DEVELOPMENT OF DISSOLVED OXYGEN CONCENTRATION EXTRACTION MODEL USING LANDSAT DATA CASE STUDY: RINGGUNG COASTAL WATERS

Muchlisin Arief
Remote Sensing Applications Center, LAPAN
E-mail: muchlisin.arief@yahoo.com

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Abstract. Water is a key component to the process of earth's life. However, with increasing industrial development and anthropogenic activities, water quality has been decreased dramatically. Therefore, monitoring is necessary to anticipate the threat of contamination and to take effective action at all levels in local or central government. Methods or algorithms were proposed for detecting or mapping or extraction the concentrations of dissolved oxygen (DO) derived from Landsat remote sensing imagery using empirical formulation. The aim of this study to monitor the quality of coastal waters over large areas. The method begins with the calculation of water surface temperature derived from Landsat data, using the correlation function obtained by correlating the temperature measurement by the infrared band reflectance values. Then the image is used to calculate the concentration of DO using the correlation function. the correlation function is obtained by correlating the results of field measurements of DO with temperature. The study conducted in the Ringgung coastal waters located in Padang Cermin District, Pesawaran municipal conducted on August 7 to 11, 2012. Based on the analysis, dissolved oxygen concentration of Ringgung coastal waters is inversely proportional to the amount of fresh water entering the coastal waters and directly proportional to the aeration process. As a result, in June the concentration of dissolved oxygen near the beach (on shore water) greater than in the offshore water. While in August, the concentration of dissolved oxygen near the coast (on shore water) is lower than in the offshore water.

Keywords: *detection, dissolved oxygen, correlation, Landsat, Ringgung*

1 INTRODUCTION

On Earth, water circulation is one of the most important processes for the maintenance of the environment. the surface water may include water runoff, streams, rivers, lakes, seas, etc. Water is an important component of the environment which is a major requirement for the process of life on earth, so there is no life on earth, without water and life is impossible. Thus, the relatively clean water is very coveted by humans' need, either for everyday life, for the city sanitation hygiene, or for agriculture, animal husbandry and so on.

Water as the main component of the environment that affect the interplay between the other components. Poor water quality will degrade the environment, that will affect the health and safety of humans and other living organisms. For that, life need a certain water quality standards, the current, the water is much polluted by waste assortment of various outcomes of human activities, so the quality, the water resources has declined. Currently, the water becomes a problem that needs serious attention. To get standardized water, is costly because there are water is much polluted by waste from a variety of various outcomes of human activity. So that quality, water resources has declined. Definition of water pollution refers to the definition of the environment specified in the Law on Environmental Law No. 23/1997. In PP 20/1990 on Control of Water Pollution. Water pollution is defined as the introduction of living organisms, substances, or energy and other components into the water by human activity so that the quality of water decreases to a certain level is causing the water does not work anymore accordance with the designation. However, based on dictionary, is the contamination of water bodies e.g. lakes, rivers, oceans, aquifers and groundwater (Dekker *et al.*, 1996).

Water pollution can be divided into three broad categories, there is physical, chemical and biological pollution. physically pollution is the pollution based on the level of water clarity (turbidity), temperature changes, the color and the change in color, odor and taste; Chemical pollution, is the pollution by chemical substances dissolved, the pH changes; While the biological pollution, is the pollution by microorganisms that are present in the water, especially the presence or absence of bacterial pathogens. Common indicator of water pollution is known to pH or hydrogen ion concentration, dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The concentration of dissolved oxygen (DO) is influenced by many factors including: temperature/water temperature, rate of photosynthesis, the light level of penetration (turbidity and water clarity), the concentration of organic matter (such as industrial waste or city) levels of water turbulence or wave or tidal motion (Reid 1974). In addition, the dissolved oxygen is used by respiration and decay of organic matter in the water (water bodies), so that the dissolved oxygen serves as an indicator of the biological health of the water body. The concentration of dissolved oxygen (DO) is the amount of chemical (not physical quantities), so that the DO concentration in the sea/water can not be detected by the remote sensing sensor directly. However, the magnitude of DO concentration can be derived from sea surface temperature, because the concentration of dissolved oxygen (DO) in the water will increase with increasing temperature and decreases the low with the high salinity (Karakaya *et al.*, 2011, Lin *et al.* 2014). Thus the concentration of dissolved oxygen can be derived from satellite remote sensing data by observing the temperature of the surface waters.

