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Application of Landsat 8 Image to Extract Waterline and Build the Relationship between Chlorophyll-a and NDVI Index for Bung Binh Thien Lake, Southern Vietnam

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--***ABSTRACT***--
Chlorophyll-a is an optically active compound commonly used as a proxy for phytoplankton biomass in an aquatic environment. In this study, an effort has been made to estimate the chlorophyll-a concentration of the freshwater Lake Bung Binh Thien. A spectral decomposition algorithm was used to determine the chlorophyll-a using the satellite images in September, 2018. Landsat 8/OLI provides data with spatial resolution 30m and has developed the model of regression analysis to define the relationship between chlorophyll-a parameters and NDVI index through the reflectance values of the spectral channels. The analysis results show that there is a strong correlation between NDVI and chlorophyll-a with a high correlation coefficient of R2 = 0.89, and the result of waterline extracting was 153 ha in rainy season.

KEYWORDS: *Landsat 8, GIS-Remote Sensing, Bung Binh Thien, Chlorophyll-a.*

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I. INTRODUCTION

Water is valuable natural resources that essential to human survive and the ecosystems health [15]. Since the past few decades, the increasing of anthropogenic activities especially in industrial area has effects to water bodies. This is the global issues which happening throughout the world and Vietnam also face these problems. Today, with the advancement of science and technology, the population, industries, agriculture activities and urban developments have grown up along the lake corridor or riverbank of Vietnam. It is evident that many inland water bodies are becoming obsolete with no steps taken towards its protection [13]. If water quality becomes degraded this resource will become degraded. Water quality is important not only to protect public health but provides ecosystem habitats, used for farming, fishing, mining and contributes to tourism and recreation. If water quality is not properly maintained, the environment as well as the commercial and recreational value of our water resources will also diminish [2].

Lakes are an important feature of the Earth's landscape. They are extremely valuable ecosystems and provide a range of goods and services to humankind. However, anthropogenic pressures on lakes have increased rapidly in recent decades [10]. Major changes have occurred in the land use in their catchments where natural vegetation is cleared and agricultural, urban and industrial activities are intensified. These anthropogenic activities (deforestation, agriculture, urban settlements and industries) have accelerated the aging process as increased amounts of sediments, nutrients and toxic substances enter lakes with the runoff [11]. Most lakes are in different stages of degradation in various ways through eutrophication, toxic pollution or habitat loss [16]. In addition the catchment based activities have been accompanied by encroachment on lake-shores by reclaiming shallow lake margins, sewage disposal, water abstraction, and diversification of in-lake recreational activities. All these activities directly cause rapid degradation of lakes.

Bung Binh Thien Lake is a freshwater ecosystem, providing water for the region mainly in the fields of agriculture, tourism and services. However, the increasing population and current climate change, Bung Binh Thien Lake is facing big challenges. Previous studies have indicated that the lake water quality showing signs of degradation due to some parameters: TAN, TSS, PO_4^{3-} increasing and exceeding standard level at some sites in lake [6]. The rapid loss of vegetative cover and land use change, tourism, due to recent agricultural intensification, is a major driver of recent increases in sedimentation, nutrients concentration and biodiversity degradation in the lake. The degradation of water quality has reduced the lake's capability to support aquatic life, and thus, impacts the sustainable utilization of the lake water resources. Therefore, the monitoring of water quality is a very necessary task to supply water quality data to government and the relevant institutions [5]. From that they can find suitable measures to improve water quality of lake. The conventional techniques for monitoring water quality are usually expensive (particularly for developing countries), time consuming, and unable to provide spatial and temporal outlook for the water bodies with limited sample points. The remote sensing technique may offer an appropriate method to integrate water quality data collected from traditional in situ measurements. Satellites images have already been widely used in monitoring many substances in water bodies [20] such as the US, Japan, India, etc. Recent advances in sensor technology and algorithm development have made quantitatively estimates of the biogeochemical composition of water [19]. Remote sensing of water color from spaceborne and airborne systems has become an indispensable tool for monitoring water quality. The main goals of this study were to explore empirical algorithms for the retrieval of chlorophyll-a for Bung Binh Thien Lake from Landsat 8 OLI images and to determine both the spatial and temporal distributions of water quality. An additional aim was to map the water quality parameters and display the possibility of using the models discovered instead of the conventional techniques to monitor the water quality of Bung Binh Thien lake.

