Distribution of total suspended solids (TSS) and chlorophyll-a in Kendari Bay, Southeast Sulawesi

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Abstract. Kendari Bay is receiving direct pressure from land clearing. This activity leads to sedimentation to the estuarine area. The sedimentation rate in Kendari Bay reaches up to 143,147 m³/year. The high amount of total suspended solids will impede light penetration. As a consequence, it will decrease the rate of photosynthesis, thus decreasing chlorophyll-a content. This research was aimed to understand the relationship between distribution total suspended solid (TSS) and chlorophyll-a concentration in Kendari Bay. Water sampling was done between January 21 and February 6, 2018. TSS and chlorophyll-a were measured in the laboratory. Data of TSS and chlorophyll-a from 2010 to 2018 were downloaded from Landsat 5 TM and Landsat 8 OLI. ENVI 5.1 and ArcGIS 10.1 software was used to visualize the distribution into a map. The relationship between two parameters was analyzed using linear regression. The TSS showed a linear increase from 2010 to 2018 with a concentration higher than 50 mg/l³. The correlation between TSS and chlorophyll-a showed a negative correlation (0.6376) which indicated that the higher TSS, the lower the chlorophyll-a.

1. Introduction
Total suspended solids is a fine-small particle in an aquatic system which having diameter larger than one μm. This particle is composed of mud, fine, sand and microorganism [1,2]. This particle is carried by soil erosion from stream to water body [3]. Chlorophyll-a is one of basic pigment which exists in phytoplankton. In ocean and coastal including estuary region, the abundance of phytoplankton represents the productivity of those aquatic environments. That is why monitoring on chlorophyll-a can be used to determine the productivity [4].

Kendari Bay is a unique water system which forms an estuary region. This bay belongs to Kendari, the capital city of Southeast Sulawesi. There are 13 rivers which run into this bay. Unfortunately, this bay is experiencing with some negative issues such as sedimentation, decreasing on water quality, chaotic land use and degradation of mangrove forest [5]. Excessive sediment load can affect the characteristics of the waters and cause problems related to human life, such as flooding and water quality degradation. Those factors probably can increase water turbidity [6]. High turbidity can prevent the penetration of light into the waters. As the light intensity goes low, it may affect the capacity of phytoplankton in photosynthesis [7]. Also, high turbidity usually indicates high TSS,
which mean that TSS influence the chlorophyll-a content indirectly [8]. In coastal water and estuary, TSS is influenced by several physical factors such as wind, rainfall, waves, currents, and tides [9].

Remote sensing is technology which enables the user to investigate the object from far place — this technology equipped with satellite which records the condition of the object through electromagnetic waves and presented in the map or accessible information. Moreover, remote sensing has been widely applied and well understand in many studies field including to monitor oceanographic parameters like TSS and chlorophyll-a [1,10,11,12]. The aim of the research was to understand the relationship between distribution total suspended solid (TSS) and chlorophyll-a concentration in Kendari Bay using remote sensing.

2. Methodology

2.1. Research Location and Time Sampling
The sampling was conducted in Kendari Bay with the coordinate location of 30°57'50" - 30°5'30" S and 122°31'50" - 122°36'30" E (Figure 1). There were sixteen stations which plotted in river mouth (station 1-7), middle of the bay (station 8-14) and mouth of the bay (station 15-17). Sampling was conducted from January to February 2017.

![Figure 1. Map of research location](image)

2.2. Measurement of Total Suspended Solid and Chlorophyll-a
Water sampling was done for total suspended solids and chlorophyll-a measurement. The result was used to verify the measurement of TSS and chlorophyll-a based on remote sensing. Total suspended solids of water were measured based on gravimetry method. For chlorophyll-a, before went to laboratories, 2 liters of water in polyethylene bottle was preserved using 10 ml of magnesium carbonate 1%. During the transport, the samples were kept in a cooler box. Measurement of chlorophyll-a was performed based on spectrophotometric method [13,14]. The measurement was carried out in the Laboratory of Mathematics and Natural Science, Hall Oleo University.

2.3. Data Analysis
This research also used satellite image data on total suspended solids and chlorophyll-a obtained from LANDSAT 5 TM and 8 OLI sensor which can be downloaded through the website (https://eartexplorer.USGS.gov) with 30 m resolution. Satellite data was processed using ENVI software version 5.1 and ArcGis 10.1. After image data was downloaded, then the data processed through several steps which were radiometric calibration, atmospheric correction, and modeling.
algorithms. A radiometric correction was done to transform the pixel value of image data downloaded from digital value (DN) to the actual reflectance value of the top of atmospheric (TOA). Atmospheric correction was done to reduce atmospheric influences when recording from downloaded image data by converting TOA radians to bottom of atmospheric (BOA) values. Modeling algorithms which used for TSS were a Budhiman algorithm, while for chlorophyll-a was Wibowo algorithm. Distribution of total suspended solids and chlorophyll-a were visualized in the map.

3. Result and Discussion
3.1. Total Suspended Solid
Based on the results of field observations, the highest TSS obtained was 81.00 mg.l⁻¹ and found in the station which located at river mouth while the lowest was 17.44 and find in the station which located at the middle of the bay. Satellite image data, showed that based on the TSS concentration at the observation point, in 2010 had the lowest total suspended solids concentration in Kendari Bay waters was 12 mg.l⁻¹ and the highest concentration was 32 mg.l⁻¹. In 2015, the lowest total suspended solid (TSS) concentrations ranged from 23.52 mg.l⁻¹, and the highest reached 69.46 mg.l⁻¹. In 2018, total suspended solids (TSS) concentrations were increased. The lowest total suspended solids (TSS) concentrations was 26 mg.l⁻¹ and the highest reaching 84.87 mg.l⁻¹ (Figure 2).

