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An integrated field and remote sensing approach for water quality mapping of Lake Burullus, Egypt.

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ABSTRACT

Lake Burullus is one of the four northern wetlands along the Mediterranean coast in Egypt. It severely suffers from deterioration of water quality due to receiving massive amounts of agricultural, municipal and industrial wastewater. Therefore, this study is presenting maps for surface water quality conditions of the Lake using the remote sensing and a geographic information system (GIS) as a tool for water quality monitoring. The maps showed spatial distribution of nitrate, chlorophyll a, turbidity, nitrogen, lead, copper and zinc, biological oxygen demand (BOD), and temperature. A Landsat image from the Enhanced Thematic Mapper plus (ETM+) sensor acquired in January 2014 was processed based on a band by band as well as band combination. Generation of these cartographic maps was based on the correlation between the measured parameters and the reflectance values of the ETM+ image.

However, parameters not correlated with the satellite image data have been processed through spatial analysis and interpolation technique using GIS. The maps showed a reasonable distribution of different water quality parameters. It was clear, that the water quality is more deteriorated in the eastern and southern parts of the lake than the other parts, due to polluted drainage water and wastewater discharging in these areas. In general, the study confirms that remote sensing coupled with GIS can be used for water quality mapping.

1. INTRODUCTION

Lake Burullus is one of the four northern coastal lakes along the Mediterranean Sea coast of Egypt. Its area is 420 km² and located between longitudes 30°31` and 31°05` E and latitudes 31°25`and 31°35`. The length of the lake is about 53 km, its width is about 13 km, and its water depths range from 0.5 to 2.5 m (Frihy and Dewidar, 1993; Shaltout and Khalil, 2005). It connects to the sea through a narrow strait called Al-burg inlet or Boughaz El-Burullus at its northeast side.

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The Lake is separated from the sea by a narrow coastal strip covered by sand sheets and sand dunes. The Lake was declared a protected area by Prime ministerial decree 1444 in 1998. Also, in 1998 Lake Burullus was approved as a RAMSAR site in Egypt.

Seven drains are discharging into Lake Burullus; Drain 11; Drain 9; Drain 8; Drain 7; Nasser Drain; Burullus East and West Drain (Fig. 1). The total drainage discharge into the Lake is 3904 million m^3/year including agricultural, industrial and domestic waste water. The lake's high nutrient environment allows aquatic plants to grow extensively. The subsequent sediment accumulating around the roots of the plants effectively sub-divides the lake and affects the water circulation. In addition, total suspended solids (TSS) values are very high, which means high pollution of organic and non-organic material from industrial and agriculture wast.

