Mapping chlorophyll-a and Total Suspended Solid (TSS) distribution in the waters of Ciletuh Bay

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Abstract. The waters of Ciletuh Bay are one of the waters located in southern Java that interact directly with the Indian Ocean, which is utilized for fishing and tourism activities. Opportunities for utilization of Ciletuh bay waters in the field of fisheries need to be maximized by monitoring the quality of the bay area's waters. Remote sensing methods can identify and analyse the results of the spectral recording of water with observations of TSS and Chlorophyll-a spreads obtained using the Budhiman algorithm et al. (2004), and the concentration of TSS results from the algorithm Wibowo et al., (1994). Observations were conducted using Citra Landsat-8 in 2019–2020. The results of the algorithm's application obtained the results of TSS concentrations in the waters of Ciletuh Bay have a maximum value of >125 mg/l – 225 mg/l, and a minimum value of 6 mg/l – 15 mg/l. Chlorophyll-a concentration reaches a maximum value of 6 mg/l – 10 mg/l, and a minimum value of 3 mg/l – 5 mg/l. The same distribution pattern is indicated by both parameters: high concentrations in coastal areas and river estuaries and lower in the high seas.

1. Introduction

Estuaries have many benefits for the life of living organisms, but estuaries are also areas that get much pressure from daily human activity. The disruption was not caused only by socioeconomic activity in coastal areas [1], but also disturbances from the mainland, such as deforestation and land. Erosion through the river system brings sediment to the sea, which eventually increases sediment concentration in the estuary.

Ciletuh Bay waters are one of the waters located in southern Java that interact directly with the Indian Ocean. There are many sites for catching larvae and eel fish around Pelabuhanratu Bay and Ciletuh [3,4,5]. Ciletuh Bay is home to two rivers, Ci Letuh and Ci Marinjung. Ciletuh Bay waters are one of the waters that have the potential as a migratory place for eel fish seed [6] and eel fishing activity. Opportunities for utilization of Ciletuh bay waters in fisheries, whether catching activities or cultivation activities, need to be maximized by monitoring the quality of the waters of the bay area. The utilization of remote sensing technology can facilitate the monitoring of the quality of Ciletuh Bay's waters. Remote sensing technology can identify and analyse water spectral recording results with water quality parameters. There are two parameters used as indicators for determining the quality of the waters by utilizing remote sensing, namely Total Suspended Solid (TSS) and chlorophyll concentration-a (Chl-a) [8]. These two parameters are optically active parameters so that they can represent the quality condition of the water. Chlorophyll-a is used to identify water fertility rates [9], and Total Suspended Solid concentrations (TSS) are used to identify water pollution levels.
Remote sensing provides a good insight and understanding of a particular ecosystem during limited field observation activities. Chlorophyll-a information is obtained using the Budhiman algorithm [2], and the concentration of TSS results in the Wibowo algorithm [6]. The study divided the observation time based on wet months and dry months to look at the water's conditions spatially-temporally. The time difference based on the season is intended because the Bay of Ciletuh region is a river estuary. The intensity of rainfall will affect the flow of the river to the estuary. This research is expected to provide information on the condition of the waters considering the management and optimization of coastal areas to implement sustainable fisheries and tourism.

The waters of Ciletuh Bay are located in the Sukabumi Regency, located on Java's southern coast. Geographically, the Gulf of Ciletuh is located at coordinates 7°11'0" south latitude and 106°27'0" east longitude. Administratively Ciletuh bay is located in the Ciemas sub-district, Sukabumi Regency, West Java. There are three villages located in the coastal area of Ciletuh Bay, including Ciwaru Village, Mandrajaya Village, and Giri mukti Village. Ciletuh Bay is the place where Ci Marinjung and Ci Letuh are part of the Ciletuh watershed. Ciletuh estuary area is used as a catchment area for Sidat larvae by local fishermen. The research area can be found in figure 1.

Figure 1. The study area is located in Sukabumi, West Java.

2. Methodology
The study used Landsat-8 satellite imagery data in the Ciletuh Bay Region temporally from August 2019 – August 2020, which was acquired for wet months and dry months. The Aquiss satellite imagery used for each season is displayed in table 1. Landsat-8 imagery data for research analysis is done pre-processing in the form of atmospheric and radiometric corrections. Corrections are done manually with ArcMap software.

| Dry Month         | Wet Month         |
|-------------------|-------------------|
| August 10\textsuperscript{th}, 2019 | January 17\textsuperscript{th}, 2020 |
| September 11\textsuperscript{th}, 2019 | February 18\textsuperscript{th}, 2020 |
| October 29\textsuperscript{th}, 2019 | March 21\textsuperscript{st}, 2020 |
| May 24\textsuperscript{th}, 2020 | April 22\textsuperscript{nd}, 2020 |
| June 25\textsuperscript{th}, 2020 |
| July 27\textsuperscript{th}, 2020 |
The chlorophyll-a concentration algorithm uses wavelengths in Landsat-8 TM 2 equals band 3 ratio, and TM 3 equals band 4 ratio in Landsat-8 [6].

\[
\text{Chl} - a = 2.41 \left( \frac{\text{TM}_3}{\text{TM}_2} \right) + 0.187
\]

Where Chl-a is a chlorophyll concentration (mg/l), TM2 is a green sensor, and TM3 is the red sensor on Landsat-8.

