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Pre and Post Effects Assessment of Marine Ranch Construction in Chlorophyll-a Concentration Using MODIS Data and a Web-Based Tool. A Case Study in Zhelin Bay, China

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Abstract

Chlorophyll-a (Chl-a) concentration in lakes can tell a lot about a lake's water quality and ecosystem. It is a measure of the amount of algae growing in a waterbody and can be used to monitor the trophic condition of a waterbody. We studied the pre and post effects of marine ranch construction in Chl-a concentration in Zhelin Bay, Southern China using Normalized Difference Chlorophyll Index (NDCI) and a web-based tool (https://mapcoordinates.info/). We used 8 day composite MODIS image collections of 500 m resolution and randomly selected two stations to extract the chlorophyll-a concentration values through the web-based tool. We recorded the slight increase in NDCI values in all stations after the construction of marine ranch which is a good indicator of the marine organisms' reproduction and survival.

Keywords

Chlorophyll-a, Water Quality, Marine Ranch, Marine Organisms, Web-Based Tool, MODIS

1. Introduction

Chlorophyll-a (Chl-a) and phytoplankton biomass in lakes are essential to understanding the carbon cycle [1], primary production [2], biogeochemical cycles [3], and overall inland and coastal water quality [4]. It is an indicator of health of the waterbodies and provides the estimation of algae in the waterbodies [1]. It can be used to monitor the algae content in lakes [5]. Although algae are a natu-

ral part of freshwater ecosystems, too much algae can cause severe problems in lakes ecosystem leading to dead zone [2]. Dead zone is the area where the aquatic organisms cannot survive due to the low oxygen level [3]. The overgrowth of algal blooms leads to harmful algal blooms which cause bad odors, health threats [1]. Therefore, an increase in algal blooms in water is the indicator of degraded water quality [1].

A number of remote sensing based algorithms have been used to estimate Chl-a presence in lakes ([4] [6] [7]). However, these techniques still face challenges because the lakes have several other constituents and components and their absorption features overlap with the Chl-a [8]. Fewer remote sensing methods have been proposed to reduce the estimation error of Chl-a in turbid productive waters ([1] [3] [9] [10]). Normalized Difference Chlorophyll Index (NDCI) is a novel method that has been proposed to study chlorophyll contents in lakes [1]. NDCI is calculated using the same bands as Normalized Difference Vegetation Index (NDVI) and its values ranges from −1 to 1 ([1] [5] [11] [12] [13]). It is being increasingly used in quantifying NDCI because it reduces the error which can occur due to seasonal variability and sun angle influences [1].

We studied the variation in chlorophyll concentration (**Table 1** and **Figure 2**) in Zhelin Bay, Southern China (**Figure 1**) in this study. Since the distinctive

Table 1. Algorithms used in the web-based tool.

Sensor Image	Index	Band combination
MODIS	NDVI/NDCI	(Sur_refl_b02 − Sur_refl_b01)/(Sur_refl_b02 + Sur_refl_b01)

Figure 1. Study area Zhelin Bay, China.

location and various resources it possessed of, this bay area has become the main site for diverse economic activities [14]. This study aims to assess the variation in NDVI values in Zhelin Bay before and after the construction of marine ranching (2011 and 2013) using the MODIS dataset. MODIS has been widely used in similar research [3]. Marine ranching is a type of aquaculture that began in 1970s to cultivate the marine organisms for food, or for other products in open sea or in an enclosed section of ocean [9]. Marine ranches attract the marine species and therefore increase the productivity in sea/ocean [14]. The outcome of our project would help to evaluate the impacts of marine ranch construction in our study area.

2. Materials and Methods

2.1. Study Area

Zhelin Bay is a natural harbor that is located between Guangdong and Fujian province in China [14]. It has a wide hinterland, many natural barriers, large water area, little storms and tides, less siltation [5]. In additions to these, this bay has diverse coastal geomorphology, fine sand beach [15]. It's a small bay with tropical and subtropical characteristics [5] [14] [15]). This bay is popular as the center for massive aquatic breeds and crib cultivation [16]. The aquaculture production of Zhelin Bay has made significant contributions to the local economy ([5] [14] [15]). It was one of the key top ten exploitation bays in Guangdong province [5].