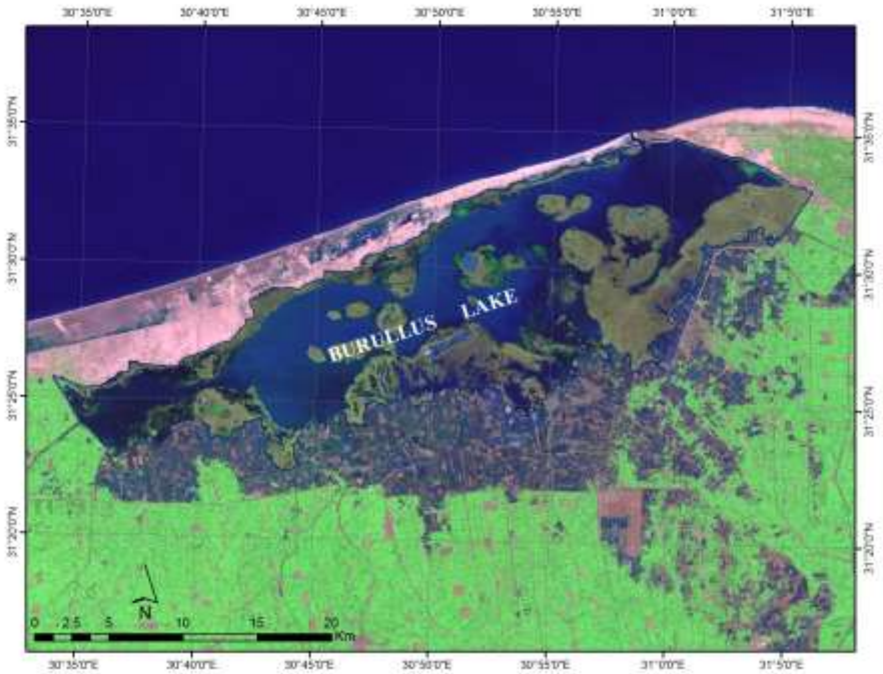

Fig. 1: Burullus Lake

Declining of salinity levels inside the lake is considered a problem. Total percentage by weight of marine fish species such as *Liza ramada* decreased from 16% in 1973 to less than 1.8 % in 2003 and freshwater fish such as Tilapia increased from about 81% to 98.2 % (Al Sayes *et al.*, 2007; Khalil, 2013).

On the other hand, remote sensing is a new technique used to map water quality parameters, such as chlorophyll content and suspended matter (Dewidar and Khedr, 2001; Vincent *et al.*, 2004). Dewidar and Khedr (2005) utilized Thematic Mapper (TM) data combined with field data measurements during April 2004 to map the depth, salinity, sand, and sediment organic matter in the Burullus Lagoon. Many studies combined remote sensing with GIS for water quality mapping (Hereher *et al*, 2010; Usali and Ismail, 2010).

Therefore the main objectives of this study are to:

1-1 Investigate the applicability of combination of remote sensing technique with GIS for assessment of surface water quality of Burullus Lake (integration of ground truth and RS data).

1-2 Identify of the optimal spectral bands (ranges) that are most sensitive to water quality indicators for Burullus Lake.

2. MATERIALS AND METHODS

2-1 Water analysis:

Field visits were conducted to Lake Burullus during January 2014 to take water samples from fifteen sites covering the entire lake body (Fig.2). Water samples were taken by cleaned one- liter polyethylene bottle immersed 20 cm below the water surface. At each site, geographic location using *Juno Sc* GPS measurements were carried out. In the laboratory, the following parameters were determined in water: 1- turbidity using the standard nephelometric method (EPA, 1983), 2- NO_3^{-2} was measured using ion chromatography (IC) model DX-500 chromatography system, 3- BOD was determined using ORION BOD fast respirometry system model 890 with a measuring range 0-4000 mg/l at 20°C incubation in a thermostatic incubator chamber model WTW, 4- chlorophyll a was measured according to APHA (1992), 5- N-NH_4 was measured according to APHA (1989), 6- the heavy metals (Zn^{+2}, Cu^{+2} and Pb^{+}) were measured using the Inductively Coupled Plasma- Emission Spectrometry (ICP-ES) with Ultra Sonic Nebulizer (USN).

