ARPN Journal of Engineering and Applied Sciences

ESTIMATION OF CHLOROPHYLL-A CONTENTS ON THE SEA SURFACE BY REMOTE SENSING TECHNOLOGY

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ABSTRACT

Chlorophyll-a is a green pigment found in primary producers like phytoplankton and has always been used as an indicator of phytoplankton abundance in water sources. The objective of this study was to estimate the chlorophyll-a content at the upper Gulf of Thailand sea surface in 2021 using Aqua/MODIS satellite data, together with relevant factors: wind currents and sea surface temperatures. The chlorophyll-a content analysis was performed using NASA's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Data Analysis System (SeaDAS). The analysis results showed that the chlorophyll-a content on the sea surface was highest during the southwest monsoon (May-October) and lowest during the northeast monsoon (November-April). The average chlorophyll-a content in 2021 was found to be the highest in October at 3.396 mg/m^{3}and the lowest in August at 0.781 mg/m^3. It was also found that the chlorophyll-a content on the sea surface was correlated with changes in wind currents caused by the influence of monsoon winds and sea surface temperatures.

Keywords: remote sensing; electromagnetic waves; chlorophyll-a.

Manuscript Received 10 January 2023; Revised 20 May 2023; Published 15 June 2023

INTRODUCTION

Photosynthesis is the process by which the inorganic substances carbon dioxide and water are converted to organic compounds in the plant with the aid of light energy. All living organisms need energy to grow and reproduce, maintain their structures, and respond to their environments. Algae, multicellular plants and some bacteria capture light energy from the sun and convert it to chemical energy necessary for living. Plants receive light energy directly from the sun because of a special mechanism, a green pigment called Chlorophylls. Chlorophylls have a structure consisting of 4 pyrrole rings arranged next to each other, with Mg in the middle, which is the light-absorbing part called the head, and the tail part is phytol. Chlorophylls are pigments in the chloroplast that capture energy from light (Bhatrasataponkul, 2004).

Chlorophyll-a is a photosynthetic pigment contained within the cells of phytoplankton, which are microscopic single-celled algae floating in the water and carried by wind and currents. Therefore, phytoplankton is important to aquatic ecosystems as a primary producer and indicator of water quality (Emmanuel & Onyema, 2007). Water quality is an important environmental factor indicating the status of water sources, directly and indirectly affecting organisms living at all levels of the food chain, from primary producers to large aquatic animals. Nutrient content in water sources is an important factor for the photosynthetic process of primary producers and affects the abundance of natural water sources (Bianchi *et al*., 2003). As Chlorophyll-a is a green pigment found in primary producers, it has always been used as an indicator for phytoplankton abundance in water sources (Plant Physiology, 2021). The sea in the upper Gulf of Thailand is a semi-enclosed bay, shaped like a square with open sides to the south, connecting with the central Gulf of Thailand (Matsumura, 2006; Intacharoen *et al*., 2018). The upper Gulf of Thailand has four major rivers in the northern part of it: Mae Klong, Tha Chin, Chao Phraya and Bang Pakong (Pier in the Inner Gulf of Thailand, 2021; The Gulf of Thailand, 2021). The climate is under the influence of monsoon winds, namely the southwest monsoon season begins around May and ends around September or early October, and the northeast monsoon season begins in November and ends in February until early March (Na-u-dom *et al*., 2013).

From many research studies on chlorophyll-a, it has been found that at present, modern and up-to-date methods and technologies have been applied, such as Remote Sensing Technology (Moses *et al*., 2012; Yu *et al*., 2014; Guo*et, al*., 2016; Lins, *et al*., 2017; Dabuleviciene *et al*., 2020; Laosuwan *et al.,* 2022). Remote Sensing Technology is a survey of resources on the earth by using electromagnetic waves as a medium to obtain information (Esa, 2016; Elachi *et al*., 2021; University of Lucknow, n.d.). Nowadays, Remote Sensing Technology has been widely used as a main tool to study various spatial phenomena by using data from natural resource survey satellites as a tool to continuously and efficiently record the area condition. It can explore natural resources on land surface, water surface and sub-surface, covering a wide area.In addition, the received data is fast and up-to-date (Laosuwan*et al*., 2016; Rotjanakusol&Laosuwan, 2018; Rotjanakusol & Laosuwan, 2019; Rotjanakusol & Laosuwan, 2020; Prohmdirek*et al*., 2020; Jomsrekrayom*et al*., 2021, Suriya *et al*., 2021; Uttaruk *et al*., 2022). However, the application of remote sensing technology for chlorophyll-a research studies is still very rare in Thailand. Therefore, the objective of this study was to estimate the chlorophyll-a content at the upper Gulf of Thailand sea surface in 2021 using Aqua/MODIS satellite data, together with relevant factors: wind currents and sea surface temperatures.

