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Comparison of LISAT and Landsat imagery for estimating chlorophyll-a (case study: Jatiluhur Reservoir)

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Abstract. Jatiluhur Reservoir located in Purwakarta Regency, West Java is one of the largest reservoirs in Indonesia. Various studies have been done to determine the quality of water in the reservoir. The presence of locally made satellites, LISAT, can be a tool for monitoring the reservoir's water constituent using satellite imagery. Our purpose here is to define the spectral reflectance properties on Jatiluhur Reservoir and determine the water column constituents that correlate with the observed lake color. In addition, this study also aims to compare the spatial, temporal, and spectral resolutions of LISAT imagery and Landsat imagery in the Jatiluhur Reservoir region. Based on the table of the relationship between TSI with chlorophyll a parameter, the TSI value is in the range of 80 - 90. TSI 80 value> falls into the category of hypereutrophic waters. The estimated result from Landsat and LISAT imageries still show different results. Chlorophyll-a value from image processing also show significance differences from Chlorophyll-a value derived from laboratory analysis.

1. Introduction

Chlorophyll a is one of important parameter in water quality that can show the trophic level in lake waters. Chlorophyll-a can be an indicator of phytoplankton abundance and algal growth in lake waters [1-4]. Nowadays, remote sensing data can be utilized for monitoring water quality in river, lake, and other water bodies [5-6]. When using satellite imageries in estimating Chlorophyll-a, accuracy of atmospheric correction and water quality parameter retrievals algorithms becomes a crucial thing to be concerned [7-9].

Since 2010, Bogor Agricultural University (IPB) and the National Institute of Aeronautics and Space of Indonesia (Lembaga Antariksa dan Penerbangan Nasional or LAPAN) have committed to work together in developing satellite in order to support the food security and environmental monitoring program in Indonesia through the LAPAN-IPB Satellite called "LISAT". The LISAT has been successfully launched on June 2016 with Polar Satellite Launch Vehicle (PSLV) Rocket in Sriharikota, India.

Unlike Landsat which has 11 bands and can be used for various analyzes, LISAT only has 4 bands consisting of Red, Green, Blue, and Near Infrared (NIR). As the newly utilized satellite data, it is necessary to compare the quality of LISAT imagery with satellite imagery which has been commonly used such as Landsat. The possible comparisons include the spatial, temporal, and spectral resolutions of both satellites. One of interesting study of remote sensing is water quality assessment.

The water quality assessment using remote sensing is imperative study considering the challenges to estimate radiance scattered out of the water, the inherent water column absorption and scattering properties, and the amount and type of water quality constituents that absorb and/or scatter light. Therefore, satellite comparison is used to evaluate satellite capability and the result can be used to enforce environmental awareness, in particularly preserving water resources.

Jatiluhur Reservoir located in Purwakarta Regency, West Java is one of the largest reservoirs in Indonesia. Various studies have been done to determine the water quality. Our purpose here is to compare chlorophyll-a value of LISAT imagery and Landsat imagery in the Jatiluhur Reservoir area.

The result of lake color spectral data can be utilized as a comparison of the water content data obtained from the laboratory analysis. While the results of comparison image resolution of both satellites can be used to determine the lack and advantages in each satellite image.

2. Methodology

2.1. Satellite data collecting
Image data processing is used as a method of analysis to obtain research objectives. Image data processing is done by geometry correction, data mosaic RGB 542, and visual interpretation of data. Geometric correction aims to determine the geographical position associated with the spatial distribution (spatial distribution). The process is performed on ArcGIS by specifying geo-referenced data, coordinate systems and other information in the data.

Data mosaic RGB 542 is used to find out the composite of Landsat image, while for image LISAT used RGB image according to the result. This data mosaic was performed on Erdas. Then the results are interpreted visually. Spectral resolution is compared by comparing the pixel size of both images. Comparison of the ability of LISAT and Landsat in spectral resolution seen from how many channels and ranges of each channel with literature study.

The remotely sensed data used for this study was a Landsat-8 OLI imagery (path: 122 and row: 64) acquired on September 8, 2018. As proved the scene was already geometrically corrected, the Landsat-8 OLI mulspectral image was radiometrically corrected and true surface reflectance was determined by converting digital numbers (DNs) to spectral radiance and spectral radiance to reflectance [10]. While LISAT Imagery was acquisied from September 5 2018 when Jatiluhur Reservoir was in position under LISAT.

