Mini Review:

Monitoring of Phytoplankton blooms by remote sensing

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ABSTRACT: In the aquatic environment, the phytoplankton or micro-algae are the primary producers of food chain upon which most marine and freshwater organisms depend on. A phytoplankton bloom has been defined as a "high concentration of phytoplankton in an area, caused by increased reproduction". Blooming can be stimulated by several abiotic and biotic factors, but the availability of nutrient in the water body seems to be the most limiting factor. Remote sensing is the acquisition of information about an object, without being in physical contact with that object. It uses electromagnetic spectra to discriminate between objects by using the reflectance, absorbance, and transmittance characteristics in different wavelengths. Aircraft and satellite measurements of spectral reflectance are an effective method for mapping the blooms of algae (spatial distribution) and detecting phytoplankton biomass pigment composition in terms of Chlorophyll concentration and its temporal occurrence. Advances in the manufacturing of high-resolution sensors together with different wavelengths and data analysis are making the tool of remote sensing attractive and applicable for use in the management and research of coastal and inland waters.

Keywords: Phytoplankton Bloom, Monitoring, Remote Sensing

INTRODUCTION

Phytoplankton, as primary producers, play a fundamental role in marine and freshwater ecosystems, and their blooms can have significant ecological, economic, and societal implications. Remote sensing offers tools and methodologies that enable efficient and comprehensive monitoring of phytoplankton dynamics across various spatial and temporal scales. Phytoplankton, comprising minute floating algae, thrive in the euphotic zone of aquatic environments, harnessing solar energy to convert carbon dioxide into organic compounds via photosynthesis (Pannard et al., 2007). Furthermore, algae/phytoplankton serve as crucial nutritional resources for a plethora of aquatic organisms, significantly contributing to energy transfer across trophic hierarchies (Pannard et al., 2007). Algal blooms represent natural phenomena within aquatic ecosystems, in eutrophic aquatic environments or resulting from anthropogenic pollution., where algae undergo rapid proliferation under specific environmental conditions Algae can grow exponentially, potentially leading to the emergence of harmful algal blooms (HABs) or nuisance algal blooms (Anderson et al., 2002).

There are different remote sensing techniques for monitoring algal bloom**:**

Ocean Color Satellites represent a milestone in remote sensing, particularly for studying chlorophyll-a concentration and phytoplankton dynamics in the ocean e.g. Coastal Zone Color Scanner (CZCS). Subsequently, the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) enhanced global ocean color data, improving spatial and temporal resolution. SeaWiFS provide more accurate estimates compared with Moderate Resolution Imaging Spectroradiometer (MODIS) in low to moderate Chlorophyll concentrations advancing our understanding of phytoplankton dynamics on a global scale (Belkin,2021; Cetinić et al., 2024).

MODIS (Moderate Resolution Imaging Spectroradiometer) One of the functions of MODIS that provides a synoptic view of coastal areas, aiding large-scale algal bloom identification and monitoring (Kahru and Mitchell, 2001; Gower et al., 2005; Qi et al., 2014).

Landsat Satellite Imagery with its multi-temporal resolution allows for tracking algal bloom dynamics over time, aiding in understanding seasonal patterns (Kloiber et al., 2002; Gitelson et al., 2007). Hamed et al., (2007) used Landsat to examine the spatial distribution of blue-green algae within the saline alkaline lakes of Wadi El-Natrun, Egypt. His data served as an initial source of insight into the proliferation of *Spirulina platensis* (Figures. 1-4). The GIS-based analysis utilized Landsat Thematic Mapper data from March 25. 2000, to observe and monitor phytoplankton blooms within the Toshka region of Lake Nasser, Egypt (Fig. 5). The combination of spatial data analysis and ground-based reference studies yielded substantial insights into the distribution patterns of bloom-forming cyanobacteria, namely *Microcystis aeruginosa* f. *flosaquae* and *Aphanizomenon flos-aquae*. From an ecological standpoint, these cyanobacterial species pose significant risks due to their production of toxic compounds (Hamed, 2000).

Sentinel Satellite Series enables the detection and tracking of relatively small-scale algal blooms, contributing to a comprehensive understanding of coastal water quality dynamics (Gholizadeh et al., 2018).

Hyperspectral Remote Sensing, studies by Gitelson et al. (2017) and Green et al. (2019) demonstrate the efficacy of these sensors in discriminating between algae species, contributing to a comprehensive understanding of aquatic ecosystem (Legleiter et al., 2022).

Aerial Surveys/Aerial Remote Sensing is effective for studying algal blooms in lakes, providing valuable insights into their spatial distribution and temporal dynamics. Unmanned aerial vehicles (UAVs) equipped with remote sensing instruments, such as multispectral or hyperspectral cameras, enable high-resolution imaging of water bodies. For example, the use of drones has become increasingly prevalent in conducting algae bloom surveys, providing a flexible and efficient means of gathering high-resolution spatial data (Kislik et al., 2018).

Understanding the spectral characteristics of phytoplankton and algae is crucial for interpreting remote sensing data and monitoring aquatic ecosystems effectively. These insights aid in assessing ecosystem health, identifying algal blooms, and understanding the impacts of environmental changes on phytoplankton dynamics. The spectral characteristics of phytoplankton/algae in remote sensing depends on the range of wavelengths used (visible portion of light and Near Infrared wavelength). Since Chlorophyll-a, the primary photosynthetic pigment, absorbs light most efficiently in the blue and red regions (at around 430 nm and 665 nm), these bands are crucial for estimating phytoplankton biomass (Gitelson et al., 2011).

