Spatio-Temporal Distribution of Chlorophyll-a in Semarang Bay using Sentinel-3

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Abstract

Chlorophyll-a is an indicator for the fertility of waters. The oceanographic conditions make the distribution of chlorophyll-a in waters always changes every season, both spatial and temporal. The aim of this research is to determine the spatial and temporal distribution of chlorophyll-a in Semarang Bay using Sentinel-3 OLCI imagery. Sentinel-3 OLCI imagery has a resolution of 300 m x 300 m, based on the spatial resolution generated by Sentinel-3 OLCI imagery to further examine the spatial distribution of chlorophyll-a in Semarang Bay with better spatial resolution. This research also used wind, current, temperature and salinity data from the Reanalysis Model which were processed using the SNAP program with C2RCC method. It is found that the distribution of chlorophyll-a in the Semarang Bay showed a varied pattern spatially and temporally. Temporally, the highest chlorophyll-a concentration occurred in January and the lowest was in June. Spatially, chlorophyll-a on the coast of Semarang and Demak is higher than that on the coast of Kendal in the west season, but entering the east season the highest chlorophyll-a is on the Kendal coast than on the coast of Semarang and Demak. Chlorophyll-a distribution in Semarang Bay mostly influenced by river run off and wind.

Keywords : *Chlorophyll-a, Sentinel-3 OLCI, C2RCC, Semarang Bay*

INTRODUCTION

Semarang Bay are tropical waters in the north of Java with a lot of rivers input and abundant nutrients with sufficient of sunlight intensity. This triggers the emergence of water fertility which characterized by the presence of phytoplankton. Maslukah *et al*., (2019) stated that the presence of phosphate greatly affects the fertility waters. The results of the simple linear model analysis between phosphate and chlorophyll-*a* are R=0.74 and R^2=0.55.

Fertility waters area can be indicated based on the value of concentration of chlorophyll-a both spatial and temporal (Zhang and Han, 2015). Eleveld *et al* (2007) stated that chlorophyll-a can be estimated using remote sensing by utilizing the spectral characteristics of chlorophyll-*a*.

Several studies have been conducted to examine the distribution of chlorophyll-*a* in Semarang Bay. The research was conducted by Shabrina *et al*., (2018) and Suprijanto *et al*., (2019). However, these two studies are using Aqua MODIS with resolution of 4 km x 4 km to observe the distribution of chlorophyll-a in the northern waters of Central Java, so the coverage does not reach the coastal area which have very dynamic values. Meanwhile, Sentinel-3 Imagery has a resolution of 300 m x 300 m so that can reach the coastal areas. Furthermore, a research with Sentinel-3 Imagery has never been carried out in Semarang Bay.

Another study that observed chlorophyll-a using Aqua MODIS Imagery in Semarang Waters was Agung *et al*., (2018). The result are spatial chlorophyll-*a* in Semarang waters has a value that tends to be higher when it is in the coastal area. Ji *et al*. (2018) added that the concentration of chlorophyll-*a* is significantly affected by sea surface temperature but also needed additional factors such as salinity, DO, surface currents, and temperature gradients.

Sentinel-3 OOLCI Imagery has a based

*Corresponding author
http://ejournal.undip.ac.id/index.php/buloma
Diterima/Received : 25-08-2021
DOI:10.14710/buloma.v11i1.40201
Disetujui/Accepted : 11-01-2022

neural network or processor called *The Case 2 Regional Coast Colour* (C2RCC) which can be used to obtain chlorophyll-a concentrations in complex coastal areas. The C2RCC processors uses a large simulation database of water reflections and Top of Atmosphere. Neural Network based processors have been used in the C2RCC to invert the wavelength spectrum for atmospheric correction and regain the inherent optical properties of waters. A bio-optical model for taking chlorophyll-*a* has been carried out by C2RCC using 5 scattering and absorption components for model parameterization. All of these optical properties were determined at a wavelength of 443 nm (Brockman *et al*, 2016).

