Remote Sensing and Water Quality Indicators in the West Flood Canal Semarang City: Spatio-temporal Structures of Lansat-8 Derived Chlorophyll-a and Total Suspended Solids

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Abstract. One of the waters that has been contaminated by industrial waste and domestic waste is the waters of West Flood Canal in Semarang City which is the estuary of the river system, which passes through the Western City of Semarang which is dense with residential and industrial. So, it is necessary to have information about the assessment of water quality in the estuary of the West Flood Canal. Remote sensing technology can analyze the results of recording the spectral characteristics of water with water quality parameters. One of the parameters for assessing water quality is Chlorophyll-a and Total Suspended Solid, can be estimated through remote sensing technology using multispectral Lansat-8 Satellite images data from April, June, and August, 2017 and there are three selected algorithms. Based on the results of TSS and Chlorophyll-A processing, the TSS shows values greater than or equal to 100 which can be said that West Flood Canal is damaged (hypertrophic). While the chlorophyll-a shows a value less than 100 indicating Eutrophic status (threatened). This is caused by the number of suspended materials in the water surface and also because of the disturbance of water vegetation in the form of weeds that destroy the function of the actual West Canal Flood.

Keywords: Chlorophyll-a, Suspended solids, Remote sensing, West Flood Canal

1. Introduction
Coastal environments throughout the world are now experiencing unprecedented anthropogenic eutrophication, hypoxia and harmful algal blooms due to increased human activities and subsequently increased nutrient loadings [1]. Because of their significant role in human well-being relying upon them, deterioration of water quality indicators (e.g., water temperature, dissolved oxygen, chlorophyll, inorganic nutrients, heavy metals, total suspended solid) can be potentially catastrophic for marine ecosystems as species are threatened by conditions which are no longer suitable for their survival [2]. As a result, monitoring changes in spatio-temporal patterns of water quality (WQ) in both terrestrial and marine ecosystems, and interpretation of the implications have been important across disciplines these days, such as environmental/marine sciences and socio-economics. However, it is inherently difficult to properly address varying spatial and temporal scales of WQ for application to coastal marine waters monitoring and assessment [2].
West Flood Canal (BKB) is a union of three major rivers namely Kreo, Kripik, and Garang River. In Gunungpati District, the three rivers merge and become upstream of BKB. The three rivers have upstream in Semarang regency. Nevertheless, about 90 percent of the river is located in the city of Semarang. One of the waters that has been contaminated by industrial waste and domestic waste is the waters. The West Flood Canal River crossing the Western city of Semarang is dense residential and industrial. Many industrial activities around this watershed (DAS). Among other things are the textile industry, foodstuff, plastic, karoseri, printing, pharmaceutical and herbal medicine, paint, furniture, lubricating oil, workshop, even there is a fish auction. These waters become domestic and urban waste disposal sites and industrial wastes generated by activities around the river basin (Riyanto, 2004 in [3]).

In coastal waters, total suspended solid (TSS) can be an important factor controlling biological processes [4] and its distribution and variations can be strongly influenced by tides and river discharge [5]. TSS is also important in light penetration and water movements in the coastal waters (Sonetal, 2014). Thus, accurate estimation of TSS is critical to understand the thermal structure of upper water columns and physical processes [6] as well as biological processes (e.g., phytoplankton photosynthesis) in the ocean euphotic zone [7]. With the amount of waste discharged along the river of West Canal Flood, Kreo, Kripik, and Garang River is so that there is need for information on the assessment of water quality in the estuary of the West Flood Canal. One of the parameters for assessing water quality is Chlorophyll-a and Total Suspended Solid. Chlorophyll-a is a parameter used to determine the level of water fertility while Total Suspended Solid (TSS) is one of the parameters used to determine the level of water pollution. By knowing the content of Chlorophyll-a and Total Suspended Solid (TSS) in the waters of this West Canal Flood will be obtained information about water quality in estuary waters of West Canal Flood.

Distribution of Chlorophyll-a and Total Suspended Solid (TSS) can be estimated through remote sensing technology, such as from Landsat satellite imagery. Remote sensing technology can analyze the results of recording the spectral characteristics of water with water quality parameters. Remote sensing technology using satellite imagery offers a variety of facilities for obtaining data on fertility and water pollution compared to using more complex and costly laboratory tests. One of the benefits of using remote sensing technology is its wide coverage area, having an uncomplicated processing and low cost. In Landsat satellite image processing to obtain information on fertility distribution data and water pollution, an algorithm is required to obtain suitable distribution value between image data and laboratory test data so that the selection of this algorithm is expected to get the value of distribution of fertility and water contamination matching in the study area.