Since the 1980s, satellite remote sensing provides an opportunity to observe the water quality synoptic and multi-temporal (Giardino, 2007). Various measurement study of water quality variables such as turbidity, brightness/ Secchi disk (S-depth), chlorophyll-a (Chl-a), suspended solids, water temperature and Colored Dissolved Organic Material (CDOM) has been monitored directly using the data of remote sensing data (Dekker *et al*, 2002;. Zhang *et al.*, 2003;. Kutser *et al*, 2005; Sudheer *et al.*, 2006; Nouri *et al.*, 2008). Other research comparing the measurement values in situ (field) with the values of reflectance spectral bands of various satellite data (Pulliainen *et al.*, 2001; Bilge *et al*, 2003).

The purpose of the research is to develop models/algorithms for prediction determination the Dissolved Oxygen concentration derived from Landsat satellite imagery. in which the method begins with deriving the sea surface temperature of Landsat satellite images, and then temperature of Landsat corrected with the temperature field measurement. and the end, the corrected temperature image is used to extract the Dissolved oxygen (DO) by using the correlation function is obtained by correlating between dissolved oxygen with temperature observations in the field.data are The data are used in this reseach are recorded on Augst 21 and Desember 12, 2012.

2 STUDY OF LITERATURE

2.1 Dissolved Oxygen

There are 4 main parameters to determine Water Quality are: 1) Disolved Oxygen/DO, 2) Biologycal Oxygen Demand/BOD 3) Chemical Oxygen Demand/COD and 4) Degree of acidity (pH) (Roland *et.al.*,1999). Dissolved oxygen in the water can occur in two ways, namely: 1) due to the diffusion process of free air, and 2) as a result of photosynthesis is released by Aquatic plants in water. In the absence of dissolved oxygen, many microorganisms can not live in water because dissolved oxygen is used for the degradation of organic compounds in water (Salmin 2000). Oxygen produced from algae photosynthesis reaction is not efficient, because the oxygen that is formed will be reused by the algae for metabolic processes in the absence of light. Dissolved oxygen in water depends on temperature and atmospheric pressure. Based on the data of temperature and pressure, then oxygen saturation in water at 25° C and 1 atmosphere pressure is 8.32 mg/L (Warlina, 1985).

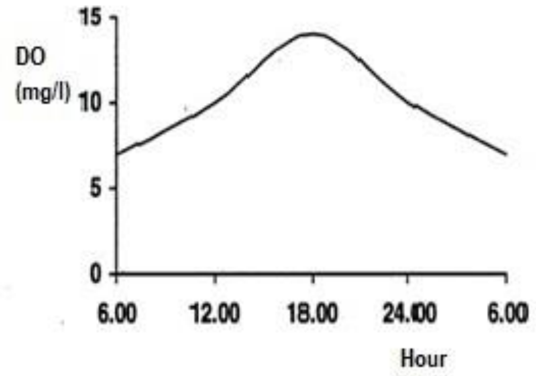
Dissolved oxygen (DO) often called the oxygen demand (OD). OD is one of the important parameters in water quality analysis. This shows the amount of oxygen (O2) is available in a body of water. The greater the value of DO in the water, indicating that water has a good quality. Conversely, if the DO is low, it can be seen that the water has been polluted. In addition, the ability of water to clean up pollution is also determined by the amount of oxygen in the water, because oxygen plays a role in deciphering the chemical components into a simple component. Oxygen has the ability to react with contaminants such as organic components and the contaminants are not harmless. Oxygen is also required by the microorganisms, both aerobic and anaerobic metabolic processes. The presence of oxygen in the water, microorganisms outlines the hard compound in water. Reactions that occur in the decomposition is as follows (Fraden, 2004):

$$\text{Organic component} + O_2 + \text{nutrient} \xrightarrow{\text{microorganism}} CO_2 + H_2O + \text{new cell} + \text{nutrient} + \text{energy}$$

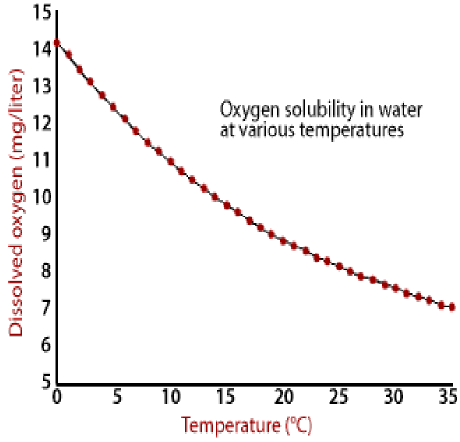
If the decomposition reaction of chemical components in the water continues to apply, then the oxygen level is reduced. At the climax, the available oxygen is not sufficient to decipher the chemical components. The situation is called severe pollution in the water.