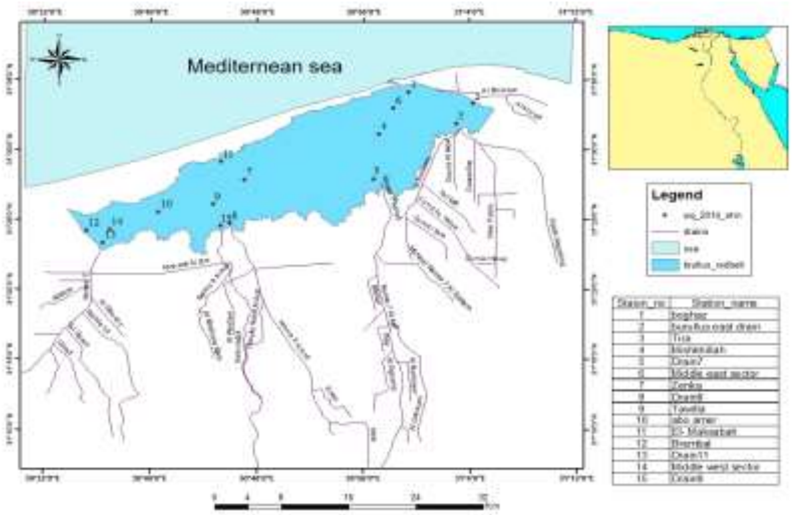

Fig. 2: Drains and Water sampling stations

2.2 Remote sensing analysis

A Landsat ETM+ image acquired in 25 January 2014 (Path 177 and Row 38) was used in this study as this date was the most available for the analysis. This image contains 7 bands (three in the visible and four in the infrared portions of the spectrum). The thermal band was eliminated from the ETM+ image and the image processing was applied to the other 1-5 and the7th bands. The image was registered to the Universal Transverse Mercator (UTM) Projection using several well distributed ground control points (GCPs) obtained from 1:50,000 topographic maps. A subset image covering the boundaries of the Burullus Lake was created. At this subset image, the raw digital numbers were converted to radiance and then the radiance converted to reflectance value. Correlation matrices were used to explore the relationship between the measured water quality parameter and the ETM+ reflectance data. Regression relationships were generated between the individual band readings and the water parameters as well as between band ratios (b1,b1/b2,b1/b3,b1/b4,b2,b2/b3,b2/b1,b3,b3/b1,b3/b2,b3/b4,b4,b4/b3,b4/b2,b5,b6,b6/b3,b6/b5) and the water parameters. Statistical analysis was carried out using SPSS software (Wilkinson, 1997). Image processing techniques were performed using Eardas 9.3 software. Cartographic maps of the correlated parameters were created in ArcGIS software.

2.3 GIS analysis

The GIS analysis was carried out using ArcGIS software in order to make spatial distribution maps of the parameters not correlated with the satellite data. The boundary of the lake was digitized using the polygon shape file. The geographic locations

(Longitudes and Latitudes) of the sampled sites were inserted as a basic separate layer and a database Table containing the results of the different water was created. For each parameter, the spatial analysis was applied based on the interpolation and surface analysis methods. Then a clip image containing the classified spatial distribution map for each measured water parameters were extracted.

3. RESULTS AND DISCUSSION

The correlation matrix between the examined water and the reflectance values of the satellite image data is shown in Table (1). The models representing the statistical relationships for the measured water parameters and the reflectance value of the ETM+ satellite image are as follows:

Table 1: Correlation matrix between measured parameters and the ETM+ data for Burullus Lake. * P<0.05

	Chlor_a,mg/l	BOD,mg/l	Turbi,NTU	N_NH4,mmg/l	NO3,mg/l	NH3,mg/l	cu,µg/l	pb,µg/l	Zn,µg/l
b1	.444	-.330	.260	.086	.019	.086	-.296	.107	-.280
b1/b2	-.251	.301	-.209	.076	-.125	.076	.535*	.014	.311
b1/b3	-.431	.301	-.379	-.145	.090	-.145	.558*	-.130	.020
b1/b4	-.161	.078	-.097	.408	.029	.408	.372	-.083	-.427
b2	.387	-.354	.246	-.016	.086	-.016	-.454	.042	-.336
b2/b3	-.442	.228	-.383	-.235	.192	-.235	.436	-.181	-.157
b2/b1	.253	-.301	.192	-.095	.136	-.095	-.527*	-.018	-.325
b3	.505	-.320	.362	.101	-.080	.101	-.508	.135	-.095
b3/b1	.459	-.278	.359	.105	-.109	.105	-.529*	.129	-.004
b3/b2	.450	-.200	.366	.189	-.212	.189	-.406	.177	.162
b3/b4	-.025	-.024	-.016	.467	.036	.467	.151	-.076	-.451
b4	.260	-.046	.181	-.264	-.159	-.264	-.263	.172	.305
b4/b3	.112	.050	.033	-.367	-.114	-.367	-.166	.135	.413
b4/b2	.198	.004	.126	-.278	-.161	-.278	-.210	.161	.365
b5	.263	-.051	.171	-.204	-.218	-.204	-.185	.137	.294
b7	.285	-.076	.135	-.188	-.193	-.188	-.165	.097	.241
b7/b3	.244	-.052	.096	-.211	-.177	-.211	-.136	.088	.273
b7/b5	.090	-.133	-.218	.044	.093	.044	.177	-.200	-.327

3.1 For (Chlorophyll-a Model), Chl_a =12.4+274 b3;

3.2 For (Turbidity model), Turbidity= 131-45.4 b1/b3;

3.3 For (NH_4-N model), NH_4-N= 0.265+0.518 (b3/b4).

Cartographic maps for the distribution of turbidity, chlorophyll, nitrogen based on these models are shown in Fig (3). The sea surface temperature (SST) data were derived from the infrared channels of AVHRR sensor on NOAA satellites from 1995 to 2002 (McClain *et al.*, 1985) (Fig. 3).

