1st Int. Symp. Phycol. (ISP).
(21-22) Oct. 2000.

Egypt. J. Phycol. Vol. 1, 2000

EARLY WARNING ON THE BLOOMING OF PHYTOPLANKTON INHABITING LAKE NASSER-TOSHKA AREA MONITORED BY REMOTE SENSING IMAGERY

Adel F. Hamed
Botany Department, Faculty of Science, Ain Shams University, Cairo , Egypt
e-mail: hadel@asunet.shams.eun.eg

Abstract

Landsat 7 Thematic Mapper data of March, 25, 2000 based on GIS were used to track and monitor of phytoplankton blooms in Lake Nasser – Toshka area. Principal component analysis (PCA) and the maximum likelihood classification algorithms were applied to separate different land use types. The spatial data analysis together with the ground reference studies were significantly revealed the distribution pattern of bloom – forming cyanobacteria of *Microcystis aeruginosa* f. *flos aquae* (wittr.) Elenk., *Aphanizomenon flos-aquae* (Lemm.) Ralfs ex Borb. et Flah. and detected the spectral signatures of the euhydrophytes intermingled with phytoplankton. The spring and summer blooming of cyanobacteria was correlated with physico-chemical characteristics of water. Ecologically, the cyanobacterial species have adverse effects through producing toxic compounds. In conclusion, this paper gives an early warning on the spatial distribution of toxic cyanobacterial species which will be used as the first trial inventory for future multitemporal studies.

Key words : algal bloom, Lake Nasser, phytoplankton, remote sensing.

Introduction

Remote sensing is a powerful tool, which provides an opportunity to monitor the spatial distribution of aquatic vegetation, including phytoplankton depending on spectral signatures acquired (Schalles *et al.*, 1998; Yacobi, *et al.*, 1995). Digital Image Processing (DIP), of true and false coloured images has been used to obtain statistical clusters, indicating detailed information about ecological variables (Lehmann and Lachavanne, 1997).

Routine limnological studies on macrophytic communities (Ali *et al.*, 1995; Murphy, *et al.*, 1990; Springuel and Murphy, 1991) and phytoplankton (Abd El-Monem, 1995; Abdin, 1948, b, c, d, and 1954; Ahmed *et al.*, 1989; Latif, 1977; Mohammed *et al.*, 1989; Nosseir and Abou-El-Kheir, 1970; Samaan, 1971; and Samaan and Gaber, 1976) have been carried out in Lake Nasser. Some observations about the blooming of blue-green algae in the lake during August and September in the year from 1987 to 1992 were reported by Ibrahim, 1993a. In addition, monitoring of the changes of water levels by space photography was takes placed by Abdel-Rahman *et al.*, 1990, and El – Baz, 1989.

In 1997, the Southern Valley Development Project (SVDP), was initiated for the aim of irrigation and colonization of an area to the north – west of Lake Nasser (TOSHKA) over a period of 30 years. The area will be supplied with water via a new canal. It is planned to reclaim 0.21 m ha by the year 2002 and at the end of the project, some 1.43 m ha will have been reclaimed (Elarabawy and Tossweel, 1998).

(ISSN: 1110-8649)

Consequently, this paper gives a highlight upon a quick accurate surviellence on the distribution of aquatic vegetation of Lake Nasser and its current state dynamics (considering information recorded in March, 2000) for the purpose of its near future impact on the ecosystem of this particular area.

Study Area

Generally, Lake Nasser lies approximately between latitudes 22 ^{0}N and 23^0 58 N in Egypt and extends south into the Sudan (as Lake Nubia) to 20^{0}N. It is considered as one of the world's largest man – made lakes (Fig. 1). The lake is surrounded by a largely barren, rocky terrain of piedmonts and peneplains of sandstone (Raheja, 1973). The total area of the lake is about 5180 square kilometers. The lake is just under 180 m a.s.l., which would give a mean lake depth of 24.9 m, and a mean lake width of 17.9 km. The lake level fluctuates in response to variations in rainfall, evaporation, and other catchment factors (Briggs and Dickinson, 1988 and Springuel *et al.*, 1990) and has the capacity of 157 billion cubic meters. The Lake shoreline is very irregualr, with numerous khors (inundated wadi valleys).