2.2. Methods

We used a publicly available web-based tool developed by the author to extract the datasets required for our study (**Figure 2**). The tool can be accessed at https://mapcoordinates.info/. The name of the tool is map-coordinates and relies on google earth engine database to extract the datasets ([7] [12]). This tool uses the MODIS datasets available from collection 2 tier 1 products. We used MODIS imagery with 500 m resolution and 8 day composite to study the NDCI values variation in our study area. We choose 2 randomly selected stations with 500 m radius in Bay area. We evaluated the value of NDCI in Zhelin Bay before and after the construction of marine ranching (2011 and 2013). Zhelin Bay marine ranching was built near Nan'ao Island in eastern Guangdong waters in 2010, with a total surface area of 68 - 70 km^2, including shellfish area, seaweed area, net-cage area, stock enhancement area, and artificial reef areas ([5] [14] [15] [16]). The web based tool uses the following band combination from MODIS to compute NDCI.

Our objective for this case study was to demonstrate and test the applicability of the web-based tool to make quick estimates of lake ecosystems by using NDCI, therefore we compared the results through visual assessment using plots and were able to estimate the pre and post effects of marine ranching construction in the area. We did not do further statistical analysis.

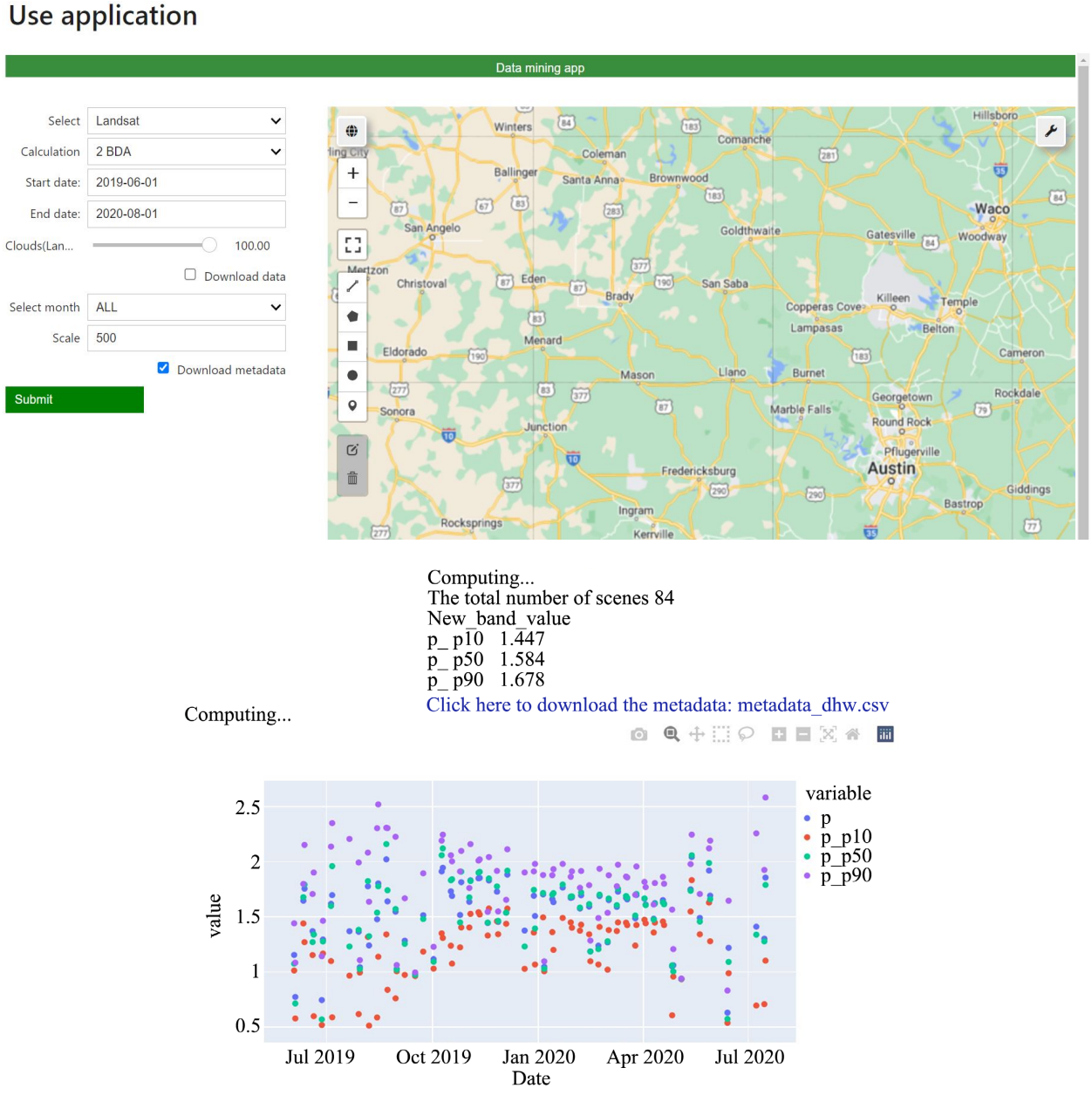


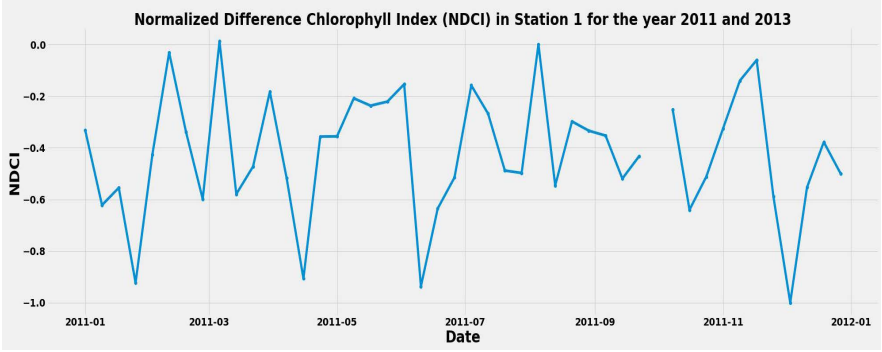
Figure 2. Graphical representation of the web-based tool used to extract the datasets for our case study area.

3. Results

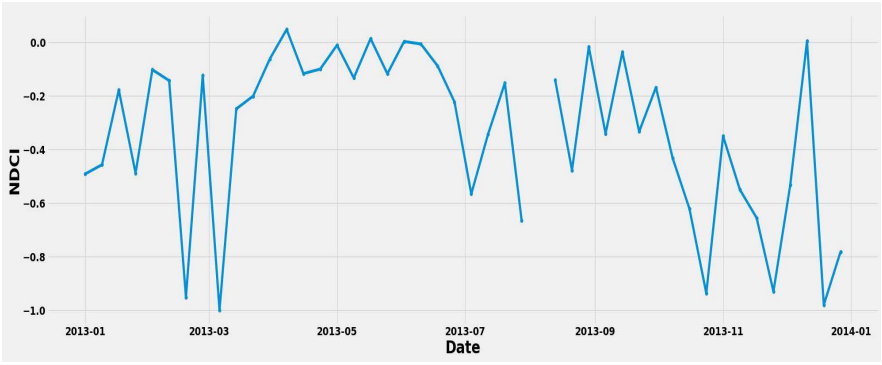
We recorded variation in NDCI values in pre (2011) and post (2013) datasets in both stations of Zhelin Bay. NDCI value at all selected stations slightly increased (**Figure 3**).