Data collected by downloading from the data source. LISAT data must be reserved in advance at the following url address: http://LISAT.ipb.ac.id/order/. After the LISAT data is declared available then the data can be used for analysis. Landsat data is downloaded from the following url: https://glis.usgs.gov/. Landsat data retrieval method by entering the location of Jatiluhur Reservoir (path / row) then can be directly downloaded.

2.2. Field studies
Field studies were used to support the interpretation of Jatiluhur Reservoir from Landsat and LISAT imagery. Ground check is done by checking the following:

1. Location (latitude and longitude coordinates)
2. Type of existing land cover

In this study, all water samples was taken on September 5 2018 from the clear water area. Between the time difference of field survey and satellite overpass, no weather perturbations were observed which may lead to fluctuations in lake water. Sample positions will simultaneously were determined by a hand-held GPS receiver. The field data will collected covering the representative sites in the different parts of the Jatiluhur Reservoir.

2.3. Chlorophyll-a prediction

Water absorption on algae pigment is the principle of remote sensing algorithm in predicting Chlorophyll-a. Usually, water absorption of high content Chlorophyll-a is on 443-675 nm [11]. Boyd [12] found Chlorophyll-a values ranged 60-150 µg/L as typical from productive fertilized fish and shrimp ponds. The relationship between Chlorophyll-a concentration and the trophic status of lakes and reservoirs is provided in table 1.

Table 1. Relationship between Chlorophyll-*a* (µg/L) concentrations and trophic condition of lakes and reservoirs (Adopted from Boyd [13]).

Chlorophyll-a (µg/L)		Conditions
Annual mean	Annual maximum	
<2	<5	Oligotrophic, aesthetically pleasing, very low phytoplankton levels
2-5	5-15	Mesotrophic, some algal turbidity, reduced aesthetic appeal, oxygen depletion not likely
5-15	15-40	Mesotrophic, obvious algal turbidity, reduced aesthetic appeal, oxygen depletion likely
>15	>40	Eutrophic, high levels of phytoplankton growth, significantly reduced aesthetic appeal, serious oxygen depletion in bottom waters, reduction in other uses

Based on Yang's research in 2016, the equation for Chlorophyll-a estimation using Landsat 8 data can be seen in the following equation:

$$LogChl = 0.7354 \times \log\left({}^{b5}/_{b3}\right) + 1.5972 \quad (1)$$

Where R^2 0.4751 and RMSE 1.3 µg/L.

2.4. Analysis of data processing and field study

After all the data collected the analysis is done. The analysis was done by comparing the results of literature studies on the spatial, temporal, and spectral resolutions of LISAT and Landsat, then comparing the results of the interpretations of LISAT and Landsat, and adding field studies as supportive of image interpretation.

2.5. Comparing water quality parameter from satellite and laboratory

In this study result of Chlorophyll-a obtained from satellite imagery and laboratory will be compared in a number of predefined points. Water quality analysis was conducted in Environmental Laboratory, PPLH IPB and Environmental Productivity Laboratory in Faculty of Fisheries and Marine Science IPB.

3. Result and discussion

3.1. Field measurement and sampling

In-situ data collection was carried out at four sampling points that represented the overall condition of the reservoir. In general, the four sampling points are located in the inlet, outlet, and center part of the reservoir. The in situ dataset of Chlorophyll-a, TSS, and turbidity in Jatiluhur Reservoir was collected on September 5, 2018, within three hours after the designated time that the LAPAN A3 Satellite/LISAT acquired local scenes. Water samples at 4 sites were collected and located with a Global Positioning System (GPS) receiver and are shown in figure 1 and table 2. The samples were taken at a depth of 30 cm using a Van Dorn water sampler (Alpha Bottle Kit - 2.2L Horizontal, Wildco, Yulee, FL, USA), preserved in 1-L cleaned, dark-colored bottles, and then refrigerated.

Table 2. Sampling location.