Materials and Methods:

Data Sources

Landsat 7 TM (Thematic Mapper) imagery for Lake Nasser – Toshka area was acquired for March 25, 2000. The total area covered by the image of 180 km x 180 km, which include the interesting study area of 8678 square kilometer (Fig.2). The longitude and latitude of the study area are as follows: for the top left corner, **long**. 31°06' 41.45'' E; **lat.** 23° 23' 20.72'' N; for the bottom left corner, **long**. 31° 07' 22.73'' E; **lat**. 22° 23' 41.23'' N; for upper right corner, long. 32° 01' 51.31'' E; **lat**. 23° 23' 55.66'' N, for the bottom right corner, **long**. 32° 02' 17.60'' E; **lat**. 23° 34' 10.33'' N. The image have a spatial resolution of 30 m and a spectral resolution of 7 bands. The percentage of the cloud cover of the imagery was 0 %. Forestry and Natural Resources Department, University of Purdue, USA provided the image, which was already rectified. Reference data, which include topological map of (1: 50 000 scale) is included as data source of the study area.

In September, 1997 and March 2000, four surface- water phytoplankton samples and aquatic vegetations were collected from standpoint of Lake Nasser facing mafeed Toshka (Toshka inundating site). One liter volume of phytoplankton sample was collected by phytoplankton net of mesh 25 µm and concentrated in a 50 ml of falcon plastic tube, followed by preservation in 4 % formaline. The hydrophytes were easily removed by hand and preserved in a clean plastic sacs in fixative solution (F.A.A. 1: 1: 3). From each sampling point, 1 liter volume of water sample was collected during the expedition of March, 2000 in a clean dark bottle and preserved by few drops of toluene for chemical analysis while, the pH and temperature of water were determined in the field by the pH meter and thermometer respectively.

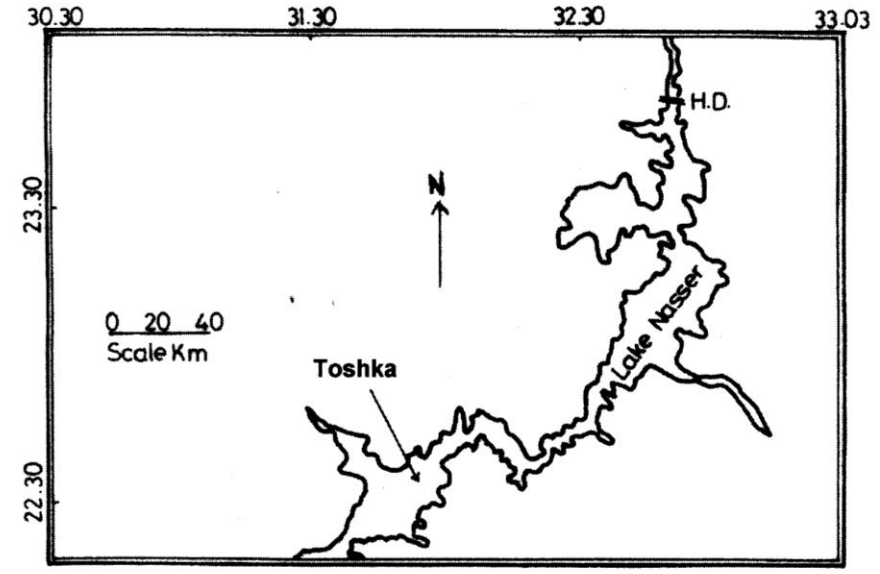


Fig. 1. Location of the study area

Methods

Image processing and classification were performed with the use of ERDAS IMAGINE system. The spectral signatures of the aquatic vegetations including phytoplankton were enhanced through an unsupervised classification procedure called PCA (Principal Component Analysis). In this study, PCA- transformation have been used the combinations of three bands 1,2,3. PCA transformation is a process that first compares the covariance of each pixel brightness value of a scene within all of the bands. The brightness values within each band are then "transformed"(processed through a series of equations), where new calculated (transformed) values will show the greatest contrast among the information within the scene. This process was necessary for separating aquatic vegetation from other land use background (ERDAS field guide-image enhanced fourth, 1997). Supervised classification was then performed on the image using the maximum likelihood classification algorithms. Supervised classification is a process that lets the computer group areas together within a scene based on spectral values that were selected. With the aid of ArcView GIS software, two layers were obtained by spatial analysis method (Introduction to ArcView GIS, 1996). One represents generally, the land use of Lake Nasser-Toshka area and the other represents the aquatic and terrestrial vegetations.

The chemical analysis of water takes placed according to APHA, 1996.Phytoplankton samples were identified following the keys of Desikachary, 1959; Philipose, 1967 and Prescott, 1961.Counting (number of units l^{-1}) was performed by Sedgwick-Rafter chamber for each sample collected and the mean number is taken from the two expeditions of September, 1997 and March, 2000.The aquatic vegetations were identified using Pieterse and Murphy, 1990.