Study area

Bung Binh Thien lake is located in An Phu District, in the Mekong Delta province of An Giang, connecting three communes including Khanh Binh, Nhon Hoi and Quoc Thai, and adjoining Binh Di River and Hau River. This beautiful lake is being become an ecotourist area. It is one of the biggest freshwater lakes in the Mekong Delta. The lake's area is said to change in accordance with seasons – 300 hectares, average depth of the lake is 4m during the dry season between December and April, and 900 hectares, with the depth increasing up to seven meters, during the rainy period between May and November. The length is about 2,900m and the average width is 430m [3]. In the flood season in Mekong Delta, most of rivers in the area are muddy with alluvium, but the water of lake still remains clear and blue; a beautiful landscape endowed with the highest biological diversity in An Giang.

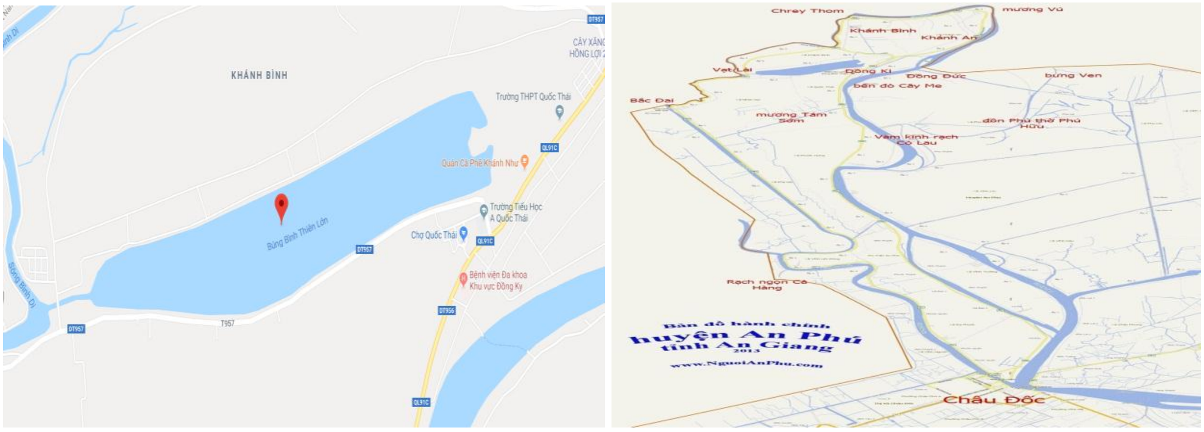

Figure 1: Location of Bung Binh Thien Lake, An Phu district, An Giang province.

II. METHODOLOGY

Data collection: The sampling took into consideration the monitoring of seasonal changes and samples covered the mesotrophic and eutrophic areas. Fifteen samples were collected in September, 20, 2018. Layout of sampling sites show in Figure 2. For measuring Chl-a, the samples of 100 ml were first filtered using GF Whatman 0.2 µm pore diameter filter paper. The material remaining on the filter paper was used to extract Chl-a pigment. The filter paper was grinded manually and extraction of Chlorophyll-a pigment was done using 5 ml acetone (98 percent aqueous solution) upon which the sample was centrifuged for 20 minutes at 4000 rpm. The centrifuged samples were placed in a cool dark place to settle the suspended material and prevent growth. Samples were analyzed four hours after storage using the emission spectrophotometer instrument at 663,664,665 and 750 nm. Chl-a was estimated using Environmental Protection Authority protocol (EPA 150.1 standard for Chl-a measurement [7]. Chlorophyll-a concentration were collected at Bung Binh Thien Lake are showed in Table 1.

Table 1: Water quality parameters surveyed in Bung Binh Thien Lake in September, 2018.