4. Discussion

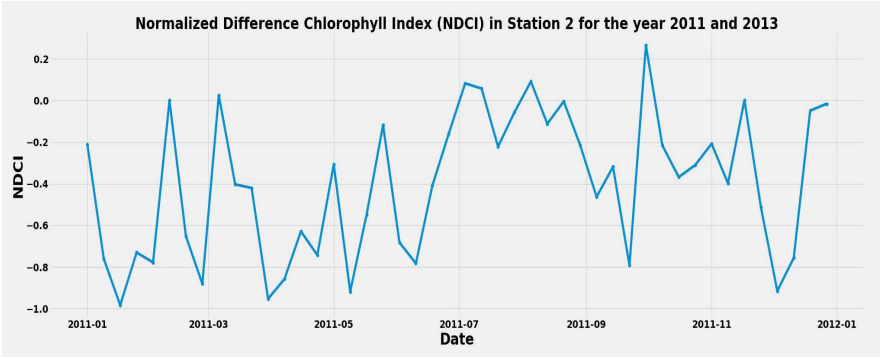
Satellite data helps to acquire long-term, large-scale datasets ([14] [17] [18] [19] [20]). We studied pre and post effects of construction of marine ranch in Zhelin Bay. Our study showed the slight increase in NDCI values in Zhelin Bay, China after the construction of marine ranch. This results corresponds with the previous



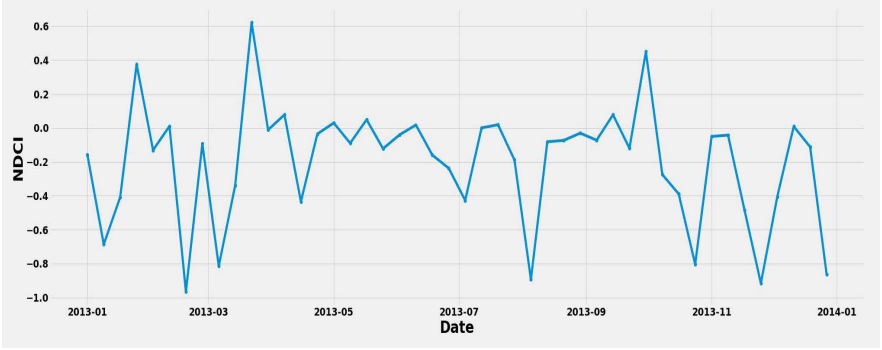
(a)



(b)



(c)



(d)

Figure 3. (a) shows the NDCI values in station 1 for the year 2011, (b) shows the NDCI values in station 1 for the year 2013, (c) shows the NDCI values in station 2 for the year 2011, (d) shows the NDCI values in station 2 for the year 2013.

research in the area [5]. Marine ranching is created by installing artificial structures to support marine life [14]. These kinds of ranches provide shelter [21], feeding to marine life [14]. Y. F. Wang *et al.* (2018) showed that there is increase in the number of species and diversity index of marine life after Zhelin Bay marine ranching was established. The biomass and density of benthos in the marine ranching also increased [18]. This supports the increase in primary productivity of the marine area after the construction of marine ranching [8]. As a result, this is a good indicator for the marine organisms' reproduction and survival ([5] [8] [16]).

The proposed web based tool helped to extract satellite remote sensing data in less than 3 minutes [12]. It has a web-client as the front-end and GEE as computing back-ends ([11] [12] [13]). The front end is the graphical user interface (GUI) web client where the users can specify the algorithms, date range, filter the datasets and send requests to run the analyses [12]. This tool can be used in similar research and the researchers from the non programming background can use this tool for their research.

5. Conclusion

We studied the variation in Chl-a concentration in Zhelin Bay, China in this study. We recorded the positive impacts of marine ranch construction in the study area. Further research in marine ecosystems after the marine ranch construction is recommended to gain in-depth understanding of the impacts imposed by ranch construction. In addition, we strongly believe that this web based application can be handy to researchers willing to conduct research using remote sensing method. This application greatly reduces the time and effort required by conventional methods to conduct similar research [12]. Moreover, it is user friendly and can be used by researchers from all backgrounds ([11] [12] [22]).

Author Contributions

Conceptualization, Ritika Prasai; methodology, Ritika Prasai; data cleaning Ritika Prasai; writing—original draft preparation, Ritika Prasai; All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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