

Spatial Pattern of Concentration Chlorophyll-a in the Waters Areas around Mouth of Cimanuk River

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Abstract. Damming rivers have an impact on the marine natural resources because it can affect the hydrological and biogeochemical cycles in a watershed. Changes influx of nutrients from upstream to downstream can affect fertility of the waters around the mouth of the river and surrounding areas. This paper discusses the differences and similarities of the spatial pattern of chlorophyll-a (chl-a) concentration in the waters areas around mouth of Cimanuk River before and after the functioning of Jatigede Reservoir in in Sumedang District. Spatial data of chlorophyll-a concentration in the study area were obtained from the processing and analysis of Landsat 8 multi temporal data and validation of data is done through water sampling and laboratory testing. This research area was divided into 3 segments, western Cimanuk Estuary region, the waters between the two estuaries, and eastern Cimanuk Estuary region. The results showed that after the functioning of the Jatigede Dam, the distribution of chl-a with a concentration 0.5 - 1 mg/m³ which tend to decrease. The watershed discharge factor significantly affects the distribution of chl-a concentration in the water nearby to land.

1. Introduction

Damming of rivers has a global impact on natural water resources such as change the characteristics of a water body, affecting not only the hydrology but also physical, chemical, and biological characteristics [1]. Reservoirs disrupt the natural biogeochemical cycles of carbon, nutrients and metals and possibly affect the whole catchment including downstream ecosystems such as wetlands, estuaries, deltas and adjacent sea area [2]. Decreased watershed discharge is the most obvious changes and directly caused by the construction of dam [3]. Watershed discharge has an important role in estuary ecosystems, either the abiotic or biotic components such as nutrients and light availability [4] as well as primary and secondary productivity [5]. Fluctuations in watershed discharge alter the influx of nutrients and may in turn affect phytoplankton standing stocks [6].

Phytoplankton are plants that contain pigment chl-a [7]. Chl-a is a green pigment that phytoplankton requires for the process of photosynthesis and forming organic matter in the waters. The content of chl-a in waters can be used as an indicator of the level of water fertility, as a guide to the availability of nutrients in the water [8] and as an indicator of eutrophication in a waters [9]. Chl-a is also used as an indicator of water quality because of chl-a is an indicator of biomass phytoplankton, where the content describes thoroughly the effects of various factors that occur due to human activity [10]. The concentration of chl-a in coastal and coastal waters is higher than offshore. This is due to high nutrient



coming from the mainland through river runoff [11]. Moreover, the distribution of chl-a is also influenced by oceanographic factors such as sea surface currents.

Jatigede Dam is the second largest dam in Indonesia after Jatiluhur Dam. This dam will hold about 1 billion m³ of water and potentially irrigate about 100,000 hectares of rice fields. Besides its functions as irrigation sources, Jatigede Dam can also be used for Hydroelectric Power Plant (PLTA) which generates 110 MW electricity and basic water source [12]. The Jatigede Dam construction project was built on the Cimanuk River body in 2007 and started inundation On August 31, 2015.

To determine the influence of the functioning of Jatigede Dam, it can be seen from the condition of waters in the waters areas around mouth of Cimanuk River by detecting chl-a. The concentration of chl-a can be obtained from direct or indirect measurement, such as through remote sensing technology [13, 14]. The development of remote sensing technology for marine is very rapid [15] so this method is very efficient for detecting chl-a in the waters and can be used to temporal and spatial study. Therefore, the purpose of this study is to determine the difference of spatial pattern of chl-a concentration in the waters areas around mouth of Cimanuk River before and after the functioning of Jatigede Dam.

2. Literature Review

The study area includes the waters areas around mouth of Cimanuk River located in Indramayu district with an area of 29.319 hectares and geographically located at coordinates 6° 9' 32.4" S - 6° 18' 10.8" S and 108° 6' 25.4" E - 108° 25' 33.6" E. This study will focus on an area of 35.2 km x 16 km or about 4 miles from the coastline of Indramayu District (Fig 1).