2. Materials and Literature Study

2.1. Materials
Location of study in this research is Semarang area which densely populated. West Canal Floods pass 5 sub-districts of West Semarang, Semarang Utara, Semarang Tengah, South Semarang and Gajah Mungkur. The West Canal Flood has limited land because its left right is flanked by 4 (four) highways between Sugijopranoto bridge to the sea flanked by Madukoro highway Kokrosono road and between Sugijopranoto bridge to Simongan dam is flanked by Bodjong Salaman road - Basudewo road. The West Flood Canal River is one of the means important urban infrastructure in Semarang City. The main function of the West Flood Canal River is as the city's flood and drainage controller that is actively used since it was first built in 1880 until today, in addition to the West Flood Canal River into a waterfront icon in Semarang.
Figure 1. Location of study in this research is West Canal Floods, Semarang City.

2.2. Literature Study

2.2.1. Remote Sensing. The application of satellite and airborne remote sensing imagery to collect WQ information has become more frequent [8]. Remotely sensed datasets are generally more comprehensive than those directly measured in situ in that they provide greater spatial coverage with finer resolution and often increased temporal frequency and resolution. This makes remote-sensing approach a rich source of data. However, the large amount of data also embeds challenges for the extraction of meaningful information of WQ parameters. Remotely-sensed sea surface temperature (SST) is one of the most important oceanic and atmospheric variables which has been widely used in a variety of researches to develop an understanding of ocean dynamics, as well as physical and biogeochemical processes in the upper ocean [9].

2.2.2. Water Pollution. Water pollution caused by humans can arise from a variety of activities, whether intentionally or not, and in general greatly affect the environment resulting from pollution by living things. Pollution if not prevented or reduced is essentially harmful and detrimental to human beings in terms of health as well as in terms of social life or the survival of living things [10]. Water pollution affects organisms and plants in water bodies. In many cases this effect destroys not only individual populations and species but also natural biological communities. According to [11], the indicator or sign that water has been polluted is that there are changes or observable signs:

1. Water temperature changes.
   The existence of this temperature change is generally due to the presence of industrial waste in terms of water cooling process to remove heat from the machines used. The hot water is then discharged into the environment. If the hot water is dumped into the river, then the river water will become hot, river water that rises temperature will disrupt the life of aquatic animals and other aquatic organisms due to dissolved oxygen levels in water will decrease along with rising temperatures.

2. Changes in pH or Hydrogen Ion concentration.
   The normal water that qualifies for a life has a pH ranging from 6.5 to 7.5. Water can be acidic or alkaline depending on the size of the water pH or the amount of hydrogen ion concentration in the water. Water having a pH smaller than normal pH will be acidic, while water having a pH greater than normal pH will be alkaline.

3. Color Changes, Odor and Flavor.
   Waste or waste materials in the form of organic and inorganic materials are often soluble in water. If the waste material and waste water dissolves in water then there will be a change of water color. Water in normal circumstances and clean will not be colored, so it looks clear and clear. Water pollution does not necessarily depend on the color of the water.
4. Occurrence of Deposition, Colloidal, and Substances Dissolved.

The precipitate and colloidal as well as the solute material are derived from the presence of solid waste materials. Solid waste materials that are not fully soluble will settle at the bottom of the river and which may dissolve in part will become colloidal. The precipitate before it reaches the bottom of the river will float in water together with colloidal.

5. Microorganisms

Microorganisms are instrumental in the process of degradation of waste materials from industrial or other activities that are discharged into the environment water, both rivers, lakes and seas. If the waste material that must be degraded quite a lot, means that microorganisms will participate multiply. In the proliferation of these microorganisms did not rule out the possibility that microbial pathogens also develop. Microbial pathogen is the cause of various diseases.

