DETECTION OF ALGAL BLOOM IN THE COASTAL WATERS OF BORACAY, PHILIPPINES USING NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) AND FLOATING ALGAE INDEX (FAI)

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KEY WORDS: algal bloom, coastal water, Normalized Difference Vegetation Index, Floating Algae Index, environment

ABSTRACT:

Boracay is a top tourist island in the Philippines known for its 4-km beach with powdery white sand. Recently, abundance of green algae, an indicator of high nutrient discharge, along the coastal waters of the island had led to concerns on its water quality and prompted its closure to allow ample time for rehabilitation. This study examined the algal bloom along the coastal waters of Boracay through the determination of Normalized Difference Vegetation Index (NDVI) and Floating Algae Index (FAI). ENVI and SNAP software were used to process the satellite images of Boracay obtained from its pre-closure to its reopening. .Necessary corrections such as scaling to Top of Atmospheric radiance were applied. NDVI was calculated using orthotile images to determine vegetation and FAI was calculated using Sentinel-2A images. Secondary data showed that the coliform level decreased from 1 million to 18.1 MPN per 100 mL after the rehabilitation of Boracay. Lower NDVI and FAI index values were observed during the reopening of the island. The NDVI value decreased while the FAI value slightly increased on the 1st month of closure which was late dry season. Both NDVI and FAI values increased to their maximum during early wet season and eventually decreased during the reopening of Boracay. Results showed that the abundance of algae had lowered after the rehabilitation of Boracay. However, fluctuating NDVI and FAI values showed the possible seasonal effects on the algal bloom in the island. Further studies considering the other factors on algal blooms may be done.

1. INTRODUCTION

1.1 Background of the Study

Sustainable use of water resources requires water quality monitoring and assessment. A well-designed monitoring and assessment program defines existing and emerging problems and serves as a basis for formulating water quality management programs. Distribution and magnitude of the pollutants and pathogens across the coastal areas which is one of the most exposed to anthropogenic impact can be observed using remote sensing satellite images. Images from PlanetScope could provide ocean, inland sea and coastal zone color assessments with 3m resolution and multispectral bands of RGB and NIR. These bands are helpful in determining the spectral signature of the area. Spectral signature, the amount of reflected solar radiation as a function of its varying wavelength, is considered as the identity of different features types such as water and soil. Different responses of each type can be observed on range of wavelengths using a software called ENVI which can be used to identify on the features types an object fall.

1.2 Problem Statement

In monitoring the water quality, ground truth samples must be collected then analysed in laboratory. Water samples are collected and analysed for dissolved oxygen, pH, temperature, oil and grease, total coliform, and fecal coliform bacteria. Technological advancement allows the use of satellite images to monitor unreachable areas. In this study, NDVI and FAI were used to detect the presence of green algae.

1.3 Objectives

This study aimed to detect the green algae present in Boracay coastal waters and verify its relation to the reported decrease in the amount of coliform bacteria after the closure.

1.4 Significance of the Study

The findings of this study could improve monitoring coastal water quality using satellite images that observes the presence of coliform bacteria. Moreover, this study could be used to prove that coliform bacteria increases the production of green algae on water. The project's goal is planned to help the community determine the possible contributor to the contamination of the water in Boracay, its number and distribution on the area, and condition where they arise in preparation to further analyzation and discussion about eliminating these organisms and improving water quality.

1.5 Scope and Limitation

This study mainly focused on the green algae coliform bacteria level on the coastal areas of Boracay Island. The PlanetScope and Sentinel satellite images (dry and wet season) of Boracay Island will be utilized in this study. Moreover, the software that were used are the Environment for Visualizing Images (ENVI) version 5.2 and Sentinel Application Platform (SNAP).

1.6 Study Area

Boracay is located on the northwest corner of Panay Island in Aklan, Western Visayas Region of the Philippines. The total area of Boracay Island is 10.32 square kilometers covering the beaches, forests, and hills. The island is approximately 200 miles to the south of the Manila City and found on the Sulu Sea and is known for powdery white sand with a summer tropical climate.

In this paper, the said decrease of the amount of coliform bacteria in the Boracay coastal waters were observed through the area of algal bloom found in the PlanetScope satellite imagery before closure and before the reopening of Boracay.

In this research, the study area is the coastal water along the Bulabog Beach. Bulabog Beach is the second largest beach in Boracay. The said beach is also known as “Sport beach” because of the presence of strong winds for some sports like kite board sailing, windsurfing, and jet skiing ("Bulabog Beach Resorts Area 4", 2018). The figures below the satellite image of Boracay Island and Bulabog Beach.