Results and Discussion

The spatial data analysis of the satellite image significantly revealed the distribution of aquatic vegetation within the interested area (Fig. 2,3). This aquatic vegetation was composed of surface phytoplankton community and euhydrophytic one.

With the help of ground – reference studies of September, 1997 and March, 2000, phytoplankton species composition particularly of the stand-point facing Toshka depression was composed mainly of blue-greens (10 taxa), diatoms (4 taxa), greens (9 taxa) and one species of dinoflagellate (Table 2). The euhydrophytic community was represented by some free floating (*Eichhornia crassipes* Solms.) and submerged (*Najas horrida* L., *Potamogeton pectinatus* L., *Potamogeton crispus* L.) forms (Pieterse and Murphy, 1990).

Regarding to the mean relative abundance of different algal groups, it was found that, the blue-green algae obviously constituted the main bulk of algal vegetation of 63.86%, followed by diatoms 19.03 %, green algae of 16.71 % and dinoflagellate of 0.27 % (Fig.4). On the species level, the major bloom - forming algal species were identified as *Microcystis aeruginosa* f. *flos-aquae* (Wittr.) Elenk., *Aphanizomenon flos-aquae* (Lemm.) Ralfs ex Born et Flah., *Cyclotella meneghiniana* (Kütz.) and *Volvox globator* (L.) Her (Fig.5).

Among the factors that determine the algal bloom and in particular the blooming of cyanobacteria are as follows: 1- pH values recorded were usually in the range of 7.2 – 8.5(mean pH: 7.9), with higher values most common in spring and summer, indicating high phytoplankton productivity at this time of year (Entz, 1976). 2- The water is eutrophic characterized by moderately high nitrate and phosphate concentrations which eventually causing the flourshing of algae (Table 1). This observation was supported by the findings of Springuel and Murphy, 1991. 3- The warm water temperature of 27 °C and the high light intensity may also stimulate the algal blooming (Resson *et al.*, 1994) and might favour *Microcystis* growth (Ha *et al.*, 1999). 4- The cell structure of cyanobacteria having gas vacuoles provide a degree of buoyancy control which allows them to maintain themselves in the water column may interpretete the lack of turbulence, this in turn favoured the cyanobacterial community formation (Reynolds *et al.*, 1987; Steinberg and Hartmann, 1988).

The dominant macrophyte, growing abundantly in the shallow marginal waters was *Najas horrida* L., less commonly associated with *Najas horrida* L. were *Potamogeton crispus* L., *Potamogeton pectinatus* L. and *Eichhornia crassipes* Solms. All the macrophyte species existing in Lake Nasser show a strong element of disturbance-tolerance traits. These macrophytes can tolerate the water level fluctuations, extreme heat and aridity (Murphy *et al.*, 1990).