STUDY AREA

The upper Gulf of Thailand is located in geographic coordinates at 100° - 101° E longitude and 12.3° - 13.3° N latitude (Figure-1).

Figure-1. Study area.

It looks like a semi-enclosed bay in a rectangular shape. The total surface area is about 10,000 km2 with an average depth of 20m. The area covers the coast of PrachuapKhiri Khan, Phetchaburi, SamutSongkhram, SamutSakhon, Bangkok, SamutPrakan, Chachoengsao and Chonburi. Since the upper Gulf of Thailand is a semi-enclosed bay, it is influenced by the diurnal tide, with 1 rise and 1 fall per day. The height difference between high tide and low tide averaged between 1- 0.8 m. Both the type and range of tidal heights affect sediment accumulation.

MATERIALS AND METHODS

Research Methods

In this study, daily chlorophyll-a (Level 2 product) data obtained from the MODIS sensor mounted on the Aqua satellite in 2021 was used. Chlorophyll-a data is available for download from the Ocean Color website at http://oceancolor.gsfc. nasa.gov. It is geometric correction data and has a pixel size of 1,000 m. In this study, chlorophyll-a data on the sea surface were processed using SeaWiFS Data Analysis System (SeaDAS) software program installed on Windows 10 operating system.SeaDAS can be downloaded from EARTHDATA at https://seadas.gsfc.nasa.gov/downloads/. Wind data can be downloaded from the Remote Sensing Systems website at www.remss.com/measurements/ wind. Sea surface temperature data can be downloaded from the EARTHDATA website at https://giovanni.gsfc.nasa.gov/giovanni/.

Wind current data and sea surface temperature data were used as factors for analyzing changes in chlorophyll-a content on the sea surface. In the process, the chlorophyll-a data was modified by geocoding under the SeaDAS processing method, creating a new map with the projection as Universal Transverse Mercator (UTM). Data were cut only for the upper Gulf of Thailand study area with boundaries at longitude 100° - 101° E and latitude 12.3°-13.3° N, data were aggregated from daily to monthly and annually. The chlorophyll-a content on the sea surface was then assessed in combination with wind currents and sea surface temperatures.

RESULTS AND DISCUSSIONS

Assessment Result of Chlorophyll-A Content

Analysis of chlorophyll-a content and distribution on the sea surface in the upper Gulf of Thailand monthly in 2021 through data from Aqua/MODIS satellite is shown in Figure-2 and Table-1. Figure-2 shows that the content and distribution of chlorophyll-a on the sea surface in the upper Gulf of Thailand in 2021 was highest in October at 3.396 mg/m3 and lowest in August at 0.781mg/m^3. The monthly average amount of chlorophyll-a on the sea surface in the upper Gulf of Thailand in 2021 was high from June to October, the southwest monsoon season. However, it was low from November to April, the northeast monsoon season. After that, it was high again in June. The trend of high and low chlorophyll-a content was based on seasonal and climatic changes, as well as the density and distribution of phytoplankton in each area. It can be said that seasonal changes affect the high and low trend of the average annual chlorophyll-a content.

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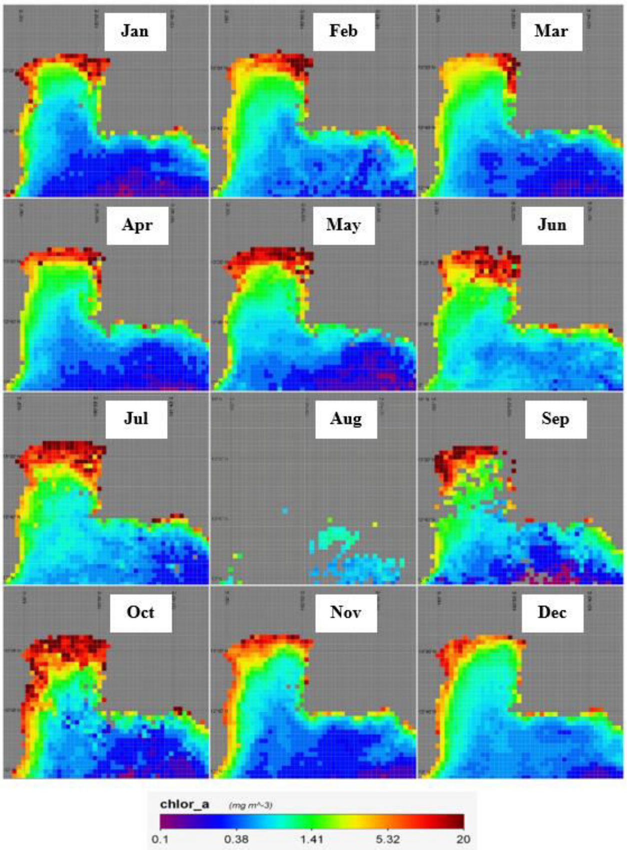

Figure-2. Chlorophyll-a content and distribution on the sea surface in 2021.