Code	Coordinate		Chlorophyll-a (µg/l)
	Latitude	Longitude	
I	10°55'29"	105° 5'48"	1.826
II	10°55'27"	105° 4'13"	1.674
III	10°55'21"	105° 5'12"	3.650
IV	10°55'13"	105° 4'11"	0.269
V	10°55'10"	105° 4'54"	0.467
VI	10°55'33"	105° 4'78"	3.578

VII	10°55'12"	105° 4'10"	2.772
VIII	10°55'45"	105° 4'10"	1.931
IX	10°55'09"	105° 4'36"	0.155
X	10°55'29"	105° 4'40"	0.044
XI	10°55'9"	105° 4'2"	0.063
XII	10°55'2"	105° 4'8"	4.860
XIII	10°55'4"	105° 3'58"	0.233
XIV	10°55'6"	105° 3'48"	0.003
XV	10°55'2"	105° 3'47"	0.025

Figure 2: Layout of sampling sites

Landsat 8 OLI/TIRS satellite images (path/row:126/52; spatial resolution:30m) on 20/09/2018 were downloaded from from http://earthexplorer.usgs.gov corresponding to the time water sampling in Bung Binh Thien lake. Landsat 8 utilizing a two-sensor payload, the Operational Land Imager (OLI) and the Thermal InfraRed Sensor (TIRS). These two instruments collect image data for nine shortwave bands and two longwave thermal bands. Providing moderate-resolution imagery, from 15 meters to 100 meters, of Earth's land surface and polar regions. Parameters for Landsat 8 are showed in Table 2 [18].

Table 2: The characteristics of the landsat 8 images

No	Bands	Wavelength (µm)	Resolution (m)	Note
1	Band 1- Coastal/Aerosol	0.433 to 0.453	30	OLI
2	Band 2 - Visible blue	0.450 to 0.515	30	OLI
3	Band 3 - Visible green	0.525 to 0.600	30	OLI
4	Band 4 - Visible red	0.630 to 0.680	30	OLI
5	Band 5- Near-infrared	0.845 to 0.885	30	OLI
6	Band 6 – SWIR1	1.56 to 1.66	30	OLI
7	Band 7 – SWIR2	2.10 to 2.30	30	OLI
8	Band 8 -Panchromatic	0.50 to 0.68	15	OLI
9	Band 9 - Cirrus	1.36 to 1.39	30	OLI
10	l 10 – Thermal infrared (TIR)1	10.3 to 11.3	100	TIRS
11	l 11 –Thermal infrared (TIR) 2	11.5 to 12.5	100	TIRS

For building maps by RS and GIS tools

This image was clipped to the study area based on the appropriate administrative map. The error satellite image on topography and radiation have to be adjusted. However, Geometric correction is not necessary in this research. Because the atmospheric condition on the image acquisition date was very pleasant which will ensure a more satellite orbit and good imaging quality; the elevation in the research area is relatively flat terrain. The satellite imagery was received with each band separated as a TIF file. Then the multiband files were re-projected to UTM Zone 48 North, WGS-84 Datum. Thereafter the image was exported to the ERDAS 2014 EX software to determine boundary of Binh Thien lake's water surface by unsupervised classification.

In this research, Normalize Difference Water Index (NDWI) (equation 1) was used to delineate the surface water of the lake. The NDWI is one of the successful methods used to extract waterline from satellite images. The index uses Green and Near infra-red bands of remote sensing images. The NDWI can enhance water information efficiently in most cases. This index uses the near infrared (NIR) and the Short-Wave infrared (SWIR) bands. NDWI can be calculated by following formula:

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR} \quad (1)$$

Where: NIR: near infrared; SWIR: short wave infrared

Plants index NDVI (equation 2) is functionally equivalent to simple band ratios of Landsat 8 images and it is a useful method to identify the vegetation depending on the density. With the level of classification the NDVI map can be performed. NDVI maps can be considered an important reference maps in the process of image interpretation. ERDAS 2014 and ArcGIS 10.2 software were used to implement for the calculation of vegetation index, as well as to measure the values of the decentralized classification of the vegetation coverage in water. Therefore for the satellite images, NDVI values were calculated using equation 2.

$$NDVI = \frac{(NIR\ band\ - RED\ band)}{(NIR\ band\ + RED\ band)} \quad (2)$$

Where: NIR band = spectral reflectance for band 5;
RED band = spectral reflectance for band 4.