2.2.3. Chlorophyll-a. Chlorophyll comes from the Greek, which consists of two syllables, chloros which means green and phylum which means leaf. Chlorophyll captures life force or solar energy and is used to split \( H_2O \) molecules into elements of \( H \) and \( O \), then combine them between elements \( H \) with \( CO_2 \) gas and produce sugar or carbohydrates. From the process of photosynthesis is also produced byproducts of gas \( O_2 \). Chlorophyll is better known as green leaf substance which is a pigment found in a producer organism that functions as a converter of carbon dioxide into carbohydrates, through photosynthesis. Chlorophyll has a chemical formula \( C_{55}H_{72}O_{5}N_{4}Mg \) with Mg atom as its center. Chlorophyll-a is one of the most decisive parameters of primary productivity in the ocean. Chlorophyll-a is an important component that is supported by phytoplankton and water plants which are both a source of natural food for fish. Chlorophyll-a is an active pigment in plant cells that play an important role in the ongoing process of photosynthesis (Prezelin, 1981 in [12]).

2.2.4. Trophic Water Status. Eutrophication is a water enrichment with nutrients in the form of inorganic materials needed by plants and leads to an increase in primary productivity of waters. Nutrients in question are nitrogen and phosphorus. Eutrophication is classified into two, namely artificial or cultural eutrophication and natural eutrophication. Eutrophication is classified as artificial (cultural) eutrophication if nutrient uptake in waters is caused by human activity; And are classified as natural eutrophication if nutrient uptake in waters is not caused by human activity but natural activity [13]. Eutrophication is classified into four categories of trophic status [14], namely:

- **Oligotrophic;** Is trophic status of lake water and / or reservoir containing low nutrient content, this status indicates that water quality is still unspoiled nature from nutrient sources N and P.
- **Mesotrophic;** Is the trophic status of lake water and / or reservoir containing nutrients with moderate levels, this status indicates an increase in levels of N and P, but still within the tolerance limit because it has not shown any indication of water pollution.
- **Eutrophic;** Is the trophic status of lake water and / or reservoir containing high levels of nutrients, this status indicates that water has been contaminated by increased levels of N and P.
- **Hypereutrophic;** Is the trophic status of lake water and / or reservoir containing very high levels of nutrients, this status indicates that water has been heavily polluted by increasing levels of N and P.

Next on the criteria of trophic water status according to [15] are listed in the following table:

| Trophic Status | Average Chlorophyll a (µg/l) |
|----------------|-----------------------------|
| Oligotroph     | <2.6                        |
| Mesotrophic    | 2.6-7.3                     |
| Eutrophic      | 7.3-56                      |
| Hypereutrophic | >56                         |
2.2.5. **Total Suspended Solid.** TSS are suspended materials (diameter> 1 μm) retained on a sieve of Millipore with a pore diameter of 0.45 μm. TSS consists of mud and fine sand and microorganisms. TSS concentrations in waters generally consist of phytoplankton, zooplankton, human waste, animal waste, sludge, crop residues and animals, and industrial waste. Suspended materials in natural waters are not toxic, but if excessive amounts can increase the turbidity value which further inhibits the penetration of sunlight into the water column [16]. TSS is closely related to soil erosion and erosion of river channels. TSS is highly variable, ranging from less than 5 mg.L-1 is the most extreme 30.000 mg.L-1 in some rivers. TSS is not only an important measure of erosion in the river channel, it is also closely related to transport through the river system of nutrients (especially phosphorus), and various industrial and agricultural chemicals [17].

2.2.6. **Pollution Index Determination.** [18], University of Texas, A.S., proposed an index relating to a significant pollutant compound for a designation. This index is expressed as the Pollution Index used to determine the level of pollution relative to permitted water quality parameters [19]. This index has a different concept with the Water Quality Index. The pollution index (PI) is determined for a designation, then it can be developed for some designation for all parts of the water body or part of a river. Water quality management on the basis of pollution index (PI) can provide input to decision makers in order to assess the quality of water bodies for a designation and take action to improve quality in case of quality deterioration due to the presence of pollutant compounds. PI encompasses a variety of independent and meaningful quality parameter groups (KMNHL No. 115 Year 2003). Results of image data processing on Total Suspended Solid (TSS) concentration and subsequent laboratory test results are calculated by pollution index in accordance with Decree of State Minister of Environment No.115 Year 2003 about Water Quality Status as comparison with quality standard to know pollution level at point location The sampling. The formula for calculating the pollution index is as follows:

$$PI = \frac{C_i}{L_{ij}}$$

Where:
- CI: concentration of water quality parameters obtained from laboratory test results (TSS).
- Lij: concentration of water quality parameters specified in the Water Quality Standard.