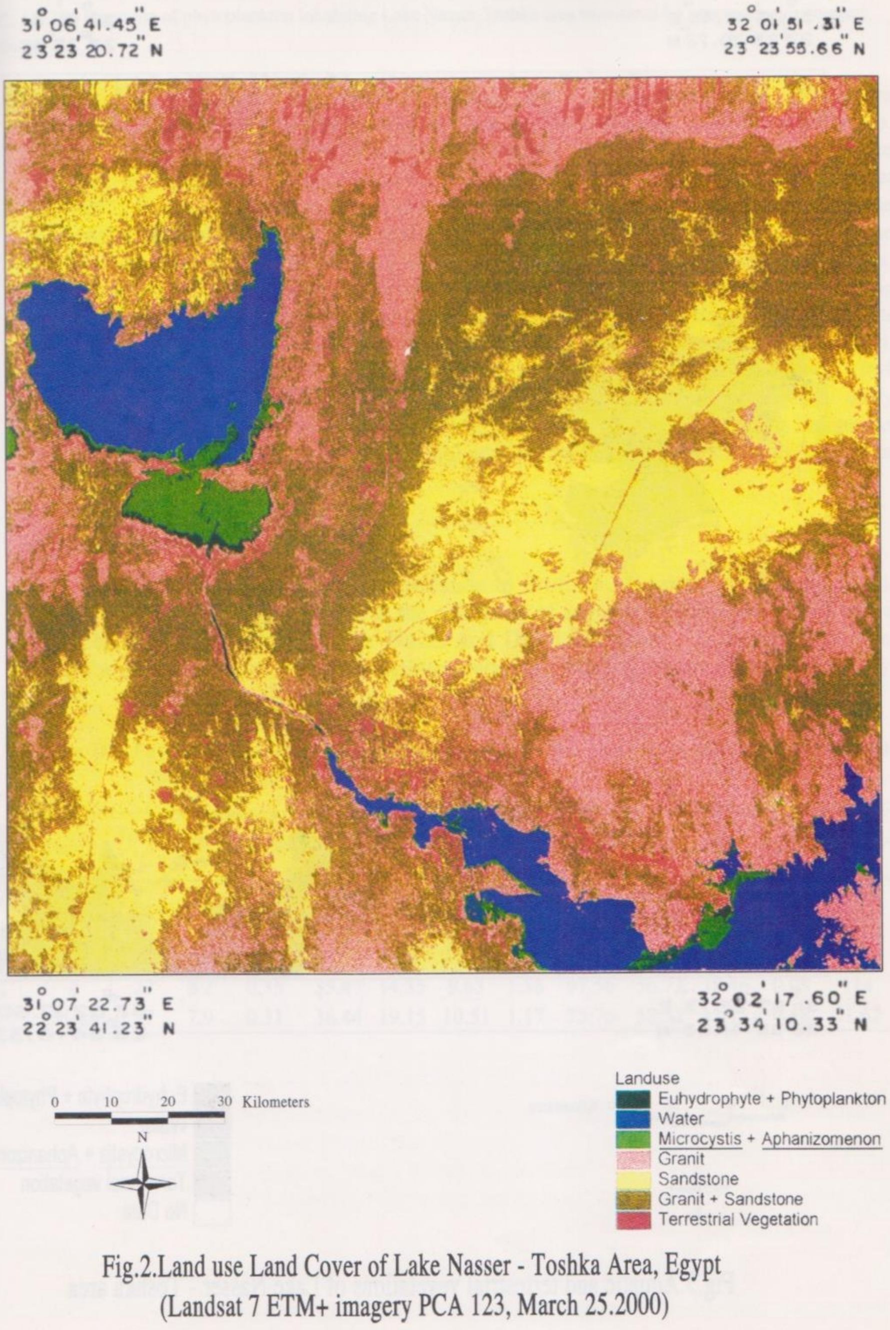


Fig.2.Land use Land Cover of Lake Nasser - Toshka Area, Egypt
(Landsat 7 ETM+ imagery PCA 123, March 25.2000)