ArcGIS was used for transformation to TIFF format by Georeferencing in the Geographic Information System (GIS). ArcGIS 10.2 was finally used to to overlay the maps and compute inundation area and water mapping for the study area.

The general methodology of this study includes measurements of Chl-a parameters over the surface of the Lake Binh Thien from 15 locations at the moment that the satellite passed over the lake. There are many algorithms used in the literature to examine the relationship between water quality parameters and remote sensing data [9]; [22]; [21]. In this study, the algorithms for regression analyses were created to examine the relationship between reflectance of Landsat 8 and Chl-a parameters in September. The performance of these equations was checked depending on R^2.

III. RESULTS AND DISCUSSION

The satellite images were classified in this study to separate the land use/land and water cover units. The following classification method was implemented using ERDAS 2014 software. Satellite images were enhanced using ERDAS 2014 software with band combinations of R:G:B = 5:4:3 for Landsat 8. Then the images were loaded and zoomed up to pixel level (scale 1: 25,000). Finally images were sharpened, stretched and properly illuminated to obtain enhanced images for screen digitising.

Unsupervised classification was done for the identification of land use types in unknown areas. All images were therefore classified into many classes and a signature file was prepared in the processing system for each class. Using those signature files bi-spectral plots, multispectral plots and NDVI graphs were prepared. Interpretation keys were then established followed by unsupervised classification which was first used to produce land cover classes for the study area using the ISODATA algorithm in ERDAS ER Mapper, which classifies the images into a pre-selected number of classes using an iterative calculation procedure to ensure maximum statistical separability based on the spectral data. This activity was able to identify 5 classes: vegetation, bare soil, water, levees, house with a 0.86 confidence interval for area around Bung Binh Thien Lake (Figure 3).