Phytoplankton has reflectance peak in the Near Infrared (NIR) due to cellular structure, allowing to differentiate between water- and phytoplankton-dominated areas (Dall'Olmo et al., 2005). Accessory pigments, including phycocyanin, phycoerythrin, Chlorophyll-b, c, and carotenoids, contribute to overall spectral characteristics, influencing absorption features and aiding in taxonomic discrimination (Lorenzoni et al., 2015).

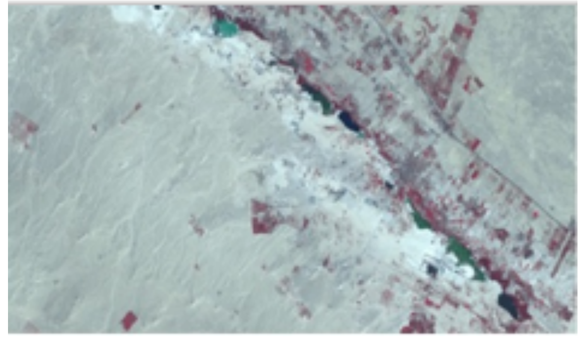

Figure 1. False color composite image of Wadi El-Natrun depression during winter season.

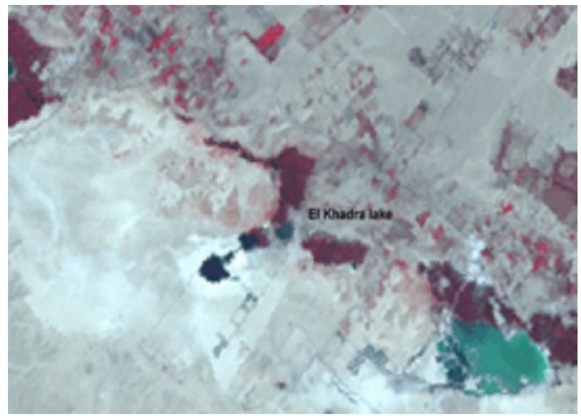

Figure 2. Magnified false color composite image showing the reddish tone which detected in El-Khadra Lake during winter season

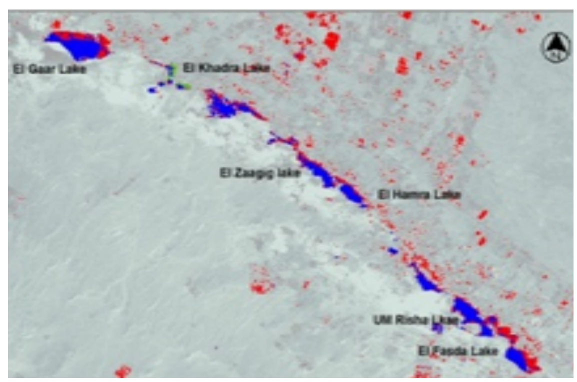

Figure 3. GIS based map of Wadi El-Natrun depression during winter season.

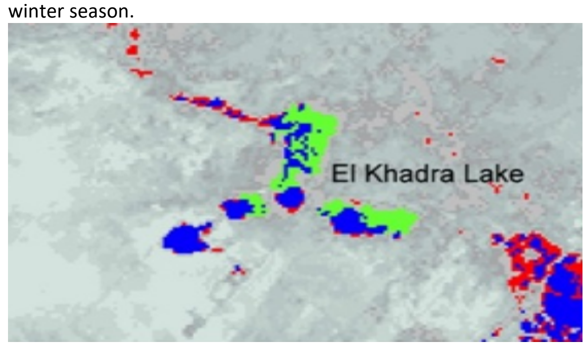

Figure 4. Magnified GIS based map of Wadi El-Natrun depression during winter season showing blooming of *Spirulina* in El-Khadra Lake.

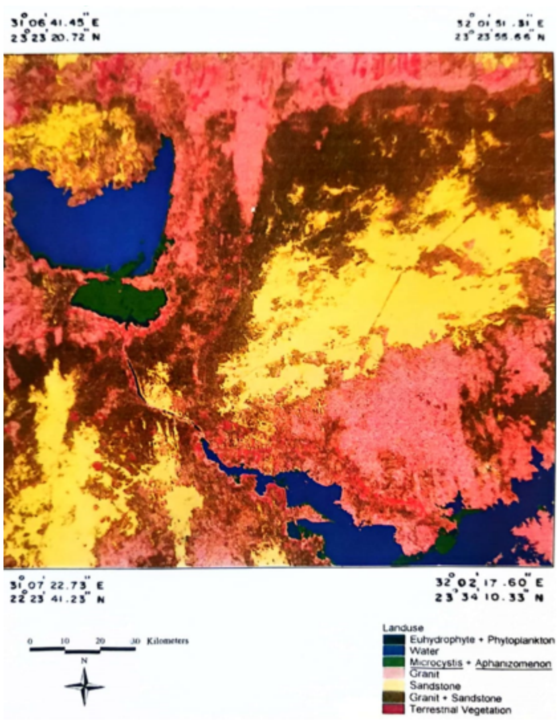

Figure 5. Land use/Land Cover of Lake Nasser – Toshka Area, Egypt (Landsat ETM + imagery PCA 123, 25 March 2000).

The dynamics of cyanobacteria blooms have been successfully mapped using satellite remote sensing in several regions around the globe, with notable examples in Lake Erie (Sayers et al., 2019), the Baltic Sea (Kahru and Elmgren, 2014), Lake Taihu (Duan et al., 2012; Huang et al., 2014), and South African Lakes (Matthews et al., 2012; Matthews and Bernard, 2015).

In conclusion, utilizing remote sensing techniques for monitoring phytoplankton dynamics is crucial and continually evolving. Various remote sensing platforms have provided valuable insights into phytoplankton populations, offering versatility in estimating biomass, distinguishing functional types, and characterizing optical properties. These capabilities have implications for monitoring harmful algal blooms, environmental management, and public health protection.

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