Evaluation of PI values are: 0 ≤ PI ≤ 1.0: meet the quality standard, 1.0 < PI ≤ 5.0: lightly contaminated, 5.0 < PI ≤ 10: moderately polluted, PI> 10: heavily polluted

2.2.7. **Chlorophyll-a Calculation Algorithm.** There are 1 algorithms that will be used in this research with the aim to get the best algorithm that can be used as formula of chlorophyll-a content processing in research area and can be used by multitemporal data of multilayered area study.

**Nuriya Algorithm et a.** The algorithm used for the determination of chlorophyll-a content using the Nuriya algorithm. So in the processing of image data the algorithm is used as follows:

$$C = 0.2818 \times \left( \frac{B_5 + B_6}{B_4} \right)^{3.497}$$

Information:
- C: Chlorophyll-a concentration (mg/L)
- B4: The reflectance value of channel 4
- B5: Reflectance value of channel 5
- B6: The channel reflectance value of 6
Because the algorithm uses the reflectance value, then the image data must be extracted first from the value of DN (digital number) to the radiance value. Then from the value of radiance to the value of Reflectance.

2.2.8. TSS Concentration Determination Algorithm. There are 1 algorithms that will be used in this research with the aim to get the best algorithm that can be used as a formula for processing Total Suspended Solid (TSS) concentration in research area and can be used by multitemporal data of Landsat study area.

- a. Doxaran algorithm (Red Band): \[5.1271 \times \exp(0.0027 \times i)\]

- b. Laili algorithm (Band 2 and Band 4): \[\text{TSS} \left( \frac{mg}{l} \right) = 31.42 \times \frac{\log(\text{RRS}_2)}{\log(\text{RRS}_4)} - 12.719\]

- c. Trisakti algorithm (Red Band): \[\text{TSS} \left( \frac{mg}{l} \right) = 4.9453e^{0.0028x}\]

3. Results and Discussion

3.1. Total Suspended Solid Algorithm Results

Distribution of water quality results of TSS parameters by using the doxaran algorithm on April 4, 2017, June 3, 2017, and August 22, 2017.

![Figure 2. Water quality results with Doxaran Algorithm](image1)

Distribution of water quality results of TSS parameters by using the Laili algorithm on April 4, 2017, June 3, 2017, and August 22, 2017.

![Figure 3. Water quality results with Doxaran Algorithm Laili](image2)
Distribution of water quality results of TSS parameters by using the Trisakti algorithm on April 4, 2017, June 3, 2017, and August 22, 2017.

![distribution of water quality results](image)

**Figure 4.** Water quality results with Doxaran Algorithm Trisakti

### 3.2 Results of Distribution Value of Chlorophyll-a
Results of Distribution Value of Chlorophyll-a April, June, and August 2017 with Algorithm Nuriya.

![distribution of water quality results](image)

**Figure 5.** Water quality results with Doxaran Algorithm Nuriya

### 3.3 Analysis of Tropical Flood Status of Western Canal
Monitoring of water quality level in West Canal Flood can be done by qualitative method which use TSS and Chlorophyll-a parameter where the hypothesis is the bigger the TSS concentration value, the smaller the water volume. Based on the results of TSS and chlorophyll-A we get the most significant result is to use the algorithm Doxaran and Trisakti where the two algorithms are not much different results. But to test the tropical status of West Canal Flood using the Doxaran algorithm. Here are the results of trophic status data of West Canal Flood with TSS and Brightness parameters using Doxaran algorithm.
Table 2. Tropical data status data of west canal floods

| Month            | TSS Value Algorithm Doxaran (mg/l) | Value of Chlorophyll-a (mg/l) | Tropic Status |
|------------------|-----------------------------------|--------------------------------|---------------|
| 4 April 2017     | 66                                | 113.9                         | Hypereutrophic|
| 3 June 2017      | 165                               | 78                            | Hypereutrophic|
| 22 August 2017   | 186                               | 58.9                          | Hypereutrophic|

4. Conclusions
Based on the results of TSS and Chlorophyll-A processing, the TSS shows values of less than or equal to 00 on June 3, 2017 and August 22, 2017 and Chlorophyll-A shows values of more than or equal to 200 on April 4, 2017 which can be said that the West Canal Flood status damaged (Hypertrophic). While on June 3, 2017 and August 22, 2017 Chlorophyll shows a value less than 100 indicating Eutrophic status (threatened). This is caused by the number of suspended materials in the water surface and also because of the disturbance of water vegetation in the form of weeds that destroy the function of the actual West Canal Flood.

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