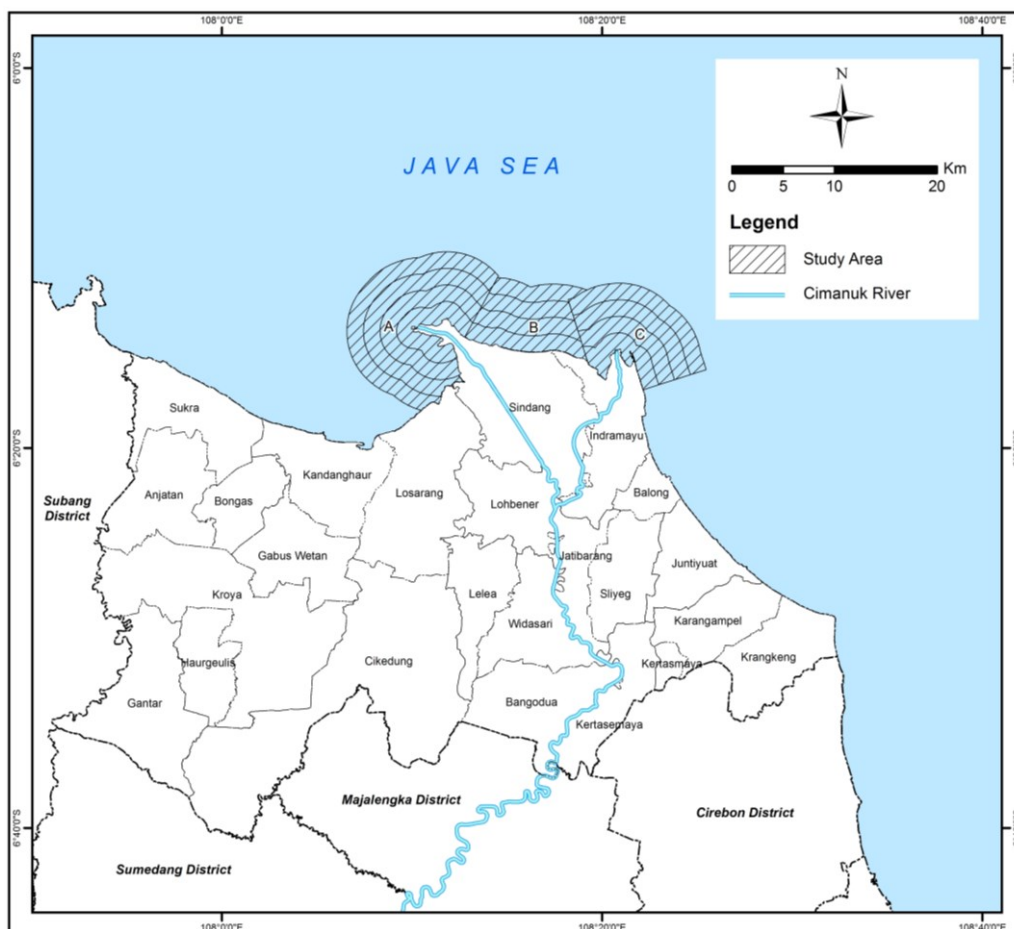


Figure 1. Study area

3. Methods

Chl-a data was obtained from the result of Landsat 8 OLI / TIRS multi temporal image processing (before and after the functioning of the dam) path 121 row 64 from on the website U.S Geological Survey (USGS) <https://earthexplorer.usgs.gov/> with cloud covered below 20%. The period before the functioning of Jatigede Dam are on June 2, 2014, June 18, 2014, August 21, 2014, March 17, 2015, May 20, 2015, June 21, 2015, July 7, 2015 and August 24, 2015. While the period after the functioning of Jatigede Dam used in this study are September 9, 2015, April 4, 2016, June 7, 2016, August 10, 2016, and October 29, 2016.

The concentration of chl-a is obtained through image processing using the algorithm equation (Wibowo, et al. 1993) using Envi Software:

$$\text{Log Chl} = 2,41 \times \left(\frac{R3}{R2} \right) + 0.187 \quad (1)$$

Where: Log Chl = Chl-a Concentration (mg/m³)

R2, R3 = Band 2 dan 3 of Landsat TM satellite images

Apart from the results of image processing, the data of chl-a is also through laboratory test results. Water samples data from 30 locations taken directly in the field on 23 April 2017. Data concentration of chl-a result of processing the image data is classified into 5 classes (Arsjad, et al., 2004) as presented in Table 1. Each raster value of chl-a concentration in an area size of 30 mx 30 m interpolated using methods Trend Surface Analysis using software ArcGIS ver. 10.2 so that generate spatial patterns of chl-a concentration of research areas.

