# ESTABLISHING CORRELATION FUNCTION BETWEEN SPECTRAL REFLECTANCE AND SEAWATER TURBIDITY IN HAI PHONG CITY BY USING EXPERIMENTAL METHOD

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**KEY WORDS:** Spectral reflectance, experiment, correlation function, Hai Phong, Landsat

**ABTRACT:** Remote sensing data provides information about objects through their spectral reflectance. Experimental studies are very essential to establish correlation between reflectance value of object on image and their other parameters. However, measuring spectral reflectance in the field has so many difficulties; one of them is a continuous change of the radiant energy from the sun leading to errors in the results analysis. So this study establish experimental process of spectral reflectance measurement in the room to assess the difference about spectral reflectance of objects.The results will be used to analysis Landsat data of coastal zone in Hai Phong city to calculate the correlation function between spectral reflectance values and turbidity of seawater.

## 1. INTRODUCTION

Water is an important resource what affects the lives of all the creatures on Earth. Therefore, the monitoring, managing and evaluating water quality is necessary. Water quality is assessed through indicators of physical, chemical and biological. In the physical indicators, water turbidity is a very important index. Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light shines through the water sample. The higher is the intensity of scattered light, the higher is the turbidity. Material that causes water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms.Unit of turbidity measurement: 1NTU SiO2 = 1mg / L = 1 unit andturbidity was measured by spectrophotometer (USGS). During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. In addition, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the streambed, causing higher turbidities.

However, the conventional measurement of water quality requires in situ sampling and expensive and time-consuming laboratory work. Due to these limitations, the sampling effort often does not represent the condition of an entire water body. Therefore, the difficulty of overall and successive water quality sampling becomes a barrier to water quality monitoring and forecasting. Remote sensing could overcome these constraints by providing an alternative means of water quality monitoring over a greater range of temporal and spatial scales (Shafique et al. 2001).

Remote sensing is the science of measuring the properties of objects by measuring the amount of radiation they absorb, emit, or reflect at various wavelengths along the electromagnetic spectrum. Optical water quality research has a broad scope for developing environmental indicators that are useful in assessing, quantifying and monitoring instream water quality. Measurable parameters for optical water quality. Many studies realized that the main differences between the two types of waters are located in the 0.4–0.7µm spectral range. The turbid water has significantly larger reflectances than the clear water (Rong-Rong Li, 2003).This study provided aclosed empirical process using hand-spectrometer to build a functional relationship between the reflectance spectra and water turbidity.

## 2. STUDY AREA AND MATERIALS

The study area is the coastal zone of Hai Phong city. where sediments are transported to the sea by Thai Binh, Van Uc, Lach tray rivers flow.A very large portion of the total sediment load is carried by the river during the summer time (rainy season).

Two images were examined in this research study to quantify water turbidity and its spatial and seasonal variation. Among them, one Landsat TM images was acquired on October $5^{th}$, 2009 (dry season) and SPOT 2 image was acquired on 10th May, 2005 (rainy season). Landsat 7 was successfully launched on April 15, 1999 from the Western Test Range of Vandenberg Air Force Base, California. The parameters of this sattelite as table 1.

Table 1. Landsat 7 spectral band information

| Spectral Band | Wavelength (µm) | Resolution (m) |
|---|---|---|
| Band 1 - Blue | 0.45 – 0.515 | 30 |
| Band 2 - Green | 0.525 – 0.605 | 30 |
| Band 3 - Red | 0.63 – 0.69 | 30 |
| Band 4 - Near Infrared | 0.75 – 0.90 | 30 |
| Band 5 - Short Wavelength Infrared | 1.55 – 1.75 | 30 |
| Band 6 - Long Wavelength Infrared | 10.40 – 12.5 | 60 |
| Band 7 - Short Wavelength Infrared | 2.09 – 2.35 | 30 |
| Panchromatic | 0.52 – 0.90 | 15 |