In the oceans the DO magnitude is very fluctuated. During the day, where the sun shines brighter, the process of photosynthesis takes place, then the release of oxygen, but the oxygen produced is consumed by respiration processes (Jeffries and Mills, 1996 in Effendi, 2003). While at night, there is no photosynthesis, but respiration continues. This pattern of change in oxygen levels result in daily fluctuations of oxygen in the waters of the euphotic layer. Maximum oxygen levels occur in the afternoon and a minimum in the morning (see Figure 2-1a).

While the correlation between DO with the opposite relationship occurs tempertaur DO mean magnitude is inversely proportional to the magnitude of the temperature. The smaller the value, the temperature grew DO reverse the higher temperature, the DO value increased ketch, (see Figure 2-1.b).



(a)
Daily fluctuations of dissolved oxygen in the layer eufatik (Boyd, 1988 in Effendi, 2003)



(b)
The correlation between DO with temperature www.cotf.edu/ete/modules/waterq3/WQasses s3f/html

Figure 2-1: Daily fluctuations of dissolved oxygen and its correlation with temperature

2.2 Remote Sensing Application in Water Quality Monitoring

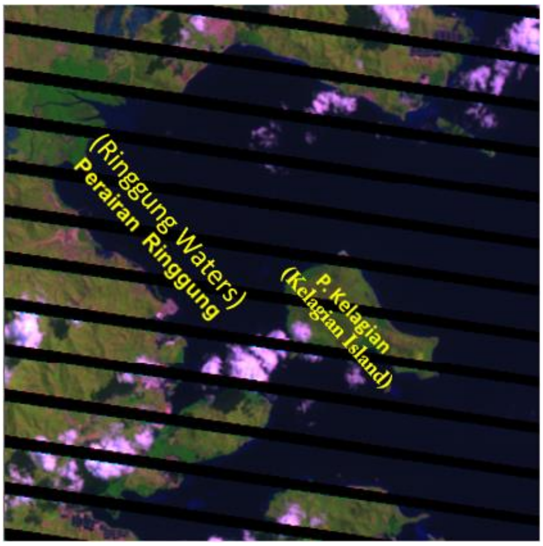
Remote sensing measurement is usually based on the interaction between electromagnetic radiation and the material is on the surface of the earth. In remote sensing, electromagnetic spectrum that is most important to observe the phenomenon of changes in water quality are visible band (approximately 400 to 700 nm), infrared/IR (700 nm to 15 μm) and microwave radiation (1 mm to 30 cm) is very high in water (Zoloratev and Demin, 1977).

Changes in water quality may occur due to the chemical, physical and biological characteristics of water bodies and identify possible sources of pollution or contamination that can lead to degradation of water quality. The water quality indicators can be categorized as: (i) Biology: bacteria, algae, (ii) Physical: temperature, turbidity and clarity, color, salinity, suspended solids (iii) Chemistry: pH, dissolved oxygen, biological oxygen demand, nutrients (including nitrogen and phosphorus), organic and inorganic (including toxicants) and (iv) Aesthetics: odors, stains, colors, and floating materials. Various studies have reported on the usefulness of remote sensing as a tool for water quality monitoring (Ritchie and Charles, 1996; Schalles *et al*, 1998 and Dekker *et al*, 2002). Remote sensing for water quality monitoring has been started in the 1970s, which has been developed through the initial empirical approach to estimate suspended sediment following general equation: $Y = A + BX$ or $Y = ABX$ where, Y is the remote sensing measurements (ie, light, reflection, energy) and X is the water quality parameter of interest (sediment, turbidity). A and B factors empirically derived from statistical relationships determined from the spectral reflectance values of water quality parameters in situ. Spectral reflectance can provide information about the band or wavelength suitable for the water quality parameters. Statistical relationships were developed by the researchers to determine or estimate the water quality parameters in different places different. In this panelitian used the satellite data of Landsat-7 ETM+ were obtained from the USGS (http://glovis.usgs.gov) which consists of six spectral bands (bands 1 to 5 and 7) which has the characteristics: 1 bands: blue 0.45 to 0.52 μm, band 2: green-from 0.52 to 0.60 μm; Band 3: red-from 0.63 to 0.69 μm, 4 bands: near-infrared from 0.77 to 0.90 μm, band 5:

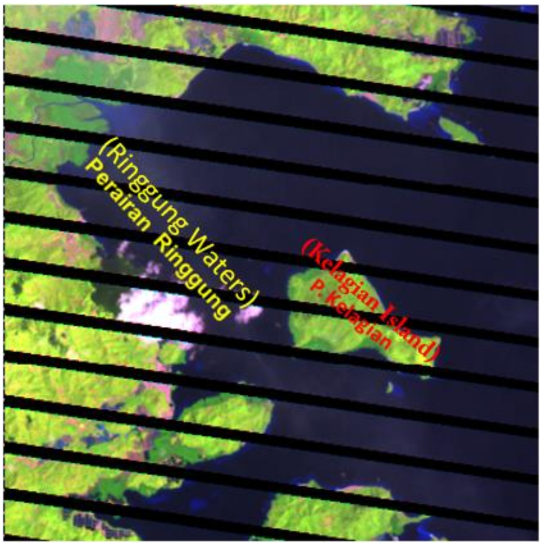
mid-infrared from 1.55 to 1.75 µm; and band 7: middle infrared: 2.09 to 2.35 µm) with 30-m spatial resolution, and band 6 (thermal infrared: from 10.4 to 12.5 µm) and 8 (panchromatic: 0.52 to 0, 90 µm) each with a spatial resolution of 60 µm and 15 µm. Band 6 to provide channel with gain (gain) low and high gain were recorded with two separate files (B6L and B6H), where the band-6H absorb more radiation sensitive than the band 6L.

3 MATERIALS AND METHODOLOGY

3.1 Data and Tools



(a)
Landsat RGB 543 dated 21-08-2012



(b)
Landsat RGB 543 dated 12-12-2012

Figure 3-1: Landsat-7 ETM+ data of Ringgung Waters (a) and (b)

This research was conducted in the Ringgung coastal waters located in Padang Cermin District, Pesawaran municipal. DO measurements conducted field August 7 to August 11, 2012.-data Landsat 7 ETM + were obtained from the USGS (http://glovis.usgs.gov) recorded 21 August 2012 and December 12, 2012 (See Figure 3-1a and b).

The equipment used for the field survey: Probe DO-550-meter, thermometer, salinity refractometer, while for the data processing is: DELL XPS computer software along with ER-Mapper 7.0, Arc View 3.3 Envi 4.5. MATLAB and other supporting software.

3.2 Algorithm of Data Processing

In general, the algorithm of DO concentration extraction using Landsat satellite data consists in several stages as shown in Figure 3-2.

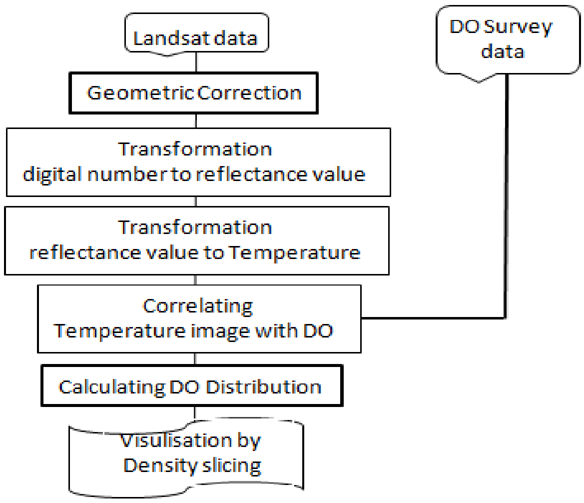


Figure 3-2: Algorithm for DO extraction

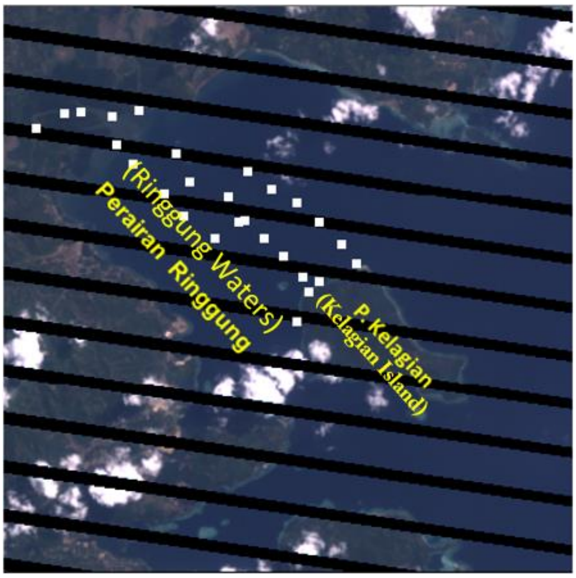
- Geometric correction of Landsat satellite data, with the aim that all the data (field data, maps and images) can be integrated.
- Tranform the digital image number into the reflectance image. For the Landsat satellite, made changes to the form values prior to use formulation radiansi Lλ = ((LMAXλ - LMINλ) / (DNMAX-

DNMIN)) * (DN-DNMIN) + LMINλ then to reflectance values using the formula:

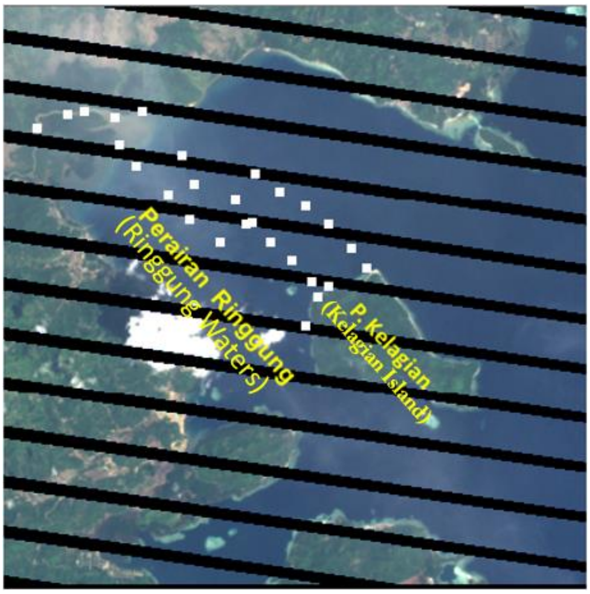
- L λ π D2/(Esun Cos Θ λ) and temperature for the band (6L and 6H) TLandsat = K2/ln ((K1 / Lλ) +1) – 273;
- Correlating temperature 6H Landsat image of the band with the temperature field measurement results for later analysis;
- Correlating the data value field observations of DO with temperature and temperature observations with the temperature of the image;
- Analysis to find the largest correlation value of some correlation between the temperature obtained from the temperature measurements derived from Landsat bands 6L and 6H, then determine the correlation function with the criteria have the greatest correlation coefficient;
- Determine or calculate the spatial distribution of temperature reflectance image using either of Landsat correlation function and the result corrected with field data;
- Calculating the spatial distribution of DO derived from Landsat imagery temperature;
- Display the image density results after slicing process.

4 RESULTS DAN DISCUSSION

First of all the data are conducted geometric correction and then conducted radiometric correction. Correction radiometric is to change the value of the digital number to value radiance then the value radiance is changed to the reflectance value but for band 6L and 6H are chnged directly to the value of surface temperature. After the data was integrated with field measurements, the results of integration can be seen in Figure 3-3 below.



(a)
Integration of Landsat reflectance image dated 21-08-2012 with the observation points



(b)
Integration of Landsat reflectance image dated 12-12-2012 with the observation point

Figure 3-3: Integration of Landsat reflectance image with the observation point (a) and (b)

Dissolved oxygen (DO) is the amount of chemical, so that these quantities can not be extracted directly through the remote sensing data. Therefore, first sought a relationship between the magnitude of the amount of his physical chemistry. Physical quantities that affect the Dissolved oxygen (DO) is the temperature (http://www. tetonscience.

org). Sea surface temperature can be derived directly using the band-6H Landsat satellite using TLandsat formula (° C) = K2/ln ((K1/Lλ) +1) - 273, sea surface temperature derived from band-6H Landsat data using the formula and Landsat imagery dated August 21, 2012 can be seen in Figure 3-4 below.

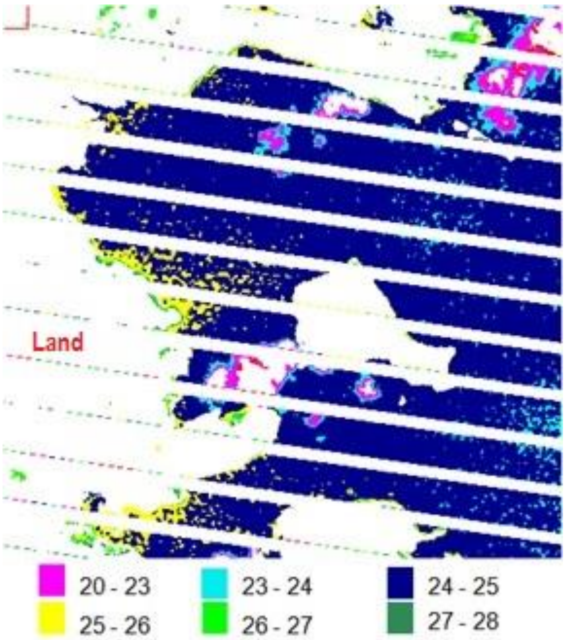


Figure 3-4: The temperature image derived from Landsat satellite band 6H

Figure 3-4 shows the spatial distribution of Ringgung surface waters termperature. In Figure 3-5. show the waters temperature on 21-08-2013, where the temperature ranges from 20° C to 28° C.