Table 1. Clasification of chl-a concentration.

Class	Concentration (mg/m ³)	Description
1	< 0.3	Low Concentration
2	0.3 - 0.5	Moderate Concentration
3	0.5 - 1	High Concentration
4	1 - 2	Chl-a and High Suspension Charges
5	> 2	High Suspension Charges

Multi-temporal analysis of the spatial pattern of chl-a concentrations before and after the functioning of the Jatigede Dam is done to see whether there is any change in the spatial pattern formed. The trend pattern of chl-a distribution before and after the functioning of the Jatigede Dam is analyzed spatially using Trend Surface Analysis method. Furthermore, statistical tests performed using Pearson's r correlation method, to see whether there is any effect of watershed discharge of Cimanuk river on changes in chl-a distribution pattern of the study area. For watershed discharge of Cimanuk River on Kertasmaya Station located downstream was obtained from Balai Besar Wilayah Sungai Cimanuk-Cisanggarung, Ministry of Public Works and Housing. The average weekly discharge until the image acquisition data is calculated based on the daily discharge data available.

4. Results and Discussion

4.1. Spatial pattern of chl-a concentration

The distribution pattern of chl-a concentration of the study area is shown in Figure 2 and 3. Spatially the chl-a concentration tends to be higher in the waters closer to the mainland and farther from land, to a distance of 4 miles the lower concentration. In general, the concentration of chl-a 0.5 - 1 mg/m³ (high classification) is in waters close to the mainland and tends to follow the pattern of the shoreline, while the lower chl-a (0.3 – 0.5 mg/m³) dominates the nothern areas.

Before the functioning of Jatigede Dam, the distribution pattern of chl-a concentration with higher classification ($0.5 - 1 \text{ mg/m}^3$) was large enough and its distribution away from the coast or up to a distance 4 miles. The distribution pattern is different after the functioning of the Jatigede Dam, where the distribution of chl-a $0.5 - 1 \text{ mg/m}^3$ tends to be more dominant around the mouth of the Cimanuk river and the area decrease away from the shoreline. An example can be taken on June 18, 2014 (before) and June 7, 2016 (after). Before the functioning of Jatigede Dam (June 18, 2014), the distribution of high chl-a concentrations tends to be more widespread and spreads to areas far offshore, while on 7 June 2016 only in waters close to the mainland (up to 1 mile). This indicates that the distribution of chl-a concentrations before and after the functioning of Jatigede Dam has a different distribution pattern.

Temporally, it is shown that the distribution area of $> 1 \text{ mg/m}^3$ chl-a concentration has a large area on March 17, 2015 and October 29, 2016 in coastal waters of the western part. It can be caused by the high supply of nutrients to waters, either from land through streams or from the mixing / mass agitation process of water which lifts the water mass from the bottom to the surface layer.