Jakovels *et al* (2016) explained that Sentinel-3 imagery has a fairly good correlation in determining chlorophyll-a with actual conditions in the field. The results of his research in the Gulf of Riga, Baltic Sea obtained a model of the relationship between the value of in situ chlorophyll a and the value of the Sentinel image of 0.61-0.83 (R2). Furthermore, from the results of research conducted by Cazzaniga *et al*., (2019) in Lake Garda and Trasimeno, Italy. It was explained that Sentinel-3 OLCI Imagery has an advantage over Sentinel-2 MSI in terms of monitoring the value of chlorophyll-a in the waters. This is because the MSI Sentinel-2 image tends to be overestimated in comparison to Sentinel-3 OLCI Image. The use of Sentinel-2 Imagery is better in smaller research area in comparison to Sentinel-3. This study aims to determine the spatial and temporal distribution of chlorophyll-a based on Sentinel-3 imagery and to determine the effect of wind, current, temperature, and salinity parameters on the distribution of chlorophyll-a in Semarang Bay.

MATERIALS AND METHODS

This research was conducted in the Semarang Bay which is located at the spatial coordinates of 6^0 - 7^0 LU; 110^0 - 111^0 BT (Figure 1).

The chlorophyll-*a* data is obtained the European Space Agency (ESA) and daily data from Sentinel-3 OLCI Level 1 EO for processing mode for Full Resolution (EFR) Imagery were used in this study. In this case, the Sentinel-3 OLCI satellite images data throughout 2020 were