When temperature derived from Landsat data compared to the actual temperature point-by-point, so temperature is lower. The difference is the graphics difference can be seen in Figure 3-5.

Therefore, the estimation of temperature must be corrected prior to field data. While Landsat satellite imagery recorded on 12-12-2012 generate temperatures far from reality (as it is covered cirrus clouds/thin clouds and cold). Therefore, the Landsat image is not used in subsequent studies.

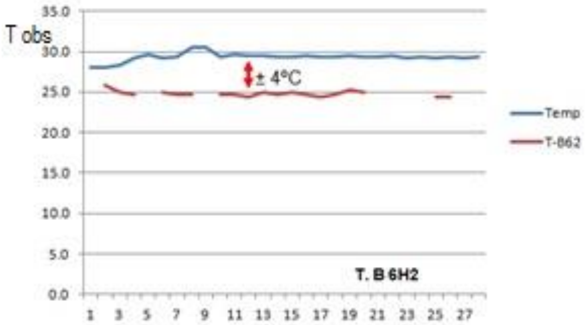


Figure 3-5: The difference in temperature observations (Tobs) with calculations derived from Landat band 6H (TB6H2)

To correlate between the data obtained from the field observations, the following table is presented together with the value of the observation point temperature Landsat image (see Table 3-1). Table 3-1 shows that not all observation points has a value of reflectance and temperature on Landsat data, is due to the stripping of Landsat data (see Figure 2.a and b). In Table 3-1 showed that for turbid waters, with a brightness value of 0.5 up to 1 meter, the DO varied from 4.6 to 5.6 ppm, meaning that the value is almost the same turbidity DO have value that is different. Similarly, for crystal clear waters, the brightness value of 4 to 14 meters, has a value of DO is almost the same (varying from 6.02 to 6.50) meaning that the value of DO in waters not dependent on the level of turbidity. These circumstances, it can be concluded that the value of the water sector in particular waters DO Ringgung not solely depend on turbidity waters or aeration process (the process of mixing the water surface) or the photosynthesis process. But is influenced also by other factors such as: Chemical Oxygen Demand (COD) is the need of oxygen needed by the chemical and Biological Oxygen Demand (BOD) or other nutrients. However, the values of BOD or COD or other nutrients are not taken into account in this study.

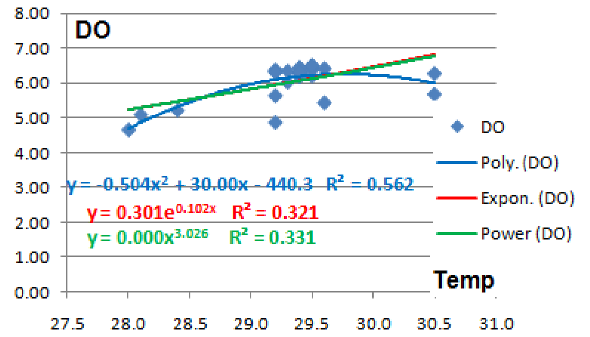
Table 3-1: The value (DO, Temp,) of the observation point and a value of reflectance and temperature from Landsat

Observation			LANDSAT 21-08-2012	
No.	DO	Temp.	T-B61	T-B62
1	4.66	28.0		
2	5.1	28.1	25.52	25.79
3	5.22	28.4	25.02	24.956
4	4.87	28.2	25.017	24.677
5	5.44	29.2		
6	5.64	29.6	25.017	24.956
7	6.02	29.2	24.514	24.677
8	5.68	29.3	24.514	24.677
9	6.28	30.5		
10	6.28	30.5	24.524	24.677
11	6.42	29.4	24.524	24.677
12	6.39	29.6	24.524	24.397
13	6.51	29.5	25.017	24.9557
14	6.31	29.5	24.514	24.6767
15	6.3	29.4	25.017	24.3971
16	6.44	29.4	24.514	24.677
17	6.33	29.5	24.514	25.2341
18	6.18	29.4	25.017	24.677
19	6.2	29.3	25.017	25.2341
20	6.43	29.5	25.017	24.956
21	6.35	29.2		
22	6.5	29.4	25.017	24.6768
23	6.32	29.2		
24	6.3	29.4		
25	6.38	29.2	24.514	24.3971
26	6.45	29.4	24.514	24.3971
27	6.33	29.2		
28	6.32	29.4		