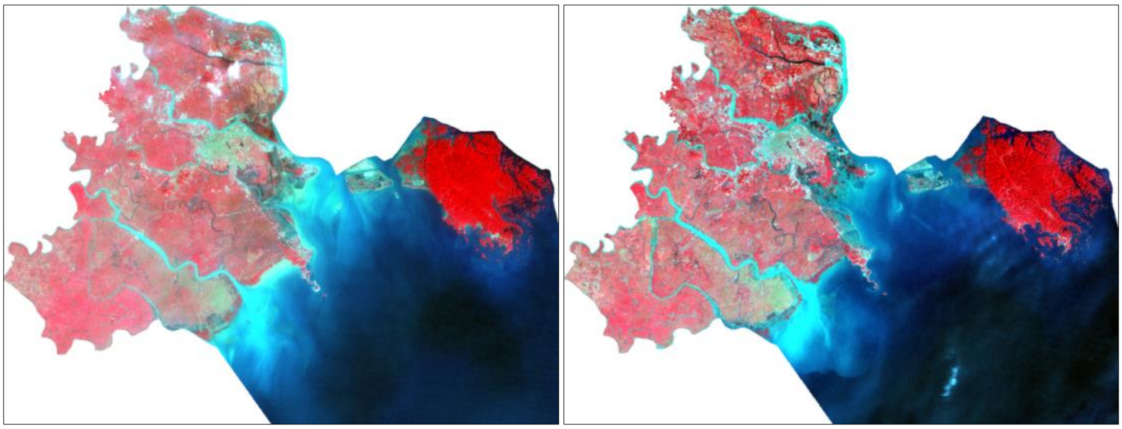


Figure 1. Standard false-color composite image of area study

## 3. METHODS

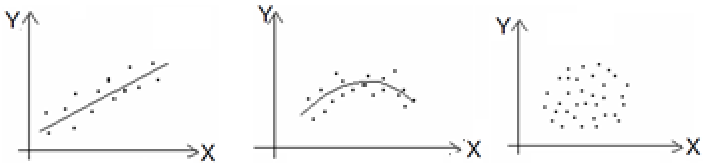
### 3.1. Experimental method

The best method - indeed the only fully compelling method - of establishing causation is to conduct a carefully designed experiment in which the effects of possible lurking variables are controlled. To experiment means to actively change x and to observe the response in y (Moore, D., & McCabe, D. 1993). This method is commonly used in not only Natural science but also in Social science, Engineering and Technology science, Medicine science and many other scientific fields. The advantage of this method is that the researcher can actively create, change the situation and consider various aspects of the research process to achieve the desired results.However experimental methods conducted in a closed room can be difficult to generate sufficient elements of the environment, so the studyresults will have the deviations. The researchers need to find ways to ensure the reliability of results.

In this study, experimental spectrometric method in the closed room will be used to eliminate thecontinuous change of solar radiation and atmospheric. Therefore, the results of spectral measurements of multiple samples will obtain higher reliability.

### 3.2. Correlational research method

The main purpose of a correlational study is to determine relationships between variables, and if a relationship exists, to determine a regression equation that could be used make predictions to a population. In bivariate correlational studies, the relationship between two variables is measured. Through statistical analysis, the relationship will be given a degree and a direction (Marilyn K. Simon. 2011). The degree of relationship determined how closely the variables are related. This is usually expressed as a number between -1 and +1, and is known as the correlation coefficient. A zero correlation indicates no relationship. As the correlation coefficient moves toward either -1 or +1, the relationship gets stronger until there is a perfect correlation at the end points.




Linear relationship | Non-linear relationship | Not relationship

Figure 2. Scatter plots and the different types of correlation

Here, we will evaluate the relationship between spectral reflectance measurements and turbidity of the water samples. Afterwards, determining linear regression function to calculate the water turbidity parameters of the coastal area in Hai Phong City through spectral reflectance values in Landsat 7.

## 4. PROCESS OF EXPERIMENT

The device used to measure the experimental spectrum: RS232 handheld spectrometers, turbidity meter, incandescent light bulb...Specifications of those devices are given in detail in Table 2.

Table 2. Device Specifications

| No | Name | Characteristic | Pictorial |
|---|---|---|---|
| 1 | RS232 handheld spectrometer | - Spectra 325-1075µm<br>- Angle of view: 7,5$^{O}$ |  |
| 2 | Hachi turbidity meter | - Measuring Range: 0 - 1000 NTU<br>- Accuracy: ± 2 %<br>- Resolution: 0.01 NTU |  |
| 3 | Light source | - Lamp<br>- 400 watt power |  |
| 4 | Other device | Tripod, water sample tank… | |

There are three step of processes of experiment as following:

*Step 1: Collecting the samples*

Sampling scheme there are numerous possible sampling schemes used in collecting accuracy assessment data including: simple random sampling, systematic sampling, stratified random sampling, cluster sampling, and stratified systematic unaligned sampling. Each scheme has its own advantages and disadvantages. Randomness provides very nice statistical properties that are important for further analysis of the results. Systematic and cluster sampling can provide practical advantages. It is important to understand each scheme and apply the one most appropriate for the situation. The analysis undertaken must then match the sampling scheme chosen.

