is a function of the sun elevation angle. Reflectance from Landsat data can be estimated according to COST model as follows:

$$R_{SATn}=\Pi\ (L_{SATn}- L_{HAZEn})/E_n\ (COS\theta_z) * (TAU_z) \qquad (1)$$

Where :

R_{SATn} is at-satellite reflectance in band n

L_{SATn} is at-satellite radiance in band n

L_{HAZEn} is at-satellite radiance due to haze in band n

E_n is exoatmospheric solar irradiance for band n

$COS\theta_z$ is the cosine of the solar zenith angle in degrees

TAU_z is the approximate atmospheric transmittance

PREDICTION OF SUSPENDED SEDIMENTS:

The main idea of using statistical regressions is to find a relationship between either reflectance from Landsat data visible bands separately or ratios of them and measured surface suspended sediments. There were several linear and multiple regressions that were correlating among Landsat reflectance and real values of the measured suspended sediments, each of these regressions was giving its own coefficient of determination R^2 and root mean square error of suspended sediment (mg l^{-1}). The development of a universal algorithm is essential for using Landsat MSS or TM data to monitor surface suspended sediment concentrations.

(Ritchie. et al, 1991) Although, Topliss et al (1990) suggested such an algorithm using two bands of Landsat MSS and the algorithm was as follows:

$$Log_e\ SS = -9.2\ R^{1/2} + 2.8\ R^{1/22} + 9.4 \qquad (2)$$

Where $R^{1/2}$ is the ratio of reflectance in MSS band 1 to reflectance in MSS band 2 and S is the surface suspended sediment concentrations in mg/l. He did not give the coefficient of determination and root mean square error of his algorithm. Ritchie et all (1991) gave such an international algorithm that correlates among Landsat reflectance and surface suspended sediments, which was as follows:

$$Log_e\ SS = -9.21\ R^{1/2} + 2.71\ R^{1/22} + 8.45 \qquad (3)$$

The standard errors of estimate for the coefficients of $R^{1/2}$, $R^{1/22}$ and the intercept are 2.12, 0.85 and 1.32, respectively. The coefficient of determination for the best-fit algorithm is 0.82. It was accepted that both equations would give the same values, as the difference in intercept would cause a difference of 8.9 mg/l in surface suspended sediment concentrations, which is an acceptable difference in a monitoring program. A comparison of reflectance values calculated from MSS and TM bands 1-4 showed that comparable bands gave similar reflectance values and they were correlated as given in Table 3.

Table 3 Correlation Coefficients ® for a Linear Relationship between Landsat MSS and TM Radiometrically Corrected Reflectance (Bandwidth in μm)

	MSS Band 1 (.5-.6)	MSS Band 2 (.6-.7)	MSS Band 3 (.7-.8)	MSS Band 4 (.8-1.1)
TM Band 1 (.45-.52)	0.09	0.52	0.37	0.50
TM Band 2 (.52-.60)	<u>0.96</u>	0.24	0.56	0.62
TM Band 3 (.63-.69)	0.31	<u>0.83</u>	0.83	0.50
TM Band 4 (.76-.90)	0.69	0.63	<u>0.88</u>	<u>0.83</u>

As could be seen from Table 3 and the underlined correlation values, MSS Band 1 is highly correlated to TM Band 2 and MSS Band 2 is highly correlated to TM Band 3 and MSS Band 3 is highly correlated to TM Band 4. Thus TM Bands 2-3 of our data were applied as a replacement of Bands 1-2 of MSS in the given algorithm in equation (2).

However, in ERDAS, another model was developed in order to estimate surface suspended sediments using equation (3). The model was applied to both scenes of Nasser Lake from 1987 and 1998, as to monitor surface suspended sediments during the lowest flood in November 1987 and the highest flood in November 1998. The estimated surface suspended sediments in 1987 were very representative for the real case of the Lake as the sediment values were ranging between 2 mg/l and 5 mg/l. In 1998, where the flood was in its highest case, it was not possible to get any prediction about the values of suspended sediments because the used model was designed for lower suspended sediments values. However, suspended sediments values during the flood are considerably high and needs another new model or even models, that should be specially designed for Nasser Lake.

RESULTS AND DISCUSSION:

Remote sensing data should play an important role to monitor environmental phenomena's of Lake Nasser at Upper Egypt. As seen in Figure 2-a and 2-b, surface suspended sediments distribution could be mapped using Landsat data and accordingly estimates and sources of dominating suspended sediments of the surface water could be detected and modeled.

Figure 2-a Surface Suspended Sediments Distribution in November 1998.

Figure 2-b Surface Suspended Sediments Distribution in November 1987.

As seen in Figure 2-b, the distribution of surface suspended sediments during normal cases will be homogeneous throughout the whole lake, i.e. there will be no significant difference in suspended sediment values along the Lake. In Figure 2-a, differences in surface suspended sediments will be higher in the lower part of the lake. Accordingly, it will be more useful to increase the annual cross sections, which are used to monitor the lower part of the lake, where higher differences in surface suspended sediments take place.

Recently, new launched satellites are giving more spectral coverage as well as higher resolutions; these data should be implemented in a larger monitoring program for Lake Nasser. New algorithms could also be developed from the recommended monitoring program. These algorithms should not only correlate among bands of different satellites data and reflectance but also to develop a universal algorithm that could correlate between reflectance or radiance as a general independent of the data source and water quality elements based on the water optical characteristics. Such a monitoring program could allow better monitoring for water quality parameters and more details about water quality elements could be monitored like this way.

CONCLUSIONS:

This research is an attempt to set up new techniques for monitoring the environment of Lake Nasser and its surroundings. Remote sensing data is giving a high spatial resolution and permanent temporal coverage for the site under investigation. Rapid developments in the science of digital image processing and with the new launching of high resolution satellites, remote sensing can play an important role in future to monitor the earth natural resources. Although, normal monitoring techniques are used to take place almost annually since the creation of Lake Nasser, remote sensing techniques are promising to supply rapid and precise monitoring for Lake Nasser’s environment and to save a lot of cost and effort that are connected to normal field monitoring.

We also would recommend to develop some algorithms that are relating water quality parameters and reflectance from other remote sensing data, such as Spot data, Hypersepectral data or multispectral data. These algorithms should have a global tendency and should be compared to other similar algorithms that are currently under development in other regions of the world.

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