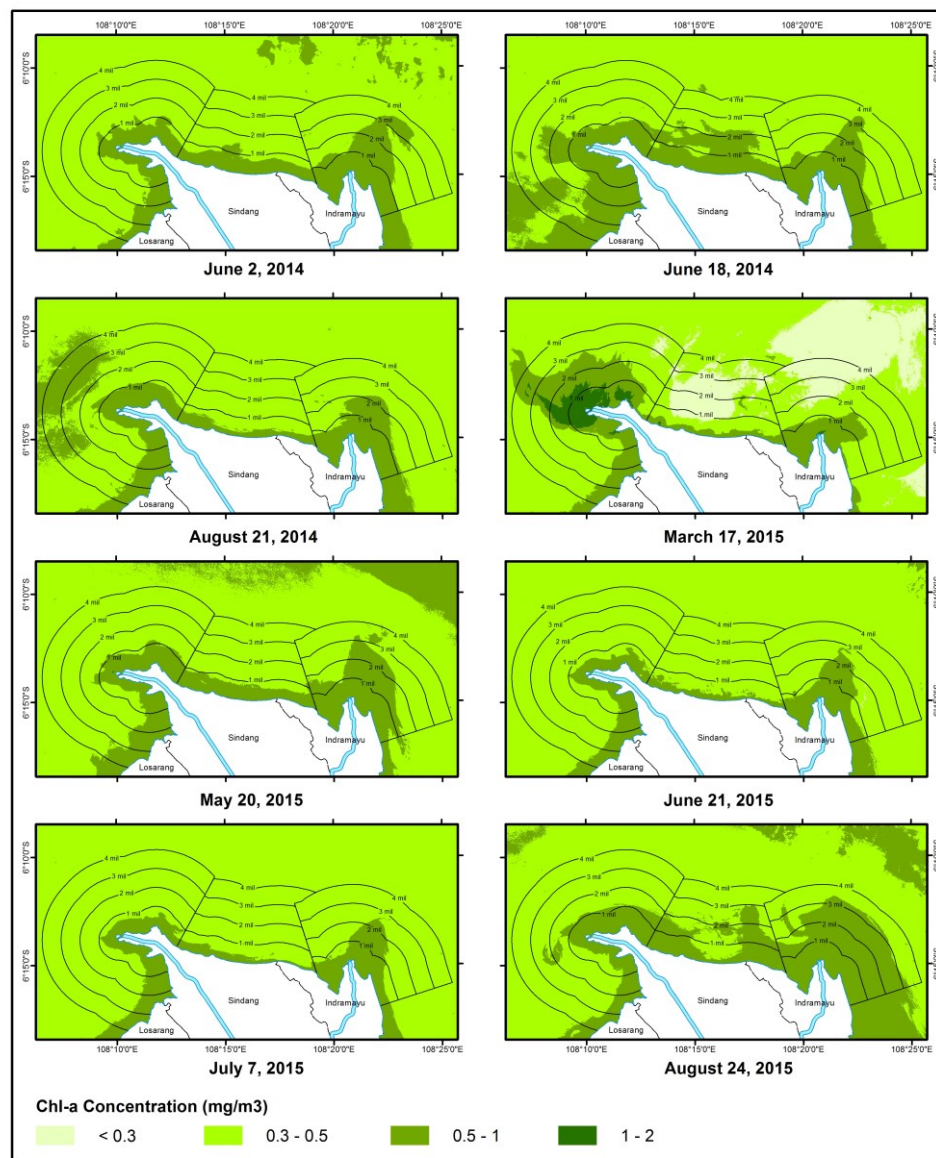


Figure 2. Distribution of chl-a concentrations before the functioning of Jatigede dam