Table-1. Chlorophyll-a content and distribution on the sea surface in 2021.

Month	chlorophyll-a (mg/m^3)
Jan	1.744
Feb	2.003
Mar	1.446
Apr	1.645
May	2.349
Jun	2.460
Jul	2.716
Aug	0.781
Sep	2.495
Oct	3.396
Nov	1.580
Dec	1.455

Assessment Result of Chlorophyll-A Content in Combination with Wind Currents

Assessment results of chlorophyll-a content and distribution on the sea surface in the upper Gulf of Thailand monthly in 2021 in combination with wind currents can be shown as in Figure-3.

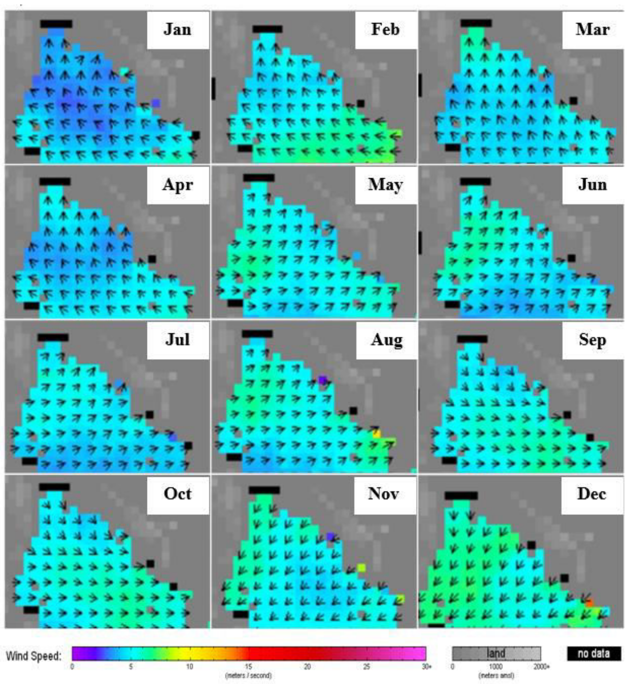

Figure-3. Chlorophyll-A Content in Combination with Wind Currents.

a) In January the tide flowed in the east, some flowed from the northeast of the upper Gulf of Thailand, flowing along to the west, then flowing out to the north of the upper Gulf of Thailand. The average chlorophyll-a content was about 1.744 mg/m^3, which was found mostly in SamutSongkhram and Chachoengsao.

b) In February, the tide flowed in the east of the upper Gulf of Thailand, turning left and flowing up to the northwest, then flowing out to the north of the upper Gulf of Thailand. The average of chlorophyll-a content was about 2.003 mg/m^3, which was found mostly in Chachoengsao.

c) In March, the tide flowed in the southeast of the upper Gulf of Thailand, flowing up along the northwest, then flowing out to the north of the upper Gulf of Thailand. The average of chlorophyll-a content was about 1.446 mg/m^3, which was found mostly in Chachoengsao.

d) In April, the tide flowed in the east of the upper Gulf of Thailand, some flowed up along the west, then flowed out to the north of the upper Gulf of Thailand. The average chlorophyll-a content was about 1.645 mg/m^3, which was found mostly in Chachoengsao.

e) In May, the tide flowed in the southwest, turning right and flowing along the northeast of the upper Gulf of

VOL. 18, NO. 8, APRIL 2023 ISSN 1819-6608
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Thailand. The average chlorophyll-a content was about 2.349 mg/m^3, which was found mostly in SamutSongkhram to Chonburi.

f) In June, the tide flowed in the southwest, turning right and flowing along the northeast of the upper Gulf of Thailand. The average of chlorophyll-a content was about 2.460 mg/m^3, which was found mostly in Chachoengsao and Chonburi.

g) In July, the tide flowed in the southwest, turning right and flowing along the northeast of the upper Gulf of Thailand. The average chlorophyll-a content was about 2.716 mg/m^3, which was found mostly in Bangkok, SamutPrakan and Chachoengsao.

