Mangrove Leaf Area Index Estimation Using Sentinel 2A Imagery in Teluk Ratai, Pesawaran Lampung

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Abstract. Mangroves are estuary dominant vegetation in tropic and subtropic area which have an important role to balance the coastal ecosystem. One of the main mangrove biophysics parameters is leaf area index, which is defined as an unitless quantity from the area of one side of the leaf on each unit of ground surface area. LAI measurement using satellite imagery is more efficient than direct measurement because it covers the isolated area in the mangrove forest. This paper discussion focus on mangrove leaf area index estimation model comparison to obtain the best estimation model based on accuracy test value. The imagery used in this research is Sentinel 2A with 10 meters resolution and generic vegetation index (NDVI) compared with nongeneric index vegetation (EVI). Normalized vegetation index is chosen because its sensitivity to chlorophyll tissue of the leaves beside, Enhanced Vegetation Index is chosen because its sensitivity to vegetation canopy structure. The LAI measurement result in Teluk Ratai, Pesawaran, Lampung showing values range from 0.37 until 1.39. The correlation analysis result showing an adequate strong relationship between NDVI and EVI with LAI field measurement value. The correlation value between NDVI and the field measurement value of LAI is 0.779 also the correlation value between EVI and the field measurement value of LAI is 0.762. Based on those value both of vegetation index have a strong relationship with the field measurement result of LAI. From the standard error estimation value, the LAI estimation model accuracy using NDVI is 79.8% and 78.78% using EVI. Visual comparison also done by compare vegetation density pattern in Sentinel 2A with estimation classes in NDVI and EVI model. The best model to estimate leaf area index mangrove is EVI model based on visual comparison, accuracy test, and saturation effect from NDVI.

Keyword: Leaf Area Index, Estimation, Accuracy, Model, Comparison

1. Introduction
Mangrove forest is commonly estuary vegetation on tropical and subtropical coastal area. Mangrove has important roles on balancing the coastal ecosystems because of its capacity to absorb carbon dioxide (CO₂) around the atmosphere and change it into sediment form [1]. Those capacity are strongly affected by their biophysics characteristic, such as primary production, total of biomass, nitrogen cycle, and
vegetation evapotranspiration. One of the main biophysics parameter is leaf area index (LAI) that can be define as vast on a leaf compare with the surface [2].

Leaves are important organ of a vegetation because in this part all of gasses exchange process to the atmosphere occur. Therefore, leaf area index is an important key on ecology process modeling such as photosynthesis, carbon dioxide absorption and gas exchange cycle on the atmosphere [3]. For instance, measuring leaf area index on mangrove vegetation are important to estimate the energy exchange between land and atmosphere also for another ecological process modeling.

Data acquisition of mangrove leaf area index through field measurement usually need more time, energy, and costly because the accessibility to mangrove area are difficult but the accuracy of this method usually higher than indirect method. LAI measurement using satellite imagery is more efficient than field measurement especially for large mangrove area because of its capacity to cover a wide area and reduce field measurement activity (direct method) [4]. Based on the problems above researcher interested to measure the accuracy level of leaf area index estimation using generic vegetation index and non-generic vegetation index. Generic vegetation index only affected by the vegetation density value, whereas non-generic vegetation index is affected by another factor.

Satellite imagery that used in this research is Sentinel-2A with 10 meters spatial resolution. The vegetation index are Normalized Difference Vegetation Index (NDVI) as the generic index and Enhanced Vegetation Index (EVI) as the non-generic index. NDVI is used because it is chlorophyll sensitive and only use two spectral bands; near infrared and red band. Advantage of using NDVI is the rationing concept that able to reduce multiplicative noise (cloud shadow, atmosphere attenuation, topographic variation). In other hand, EVI is used because of its sensitivity to respond canopy structure variation [5].

The research location is in Padang Cermin Village and Sanggi Village, Padang Cermin Sub District, Pesawaran District, Lampung Province. The study sites are located at the Way Sabu River Estuary that empties into Ratai Bay with coordinates 105°9'38.984" BT - 105°10'58.957" BT and 5°34'43.172" LS - 5°36'3.543" LS.

Based on the figure 1 the research location is broadly part of Lampung Bay with calm water conditions which tend to have high sedimentation rate. The study area has a tropical climate, in 2008 with average rainfall in Pesawaran District ranging from 161.8 mm/month, and the average number of rain days 13.1 days/month. The mean intermediate temperature is 22.9°C - 32.4°C. The average relative humidity interval is between 56.8% to 93.1%.

![Figure 1. Map of Lampung Bay](image-url)
2. Data and Method
2.1. Data
2.1.1. Sentinel-2A image of Ratai Bay study area Pesawaran District Lampung Province 10 meter resolution, recording September 10, 2016.