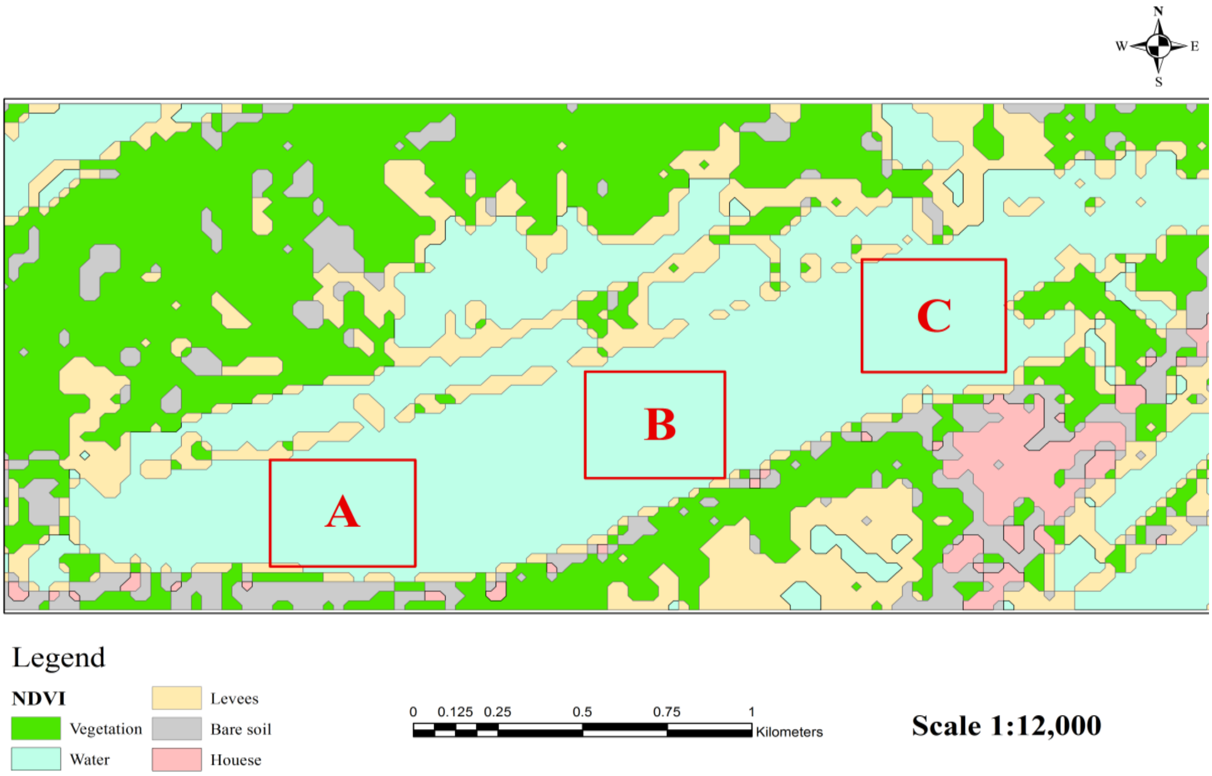

Figure 3: The vegetation and water cover map around Bung Binh Thien Lake in September, 2018 built by unsupervised classification.

A spectral class is defined as a cluster of pixels which are characterised by a common similarity in their DNs in the multi-spectralspace [8]. If the distance between a pixel and a group of pixels falls within the specified threshold, this pixel is considered a part of that cluster. In this study, designing the NDWI landsat 8 by NIR and SWIR bands aimed to maximize the reflectance properties of water [4]. The NDWI landsat 7 and landsat 8 used is similar to Gao's index [8], where the SWIR is sensitive to soil moisture, plant water content, and high absorption by water (even turbid water) [1]; [17]. As a result of these characteristics, the waterline extraction for Binh Thien lake by applying Gao's index is more correct. The values of NDWI are in a range of −1 to 1. The values that are greater than 0 refer to water area while values which are less than or equal to 0 refer to non-water [14]; [12]. Figure 4 shows the waterlines extraction for Binh Thien Lake on September 20, 2018, the surface area of the lake was 153ha. This result is very small compared with the results of the Department of Natural Resources and Environment, 2012. But our results are consistent with the results of Quyen, 2015 (174ha). The values of NDWI are in a range of -0.16-0.6. NDWI value from -0.16 to 0 refer to non water and from 0 to 0.6 are water (Figure 5).

Based on the results of water extract, clusters of pixels representing aquatic plant were selected as training samples and their spectral response patterns were subsequently generated. These classes were separability analysed by computing the NDVI. Finally the images were classified by a Gaussian maximum likelihood per pixel classifier using the spectral pattern which was derived and modified from spectral separability of the training areas.