Figure 1. PlanetScope Imagery of Boracay

2. REVIEW OF RELATED LITERATURE

Boracay, a well-known white beach located on the northwestern tip of Panay, Aklan, is one of the prime tourist destinations in the Philippines because of its powdered white sand, tropical palms, diverse marine life, and its crystal blue water. However, in 2015, high coliform bacteria levels were found in Sitio Bulabog, Boracay. The bacteria level reached 47, 460 most probable number (mpn) per millimeter (ml) which exceeded the safe level of 1, 000 mpn/100 ml for waters used for swimming and other human contact activities (Locsin, 2015). In the same year, former Department of Environment and Natural Resources (DENR) Secretary Ramon Paje indicated that Boracay’s water quality is deteriorating as time passes. It is also in this year that the Environmental Management Bureau of Western Visayas reported that the coliform bacteria present in the nearby Bulabog Beach exceeded the acceptable level. In the joint study of Japan International Cooperation Agency, it was reported that untreated water wastes that goes straight to the sea causes the increased level of the bacteria (Buccat, R., 2017). In coastal water quality monitoring report in Boracay 2014 of Environmental Management Bureau (EMB), samples were collected and analyzed for Dissolved Oxygen, pH level, Temperature, Oil and Grease, Total Coliform and Fecal Coliform (EMB, 2014). The samples taken were in-situ (ground data) recovered from different stations in Boracay Island.

Parameter	Unit	Class SC
Total Coliform	MPN/100ml	5000
Fecal Coliform	MPN/100ml	-

Table 1. Standard Value of Class SB and SC Water Classification

It was found out that the drainage outfall in Brgy. Balabag near Bulabog beach failed to comply to the water standard with a value of 47, 460 MPN/100mL (EMB, 2014). The total coliforms include bacteria found in soil and in human or animal wastes. Fecal coliforms are the subgroup of total coliform that signifies the feces of warm-blooded animals ("Coliform Bacteria in Drinking Water Supplies", 2018). Moreover, coliform bacteria are commonly found in the digestive tract of animals including humans and are present in their wastes. The presence of coliform bacteria boosts up growth since it is identified as a nutrient bacterium and produces nitrogen wastes. Algae on the other hand, are organisms present in water bodies that are capable of producing oxygen by photosynthesis. Nitrogenous waste present in the environment can contribute to an increase in the population of algae thus, it can be inferred that coliform bacteria can affect the production of algae (Jensen, J., 2014).

Since microbiological organisms present in the water bodies are hard to identify using spectral analysis, the reflectance of the green algae can be used to relate the presence of coliform bacteria and other pollutants present in the water. The book “Remote Sensing of the Environment” discusses remote sensing in bodies of water. In the example given, green algae were used to determine the reflectance values of its chlorophyll content. The reflectance peak occurred between 690-700 nm that is caused by the scattering of the algae present. The height of the peak above the absorption baseline can be used to infer the chlorophyll amount. It was inferred in this book that as the chlorophyll concentration increases in a body of water, a decrease of reflectance in blue and red wavelengths and an increase in green reflectance can be observed. For this study, data of Sea-viewing Wide Field of View Sensor (SeaWiFS) by NASA was used to identify yellow substances, increase chlorophyll sensitivity and remove atmospheric attenuation since it has additional bands. Inorganic and organic suspended materials present in the near-coastal area affects the information collected and it is required for a study near coasts to implement a sophisticated atmospheric correction and a complex multiple-component extraction methodology. An example was given wherein Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) hyperspectral data was used to accurately map the chlorophyll data. As for the dissolved organic materials present in the water produces humic substances that would appear yellow in color. This can impact the scattering of light in the water and can change its appearance in the images acquired (Jensen, J. ,2014).

On the study conducted by a conservation group, Global Coral Reef Alliance, green algae was a “strong indicator of very high nutrient pollution”. During summer season where an influx in the number of tourists can be observed, the waters in Boracay were often calm that allows the green algae to gather at certain areas (Ranada, 2015). Moreover, based on the coastal water quality monitoring report in Boracay released by EMB in 2014, the coliform bacteria has increased in March and May, during summer season in the Philippines

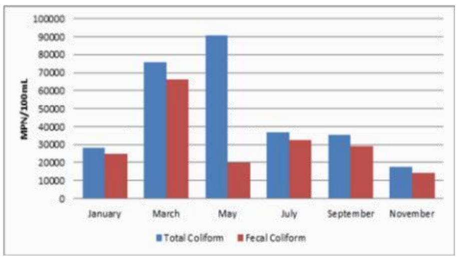

Figure 2. Total and Fecal Coliform Monitoring Results of the Drainage Outfall, CY 2014.