No	Location	Coordinate	Sampling Time
1	Cilalawi River Estuary	-6.5753533,107.4010733	01:30 pm
2	Dam outlet	-6.52686318,107.38724769	02:05 pm
3	Aki Island	-6.50728191,107.37934381	02:20 pm
4	Ciririp River Estuarry	-6.54195049,107.29450244	03:07 pm

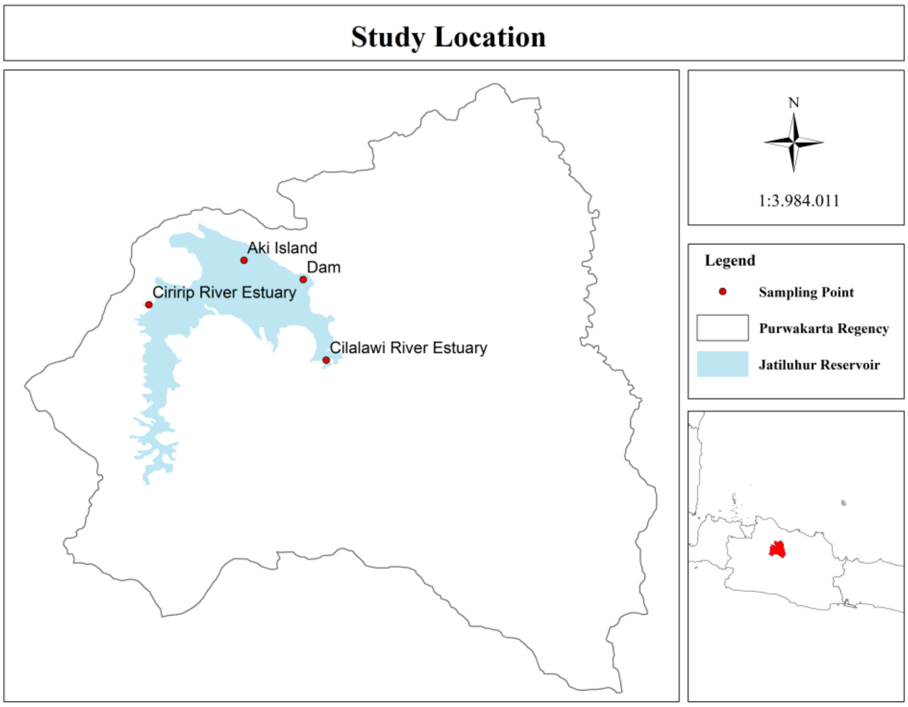

Figure 1. Study location.

3.2. Image pre-processing

LISAT acquired data over Jatiluhur Reservoir at approximately 02:23:55 GMT (corresponding to 09:23:55 local time) at UTM zone 48S with 30 m resolution. Level-1C (L1C) MSI data downloaded from LISAT ftp contained orthorectified, georeferenced, and radiometrically calibrated top-of-atmosphere (TOA) reflectances in Universal Transverse Mercator (UTM) projection with the WGS84 datum. ArcGIS 10.3 were used for analyses.

3.2.1. Comparison of laboratory-derived Chlorophyll-a data and the satellite-predicted Chlorophyll-a data

Eutrophication is an enrichment of water with nutrients or nutrients in the form of inorganic materials needed by plants and results in an increase in primary water productivity. Eutrophication is classified into two, namely artificial or cultural eutrophication and natural eutrophication. Artificial (cultural) eutrophication is an increase in nutrients in the waters caused by human activity, while natural eutrophication is an increase in nutrients in the waters not caused by human activities but natural activities [14].

Chlorophyll-a is one parameter that determines primary productivity in waters. The distribution of high and low concentrations of chlorophyll-a is strongly related to the physical condition of a waters. Some physical-chemical parameters that influence chlorophyll-a distribution are light intensity, nutrients (especially N and P). The difference in physical-chemical parameters is directly the cause of the variation in primary productivity. Chlorophyll-a is an important component supported by phytoplankton and aquatic plants where both are natural food sources for fish. Chlorophyll-a is an active pigment in plant cells that has an important role in the ongoing photosynthesis process [15]. The result of laboratory analysis and satellite predicted data on chlorophyll-a can be seen on table 3.

Table 3. Chlorophyll-a values from laboratory analysis and satellite predicted data.

No.	Location	Chlorophyll-a (mg/m³)		
		Laboratory	Landsat	LISAT
1	Cilalawi River Estuary	312.24	31.7761898	65.85329437
2	Outlet (DAM)	184.19	29.84687453	65.85329437
3	Aki Island	191.62	27.13491249	39.55487823
4	Ciririp River Estuary	469.98	28.20877665	39.55487823

Determination of trophic status in the Jatiluhur Reservoir using the Trophic State Index (TSI) Carlson (1977). Based on the table of the relationship between TSI with chlorophyll a parameter, the TSI value is in the range of 80 - 90. TSI 80 value> falls into the category of hypereutrophic waters. Water conditions in the hypereutrophic category are generally characterized by the presence of algae clumps, the number of water plants a little, and the presence of algae dominated.