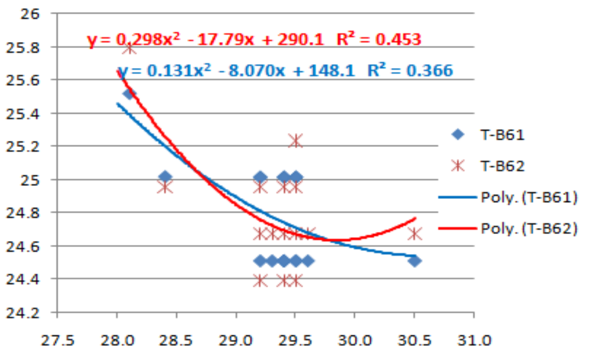
Furthermore (Tabel 3-1), as explained above that DO have a relationship with temperature. Therefore it is done, the correlation between DO with temperature field and temperature measurement results with the field measurements derived from the temperature-6H band Landsat satellite data. The second correlated result can be seen in Figure 3-6a and b below.

In Figure 3-6a shows that the correlation function between the DO with temperature observations with the largest correlation coefficient is:

$$DO = -0.504x^2 + 30.00x - 440.3 \quad \text{with: } R^2 = 0.562 \qquad (3\text{-}1)$$



(a)
The correlation between DO with temperature observations



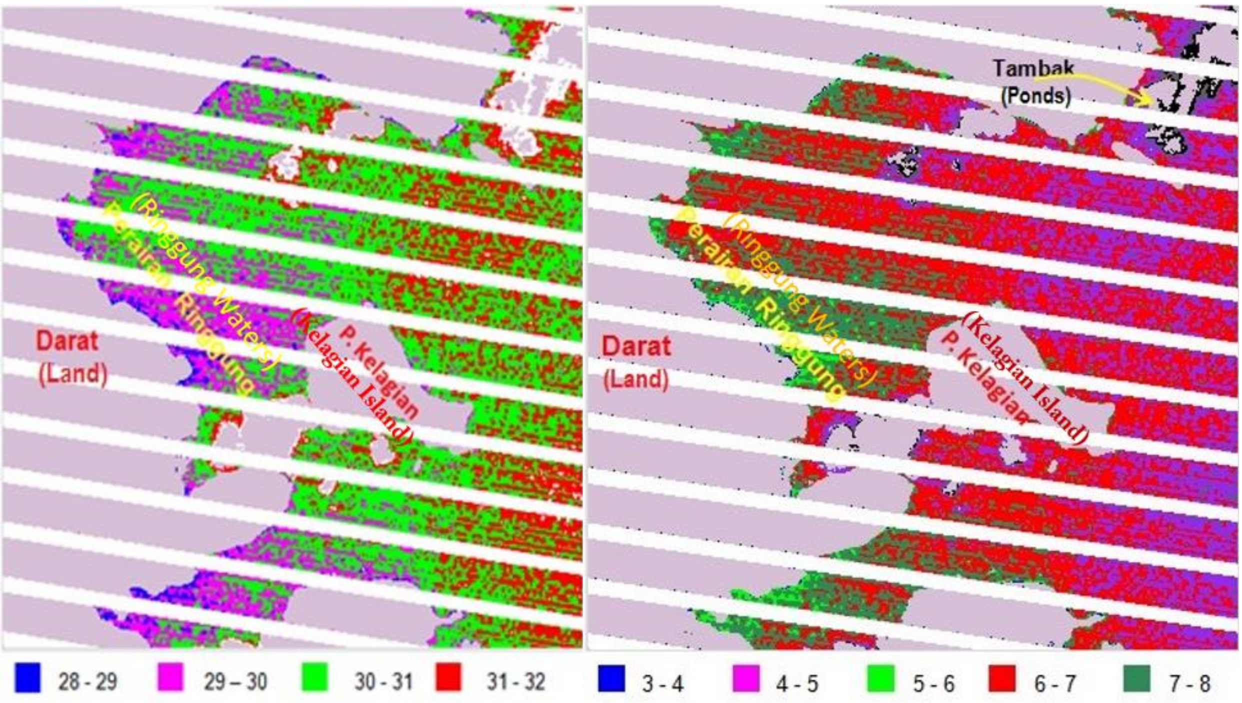
(b)
The correlation between temperature observations with a temperature of Landsat

Figure 3-6: Correlation between temperature data observed with DO and temperature calculation results of Landsat data

It shows that the correlation function is proportional to the temperature DO. This is contrary to what has been done by the USGS (http://www.tetonscience.org) which says that the value of DO varies inversely with temperature (Figure 3-6b). This incident probably by many factors: among others, the gauge is not calibrated or natural conditions in waters Ringgung much different nature ever undertaken (Farag and El-Gamal, 2011). Both of these factors are not taken into account in this study shows that the correlation function is proportional to the temperature DO. This is contrary to what has been done by the USGS. which says that the value of DO varies inversely with temperature (Figure 3-6b).