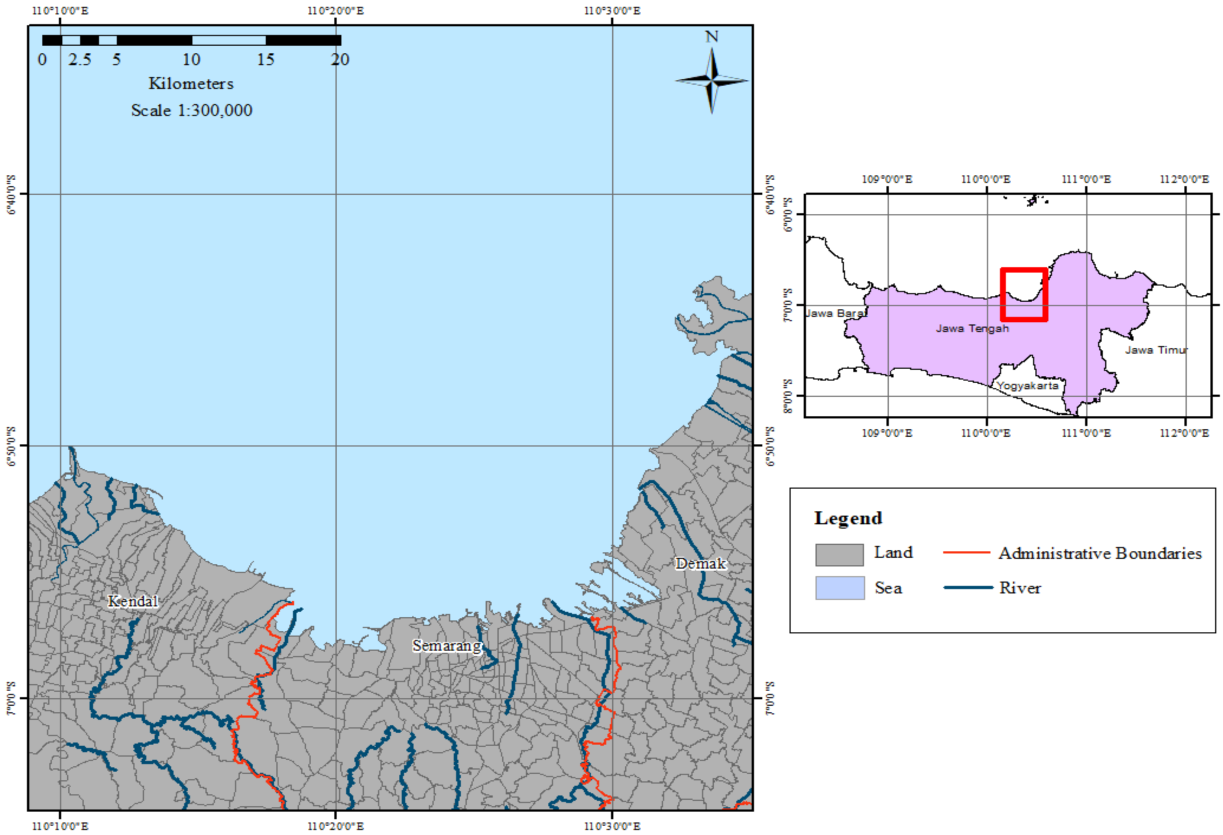

Figure 1. Research area of Semarang Bay

used with the image category that have less cloud disturbance in the research location. With this condition, 2-3 images were downloaded in the same month are used at the beginning of the month, the middle of the month, and the end of the month that represent the month then the images will be binned into monthly chlorophyll-*a* image data. Furthermore, the images were cropped, projected, processed with C2RCC algorithm and it's ready to be visualized. C2RCC itself has 2 main roles in extracting chlorophyll-a values. It is atmospheric correction, and extraction of chlorophyll- *a* values from waters. (Brockman *et al*., 2016).

The Level 4 reanalysis with 0.25^0 x 0.25^0 resolution through 2020 was used for the wind analysis. This data are obtained for free via *https://cds.climate.copernicus.eu.* The Level 4 reanalysis with 0.083^0 x 0.083^0 resolution through 2020 were used for the current, temperature, and salinity. This data are obtained for free via *https://marinecopernicus.eu.*

RESULTS AND DISCUSSION

The results of processed chlorophyll-a data using Sentinel-3 OLCI Images from January to December 2021 shows that the distribution of chlorophyll-a values in Semarang Bay has a different distribution in every month (Figure 2). The thickness of the cloud in the raw images make the data in several months have a value that disturbed by clouds as seen in January, February, March, April, and worst in December. It can be seen that the red color that appears in the middle of the sea is not appropriate, especially those waters generally have chlorophyll-a levels ranging from 0-6 mg/l.

However, we can still identify the rest especially for coastal areas from Semarang Bay. The distribution of chlorophyll- *a* in the waters of Semarang Bay has a different distribution pattern every month and tends to be higher in the coastal area and getting smaller in the middle of the sea. In the middle sea