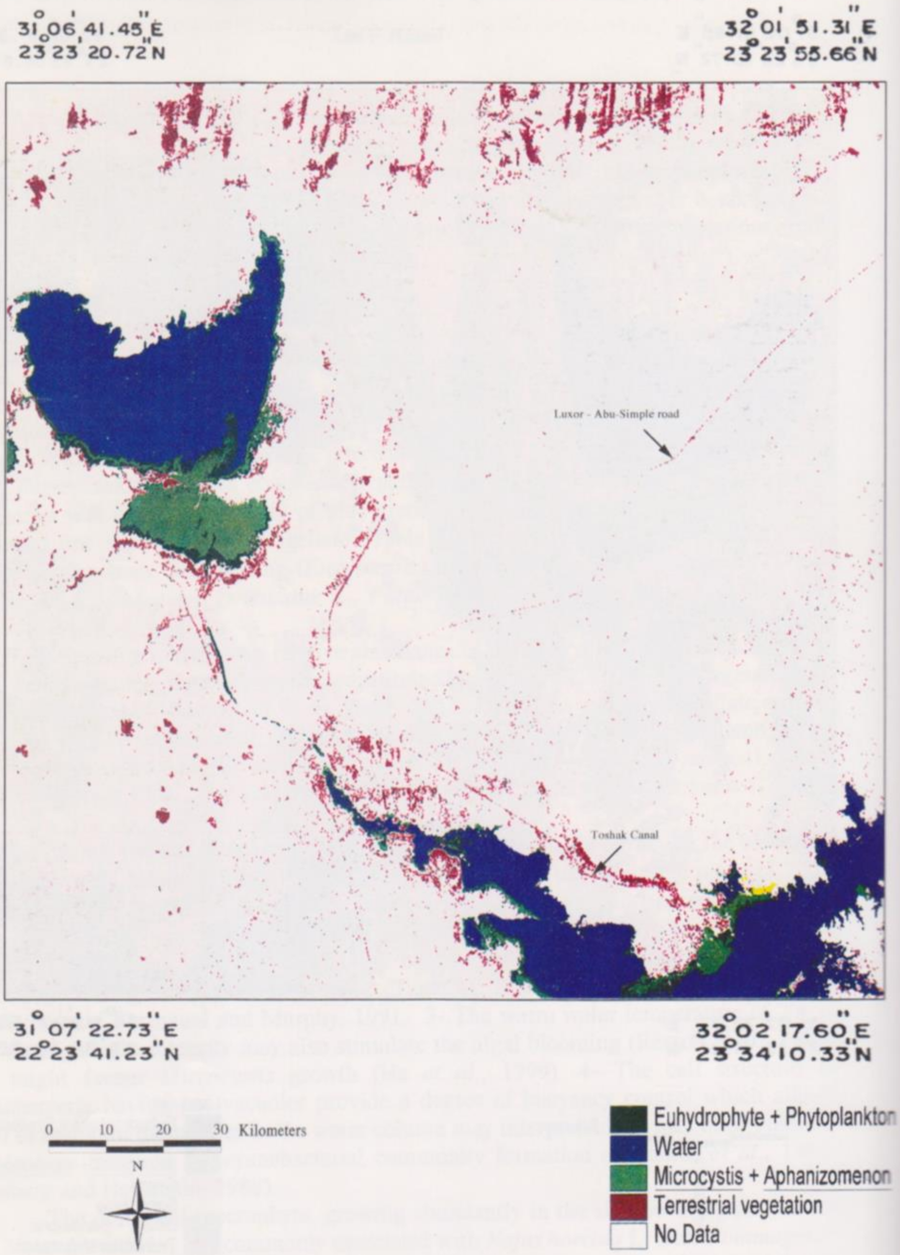


Fig.3.Aquatic and terrestrial vegetations of Lake Nasser - Toshka area

The total area covered by *Microcystis* and *Aphanizomenon* was 169 square kilometers, while those covered by euhydrophytic community was relatively smaller (i.e. about 28 square kilometers). These results confirm the phenomena of conicidence decrease in submerged aquatic plants where cyanobacterial blooms occur (Casanova *et al.*, 1997; Moss, 1991; Moss *et al.*, 1996; and Phillips *et al.*, 1978). This is because cyanobacteria could affect aquatic plant establishement and growth by 1- changing the physical environment of germinating and growing plants and 2- production of toxins, which could affect plant metabolic processes (Casanova *et al.*, 1999). Unfortunately, the cyanobacterial species produce toxins of several different types. Many of such blooms were reported to cause poisoning of livestock (Carmichael, 1992 and Codd and Poon, 1988), as well as being implicated in human illnesses as hepatotoxic (Carmichael, 1994 and Carmichael and Falconer, 1993). In conclusion remote sensing can allow early detection of toxic species, making it possible to take action before reaching dangerous levels. The technique can also serve multitemporal monitoring study of this particular area.

Acknowledgments.

I would like to express my gratitude to Prof. Dr. Shaaban, A. S. and Dr. El-Awamri, A. A. for their assistance in the collection of samples of September 1997. Also, my deepest thanks to Prof. Dr. Le Master and Dr. Gufan Shao , University of purdue, USA for giving the remote sensing facilities during my visiting scholar from April to July, 2000.

Table (1): Physico-chemical characteristics of water of the study area (during March, 2000) units mg l^{-1}, unless stated

Sample	Temp. °C	pH	EC ds/m	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^-	NO3 -	PO_4^{--} μgl⁻¹
1	27	7.2	0.32	36.47	20.68	9.42	0.78	70.12	59.57	15.38	0.04	20
2	26	7.8	0.35	37.07	20.68	11.03	0.78	67.07	60.28	38.94	0.58	48
3	28	8.5	0.35	36.76	20.92	11.95	1.56	68.29	56.73	31.73	0.05	24.5
4	27	8.2	0.35	35.47	14.35	9.65	1.56	97.56	56.73	38.46	0.08	114
Mean	27	7.9	0.31	36.44	19.15	10.51	1.17	75.76	58.32	31.12	0.18	51.62

Table (2): Average number of cells (units l^{-1}) and relative abundance of algal taxa identified from the samples collected during September, 1997 and March, 2000.