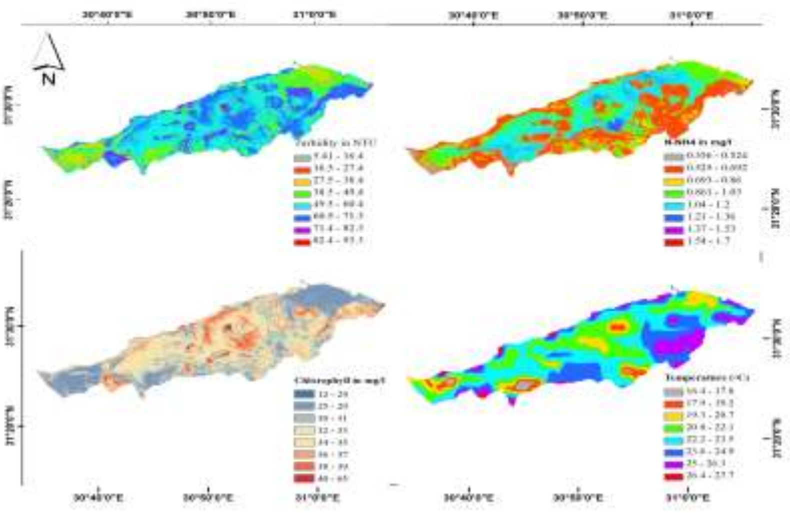

Fig. 3: Cartographic maps of chlorophyll, turbidity, nitrogen –ammonia, and temperature distribution as obtained from remote sensing analysis.

These maps show that the Chlorophyll_a concentrations are higher at the southern part of the Lake than the other sides and the Lake has low water turbidity for its major basins. In addition, the nitrogen distribution coincides with the chlorophyll distribution (except for N-NO_3, NO_3). Biological oxygen demand (BOD) is generally lower at the western sector of the lake basins. The heavy metals' distribution indicates that lead and Cupper levels are lower at the northern part of the lake, whereas zinc distribution is high in the west sector (Fig. 4).