![Figure 2. Value TSS concentration value based on the sampling point.](image)

To ascertain the accuracy of satellite imagery on the actual conditions at the research location, a correlation test was used to compare between satellite image data and survey results (Figure 3) [15].

![Figure 3. Linear regression for total suspended solid in-situ data and satellite imagery in 2018](image)

R² value obtained from the linear regression results explains that the coefficient of determination is 80.72%. From this relationship, it is explained that most of the in-situ TSS can be explained by
satellite imagery, while the remaining 19.28% are other factors that cannot be displayed by satellite imagery. This factor comes from the difference in sampling time in the field and the time of recording satellite imagery, because of its location in a very dynamic bay so that differences occur mainly from the tidal effects that carry the total suspended solids and also can be from radiometric effects or wave propagation interference in air [16]. TSS concentrations in the waters of Kendari Bay are based on the results of processing satellite imagery, showing that the largest concentration of total suspended solids is in the bay area of the river mouth to the center of the bay. For more details, we can see from the following TSS distribution map (Figure 4).

Figure 4. Distribution of TSS Concentration in : (a) 2010, (b) 2015, and (c) 2018.

Until 2018, the concentration of total suspended solids continues to increase. In Figure 4A, it is explained that TSS at river mouths in 2010 ranged from 25-30 mg.l⁻¹. In 2015 it rose to 50-80 mg.l⁻¹ (Figure 4B). While in 2018 the concentration of total suspended solids was 50-80 mg / L spread to the middle of the bay even in the middle of the bay the concentration of total suspended solids reaches a range of >100 mg.l⁻¹ (Figure 4C). From figure 4, it is also clear that TSS concentrations in the river mouth prove to tend to be higher than the bay. In Kendari Bay, suspended materials were mostly brought by Wanggu River. The higher TSS in river mouth probably, because almost the materials were came from land activities. In middle and mouth of the bay, concentration tends to lower, because the materials were diluted toward to the sea [9]. Moreover, it might be said that the sedimentation occurring in the Kendari bay comes from soil erosion carried by the river flow.

3.2. Chlorophyll – a
The high concentration of total suspended solids will reduce light penetration. As a consequence, it will reduce the rate of photosynthesis; it will cause a decrease in chlorophyll-a content. Based on total suspended solids (TSS) concentration at the observation point, in 2010, the lowest chlorophyll concentration in Kendari Bay was 0.72 mg.m\(^{-3}\) and the highest concentration was 0.96 mg.m\(^{-3}\) (Figure 5).

![Figure 5. Value Chlorophyll-a concentration value based on the sampling point.](image)

In 2015, the chlorophyll-a concentration at several observation points was higher than in 2010 and 2018 (Figure 6). The lowest chlorophyll-a concentration in 2015 was 0.62 mg.m\(^{-3}\) at the mouth of the
river, and the highest reached 1.19 in the mouth bay (Figure 6B). Whereas in 2018 the lowest chlorophyll-a concentration was observed with the lowest chlorophyll-a value reaching 0.57 mg.m$^{-3}$ located in the central region of the bay (Figure 6C). According to [17], the Kendari bay belong to mesotrophic and eutrophic with concentration chlorophyll-a < 5 mg.m$^{-3}$. Moreover [12] stated that coastal area and estuary showed higher concentration compared to the open sea. It might cause the coastal were supplied more nutrient through runoff from land.

3.3. Relationship of Total Suspended Solid and Chlorophyll – a.
To determine the relationship of total suspended solids and chlorophyll-a, can use simple regression analysis was used. The results of processing satellite imagery also showed a decrease in chlorophyll-a concentration in the direction of increasing the concentration of TSS at each observation point (Figure 7).

![Figure 7](image)

**Figure 7.** Linear regression for total suspended solids and chlorophyll-a : (a) Correlation value of TSS and chlorophyll-a from in-situ ; (b) Correlation value of TSS and chlorophyll-a from the satellite image

From the results of a simple regression test, it can be seen how the effect of total suspended solids on chlorophyll-a concentration for in-situ data obtained is the total coefficient of suspended solids is 0.8248 and the results from simple regression test of satellite imagery it is obtained a suspended total solid coefficient of 0.7977. From both regression tests through in-situ data and satellite imagery both show positive coefficient values, this means that there is a negative relationship between total suspended solids and chlorophyll - a. An increase in the concentration of total suspended solids will cause a decrease in chlorophyll-a concentration in the Kendari bay area. Our result was similar to [18] which showed that concentration of chlorophyll-a have negative correlation with TSS but contrast to [4] which showed that concentration of chlorophyll-a has a positive correlation with TSS in Cirebon waters. It might cause tides and river discharge strongly influenced both factors. Chlorophyll-a which represent the phytoplankton abundance from nutrient which comes from river or sea its self [19]. The TSS represent materials/particle which stream brought or tide which also needed by organism like plankton. For that point of view, both factors will perform a positive correlation. However, in the other point of view, if TSS itself was described as increasing of turbidity, which means low light penetration, then it will show a negative correlation since there is the limit for phytoplankton to do photosynthesis.

4. Conclusion
The total suspended solids in Kendari Bay range between 31.58 – 67.11 mg.l$^{-1}$, while the concentration of chlorophyll-a 0.49 – 0.88 mg.m$^{-3}$. The total suspended solid seem rising trend compared to chlorophyll-a showed during 2015-2018 based on remote sensing. A strong negative correlation indicates that both factors were corresponded in unline correlation. More complex and more time series are needed in order to give a better understanding of how those factors were correlated and
interact in the ecosystem including other oceanographic and also monitoring program for environmental quality.

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