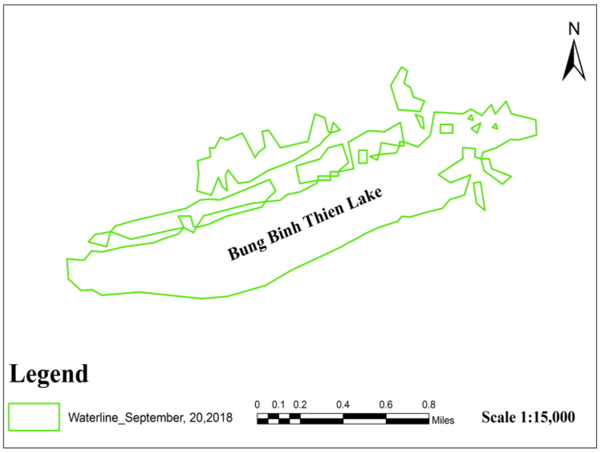

Figure 4: Watertline of Bung Binh Thien Lake

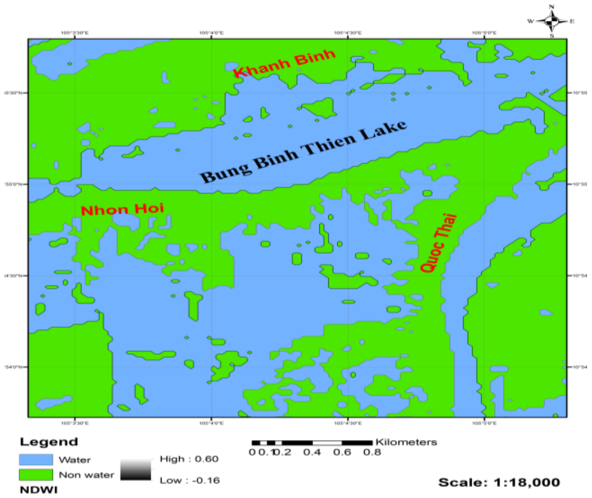

Figure 5: Map of water and non-water parti

NDVI (Normalized difference vegetation index) is a number that is generated by a combination of remote sensing bands and have a relationship to the amount of greenery in a given image pixel. NDVI is also widely used to detect aquatic plants in multi-spectral remotely sensed data. The NDVI in the study of Bung Binh Thien lake was calculated for abundant differentiation of algae, aquatic plants (Chlorophyll-a) in water. This is a useful method for determining chlorophyll-a in water depending on the distribution density of aquatic plants. 15 samples Chlorophyll-a were collected in Bung Binh Thien Lake, divided into 3 clusters: A, B, C (Figure 3). The results showed that The Bung Binh Thien lake's NDVI values ranged from - 0.11 to 0.37 (Figute 6).

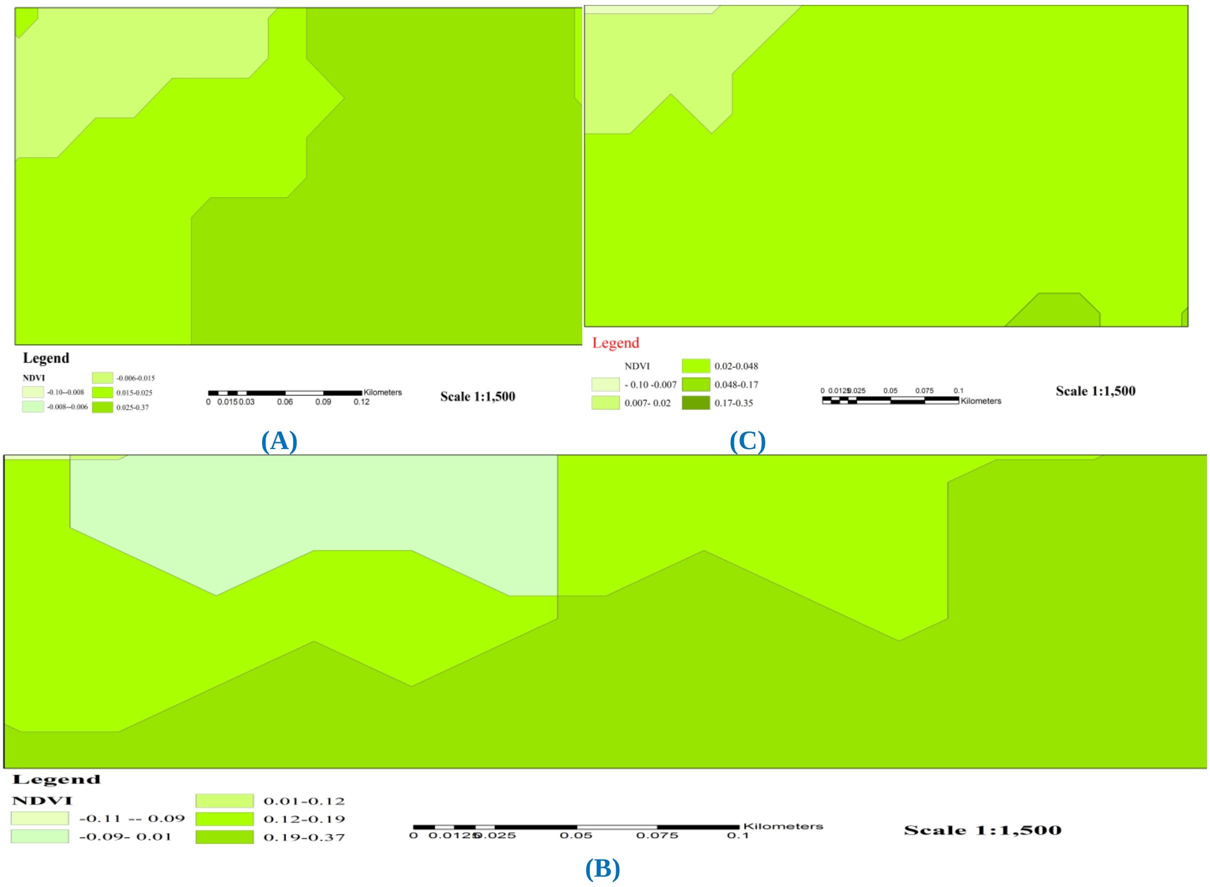

Figure 6: NDVI map in Bung Binh Thien Lake – at segments: A; B; C.