Figure 3-6b is a correlation between temperature observations with the temperature derived from the band-6L and 6H Landsat data. And it turns out that the correlation function has the largest correlation coefficient obtained between the temperature of the band-6H with the equation T = 0.298x2 - 17.79x + 290.1, and R^2 = 0.453 (see Figure 3-6.b). Although the correlation coefficient (R^2) gained less than 0.5 which is supposed to be a temperature field with the temperature derived from satellite data should occur linear correlation (R^2 = 1). Such differences may result from, among others: the observation time is not the same as the image recording time, so the most likely state of the environment/atmosphere is not the same. Temperature estimated from Landsat satellite data and after correction with field data can be seen in Figure 3-7.a, while the image of dissolved oxygen derived from the temperature image can be seen in Figure 3-7b.

Figure 3-7a shows that the sea surface temperature interval ranged from 28.0 ° C to 32.0 ° C with. (2.0 ° C hotter than the actual temperature). This is most likely due to atmospheric correction factors that are not taken into account in this study. Mapping Dissolved oxygen (DO) is determined/calculated from the temperature image by using the correlation function: DO = -0.504x2 + 30.00x - 440.3 (see Pers.1) and the results of these calculations can be seen in Figure 3-7b.



(a)
Sea surface temperature derived from Landsat and corrected with survey data

(b)
Dissolved oxygen is derived from a Landsat image

Figure 3-7: Temperature and dissolved oxygen imageries derived from Landsat data bands 6H

In Figure 3-7b shows that dissolved oxygen has the interval between 3 mgl-1 up to 8 mgl-1 and color thistle is land and clouds, while the black color is a suburb of the pond. DO in beachside range (3-4 mgl-1) is lower than the middle of the ocean DO. This is due to occur off the coast of the aeration process (mixing of water in surface waters) or mixing fresh water with sea water causing low DO waters. The images show that the value of the DO of oceans are influenced by the amount of fresh water entering the coastal waters and stirring process/aeration or it can be said that the value of DO is inversely proportional to the amount of fresh water entering the coastal waters and compared straight to the mixing process. That is increasingly ketch DO value in a coastal waters, the more the amount of fresh water entering into the waters or the more fresh water coming into ocean. the smaller the value of DO in the water and also more and more a process of aeration in the water, the greater the DO values in those waters and vice versa.

Based on the above analysis, the processing method proposed by using remote sensing satellite (Landsat) can provide enormous possibilities for monitoring/mapping water quality in coastal waters and have very high efficiency compared with conventional monitoring (through the stations observations in specific locations directly in the field). But somehow in providing information on water quality, remote sensing data can not stand alone. Therefore, in the future, in order to have accuracy in monitoring results, the system needed equipment measuring in situ water quality is more accurate or sophisticated.

While the remote sensing data are used to extend these measurements are spatially and temporally. Images are also showed that interval calculation result is wider than the interval means DO measurement results of the estimation exceeds the range of the observations. This is most likely caused by the propagation of errors (error sustainable) as a result of the calculation is done several times. In this research error propagation is also not taken into account in this study.

5 CONCLUSION

This paper proposed extraction algorithm dissolved oxygen using Landsat satellite data. The proposed algorithm begins with the calculation of water surface temperature derived from Landsat near infrared band, and then determine the correlation function between dissolved oxygen (DO) with temperature measurement results in the field. After that, the obtained correlation function is applied on Landsat satellite imagery to derive dissolved oxygen concentration. Based on the above analysis, it can be some of the conclusions are:

- DO is directly proportional to the temperature different from that performed by the USGS. The difference is caused by, among others: the measuring instrument is not calibrated and natural conditions in waters Ringgung a much different nature that are not accounted for in this study
- The difference between the derived temperature and observed temperature is of ± 4 °C. The difference is caused by the data recording time is not the same as the time of field measurements.

Concentration of dissolved oxygen in Ringgung coastal waters is inversely proportional to the amount of fresh water entering the coastal waters and directly proportional to the aeration process. As a result, in the coastal waters Ringgung, in June the concentration of dissolved oxygen near the beach (on-shore water) is greater than in the middle of the waters (offshore), while in August the dissolved oxygen concentration is lower near the coast than in the middle waters.

However, these methods are discussed with all the limitations and needs to be refined by using the data with the same recording time with the time of survey. Nevertheless, the results presented are advances increased knowledge valuable for remote sensing applications, especially for the extraction of chemical water quality parameters such as dissolved oxygen.

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