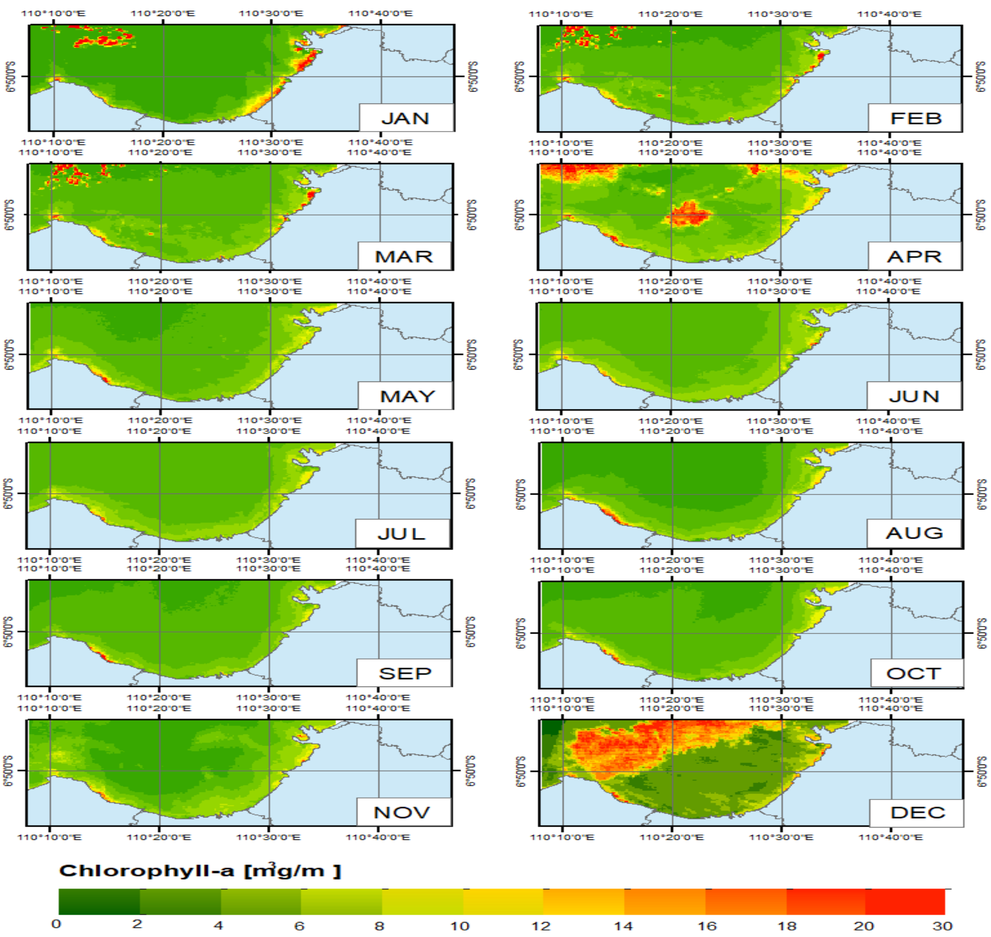

Figure 2. Spatial distribution of Chlorophyll-*a* during January – December 2021 in Semarang Bay

area, the distribution of chlorophyll-*a* values tends to be homogeneous.

The results of processed wind data shows that the distribution of monthly winds in the waters of Semarang Bay has a direction pattern that tends to be the same in certain months, but has a different average wind velocity every month (Figure 3). The average wind velocity in the coastal area of Semarang Bay ranges from 0.660 m/s – 5,784 m/s. The results of the processed current distribution data can be seen in Figure 4. In the January and February, it seems to be moving northeast towards the Java Sea at a fairly low velocity of 0.083 – 0.296 m/s. The current velocity continued to decrease in the period of March and April where it appears that the current velocity continued to decrease and the peak decreased in March with an average velocity of 0.004 m/s, but the current direction has started to turn eastward towards the coastal waters of Demak in March, and turn southeast towards the coast of Semarang in April.

The period of May, June, July, and August, the current distribution began to turn south again towards the coast of Java, but the current velocity tends to be slower. In the period of September, October, November, the current distribution is seen turning eastward towards the coast of Demak with a fairly slow current velocity of only around 0.004 – 0.248 m/s where the recorded velocity of 0.248 m/s was in December.

Based on the results of research conducted regarding the distribution of chlorophyll-*a* in the waters of Semarang Bay, it can be seen that the distribution of chlorophyll-*a* will increase in the west season and will decrease in the east season. The wind that blows in the west monsoon generally has a fairly strong velocity as shown in Figure 1. The distribution of chlorophyll-*a* moves according to the wind velocity pattern, where when the wind velocity increases the value of chlorophyll-*a* will also increase and vice versa, as shown in Figure 2.

When the wind velocity is higher, the average chlorophyll-*a* also increases. The strong wind causes mixing so that the nutrients in the lower layers of the water move to the surface. This statement is in accordance with the research results of Muskananfola *et al*., (2021). Kunarso *et al*., (2019), stated that the distribution chlorophyll-*a* was influenced by wind velocity and related to the mixing process (Figure 4).