Algal Taxa	Average number of units/l	Relative mean abundance %
Division Cyanophyta		
Gloeocapsa turgida (Kutz.) Naeg.	2250	0.32
Microcystis aeruginosa f. *flos aquae* (Wittr.) Elenk.	267500	38.61
Microcystis pulverea f. *elachista* (W.et G.S. West) Elenk.	525	0.07
Merismopedia tenuissima Lemm.	187.5	0.02
Merismopedia punctata Meyen	750	0.1
Gomphosphaeria lacuastris Chodat	31250	4.5
Oscillatoria limnetica Lemm.	6765.25	0.97
Oscillatoria planctonica Wol.	2191.25	0.31
Phormidium corium (Ag.) Gom.	3452	0.49
Aphanizomenon flos-aquae (Lemm.) Ralfs ex Born.et Falh.	128000	18.47
Division Bacillariophyta		
Melosira granulata Ehr. Ralfs.	5250	0.75
Melosira distans Ehr Kutz.	4000	0.58
Cyclotella meneghiniana Kutz.	79250	11.43
Synedra ulna (Nitzsch.) Ehr	43500	6.27
Division Chlorophyta		
Volvox globator (L.) Her	67500	9.74
Chodatella ciliata (Lager.) Lemm.	5500	0.79
Coalastrum microporum Naeg.	1625	0.23
Dictyosphaerium pulchellum Wood	22500	3.24
Oocystis elliptica W. West	4625	0.66
Pediastrum simplex Meyen	2500	0.36
Pediastrum simplex var. *duodenarium* (Balley) Rabenh.	3463.25	0.5
Scenedesmus quadricauda Breb.	3510	0.5
Cosmarium reniforme (Ralfs) Arch.	4787.75	0.69
Division Pyrrophyta		
Gymnodinium simplex (Lehmann) Kofoid and Swezy	1875	0.27
Total	692757	99.87

Fig. (4). Population density percentage of algal groups

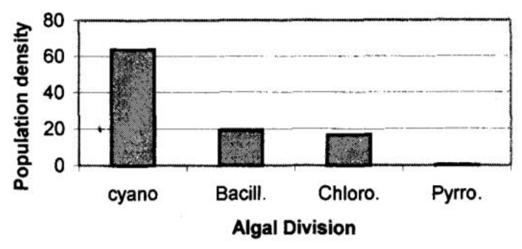
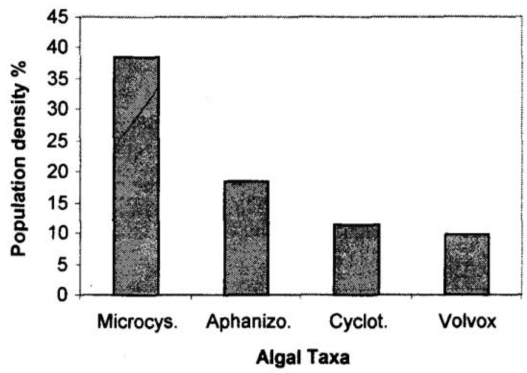


Fig. (5). consistent population percentage of major bloom forming algae



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تحذير مبكر عن غزارة نمو الهائمات النباتية ببحيرة ناصر بمنطقة توشكى باستخدام صورة مستشعرة عن بعد

عادل فهمى حامد

قسم النبات– كلية العلوم- جامعة عين شمس

تم استخدام بيانات القمر الصناعى الأمريكى لاندسات ٧ والمعتمدة على نظم المعلومات الجغرافية فى التقاط وتحديد النمو الغزير للهائمات النباتية فى بحيرة ناصر بمنطقة توشكى. وبمعالجة البيانات الرقمية للصورة الفضائية، فلقد تم زيادة ايضاح الصورة بتطبيق التقسيم بطرق تحليل المركبات الأساسية وتقسيم التشابه الأكبر. وأوضحت البيانات الفضائية والدراسات الحقلية عن الانتشار والنمو الغزير للبكتيريا الخضراء المزرقة *Microcystis aeruginosa* f. *flos aquae* , *Aphanizomenon flos aquae* **والنامية مع نباتات وهائمات نباتية اخرى. ويرجع سبب النمو الغزير للبكتيريا الخضراء المزرقة فى فصلى الربيع والصيف الى الصفات الفيزيائية والكيميائية لمياه البحيرة. وتسبب أنواع البكتيريا الخضراء المزرقة تأثيرات ضارة على البيئة حيث تفرز مواد سامة تهدد صحة الانسان والحيوان. ويتعبر هذا البحث محاولة أولية يستفاد منها لدراسات مستقبلية على فترات زمنية مختلفة لمتابعة نمو وانتشار الأنواع السامة من البكتيريا الخضراء المزرقة فى البحيرة.**