h) In August, the tide flowed in the southwest, turning right and flowing along the northeast of the upper Gulf of Thailand. The average of chlorophyll-a content was about 0.781 mg/m^3, which was found mostly in SamutPrakan and Chachoengsao.

i) In September, the tide flowed in the north, turning right and flowing along the northeast of the upper Gulf of Thailand. The average chlorophyll-a content was about 2.495 mg/m^3, which was found mostly in SamutSongkhram and SamutSakhon.

j) In October, the tide flowed in the north, some flowed from the northwest, turning right and flowing along the northeast of the upper Gulf of Thailand. The average of chlorophyll-a content was about 3.396 mg/m^3, which was found mostly in SamutSongkhram to Chonburi.

k) In November, the tide flowed in the north, some flowed from the northeast, turning left and flowing along the southwest of the upper Gulf of Thailand. The average chlorophyll-a content was about 1.580 mg/m^3, which was found mostly in SamutSongkhram and SamutSakhon.

l) In December, the tide flowed in the north, some flowed from the northeast, turning left and flowing along the southwest of the upper Gulf of Thailand. The average chlorophyll-a content was about 1.455 mg/m^3, which was found mostly in SamutSongkhram and SamutSakhon.

Assessment Result of Chlorophyll-A Content in Combination with Sea Surface Temperature

Assessment results of chlorophyll-a content and distribution on the sea surface in the upper Gulf of Thailand in combination with sea surface temperature can be shown in Figure-4. From Figure-4, in March, the sea surface temperature was high (approximately 28-29°C). The sea surface temperature increased steadily until May (more than 30°C), which was the monsoon transition period from the northeast monsoon to the southwest monsoon. In the summer, plankton reproduction increases significantly with sea surface temperatures. June is the south monsoon season. In the rainy season, the sea surface temperature decreases (approximately 27-29°C). After that, in July to October, the sea surface temperature decreases (approximately 27-28°C), resulting in a decrease in the amount of plankton reproduction. November to February is the northeast monsoon season. In the cool season, November to February is the northeast monsoon season. The sea surface temperature is lower (approximately 27-28 °C), resulting in a limited decrease in the number of plankton in accordance with the low sea surface temperature.

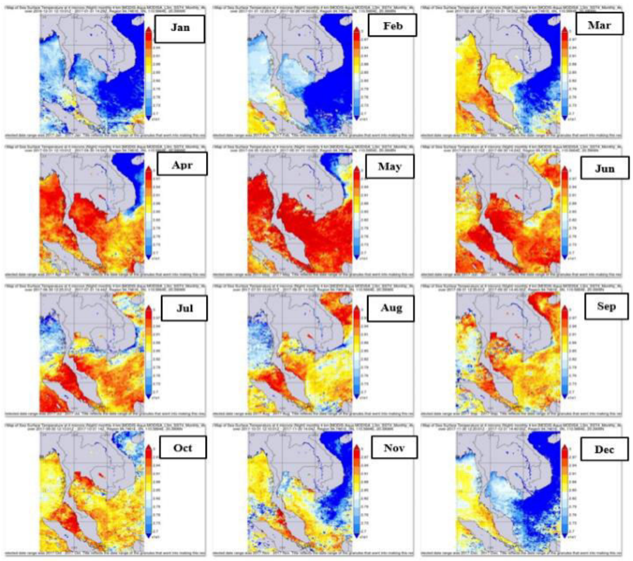

Figure-4. Chlorophyll-a content in combination with sea surface temperature.

CONCLUSIONS

Assessment result of chlorophyll-a content and distribution on the sea surface in the upper Gulf of Thailand monthly in 2021 using Aqua/MODIS satellite data in combination with relevant factors: wind currents and sea surface temperatures in this study revealed that chlorophyll-a content on the sea surface tended to change according to the influence of the monsoon wind. That was, the chlorophyll-a content was high during the southwest monsoon and it was low during the northeast monsoon. In addition, monthly highs and lows of chlorophyll-a on the sea surface were likely to be consistent with current flow and coastal sea surface temperatures. However, there is no such study to support this idea. This is consistent with the research titled “Analysis of Content and Distribution of Chlorophyll-a on the Sea Surface through Data from Aqua/MODIS Satellite” by Laosuwan (Laosuwan *et al*., 2022). The results of this study showed that the factors of chlorophyll-A formation at the sea surface in the upper

Gulf of Thailand were unlikely to consist solely of wind currents and sea surface temperatures. Other factors should also be studied, such as light intensity, water quality, salinity, nutrient contents, competition for nutrients among different plankton species or the ability of some phytoplankton to generate and release certain substances to inhibit other plankton's growth.

ACKNOWLEDGEMENTS

This research project is financially supported by Mahasarakham University.

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