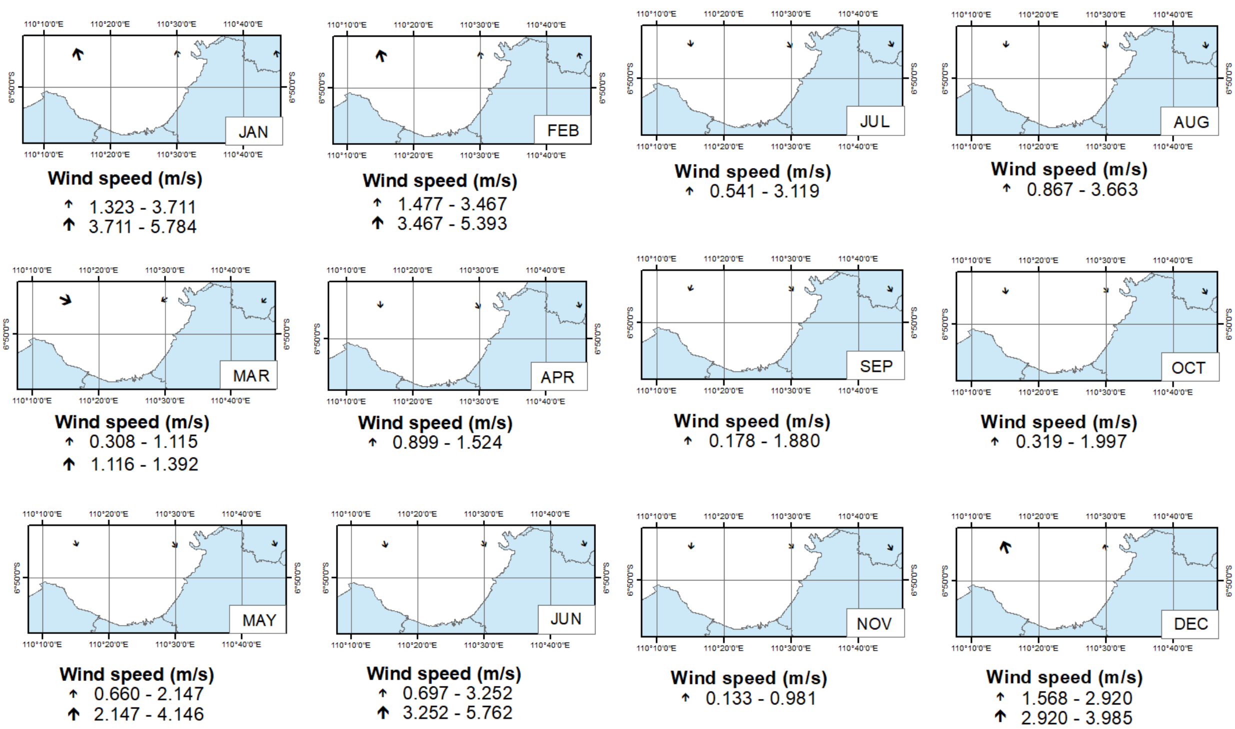

Figure 2. Spatial distribution of wind speed during January – December 2021 in Semarang Bay