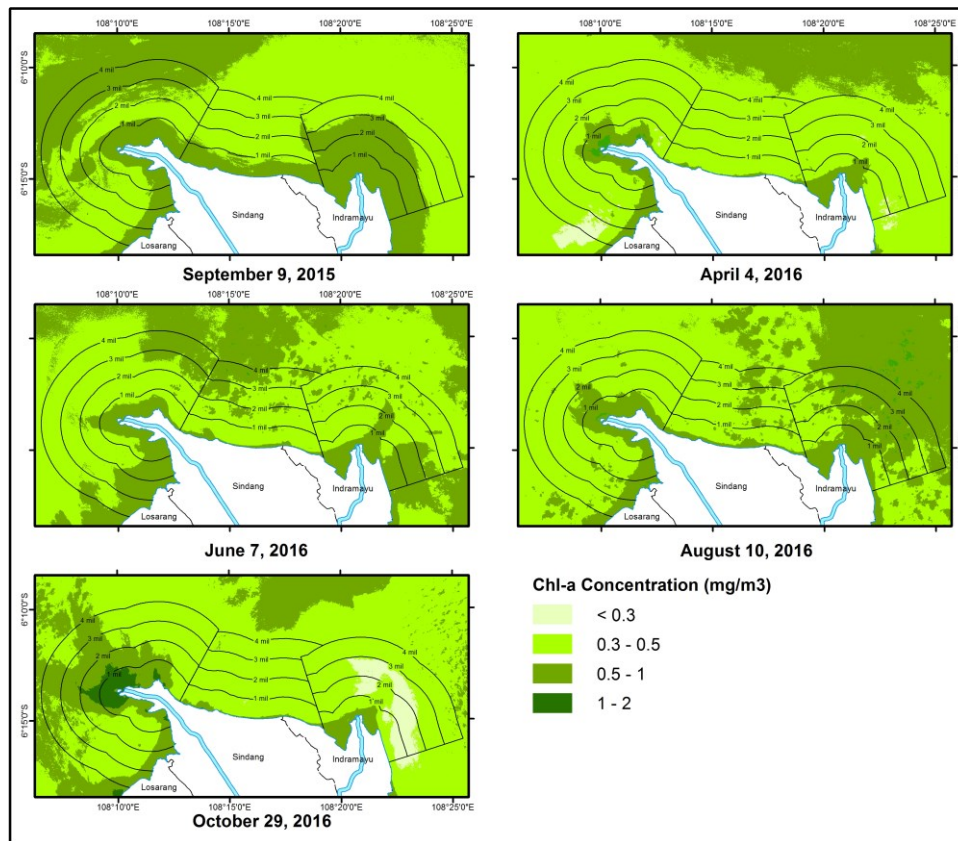


Figure 3. Distribution of chl-a concentrations after the functioning of Jatigede dam

The difference of chl-a distribution pattern before and after functioning Jatigede Dam seen from the Trend Surface Analysis (Fig 4 and Fig 5). Before the functioning of the Jatigede Dam the distribution of chl-a with high concentrations was dominant in waters close to the mainland and spread from southeast to northwest. While the distribution of a-chlorophyll with low concentration ($< 0.3 \text{ mg/m}^3$) is dominant in the northeastern waters area away from the mainland. After the functioning of the Jatigede Dam the tendency of high concentration chl-a spreads from the southeast to the northwest in areas close to the waters. While for the distribution of chl-a with low concentration tends to be only in the northeast and southwest areas. This indicates that the reduced supply of sediments carried by the Cimanuk River to the Java Sea, especially the waters areas around mouth of Cimanuk River, affects the distribution of chl-a formed.

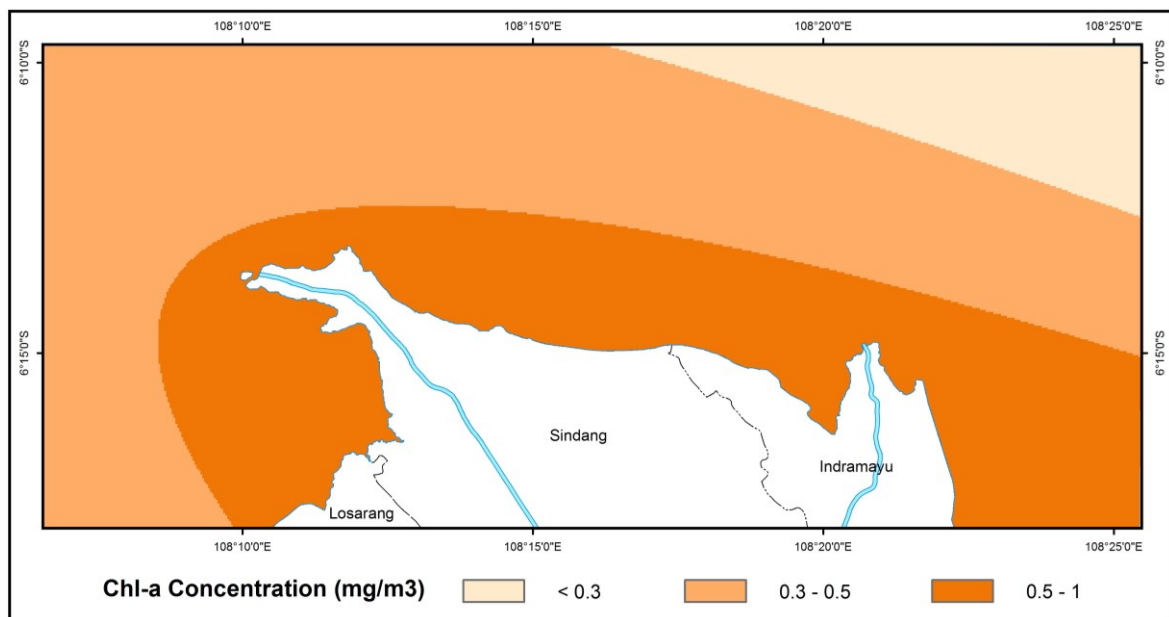


Figure 4. Chl-a distribution using trend surface analysis methods before the functioning of Jatigede dam.