Consequently, on April 5, 2018, the presidential spokesperson officially announced that Pres. Rodrigo "Rody" Roa Duterte passed the recommended total closure of Boracay Island for a maximum duration of six months starting on April 26, 2018. The total closure of Boracay was approved for the rehabilitation of the island. The main priority of the rehabilitation was the construction of new sewage lines since the sewage lines were proven to be deficient that caused backflows ("Palace: Duterte approves 6-month total closure of Boracay – Presidential Communications Operations Office", 2018).

A dry run of Boracay reopening took place on October 15, 2018, a few months after its closure. Before the closure, the water quality test result was 1 million mpn (most probable number) per 100 ml of coliform. And based on the latest water quality test done before the dry run, the amount of coliform lowered to 18.1 mpn per 100 ml of coliform ("Boracay no longer a cesspool, now fit for swimming — Cimatu", 2018).

It is significant to understand the distribution and magnitude of the pollutants and pathogens across the marine environments to be able to monitor and manage the possible consequences. The marine science community had been detecting and analysing hazardous substances and organisms as well as other related parameters to prevent and mitigate the adverse effects. According to GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, 1983) the definition of the term pollution is "... the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance of marine activities, including fishing, impairment of quality of use of seawater, and reduction of amenities." Remote sensing techniques can be applied on the detection and identification spatial characteristics of the ocean surface. To be able to conduct subsurface observation of ocean, remote ocean sensors requires change in absorption, scattering, and reflection of water over a certain wavelength using either the passive or acting sensing illumination sources (Zielinski et al., 2009). The recorded major factors that affected the water quality of the marine ecosystems are suspended sediments, nutrients, pesticides and chlorophyll accumulation. The limited set of in situ measurements of phytoplankton biomass makes it difficult to characterize the temporal and spatial variability of chlorophyll content from the coastal ecosystems. Application of remote sensing technique involves the extraction and conversion of digital numbers from the sea-truth values into radiance and reflectance values used for calibration of a chlorophyll algorithm. The Advanced Land Observing Satellite (ALOS) satellite data can be utilized for chlorophyll estimation of coastal areas. For observing land and coastal areas, the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) can be used (Lim, et al., 2008).

Macroalgae blooms can be quantified using algorithms such as the normalized difference vegetation index (NDVI) and the floating algae index (FAI). The NDVI is defined as the ratio of the difference between the top-of-atmosphere (TOA) radiance or reflectance or red and near-infrared (NIR) divided by their sum. The NDVI of the vegetation spectral signature ranges approximately between 0.2 and 0.9. The FAI algorithm measures the height of the NIR peak relative to a baseline value linearly interpolated from adjacent bands in the red and short wave infrared (SWIR) wavelengths. It reduces the variability of the effects of sun-glint or hazy atmosphere and causes partial atmospheric aerosol correction since aerosols tend to dominate the SWIR radiance signal over ocean (Garcia, Fearns, Keesing & Liu, 2013).

PlanetScope image has a high-spatial resolution of 3m, high radiometric resolution of 12-bit, has sufficient water penetration bands (Visible-Near-infrared) and very high daily temporal resolution. Images are fit for monitoring the dynamic and changes of benthic habitat as well as rapid assessment of extreme event impacts especially in coastal areas. Multispectral remote-sensing system can be utilized to provide efficient data source to map coastal areas. PlanetScope 3B level image is an orthorectified scene where pixel value is scaled to Top-of-Atmosphere (TOA) radiance necessary for radiometric quality control (Wicaksono & Lazuardi, 2018). In the study "Remote Sensing Models of Algal Blooms and Cyanobacteria in Lake Champlain", an estimation of chlorophyll a concentrations and cyanobacteria was done using Landsat Enhanced Thematic Mapper Plus (ETM+) data. Using the wavelength values of the reflectance of algal blooms, the Normalized Difference Vegetation Index using the NIR and Red band was computed to identify the presence of algae in the water. Alongside with this, the spectral profile for the algae was observed. It exhibits four distinct characteristics in its plot, high absorbance of blue light between 400 and 500 nm, reflectance peak in the green region at 550 nm, strong absorption of red light near 675 nm and a reflectance peak between 690 and 700 nm (Jensen, 2007). The image acquired in this study has a time window of 1-2 days to ensure that the algae were accurately detected (Stadelmann et al., 2001). Necessary corrections were applied before the images were processed using ENVI software (Trescott, 2012).
On the study, "Improved Detection of Tiny Macroalgae Patches in Korea Bay and Gyeonggi Bay by Modification of Floating Algae Index", modification of FAI at 12% to 27% increased detection of tiny macroalgae patches was successfully achieved. Modification of FAI through contrast enhancement using moving median filter and applying a scene-wide single threshold resulted in better separability of macroalgae from the surrounding sea. As observed from the results of the study, the frequent existence of the tiny patches and its blooming period every summer indicate that they might have originated locally (Harun-Al-Rashid & Yang, 2018).