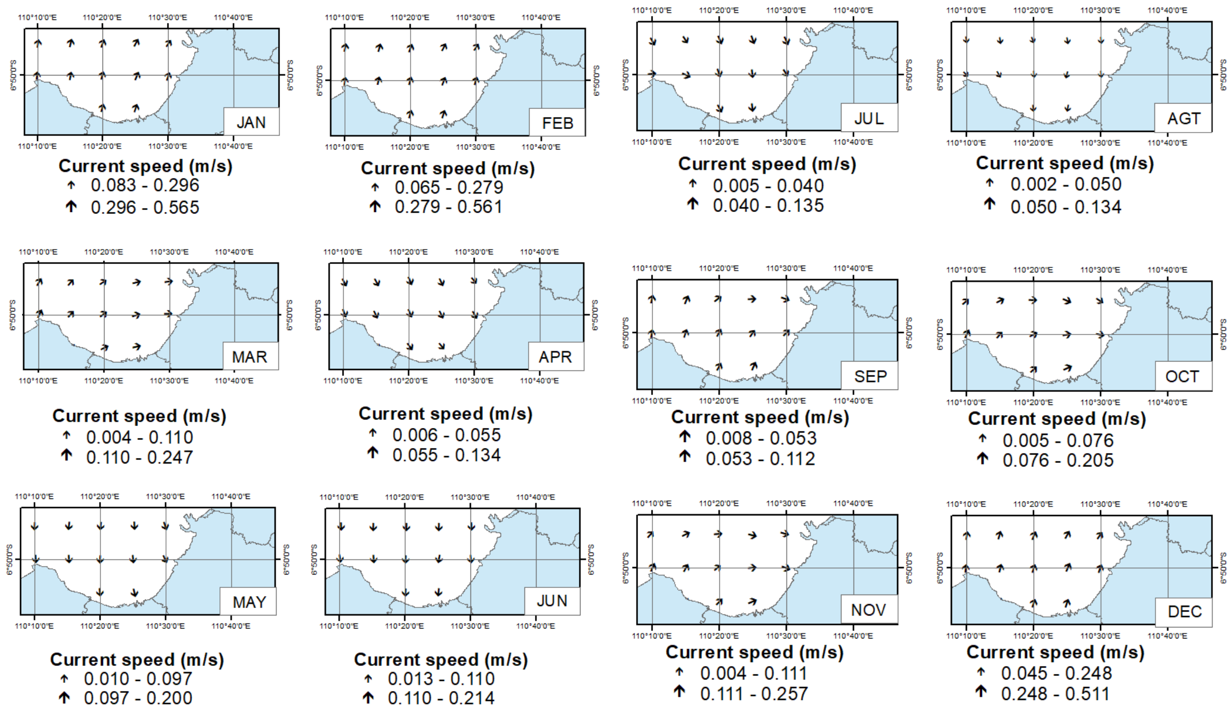

Figure 3. Spatial distribution of Current speed during January – December 2021 in Semarang Bay

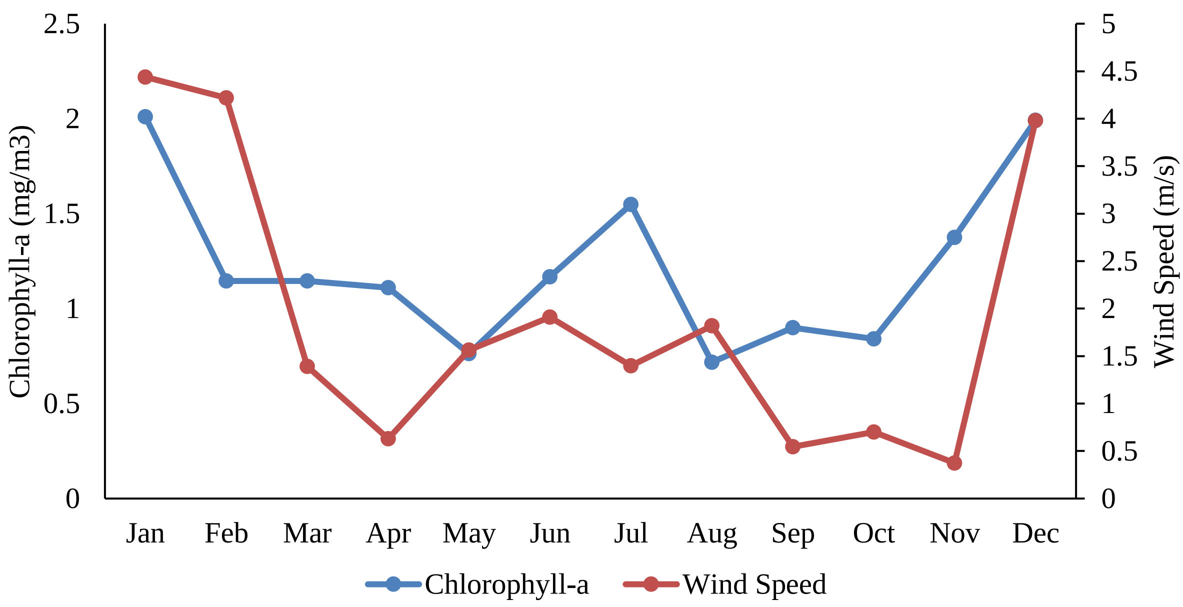

Figure 4. Correlation of average chlorophyll-a and wind velocity on area

The correlation between chlorophyll-a and wind velocity shows a positive correlation with a value of R=0.634. From January to February, there was a decrease in wind velocity followed by a decrease in the mean average of chlorophyll-a. From May to June, it was seen that there was an increase in wind velocity followed by an increase in the average chlorophyll-a in the waters. This is in line with the research conducted by Suprijanto *et al*., (2019) which states that the distribution of chlorophyll-a in the Java Sea is mainly influenced by monsoon winds and spatially it is known that high chlorophyll-a concentrations occur during the West and Transitional Seasons 1.

