
UNIVERSITI PUTRA MALAYSIA

# CHLOROPHYLL-A ESTIMATION FROM REMOTELY SENSED DATA

FATIMA AWAD ALLAH MOHAMMED ALI

# CHLOROPHYLL-A ESTIMATION FROM REMOTELY SENSED DATA

**By**

**FATIMA AWAD ALLAH MOHAMMED ALI**

**Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia**

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*Dedicated to*

*My parents and my sister for their encouragement and support*

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science.

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**Chairman: Assoc. Prof. Dr. Shattri B. Mansor**

**Faculty: Engineering**

The science of remote sensing is commonly defined as method that employs electromagnetic energy to detect, record, and measure characteristics of a target. Concentrations of chlorophyll-a in water have been estimated from the spectral distribution of back-scattered light, related to reflectance. Remote sensing in general has been used much more extensively for oceans than for inland waters. Advanced image processing techniques introduced and applied using Landsat Thematic Mapper data acquired on February 22, 1994 over the indicated region of South China Sea.

The objective of the study was to calculate the chlorophyll-a concentration along Kuala Terengganu. The method was carried out to calculate the chlorophyll-a concentration in the study area that is, digital image processing which include preprocessing, display, enhancement, information extraction, and algorithm to calculate the estimated chlorophyll-a.

Results of the regression analysis of DNs against referenced chlorophyll-a was used to calculate the actual chlorophyll-a concentration (calculated chlorophyll-a) of Landsat TM bands1, 2, and 3.

The results show that the chlorophyll-a concentrations in the study area are significantly correlated with band 1, 2, and 3. The lower chlorophyll-a concentration with levels (0.031-0.019) $mg/m^3$, the higher chlorophyll-a concentration with levels (0.404-0.391) $mg/m^3$. Finally, band 2 was the best in terms of all the parameters evaluated

In conclusion, remote sensing is an important technology for measuring chlorophyll-a concentration in the coastal water of South China Sea. From the result, TM sensor has been found a useful tool for studying chlorophyll-a concentration.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia untuk keperluan Ijazah Sarjana Sains

# ANGGARAN KLOROFIL-a DARIPADA DATA PENDERIAAN JAUH

**Oleh**

**FATIMA AWAD ALLAH MOHAMMED**

**April 2000**

**Pengerusi: Prof. Madya Dr. Shattri B. Mansor**

**Fakulti: Kejuruteraan**

Teknologi penderiaan jauh merupakan satu kaedah yang menggunakan tenaga elektromagnet untuk mengesan, merekod dan mengukur kriteria sesuatu sasaran. Konsentrasi klorofil-a pada badan air telah dihitung daripada taburan spektra hasil penyerakan semula cahaya, yang mana ia berkaitan dengan pantulan. Penderiaan jauh secara amnya, lebih banyak digunakan secara ekstensif dalam kajian perairan laut berbanding badan air di kawasan daratan. Teknik memproses imej lanjutan diperkenalkan dalam kajian ini dan diaplikasikan ke atas data imej Landsat Thematic Mapper yang diperolehi pada 22 Februari 1994 bagi kawasan perairan Laut China Selatan.

Objektif kajian adalah menghitung konsentrasi klorofil-a di sepanjang pantai Kuala Terengganu. Metod pemprosesan imej yang digunakan merangkumi pra-pemprosesan, pemaparan, penjelasan imej dan pengekstrakan maklumat serta algoritma yang digunakan untuk menghitung anggaran klorofil-a. Kedua-dua langkah ini akan

diintegrasikan merangkumi pengekstrakan maklumat daripada imej dan anggaran klorofil-a menggunakan algoritma.

Keputusan daripada analisa regression DN dengan klorofil-a rujukan digunakan untuk mengira kepekatan sebenar klorofil-a (klorofil-a yang dikira) bagi jalur Landsat Tm 1, 2 dan 3.

Hasil kajian menunjukkan korelasi konsentrasi klorofil-a di kawasan kajian adalah signifikan dengan jalur 1,2 dan 3. Nilai terendah konsentrasi klorofil-a adalah 0.031- 0.019 $mg/m^3$, manakala nilai tertinggi konsentrasi klorofil-a adalah 0.404 - 0.391 $mg/m^3$. Akhir sekali, didapati jalur 2 adalah paling baik untuk parameter-parameter yang dikaji.