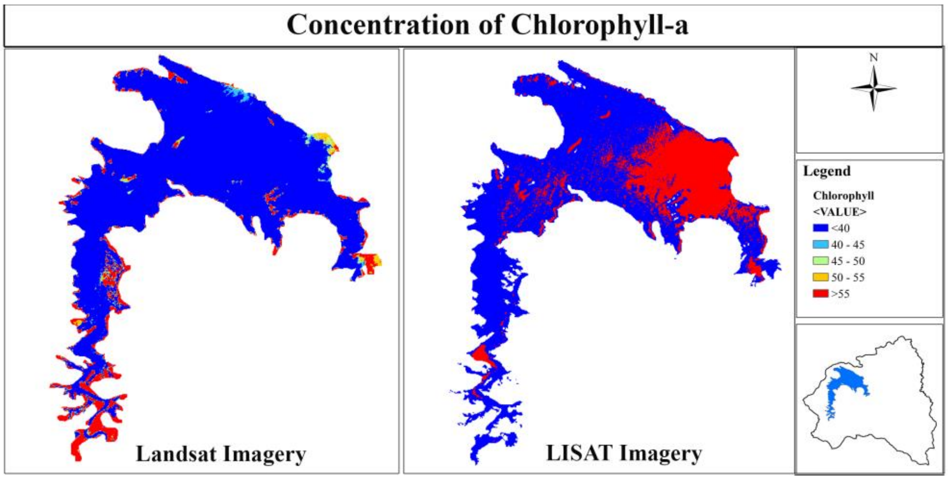

Figure 2. Map of Chlorophyll-a predicted from Landsat and LISAT.

Figure 2 show significance differences of Chlorophyll-a value derived from laboratory analysis. From Landsat analysis, chlorophyll-a ranged from 28-31 mg/m^3. While, LISAT predicted chlorophyll-a values ranged from 39-65 mg/m^3.

Although using the same band in processing spectral data (NIR, Red, Green, Blue), the results of estimating several parameters using Landsat and LISAT images still show different results. This can be influenced by several factors, such as: different data resolution; satellite stability; satellite azimuth; atmospheric and radiometric calibration; and acquisition time between two different satellites.

The difference between the results of estimating the calculation of water quality parameters using satellite imagery and laboratory analysis can be caused by several things; including:

1. The images obtained are directly analyzed using regression obtained from reference without processing atmospheric and radiometric corrections
2. Landsat imagery can't be used for interpreting certain water depth so it is difficult to estimate water quality parameters in a certain water depth
3. Linear regression referenced from the results of other researches may not be used properly in this study. This is because linear regression is closely related to the condition of a waters and certain atmospheric conditions.
4. To determine linear regression that approximates the results of laboratory analysis; analysis should be used using several bands so that the right band combination can be determined to find the appropriate regression.
5. The time to collect water samples ranges from 3-5 hours after the time of LISAT image acquisition so that the water conditions are likely different from retrieved imageries.

4. Conclusion and recommendation

4.1. Conclusion

Based on the table of the relationship between TSI with chlorophyll a parameter; the TSI value is in the range of 80 - 90. TSI value >80 falls into the category of hypereutrophic waters. Water conditions in the hypereutrophic category are generally characterized by the presence of algae clumps; the number of water plants a little, and the presence of algae dominated.

Analysis of Landsat data showed different results with LISAT data in estimating chlorophyll-a. This difference can be affected by several factors such as differences in data resolution, stability, satellite azimuth, atmospheric and radiometric calibration, and acquisition time.

While the estimation of water quality parameters using image data also shows different results from laboratory analysis. This is influenced by the limitations of satellites in capturing spectral water data to a certain depth and the linear regressions from reference that can't be used in analysis. This is because the linear regression used comes from the results of other researches that has been carried out in different locations and atmospheric conditions.

4.2. Recommendation

On the next research, linear regression must be calculated directly from the results by comparing spectral data with laboratory analysis so that the estimation of water quality parameters gets better results. Data collection time also need to be considered considering different times will lead to change of water quickly. In addition, geometric, atmospheric and radiometric corrections need to be done so that the spectral data produced by both satellite can estimate water quality as well as handheld spectrophotometers.

5. Acknowledgement

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