The distribution of chlorophyll-a in Semarang Bay waters also moves according to the current velocity pattern, where when the current weakens, the average chlorophyll-*a* will increase and vice versa as shown in Figure 5.

The correlation between chlorophyll-a and currents velocity in Semarang Bay shows a positive correlation value of 0.589. From January to February, there was a decrease in current velocity followed by a decrease in the average chlorophyll-*a*. From March to April, there is an inverse relationship that occurs in the relationship between the average chlorophyll-a and the current velocity with a decrease in current velocity followed by an increase in the average value of chlorophyll-*a*. This relationship has been recorded in a study conducted by Effendi *et al*. (2012) in Makassar Sea which showed that in January - February there was an increase in the value of chlorophyll-*a* followed by a decrease in current speed, and in August - November there was a decrease in the value of chlorophyll-a followed by an increase in chlorophyll-*a*. So it can be concluded that the current velocity does not have much effect on the distribution of chlorophyll-*a*, but in stable conditions the current velocity has a major influence with increasing the value of chlorophyll-*a* followed by a decreasing of current velocity, and vice versa. This is also stated by Shabrina *et al*. (2018) that ocean currents do not fully influence the distribution of chlorophyll-a.

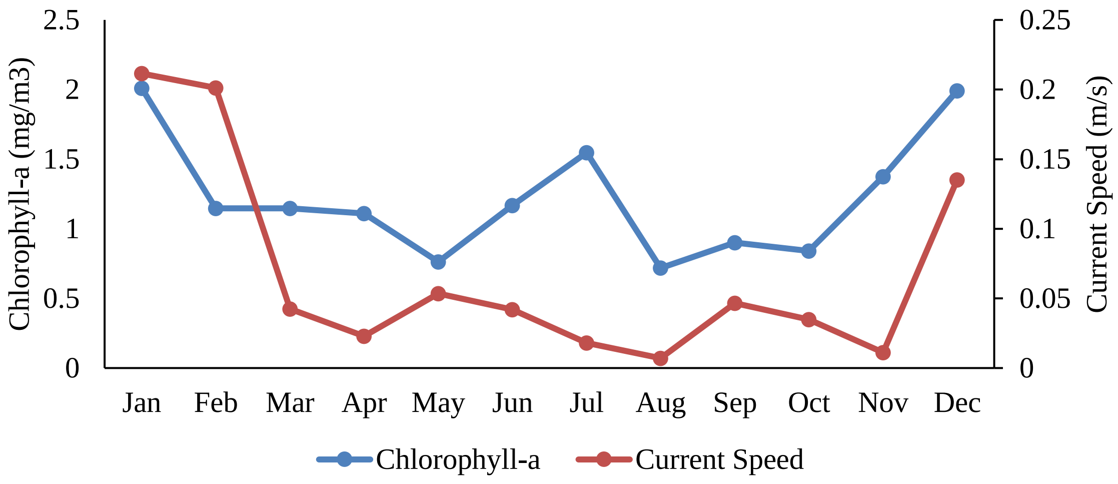

Figure 5. Correlation of average chlorophyll-a and current velocity on area

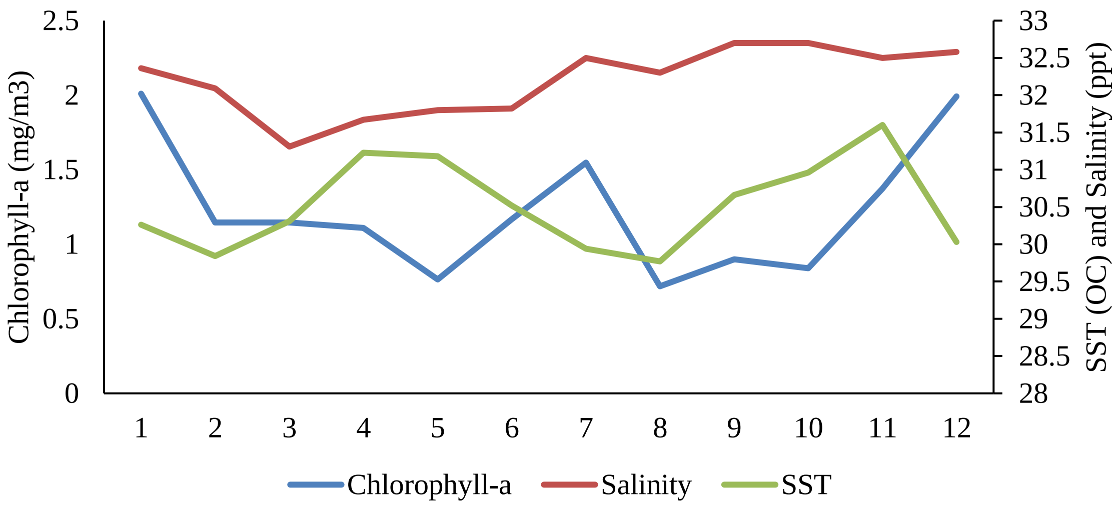

Figure 6. Correlation of average chlorophyll-a, salinity and sea surface temperature

The phenomenon of spatial distribution of chlorophyll-a in Semarang Bay shows that in general, chlorophyll-*a* in the coast is higher than in the middle of the waters. The abundance of chlorophyll-*a* levels on the coast is due to the fact that the coastal area of Semarang Bay has a lot of rivers depicted in Figure 1 with coastal conditions where the settlements are quite dense, as researched by Ain *et al*. (2015). This river carries surface run off water from the land, thus triggered an increase in N and P values in the waters. The presence of organic phosphate greatly affects the fertility of the waters. The results of the simple linear model analysis between phosphate and chlorophyll-*a* have R = 0.74 and R2 = 0.55 (Maslukah *et al.