The dynamic trend of change of pollutants concentration in time and space can be observed through the construction of data association and semantic association of System Dynamics (SD) and GIS. System dynamics (SD) is a theory of system structure and a set of tools for representing complex systems and analysing their dynamic behaviour (Forrester, J. W, 1961). Geographic information system (GIS) is a computer system for collection, storage, analysis and display of spatial information, and a common technology for processing and analysing geographic data (Chen, Sh. P., Lu, X. J., Zhou, Ch. H. 2000.). The temporal and spatial change of the concentration can be simulated by building a one-dimension SD model using the array function of STELLA software. The analysis of the trend of the change of water pollutants concentration through time will serve as a basis for authorities to conduct more effective emergency response strategies on the situation (Zhang et al., 2011)

3. METHODOLOGY

3.1 Materials Used

3.1.1 Software Used: Two different software were utilized in this study. The Environment for Visualizing Images (ENVI 5.2) was used to process the PlanetScope Ortho tile images and to execute NDVI analysis. Sentinel-2A images were processed using the Sentinel Application Platform (SNAP) where all Sentinel toolboxes, a built-in function of Rayleigh correction function is available.

3.1.2 Data Used: PlanetScope (PS) satellite imagery is one of the Planet satellite imagery products that captures a continuous strip of single frame images also known as scenes. It employs an "always on" image capturing method thus obtaining photos daily and it produces scenes as single RGB frame or half RGB and half NIR frame depending on the capability of the satellite.

There were three products PlanetScope offers; Basic Scene, Ortho Scene, and Ortho Tile Product. Images used were Ortho Tile because it was orthorectified, color-corrected, and removed distortions caused by the terrain which was very useful on cartographic mapping and visualization purposes. It has four band multispectral images (Red, Green, Blue, and Infrared) with a 3.125 m resolution and daily revisit time.

Copernicus Open Access Hub, previously known as Sentinels Scientific Data Hub, is an open source that provides complete and free Sentinels products.

There were different products offered by Copernicus; Sentinel-1, Sentinel-2, Sentinel-3, and Sentinel-5P. Sentinel-2 images were used because aside from its multispectral images and high revisit time of 10 days and spatial resolution of 10m, it has band SWIR which is needed in analysing algae on the coastal waters using Floating Algae Index algorithm.

	Spatial Resolution (m)	Bands (nm)			Revisit Time
		RED	NIR	SWIR	
Sentinel-2A	10	665	865	1650	10 days
Planet Scope Ortho Tile	2.125	630	820	-	Daily

Table 3. Satellite Image Specification Parameters

PlanetScope Ortho tile and Sentinel-2A datasets were selected according to their dates of acquisition following the closing and reopening of Boracay Island as well as the dry and wet seasons. High tide conditions for each dataset were also considered in order to avoid seagrass misclassification.

Date	Time (UTC)	Tide	
April 25, 2018	01:47:25	0.8 m	High
May 18, 2018	01:48:14	1.2 m	High
July 2, 2018	02:22:26	0.9 m	High
October 5, 2018	02:16:01	0.7 m	High

Table 4. Time of Acquisition and Tides of PlanetScope Ortho Tile Images

Date	Time (UTC)	Tide	
April 25, 2018	02:23:31	0.8 m	High
May 18, 2018	02:16:51	1.3 m	High
July 4, 2018	02:23:31	0.5 m	High
October 5, 2018	02:16:01	0.7 m	High

Table 5. Time of Acquisition and Tides of Sentinel-2A Datasets

3.2 Procedure

3.2.1 General Procedure: PlanetScope Ortho Tile images of the study area were collected and necessary corrections were applied. After necessary data calibrations, algorithms such as Normalized Difference Vegetation Index and Floating Algae Index (FAI) algorithm were applied. NDVI resulting values were expected to be in ranges between 0.2 and 0.9 while FAI results should be 0.02 and above to be considered as 100% macroalgae concentration. Accuracy assessment was done by comparing the trends of algae processed on ENVI and SNAP and visual inspection of GeoEye and KOMPSAT images with spatial resolutions of 1.84m and 2.20m respectively.