In this study, we selected systematic sampling procedure. Using this procedure each element in the population has a known and equal probability of selection. This makes systematic sampling functionally similar to simple random sampling. It is however, much more efficient. Systematic sampling is applied only if the given population is logically homogeneous, because systematic sample units are uniformly distributed over the population. The researcher must ensure that the chosen sampling interval does not hide a pattern. Any pattern would threaten randomness.

With this research area, the research team has identified line for the systematic sampling procedure as figure x because, according to the natural laws of the region is the distribution of water turbidity decreases from the estuary to the sea. 30 samples have been collected to ensure reliability of statistical calculations.

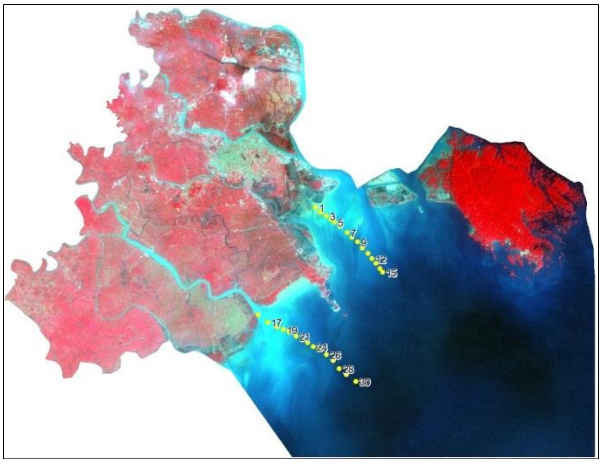


Figure 3. Locations of samples (yellow points)

*Step 2. Measuring turbidity of the samples*

Firstly, calibrating turbidity meter by the standard sample supplied by manufacturer, then study team measured all samples collected in the field and recorded the corresponding parameters.

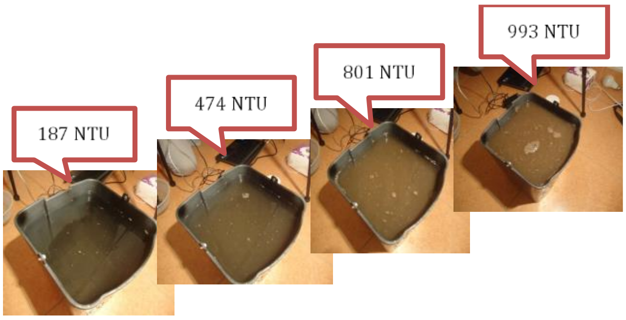



Figure 4. Water turbidity samples

*Step 3. Measuring spectral reflectance of the samples*

- *Designing model*
  - Handheld spectrometercan be mounted on a tripod with a height of 1 meter over the sample surface (according to the technical requirements of the manufacturer).
  - Fixed lamp tilts an angle of 70 degrees, corresponding to the sun angle at the time Landsat satellite capturing.

- *Measuring spectral reflectance*

Spectral reflectance spectra of objects as a percentage of energy on the surface of the object and is reflected back. With the same object, different spectral reflectance at wavelengths is different. The spectral reflectance was calculated using the formula:

$$\rho\lambda = \frac{ER(\lambda)}{EI(\lambda)} * 100 \text{ (Floyd F. Sabins)}$$

Where: ρλ: The material reflectance spectrum
ER(λ): Energy falls to object
EI(λ): Energy reflected back from object

To measure the spectral reflectance of the object, we first measured reflection is almost part of the standard white surface, this surface provided by the manufacturer, together with the gauge, the measured value is approximately equal to the radiant energy considerable amount of light. Afterwards, respectively measuring 30 water samples collected in the field will be the value corresponding to the reflected energy. Using the formula described above to calculate the spectral reflectance values for each sample.