If the NDVI value decreases, Chlorophyll-a concentration decreases accordingly. Further, NDVI values of negative or zero were placed where there was absolutely no presence of Chlorophyll- a such as at sites: XIV, XV, X. The NDVI values at other places was > 0, Chlorophyll-a was highest at sites III, VI, XII. This means that, with high Chrolophyll-a concentrations towards nearly lakebank while the low concentrations were in the middle of lake. This distribution indicates the dominant effect of photosynthesis on water quality for Bung Binh Thien Lake during in September. This dominance could be a result of the source of nutrients which were flow out from agricultural activities and tourist services nearby lakebank. Moreover, the water level near lakebank is shallow, less volatile, is a favorable opportunity for algae to grow. The results also indicated that the NDVI has a linear relationship with Chlorophyll-a by equation $y = 3.5106x^2+8.3298x+0.601$ with (correlation coefficient) $R^2 = 0.89$ where y = Chlorophyll-a, x = NDVI. This is shown in Figure 7.

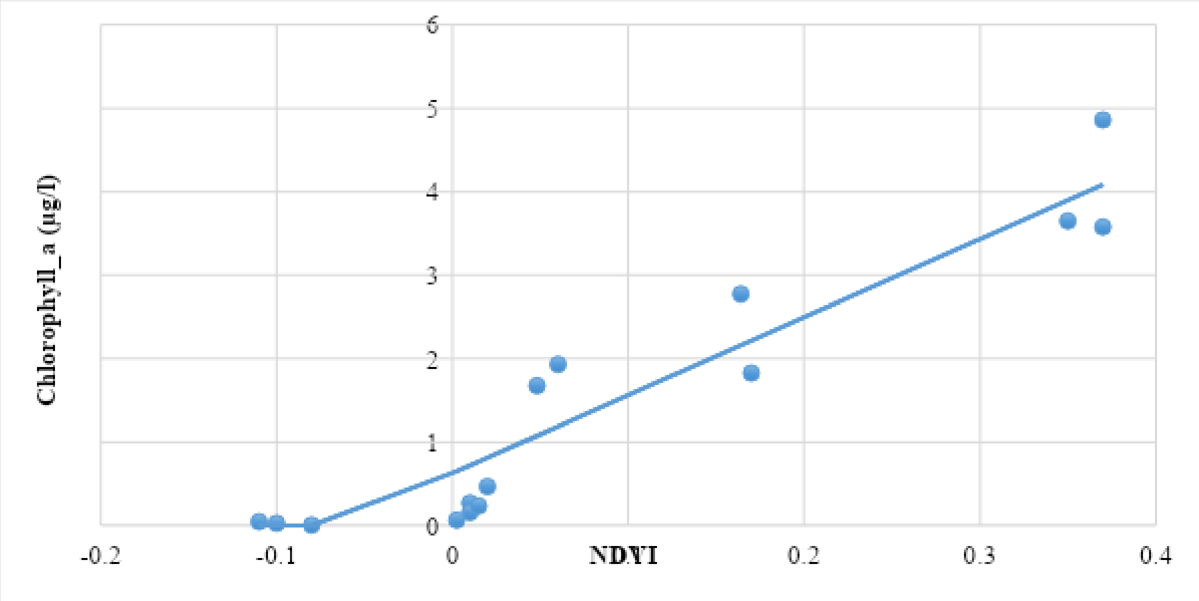

Figure 7: The relationship between NDVI and Chlorophyll-a in water for Bung Binh Thien Lake.