*, 2019). The high value of N and P at the mouth of the river is caused by the many activities in the watershed that discharge waste into water bodies according to research conducted by Cong *et al*. (2006) and Maslukah *et al*. (2017). The presence of river water that enters sea waters causes high values of chlorophyll-a followed by low values of surrounding salinity followed by high SST in these waters. In January in the in the eastern part of Semarang Bay (coast of Demak regency waters), it was very clear that the distribution value of chlorophyll-a was very high. The same month when chlorophyll-*a* was seen high in the eastern part of Semarang Bay the SST value in the in the eastern part of Semarang Bay on January was higher, and the salinity value was lower, this can be seen in Figure 6. The low salinity value is in accordance with the study conducted by Purnaini *et al*. (2018) which states that dense settlements and activities in river water areas will affect the decrease in salinity values in these waters. While the heat of the coastal waters is caused by the effect of hot land due to settlements and activities as stated by Suyarso (1997).

CONCLUSION

The present study shows that the spatial distribution of chlorophyll-a in the waters of Semarang Bay showed in general high concentrations on the coast and decreasing towards the middle. The temporal distribution of chlorophyll-*a* in Semarang Bay shows the highest chlorophyll-*a* concentration value in the West Season with a peak in January and the lowest occurring in the East Season. The highest peak value of chlorophyll-*a* concentration in January was in the eastern part of Semarang Bay (coast of Demak regency waters) with a range of chlorophyll-a concentrations in January of 10-26.433 mg/l along the eastern part of Semarang Bay and the coast of West Semarang and in June it ranged from 6 - 20.341 mg/l. l due to the river estuary with run off which causes an increase in the value of chlorophyll-*a*. The most influential factors on chlorophyll-*a* levels in Semarang Bay waters are river water input and wind parameters, while the salinity and temperature parameters are not very influential when viewed temporally.

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