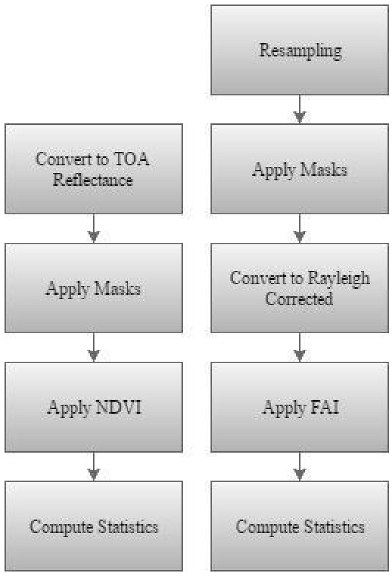

Figure 3. (a) Workflow of applying NDVI (Normalized Difference Vegetation Index) and (b) FAI (Floating Algae Index) on datasets.

3.2.2 Specific Procedure: The images used were the PlanetScope Ortho Tile images that were orthorectified and pixel values were scaled to Top-of Atmosphere radiance. It was recommended to have image dataset every 1 or 2 days to ensure that algae were properly detected. Since algae could be affected by the wind, it was necessary to obtain coincident pairs from the images that will be used. The images were processed using ENVI. Each image was converted to exoatmospheric reflectance by multiplying the reflectance value to band NIR and Red to allow standardized comparison of images taken from different days then performed layer stacking.

After the images were converted, seamless mosaic was done on dataset with two images to combine these images and form one scene. Then, masking was done to remove other features present on the area except the ocean. Three masks were created and applied on the images; near-coast mask, innercoast mask, and cloud mask. Near-coast mask was used to remove the bigger part of the image and only focus on the specific study area. Inner coast mask was used to mask the island and cloud mask for clouds. It was recommended to retain only the ocean for easier detection and analysis of algae on the water.

After the images were masked, ENVI analytics was used and an assumption that vegetation had a strong reflectance in NIR band and absorbed the red band. A Normalized Difference Vegetation Index was executed using band math and statistics of each image were obtained and compared. The equation used was

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

where NDVI values for vegetation are expected to be in between 0.2 and 0.9. Variability in the atmospheric aerosols can be reduced using the Floating Algae Index (FAI). The nature of this algorithm measures the height of the NIR signal relative to the red and SWIR signals where atmospheric aerosols dominate. Atmospheric correction will then be applied on the images. PlanetScope images are converted from DN to TOA reflectance and Dark-Object Subtraction (DOS) method will be applied to obtain the Bottom-of-Atmosphere reflectance image.

Sentinel 2A images that coincides with the date of acquisition of PlanetScope Orthotile was used. Since Sentinel 2A covers a large area, the subset of Boracay Island was taken. Masks were applied so that only the area of interest remain. Masks used in PlanetScope Orthotile were also used in Sentinel 2A so that the ocean coverage will remain the same for both dataset. The masks used were imported as shapefile. The first mask used was the Boracay Subset that covers the Boracay Island and its waters. The second one is the land mask for the removal of the land area. Lastly, the near coast mask wherein waters near the shore remained. After the masks were applied, rayleigh correction was applied to each data set to correct the atmospheric pressure that impacts the molecular scattering. The rayleigh corrected bands were used for the computation of FAI.

The floating algae index (FAI), which was used in detecting floating algae, is defined as,

$$FAI = RRC(NIR) - R'RC(NIR) \qquad (2)$$

$$R'RC(NIR) = (RRC(RED) * (\lambda NIR-\lambda SWIR)) + (RRC(SWIR)*(\lambda RED-\lambda NIR)))/ (\lambda RED-\lambda SWIR) \qquad (3)$$

where, RRC is the Rayleigh top-of-atmosphere (TOA) reflectance and λband is the central wavelength (Red, NIR, SWIR)

4. RESULTS AND ANALYSIS

4.1 Normalized Difference Vegetation Index (NDVI) Results

From the figure below, a fluctuating trend of NDVI mean values can be observed from the four datasets. The recorded NDVI mean value in April 25, 2018 resulted to -0.206906 with a standard deviation of 0.111982. There is an observed decrease of 0.09 from April 25 to May 18, 2018 and a 0.156 increase from May 18 to July 2, 2018. The recorded NDVI mean value for October 7, 2018 resulted to -0.212715 which is 0.006 lower than the NDVI mean value in April 25, the day before the closing of Boracay Island. NDVI mean value recorded in July 2, 2018 holds the highest mean among the four datasets. This may be caused by factors such as sunlight transmission, pH level, clarity and nature of water during the date of the image acquisition was done.