Chlorophyll strongly absorbs light at wavelenght around 0.45 (blue) and 0.67µm (red) and reflects strongly in green light, therefore our eyes perceive healthy vgetation as green. The high reflectnce between 0.7 and 1.3 µm results primarity from the internal structure of plant leaves. As this internal structure varies amongst different plant species, this wavelength range allows the distinction between plant species. Absorption minima found in higher wavelength are caused by the leaves retaining water. The water curve is characterised by a high absorption at near infrared wavelengths range and beyond. Because of this absorption property, water bodies as well as features containing water can easily be detected, located and delineated with remote sensing data. Turbid water has a higher reflectance in the visible region than clear water. This is also true for waters containing high chlorophyll concentrations. These reflectance patterns are used to detect algae colonies as well as contaminations. A spectral signature is a plot of the amount of light energy reflected by an object throughout the range of wavelengths in the electromagnetic spectrum. ... We can extract reflectance values in the NIR and visible spectrums from hyperspectral data in order to map vegetation on the earth's surface. The pixel distribution of spectral bands used to calculate the NDVI at 15 Chlorophyll-a samples for Bung Binh Thien Lake is presented in Figure 8.

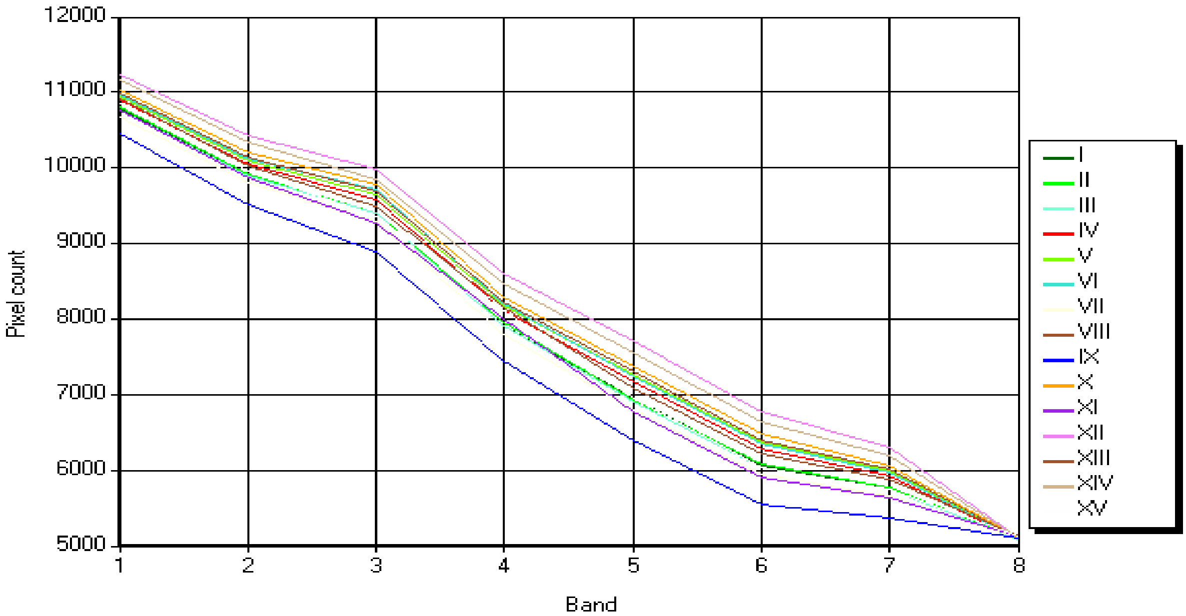

Figure 8: The pixel distribution of spectral bands at 15 samples Chlorophyll-a in Bung Binh Thien Lake.

IV. CONCLUSIONS

The review paper highlights the different techniques in which water quality can be assessed with the help of remote sensing and GIS. GIS is an effective tool not only for collection, storage, management and retrieval of a multitude of spatial and non spatial data but also for spatial analysis and integration of these data to derive useful outputs and modelling. Remote sensing gives valuable additional information compared to the other water quality assessment tools. It has also been proved to be a powerful tool to trace the impact of contaminated water. Multi-temporal Landsat 8 images with a 30m spatial resolution can be used for the quick assessment of flooded area with guaranteed results. In terms of parallel calculation, the application of these techniques has brought significant benefits and performance improvements.

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