Kesimpulannya, penderiaan jauh merupakan teknologi yang penting untuk mengukur konsentrasi klorofil-a di kawasan perairan pantai Laut China Selatan. Berdasarkan hasil yang diperolehi, didapati penderia Thematic Mapper merupakan alat yang berguna untuk mengkaji konsentrasi klorofil-a.

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| | |
|---|---|
| ADEOS | Advanced Earth Observation Satellite |
| AVHRR | Advanced Very High Resolution Radiometer |
| CZCS | Coastal Zone Color Scanner |
| CHL | Chlorophyll-a |
| $Co_2$ | Carbon Dioxide |
| DN | Digital Number |
| GCPs | Ground Control Points |
| m | Meter |
| MSS | Multspectral Scanner |
| mg | Milligram |
| NASA | National Aeronautics and Space Administration |
| NASDA | National Space Development Agency of Japan |
| NOAA | National Oceanic and Atmospheric Administration |
| NIR | Near Infrared |
| OCTS | Ocean Color and Temperature Scanner |
| RS | Remote Sensing |
| S | South |
| SCS | South China Sea |
| SeaWiFS | Sea-Viewing Wide Field of View Sensor |
| SAS | Statistical Analysis System |

| | |
|---|---|
| TM | Thematic Mapper |
| VICAR | Video Image Communication and Retrieval |
| JPL | Jet Propulsion laboratory |

# CHAPTER I

## INTRODUCTION

The science of remote sensing is commonly defined as methods that employ electromagnetic energy to detect, record and measure characteristics of a target, such as the Earth's (Sabins, 1986). The remote sensing process involves the collection and analysis of data about the electromagnetic energy reflected and/or emitted from an object in order to obtain useful information about the object (Lillesand and Kieffer, 1994). One of remote sensing application is the study of the concentration of Chlorophyll-a in coastal areas. Algal chlorophyll-a is measurable and quantifiable in a laboratory by extracting the plant pigments from cells and analyzing pigment concentration in the extract (Nusch, 1980). However, because the amount of algal chlorophyll is indicative of the productivity and tropic status of surface waters, it is desirable to monitor pigment densities over expanses of geographic space and at numerous points in time, both within one 'growing season' and from one year to the next. Therefore, remote sensing is viewed as an important technology for assessing chlorophyll-a concentration (e.g., Johnson, 1978).

The remote sensing tool can be utilized to give a more comprehensive spatio_temporal perspective on a coastal zone. There have been many satellites and airborne studies of different coasts. This has resulted in the development of several different algorithms for the retrieval of phytoplankton from the optical properties of

water. These algorithms are based on an understanding of the reflection, absorption and scatter of light by water and its constituents (Gordon & Morel, 1983).

The potential of remote sensing techniques to quantify plankton alga populations has been recognized by several authors (Huang and Lulla 1986, Lathrop and Lillesand 1986). Quantification of algae in these studies involved the development of empirical relationships between chlorophyll concentrations and radiance measured at the sensors.

Multi-spectral satellite imagery is a relatively new tool in aquatic sciences. It can provide synoptic data on environmental parameters that may affect the eutrophication process of the aquatic system. By applying appropriate algorithms, a group of detailed images or maps can be prepared that quantify the spatial distribution of such important water quality components as phytoplankton chlorophyll-a and suspended matter, in ocean and even coastal waters (Gordon 1973, Ritchie et al. 1976, Johnson 1978, Gordon and Clark 1980, Gordon et al. 1980, Gower 1980, Morel 1980, Gordon and Morel 1983). These bio-optical algorithms are derived from in situ measurements and differ mainly in their used coefficients. These latter distinguish between low and high phytoplankton concentrations. For coastal waters, the algorithms are highly sensitive to the water region presently considered.

Satellite remote sensing has demonstrated its usefulness in estimating the concentrations of both suspended sediments and chlorophyll-a. Suspended sediment concentrations have been determined in the Delaware Bay by using the Landsat Multi-Spectral Scanner (MSS) (Klemas et al; 1974), and the Advanced Very High Resolution

Radiometer (AVHRR) (Stumpf and Pennock, 1989). Chlorophyll-a concentrations have been estimated in other study areas with the Coastal Zone Color Scanner (CZCS) (Gordon et al; 1983) and the Landsat Thematic Mapper (TM) (Tassan, 1987; Pattiaratchi et al; 1994). The concentrations of optically active water constituents can be estimated from satellite images by the interpretation of received radiance at the sensor at different wavelengths (Gordon and Morel, 1983).