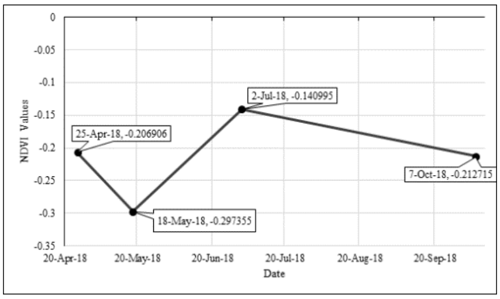

Figure 4. Mean and standard deviation of NDVI (Normalized Difference Vegetation Index) values.

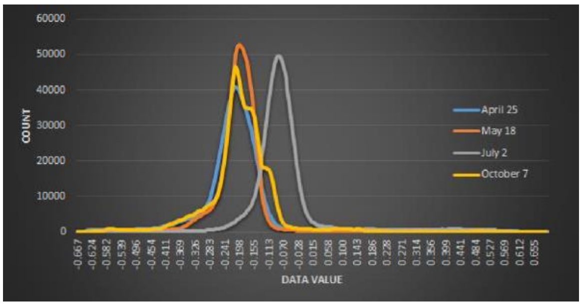

Figure 5. Histogram of NDVI (Normalized Difference Vegetation Index) values

The Ortho Tile images on Figure 6 displayed in true color (RGB) were sample overview of the specific target area in comparing algae for April 22, 2015. The images provided the whole extent of Boracay Island and enlarged areas which is convenient in identifying algae. As shown in the full extent of Boracay, the presence of algae cannot be determined visually but when zoomed in, a large number of algae could be observed especially near coastal areas.

Figure 6: Whole extent of Boracay Island on April 25, 2018 in RGB display.

Figure 7: Zoom display of sample area with visible algae presence from April 25, 2018 dataset

The following images below were the processed Normalized Difference Vegetation Index (NDVI) for all datasets focusing a specific area near the coastal with their corresponding true color image on the left side. The green color had high values while red were low. High NDVI values indicates vegetation because healthy plants have high reflectance in NIR band. It could be noticed that in the month of April, algaes were concentrated on the coastal area of the island. On May, algae were lessen as verified on true color however, on the processed NDVI, it produced a larger amount of vegetation. A large increased on algae happened in the month of July as shown on Figure F. Lastly, the trend on the presence of algae for October greatly showed a decrease in number as observed on both true color and NDVI image.

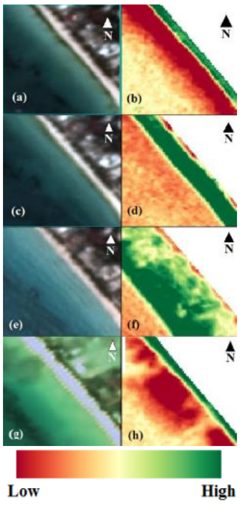

Figure 8: True Color and Normalized Difference Vegetation Index (NDVI) Image for (a & b) April 25 (c & d) May 18 (e & f) July 2 (g & h) October 7.

Floating Algae Index (FAI) Results

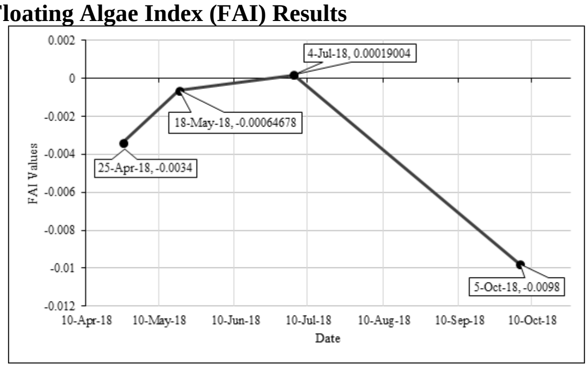

Figure 9. Floating Algae Index trend from April 25 to Oct 5.