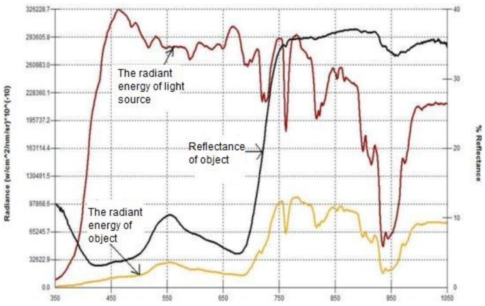


Figure 5. Reflectance curve of object

**5. IMAGE PROCESSING**

Measurement results of our spectrometer for spectral reflectance values of model objects in the room and not influenced by the atmosphere. Therefore, to put the results on the analysis of Landsat 7 images need preprocessing steps to convert from DN values to spectral reflectance values of atmospheric and noise reduction as follows:

*Step 1.Convert DN data to radiance data*

$$L\lambda = (Gain\lambda * DN7) + Bias\lambda$$

Where: Lλ is the calculated radiance [in Watts / (sq. meter * µm * ster)], DN7 is the Landsat 7 DN data and the gain and bias are band-specific numbers. The latest gain and bias numbers for the Landsat 7 sensor are given in Chander et al. (2009) and are shown in the following table.

Table 3. Gain and bias numbers for the Landsat 7

| Band | Gain | Bias |
|---|---|---|
| 1 | 0.778740 | -6.98 |
| 2 | 0.798819 | -7.20 |
| 3 | 0.621654 | -5.62 |
| 4 | 0.639764 | -5.74 |
| 5 | 0.126220 | -1.13 |
| 7 | 0.043898 | -0.39 |

*Step 2. Convert radiance data to reflectance data*

$$R\lambda = \frac{\pi \; * \; L\lambda * d^2}{Esun\lambda * \; \sin(\theta SE)}$$

Where Rλ is the reflectance (unitless ratio), Lλ is the radiance calculated in step 1, d is the earth-sun distance (in astronomical units), Esunλ is the band-specific radiance emitted by the sun, and θSE is the solar elevation angle. One needs three pieces of information (in addition to the radiance calculated in step 3) in order to calculate the reflectance. The first is the band-specific radiance emitted by the sun. These values are given in Chander et al. (2009) and are repeated in the following table.

Table 4. The band-specific radiance emitted by the sun

| Band | ***Esun,*** **λ [Watts / (sq. meter * µm)]** |
|---|---|
| 1 | 1997 |
| 2 | 1812 |
| 3 | 1533 |
| 4 | 1039 |
| 5 | 230.8 |
| 7 | 84.9 |

The second and third pieces of information are d, the earth-sun distance, and θSE, the solar elevation angle. These two values are dependent on the individual scene, specifically the day of the year and the time of day when the scene was captured. The solar elevation angle and the day of year are listed in the header file for each scene.

## 6. RESULT

### 6.1. Reflectance curve of water samples

After conducting spectrometry 30 samples taken in the field, researchers obtained the first result is the graph of the reflectance spectra of the samples corresponding to the different opacity. Looking at Figure 6 shows a probability sample reflective of the larger countries is more opaque at all wavelengths from band 1 to band 4 of Landsat 7.

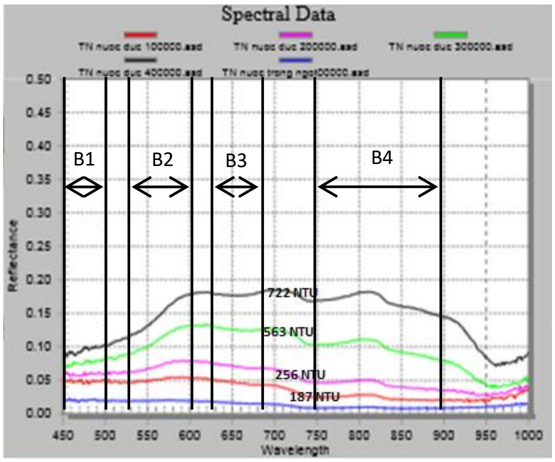


Figure 6. Graph of reflectance spectrum of some water samples
(B1, B2, B3, B4 is the wavelength range of Landsat 7 bands)

### 6.2. Correlation between reflectance and water turbidity

To reflect the impact of turbidity water spectral reflectance values to this study uses the ratio of the channel NIR/Green (Javier Bustamante, 2008). Calculate the average spectral reflectance in the NIR channel (band 4) and Green (band 2) spectrometer that measured water samples corresponding to each other and we are sharing the table 5.