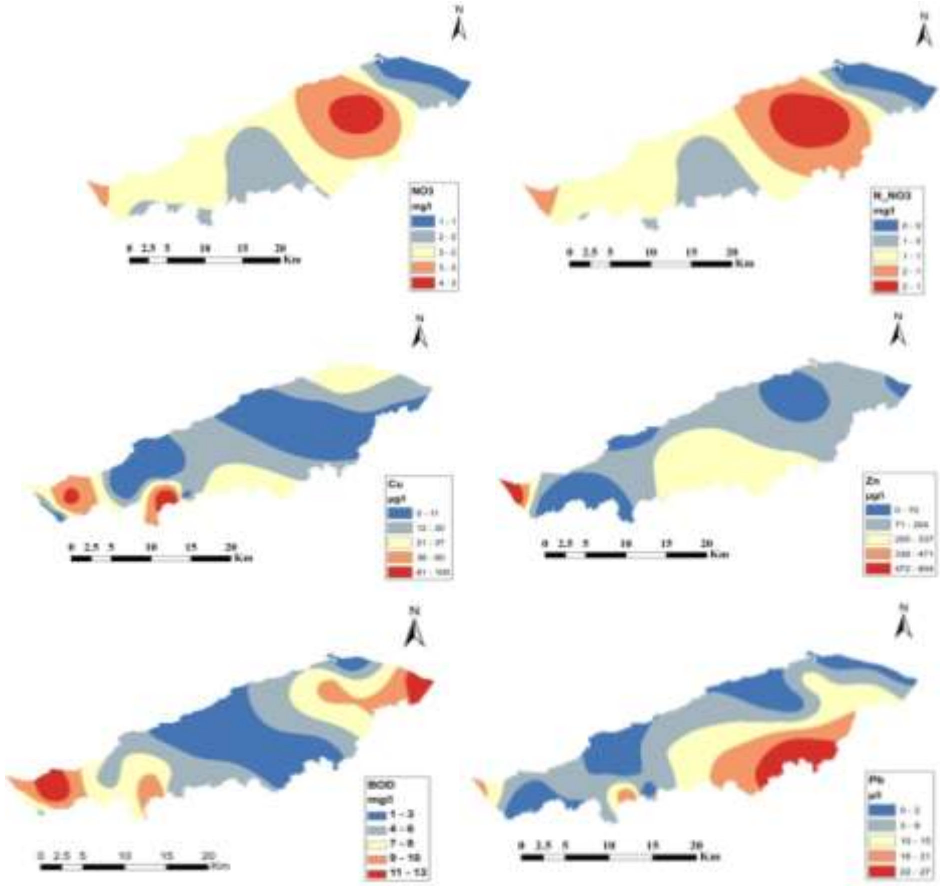

Fig. 4: Cartographic maps of NO_3, N-NO_3, Pb, Cu, zn and BOD as obtained from the GIS interpolations

Cartographic maps in this study confirm that the turbidity, nitrogen, copper, lead and chlorophyll are much higher at the southern and eastern parts of the lake. This is because these parts receive agricultural drainage water as well as municipal and industrial wastewater from seven main drains. The chlorophyll content is also minimal at the western side due to the discharge of fresh Nile water into this side through Brimbal Canal.

It is obvious from the results of this study that the Landsat reflectance data can be successfully used to map some surface water quality parameters for Burllus Lake. However, additional investigations are still needed in different times of the year and under different conditions in order to develop generalized models. Finally, repetitive remote-sensed data should be considered by agencies as having the potential to provide an alternative method for gathering and processing surface water quality information.

5. REFERENCES

Al Sayes, A.; Radwan, A. and Shakweer, L. (2007). "Impact of drainage water inflow on the environmental conditions and fishery resources of lake borollus," Egyptian Journal of Aquatic Researches, 33(1): 312–321

APHA (1992). Standard Methods for the Examination of water and waste water, 18th Ed., American Public Health Association, Washington, D.C., USA.

Dewidar, K., and Khedr, A. (2005). Remote sensing of water quality for Burullus Lake, Egypt. Geocarto International, 20: 43 - 49.

Dewidar, Kh. and Khedr, A. (2001). Water quality assessment with simultaneous Landsat-5 TM at Manzala Lagoon, Egypt. Hydrobiologia, 457: 49– 58.

EPA (1983). Methods of chemical analysis of water and waste water USA. Environmental Protection Agency (EPA), 690: 4 -79.

Frihy, O. and Dewidar, Kh. (1993). Influence of shoreline erosion and accretion on texture and heavy mineral compositions of beach sands of the Burullus coast, north central Nile delta, Egypt. Marine Geology, 114: 91–104.

McClain E. P.; Pichel, W. G. and Walton, C. C. (1985). Comparative performance of AVHRR-based Multichannel Sea Surface Temperatures, J. Geophys. Res., 90 (C6). 11587-11601.

Khalil, M. T. (2013). Environmental management of Burullus Protectorate (Egypt), with special reference to fisheries. Int. J. Env. Sc. Eng., 4: 93-104.

Shaltout, K. H. and Khalil, M. T. (2005). Lake Burullus (Burullus Protected Area). Publication of National Biodiversity Unit, No. 13, Egyptian Environmental Affairs Agency, Egypt, 578 pp.

Usali, N. and Ismail, M. (2010). Use of remote sensing and GIS in monitoring water quality. J. Sust. Development, 3: 228-238.

Vincent, R. K.; Qin, X.; Michael, R.; McKay, L.; Miner, J.; Czajkowski, K.; Sayino, J. and Bridgeman, T. (2004). Phycocyanin detection form LANDSAT TM data for mapping cyanobacterial blooms in Lake Erie. Remote Sensing of Environment, 89: 381–392.

Wilkinson, L. (1997). SYSTAT: The system analysis for statistics. SYSTAT, Evanston, III.