As shown on the figure above, the Floating Algae Index (FAI) mean values increases from April 25, 2018 to July 4, 2018, then on October 5, 2018 the FAI value suddenly decreased to -0.0098. The typical weather in Boracay during mid-November to mid-May was dry season with cool breeze, during mid-May to mid-July was windy with light rainfall, lastly, mid-July to mid-November was rainy season or typhoon season (Rich, 2018).

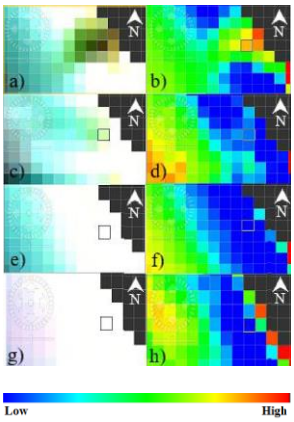

Figure 10. a) April 25 - True Color b) April 25 - FAI c) May 18 - True Color d) May 18- FAI e) July 4 - True Color f) July 4 - FAI g) October 5 - True Color h) October 5 - FAI

A decrease of floating algae was observed on the true color image of Sentinel-2A found on the left column of Figure 11 from April 25 (a) to October 14 (g) also shown on the FAI image on the right column. The red pixels on the right column indicates high FAI value whereas blue pixels indicate low FAI value. On the left column of the image, green pixels were identified (a) which indicates the presence of vegetation. It can be observed that the green pixels on the left column became white whereas the orange pixel in image (b) turned into a blue pixel on October 5 (h). Both the RGB and FAI presentation showed similar trend which is a decrease in the presence of algae.

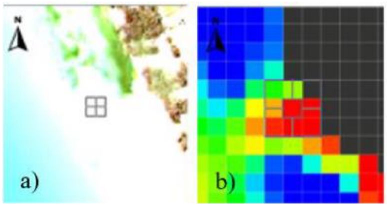

Figure 11. a) KOMPSAT-3A b) April 25 - FAI
Figure (a) showed the zoomed in area of the selected pixel in the FAI values of April 25 using KOMPSAT-3A. It can be seen that there are algae present in that specific area.

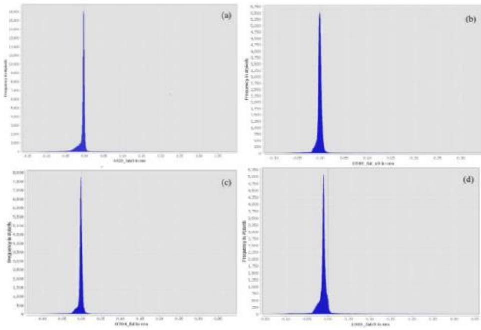

Figure 12. a) April 25 b) May 18 c) July 4 d) October 5

The Figure 13 showed the histogram plot of the FAI values of the four dataset. It can be observed that the plot shifted to the left of 0 (negative values) on October 5 and is somehow dispersed whereas the plot of July 4 appeared to be more concentrated. The histogram plot showed the frequency of occurrence of the FAI values in the whole masked image. It can be seen that the values in October are more varied as compared to the values obtained in July which yields the highest mean value out of all the dataset.

As shown in Figure 14, NDVI results of the processed datasets of Boracay Island, the trend and behaviour of vegetation specifically algae on the ocean is observed. The overall trend of the algae on the area for the past months of closure could be viewed from the figure. The overall trend of vegetation (dark green) was decreasing. Algae were concentrated along the coastal areas in Boracay during April 25. On May 18, a decrease on the area of concentration of algae occurred. There was also a decrease in concentration of algae in some areas for July, however, on the remaining concentrated areas, there were more algae observed especially the southwest part the island. Last October 7, the trend decrease almost on the same values with April 25 and less vegetation were scattered.

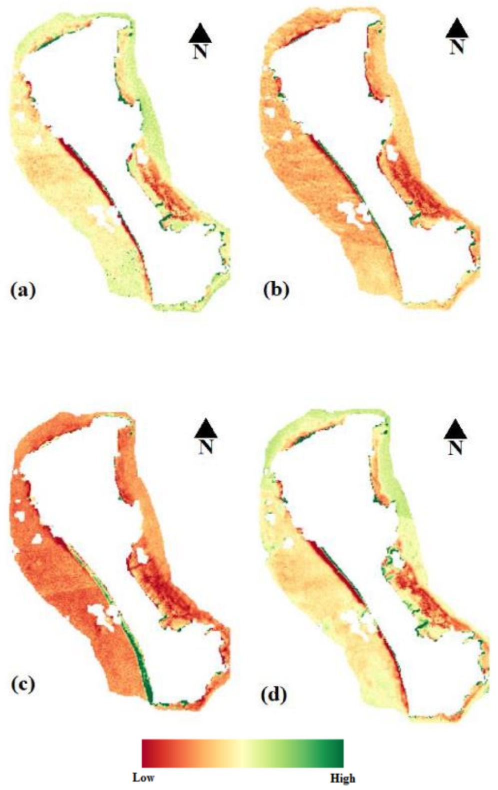

Figure 13: Processed Normalized Difference Vegetation Index (NDVI) on the inner coast of Boracay Island for (a) April (b) May (c) July (d)