Table 5. Value turbidity and the ratio of the average value between Green and NIR channel.

| Sample No | NIR/Green | Water turbidity (NTU) | Sample No | NIR/Green | Water turbidity (NTU) |
|---|---|---|---|---|---|
| 1 | 0.2368 | 187 | 16 | 0.2369 | 204 |
| 2 | 0.237 | 201 | 17 | 0.2371 | 217 |
| 3 | 0.2414 | 219 | 18 | 0.2511 | 233 |
| 4 | 0.2424 | 256 | 19 | 0.2627 | 236 |
| 5 | 0.226 | 302 | 20 | 0.3146 | 458 |
| 6 | 0.2354 | 330 | 21 | 0.3197 | 474 |
| 7 | 0.2551 | 369 | 22 | 0.3211 | 616 |
| 8 | 0.3135 | 563 | 23 | 0.375 | 669 |
| 9 | 0.335 | 587 | 24 | 0.395 | 702 |
| 10 | 0.355 | 722 | 25 | 0.4124 | 741 |
| 11 | 0.3719 | 746 | 26 | 0.4151 | 801 |
| 12 | 0.4178 | 829 | 27 | 0.4365 | 810 |
| 13 | 0.4197 | 835 | 28 | 0.445 | 902 |
| 14 | 0.4351 | 959 | 29 | 0.4617 | 926 |
| 15 | 0.4622 | 981 | 30 | 0.4693 | 993 |

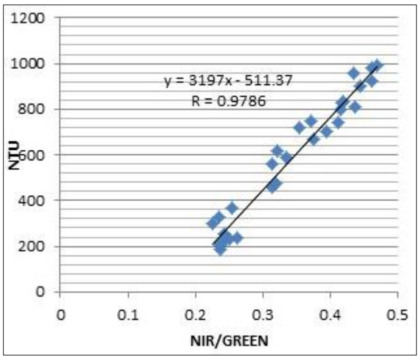



Figure 7. Graph of correlation between turbidity and index

Figure 7 is a graph showing the correlation between the proportion of water turbidity and channel ratio NIR/Green with a correlation coefficient r = 0.9786 > 0.8 indicates that this is a very tight correlation.

### 6.3. Water turbidity of coastal areas in Hai Phong city

After converting values Band 2 (Green) and band 4 (NIR) image from DN values to spectral reflectance values, we calculate the ratio band 4/band 2 results turbidity index (Figure 8a). Using the NTU = 3197x (NIR/Green) - 511.37de seawater turbidity calculations Hai Phong City area (Figure 8b).

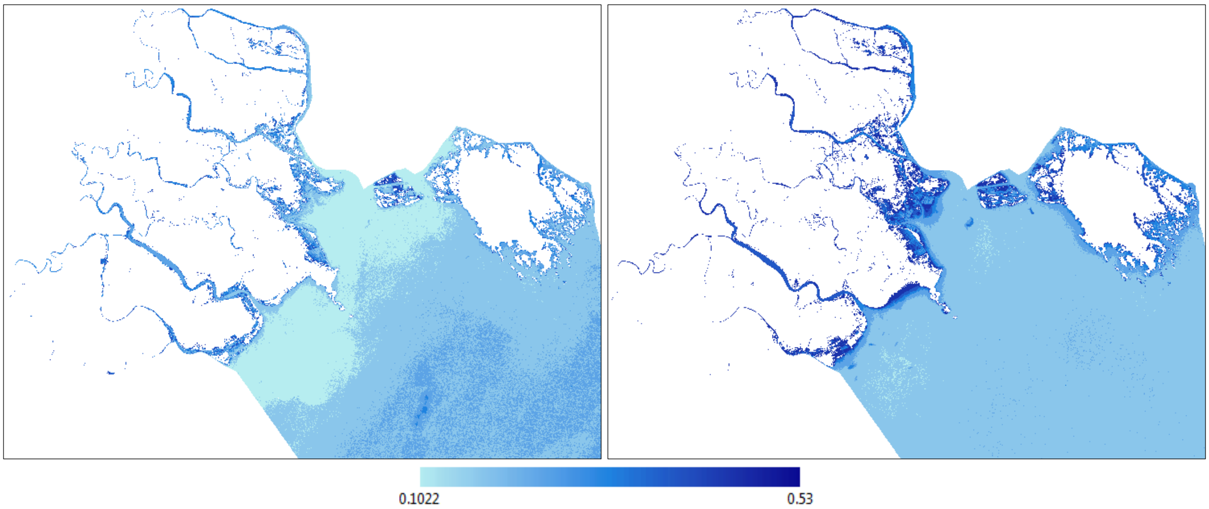



Figure 8. Turbidity index (NIR/Green)