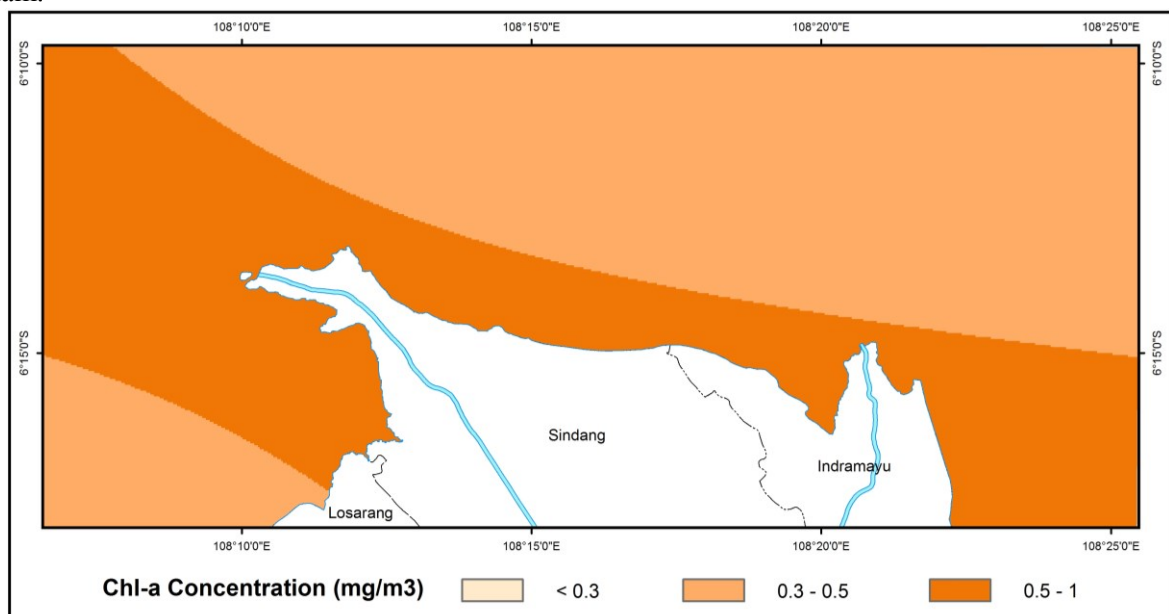


Figure 5. Chl-a distribution using trend surface analysis methods after the functioning of Jatigede dam.

4.2. Changes in the area of distribution of chl-a, before and after the functioning of Jatigede dam

In this section, not all classes of chl-a concentration will be discussed only a high concentration of chl-a class ($0.5 - 1 \text{ mg/m}^3$) before and after the functioning of the Jatigede Dam. This research area was divided into 3 segments, western Cimanuk Estuary region (segment A), the waters between the two estuaries (segment B), and eastern Cimanuk Estuary region (segment C). Each segment is further divided by the distance from the coastline up to 1 mile (Segment A/B/C_1), 1-2 mile (Segment A/B/C_2), 2-3 mile (Segment A/B/C_3) dan 3-4 mile (Segment A/B/C_4).

As shown in Table 2, 1, on Segment A/B/C_1, the region with a high chl-a concentration dominant with a proportion range of between 44% and 72% (before the functioning of Jatigede Dam) and the

proportion range between 28% -60% (after the functiong of Jatigede Dam). Thus there is a decrease in the area of chl-a with high concentrations in waters close to the mainland. The largest decrease occurred in B_1 and Segment Segment C_1, each of them 27% and 24%. The same phenomenon is also shown for Segments A_2, B_2 and Segment C_2. The area of water with a high chl-a concentration tends to decrease. The largest decrease occurred in Segment B_2 and Segment C_2, each of them 27% and 24%. As for Segments A/B/C_3 and A/B/C_4 changes in area of chl-a are relatively insignificant.