## Chlorophyll-a

Chlorophyll-a is a pigment present in living plants, which is responsible for photosynthesis. In productivity studies, chlorophyll-a is usually taken as the measure of phytoplankton biomass (Gordon and Morel 1983). Elevated chlorophyll-a concentrations associated with algae, most often result from high levels of water-borne nutrients, which can generate foul smelling and even toxic water conditions. While the measurement of the chlorophyll-a content of surface waters is well established, the reliability of optical properties measurements and the effects deriving from the scattering and absorption by organic and inorganic particles in the water column in turbid water, such as occurs along the Terengganu coast, has not been established. The thrust of this preliminary investigation is to provide a basis for future and more intensive analysis of such parameters along Terengganu coasts based upon the technology of remote sensing.

Concentrations of chlorophyll-a in water have been estimated from the spectral distribution of back-scattered light (Gitelson *et al.* 1993a, Kirk 1994) and tripton have

been related to reflectance, but much less frequently. Remote sensing in general has been used much more extensively for oceans than for inland water, especially those of small to moderate size. Estimation of the Chlorophyll-a content in water is important due to its indication of phytoplankton, which is the basis of the marine food chain. A high level of accuracy for the direct estimation of phytoplankton can be obtained by using color change from blue to green as chlorophyll-a pigments in water becomes more abundant (Sathyendranath and Morel, 1983).

Photosynthesis by phytoplankton depends on a group of very similar photosynthetic pigments, know collectively as chlorophyll-a, which strongly absorb light in the region of 450 nm. Increasing the concentration of chlorophyll-a in water results in a progressively greener coloration due to a combination between this absorption and increased backscatter at 500 to 600 nm. The color change can be measured either in the laboratory or remotely from aircraft or satellite, and used to quantify phytoplankton biomass (Gorden *et al.* 1983).

The mapping of phytoplankton concentrations and suspended sediment in coastal waters is now preferably performed using remotely sensed data to remotely determine the quantity of phytoplankton in water and the spectral response of its chlorophyll-a concentration. Algorithm that was used for the computation of chlorophyll-a concentration has generally the formula of the form (Sathyendranath *et al* 1988).

$$Chl = A\,[L_w(\lambda_1)/L_w(\lambda_2)]^B \qquad (1)$$

Where $L_w$ is the radiance, $\lambda_1$ and $\lambda_2$ are wavelengths, Chl is the concentration of chlorophyll-a (mg/ $m^{-3}$), and A and B are constants which depend on optical properties of water and the chosen channel combination 1 and 2.

Chlorophyll-a absorbs light most efficiently at the ends of the visible spectrum, in the ranges of red and violet-blue light. Absorption is weak between 450 and 650 nm, hence, the green color of the pigment. In the ocean, most of the chlorophyll-a is contained in the members of the phytoplankton, microscopic green plants forming the lowest tropic level of the marine food web. Ocean water, when containing very little particulate matter, scatters as a Raleigh scatter with the well-known deep purple or bluish color of the ocean. When particulate matter is added to the water, the scattering characteristics and the color changed, as well. As the concentration of phytoplankton increases, ocean color shifts from blue to green. However, some phytoplankton, such as the various red tide, can change the water to colors such as red, yellow, blue-green, or mahogany. Hence, the measurement of ocean color from space can give us an indictor of the chlorophyll-a content of the ocean.

## Objectives Of The Study

The main objectives of this study are:

- To measure the concentration of chlorophyll-a in Trengganu coast near-shore waters.
- To use digital image processing techniques in detection of chlorophyll-a concentration.
- To estimate the distribution of the chlorophyll-a concentration of the study area.

## Research Problem

Using the traditional methods to calculate the chlorophyll-a is costly, time consuming and not accurate, so as a result of that a new technology should be used to answer those problems. Remote sensing is a new vision that can be used to calculate the chlorophyll-a concentration. In addition of that remote sensing can cover a very big area compare with the traditional methods.