Total Suspended Solid Concentration (TSS) is calculated by the Budhiman (2004) algorithm using a red band 4 (B4) sensor (0.630 – 0.680 μm) [2]. Algorithm equations are used as follows:

\[
\text{TSS} = 3.3238 \times \exp(34.099 \times \text{B4})
\]

3. Results and discussion

3.1. Distribution of TSS at Ciletuh bay in the dry month

TSS distribution based on the Budhiman (2004) shows higher TSS values in coastal areas and river estuaries than in deeper high sea waters [2]. In the dry month, the concentration of TSS in the waters of the Gulf of Ciletuh reaches 125 mg/l - 255 mg/l shown in figure 2. Up to 2000 m from the coastline, each month is dominated by a concentration of TSS of 125 mg/l.

In the two dry months of October 2019 and June 2020, there is very little dissolved material, so in the blue coastal waters that indicate the absence of TSS concentrations. TSS's minimum value in bay waters is in the range of <6 mg/l – 12 mg/l.

Figure 2. TSS distribution in dry months.
3.2. Distribution of TSS at Ciletuh bay in wet month
In wet months, TSS concentration in wet months tends to spread throughout the bay waters with a value of \(<100 \text{ mg/l} – 255 \text{ mg/l}\). The minimum value in wet months that dominate the bay waters is \(5 \text{ mg/l} – 75 \text{ mg/l}\). In November 2019 and January 2020, the distance of 200 m from the coastline is not concentrated TSS and is more concentrated in the Ciletuh river estuary.

Figure 3. TSS distribution in the wet month.

3.3. Distribution of chlorophyll-a at Ciletuh bay in the dry month
In dry months, chlorophyll-a concentrations have a minimum value of \(<2 \text{ mg/l} - 5 \text{ mg/l}\) with a maximum value of between \(6 \text{ mg/l} – 8 \text{ mg/l}\). In figure 4, higher chlorophyll-a concentrations are present in coastal and river estuaries and decrease their concentration in the high seas. In comparison, most waters have a value range of \(<5 \text{ mg/l}\). Chlorophyll-a concentrations recalled in October 2019 and June 2020 reach a range of \(4 - 8 \text{ mg/l}\).

Figure 4. Chl-a distribution in the dry month.
3.4. Distribution of chlorophyll-a at Ciletuh bay in wet month
Chlorophyll-a concentrations in wet months indicate more variation in value. The minimum value range is <3 mg/l, and the maximum value reaches 7-10 mg/l, with the dominance of the average value being in the range of 3mg/l – 4 mg/l. Chlorophyll-a concentrations tend to be high in Ciletuh river estuaries until they reach a maximum value of 7 – 10 mg/l by January 2020. The following month, February 2020, the chlorophyll-a concentration at the Ciletuh river’s mouth is in the range of values 3 – 6 mg/l. Higher concentrations at a distance range of 50 – 200 m from the coastline.

3.5. The concentration of TSS and chlorophyll-a of Ciletuh Bay 2019-2020
TSS and chlorophyll-a distribution patterns tend to be the same as high concentration values in coastal areas and estuaries and decrease on the high seas. The dominance of large TSS values in coastal and river estuaries is due to the meeting of river and sea flows (waves and currents), so there is a lot of concentrated TSS material [11]. The rate of flow caused by tides, currents, wind, and rainfall is a significant factor in changes in TSS conciliation and chlorophyll-a in the waters. Increased rainfall will increase river water discharge to the estuary by carrying large amounts of particles and sediment. Rainfall that carries nutrients from the land through the river will be used by phytoplankton to photosynthesis to increase chlorophyll-a concentrations [12].

4. Conclusion
From the distribution of TSS and chlorophyll-a concentrations produced, it can be known that the distribution patterns of TSS and chlorophyll-a concentrations in the waters of Ciletuh Bay have no similarities that are high in coastal areas and river estuaries and lower in the high seas. The highest TSS and chlorophyll-a concentrations throughout 2019 – 2020 for the range of >125 – 255 mg/l and 6 – 10 mg/l, respectively.

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