Table 2. Percentage Area of Chl-a Concentration 0.5 - 1 mg/m³ Based on Segment Areas (%)

(Source: Data Processing, 2017)

Before The Functioning Jatigede Dam												
Date	Segment A				Segment B				Segment C			
	1	2	3	4	1	2	3	4	1	2	3	4
June 2, 2014	72.97	13.79	9.26	4.46	73.95	6.46	0.00	0.00	99.50	44.24	19.17	11.20
June 18, 2014	94.39	42.08	31.54	23.99	89.27	68.06	16.92	0.00	98.30	43.34	13.40	2.35
August 21, 2014	77.32	17.57	34.50	41.97	41.91	0.00	0.09	0.01	94.88	41.01	5.77	0.11
March 17, 2015	46.82	45.32	31.30	13.78	31.47	2.10	0.51	0.00	70.76	20.03	0.02	0.00
May 20, 2015	80.23	16.15	10.89	8.93	73.88	0.61	0.00	0.00	97.62	60.73	21.72	4.42
June 21, 2015	57.22	10.17	7.94	5.05	34.54	0.02	0.00	0.00	83.04	28.27	6.65	0.00
July 7, 2015	61.43	11.44	8.10	5.42	31.63	0.01	0.00	0.00	77.78	26.60	5.25	0.04
August 24, 2015	82.29	23.82	8.86	5.27	77.14	54.53	21.37	0.03	99.86	91.81	79.19	14.56
Average	71.58	22.54	17.80	13.61	56.72	16.47	4.86	0.01	90.22	44.50	18.90	4.08
After The Functioning Jatigede Dam												
Date	Segment A				Segment B				Segment C			
	1	2	3	4	1	2	3	4	1	2	3	4
September 9, 2015	79.10	24.83	12.18	4.80	80.68	7.07	4.08	0.00	99.86	99.30	66.35	2.40
April 4, 2016	51.05	14.38	5.74	2.78	10.05	0.00	0.00	0.00	46.30	1.42	0.00	0.00
June 7, 2016	63.44	21.93	17.14	11.22	17.23	0.00	0.00	0.00	71.74	40.57	27.72	12.85
August 10, 2016	63.12	23.39	11.01	5.75	27.39	0.00	0.00	0.00	74.00	0.00	0.00	0.00
October 29, 2016	44.01	45.22	37.30	34.07	11.52	0.00	0.00	0.00	39.11	0.00	0.00	0.00
Average	60.14	25.95	16.67	11.72	29.38	1.41	0.82	0.00	66.20	28.26	18.81	3.05

Temporally, the area of chl-a distribution is very dynamic as a result of a combination of hydrological factors (watershed discharge) and oceanography factor. In this paper, we only discuss the watershed discharge variable as an important factor affecting the area of chl-a distribution. Fluctuations in watershed discharge alter the influx of nutrients and may in turn affect phytoplankton standing stocks [6]. The existence of differences in the supply of nutrients entering the waters can lead to differences in chl-a concentration either spatially or temporally. To find out how much the effect of watershed discharge on changes in the area of distribution of chl-a concentration, we used the Pearson r correlation test. Statistical test results are shown in Table 3.

Table 3. Correlation Value (R) Between Watershed discharge of Cimanuk River with Area of High Chl-a Concentration Before and After The Functioning Jatigede Dam

Segment	Range			
	1	2	3	4
Before				
Segment A	0.636	0.657	0.425	0.015
Segment B	0.401	0.232	0.222	0.213
Segment C	0.673	0.410	0.299	0.284
After				
Segment A	0.959 ^a	0.364	0.450	0.567
Segment B	0.747	0.610	0.610	0.000
Segment C	0.972 ^a	0.735	0.741	0.407

^aLevel of Significant 5%

The result of statistical test shows that after the functioning of the Jatigede Dam, the influence of the watershed of Cimanuk river to the area of high concentration of chl-a concentration in the waters areas around mouth of Cimanuk River is stronger and significant in all Segments A and B. This is indicated by the correlation r value of 0.64 (before) to 0.96 (after) on Segment A and the correlation r value from 0.67 to 0.97 in Segment C and the value of $r = 0.40$ to 0.75 in Segment B. The farther the distance from the mainland the correlation value tends to be smaller than the correlation value of the waters close to the mainland.

5. Conclusions

The functioning of the Jatigede Dam causes a change in the distribution pattern of chl-a concentration in the waters area in the Cimanuk and surrounding areas. After the functioning of Jatigede Dam, the water area with high chl-a concentration tends to decrease significantly by 30%. Temporally, the factor watershed discharge of Cimanuk river affect the area of chl-a concentration in waters close to the mainland both in the western Cimanuk Estuary region, the waters between the two estuaries, and eastern Cimanuk Estuary region.

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