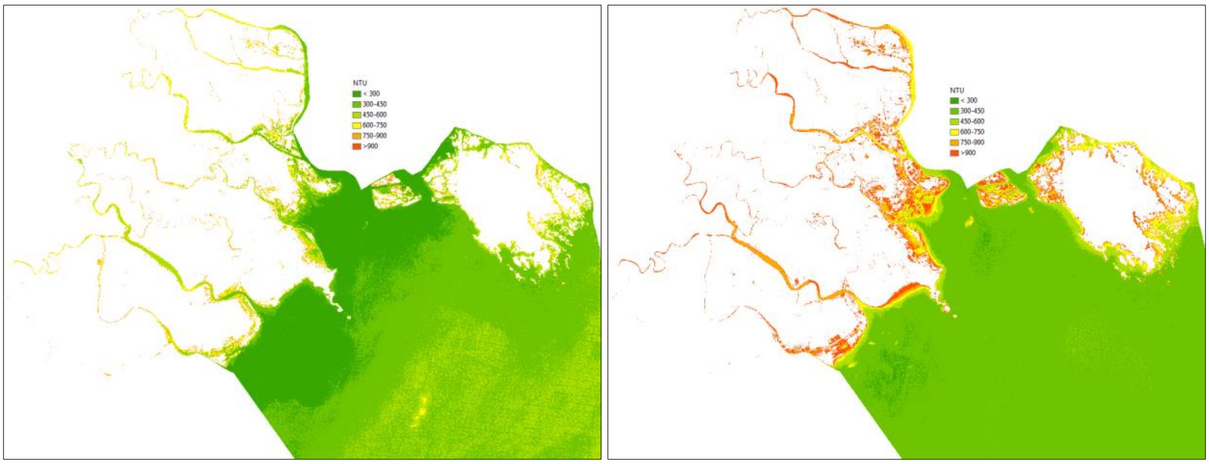


Figure 9.  Turbidity index NIR/Green (a) và NTU index (b) calculated from Landsat 7

Table 6. Area of some turbidity ranges in dry season and rainy season

| **Dry season** | | | **Rainy season** | | |
|---|---|---|---|---|---|
| **NTU** | **Area (ha)** | **Percent** | **NTU** | **Area (ha)** | **Percent** |
| < 300 | 36352.6 | 25.3 | < 300 | 1756.1 | 1.2 |
| 300 - 450 | 73632.3 | 51.3 | 300 - 450 | 115634.6 | 80.6 |
| 450 - 600 | 25380.1 | 17.7 | 450 - 600 | 6961.8 | 4.9 |
| 600 - 750 | 4829.4 | 3.4 | 600 - 750 | 5487.7 | 3.8 |
| 750 - 900 | 3078.5 | 2.1 | 750 - 900 | 5045.3 | 3.5 |
| > 900 | 225.4 | 0.2 | > 900 | 8612.9 | 6 |

## 7. CONCLUSION

Radiation energy spectrum of experimental measurements in a closed room with very high stability by using artificial light sources and eliminates the constant changes of atmospheric environment during the measurement.

The turbidity of the NIR / Green and water turbidity Haiphong coastal areas has proportional correlation function: NTU = 3197x (NIR / Green) - 511.37 with the correlation factor r = 0.9786. Where there is high turbidity estuary to transport the material flow from the river to the sea and the shoreline where the direct impact of the river and the sea, the shore as the turbidity of the water decreases. In the rainy season, the river brings more material to the sea that makes water turbidity increase. According to the calculation in this study, the area of water turbidity of 300-450NTU has increased from 51.3% (in dry season) to 80.6% (in rainy season), the area of water turbidity more than 900NTU has increased from 0.2% (in dry season) to 6% (in rainy season). Besides, the area of water turbidity less than 300NTU has decreased from 25.3% (in dry season) to 1.2% (in rainy season).

## ACKNOWLEDGEMENT

This research is funded by the VNU University of Science under project number TN.16.16

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