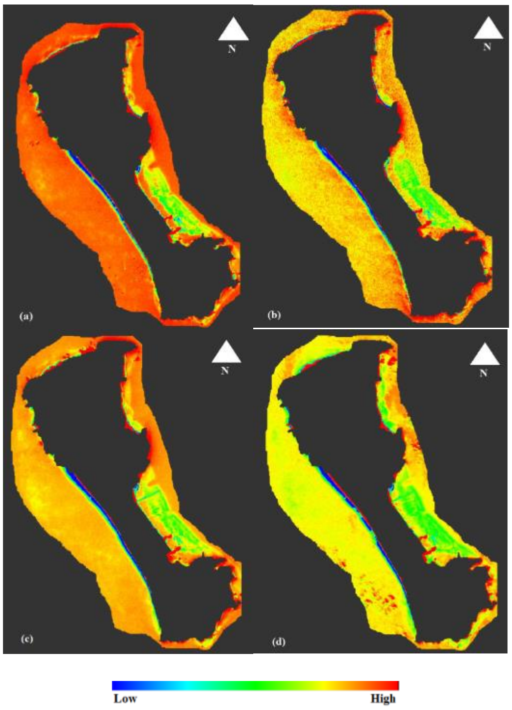

Figure 14: Processed Floating Algae Index (FAI) on the inner coast of Boracay Island for (a) April 25 (b) May 18 (c) July 4 (d) October 5

In Figure 15 above showed the distribution of FAI values of the four datasets. Red areas had high values of FAI while blue areas had low FAI values. From April 25 (a) to May 18 (b), the color of the coast changed from red-orange to mostly yellow with some orange areas which indicates a decrease in FAI values for the whole coastal area of Boracay. Whereas, from May 18 to July 4, the increase of FAI values was observed as the color of the coast became yellow-orange then, on October 12, two days before the soft opening of Boracay, the coastal area was mostly yellow which means decrease of algae in Boracay. The images above showed a decreasing trend in the overall values of FAI.

Several factors such as the pH value, sunlight transmission, nature and clarity of the water, and the number of other nutrients present in the water are affected by changing weather conditions. (Kheiralla, 2014). The fluctuating trend in the obtained values may be affected by weather conditions or seasonal changes. From April to May, the general trend for algae decreased and one factor might be the weather condition of the month. When the place is dry, algae increases their number due to their need of sunlight for production and the average weather condition for the month of April was relatively drier compared on May, thus making more algae present on April. May to July gave a large increment on the number of algae. Still, one possible reason was the weather because July was relatively drier compared to May and on this month, algae multiply their number. Lastly, from the month of July to October, the trend decreased and relatively smaller than April which was expected because October was a rainy month, however still a lot of factors might affect the number of algae.

5. CONCLUSION

The presence of algae along coastal waters of Boracay Island after its closure and before reopening was observed using the combination method of Normalized Difference Vegetation Index, an algorithm for detecting vegetation, and Floating Algae Index, an algorithm for detecting floating algae in an aquatic environment. These methods were convenient as a pair due to their common function and proved the correlation of coliform bacteria to the increasing number of algae. Secondary data reported was only limited to the water quality during the pre-closure and during the reopening of the island. Coliform level decreased from 1 million mpn (most probable number) per 100 ml to 18.1 mpn per 100 ml. Results of this study showed a decrease in both NDVI and FAI values which coincides with the coliform level data. Furthermore, additional within the closure period showed fluctuating trends in the values. These trend may have arisen from the seasonal changes in the study area. Further studies regarding the correlation of other factors to the algae could be implemented. Still, the present study verified the relation of the obtained NDVI and FAI algorithms to the reported decrease in the amount of coliform bacteria after rehabilitation.

6. RECOMMENDATION

In this study, the ground truth data were requested from the Environmental Management Bureau national office. However, the request for the desired data were still in process in the regional level. Further study using the ground data is highly recommended to fully validate the results of the processing done in the images.

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