2.1.2. Image of Google Earth study area of Ratai Bay of Pesawaran Regency of Lampung Province.

2.2. Method
2.2.1. Flow Diagram of Research

![Flow Diagram of Research](image)

Figure 2. Flow Diagram Of Research

2.2.2. Pre-Processing Data. Pre-processing data phase is a step before conducting the research and this is an extraction of information from Sentinel-2A imagery. The phase includes literature review which is the preparation phase in collecting information regarding the research methods, theoretical basis to the analysis techniques that needs to be performed in this research. The references referred to were literature in the field of remote sensing, leaf area index (LAI), and vegetation index. Subsequently, image correction which was conducted through the improvement of image quality. This correction was an atmospheric correction. In this research, the data used was Sentinel-2A image with 1C radiometrically corrected level (reflectance at sensor). Conversion was performed by using ENVI 5.3 software.

Transformation of the imagery was a phase following the correction. This imagery of Ratai Bay mangrove area in LAI analysis has used two image transformations. The two transformations are utilized based on their effects, i.e., generic in the form of Normalized Difference Vegetation Index (NDVI) and non-generic in the form of Enhanced Vegetation Index (EVI). The phase of selecting the research area has used the imagery masking method. It was conducted by using ENVI 5.3 software, with an input in...
a form of layer masking. This layer masking is created by conducting visual interpretation of the mangrove area.

The final step was camera calibration. The aim of camera calibration was to set the camera and hemisphere lens prior to Leaf area index (LAI) sampling. Camera calibration performed includes several steps such as optical center calibration and projection function calibration. Optical center calibration was conducted to determine the coordinate from the center point during the shoot. In this stage, hemisphere lens is perforated at some point to determine the pixel coordinates. Projection function calibration was based on pixel value from optical center calibration. This calibration was conducted by two shoots with different coverage area. The aim was to determine the minimum and maximum distance.

2.2.3. Field Data Collecting. Leaf area index (LAI) sampling of the mangrove area was conducted by using purposive random sampling due to the consideration on the difficulty of access to the mangrove area in Ratai Bay, Pesawaran District. The difficulty of access to mangrove area is affected by the sea tides. The location of mangroves also located in several major river estuaries, high mangrove density, and so forth. The distribution of sampling in Sentinel-2A imagery was placed for sampling area with the size of 15m x 15m. In the area, the leaf area index (LAI) shooting was conducted at the midpoint and elsewhere in the sampling area. In addition, in this area of 15m x 15m, plotting has been carried out with the aim to coordinate the measurement of leaf area index (LAI) obtained and to be compared with image transformation data.

![Figure 3. Scheme of taking a picture in the field](image)

2.2.4. Field Data Processing. The sample measurement process of mangrove LAI was conducted through several steps that are shown in the following photos. Photo was taken sequentially from the north at each sample point which are assumed for ESU conformity (Elementary Sampling Unit) in the field. The lighting conditions in each photo should be the same, therefore photos were selected before being processed with Can-Eye software. The number of photos taken were amounted to 9 pieces of photos for ESU characterization [6]. Photos used are photos with upward conditions, i.e., photos which were taken from the bottom to the top.

The process parameters performed should already have optical calibration and projection on the camera lens as they are required to process Angular resolution and FAPAR computation. The parameters were username, image size, optical center & projection function, Circle of Interest (COI), Subsample factor, Angular resolution, Fcover, and FAPAR. Photo masking needs to be performed in order to remove non-vegetation objects and sky background. In advance to masking, gamma factor correction was conducted to clarify the appearance of vegetation and non-vegetation.

Class definition used was no mixed pixel. This option merely classified the pixels based on one class. The class used was green vegetation. Prior to classification, it is necessary to determine the effective leaf zone in the photograph. Therefore, the classification was merely conducted based on leaf area and its canopy.
2.2.5. **Statistical Analysis of Data.** The processing of field data and Sentinel 2A imagery in this research has also used statistical analysis. Statistical analysis conducted includes correlation and regression analysis, to determine the strength and the form of correlation between dependent variable and independent variable. Regression analysis also yielded the value of determinant coefficient ($R^2$) which stated the magnitude of the independent variable affecting the dependent variable.

The vegetation index values (NDVI and EVI) was determined as the independent variable, whereas the field LAI value considered as the dependent variable. The regression equation of the two variables was used to construct the LAI estimation model, with 15 samples of the LAI model.

Model accuracy test was conducted by using 10 test samples. Accuracy test was performed by using standard error estimate method, 1:1 plot, and visual comparison. Through SEE, the percentage of estimated accuracy was obtained and the 1:1 plot provided the information on the accuracy of the estimation result (over/underestimate).

3. **Result and Discussion**

Field measurement result from 25 samples in Ratai Bay indicated the range value of LAI between 0.37—1.39. The LAI field measurement result was strongly affected by the photo exposure, therefore the over-and under-exposure photos were not chosen to be analyzed. This samples were then divided into two, 15 samples as model and 10 as the validation samples.

The distribution of mangrove species in Ratai Bay identified was various in types, among others are *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicennia lanata*, *Xylocarpus moluccensis*, and *Bruguiera cylindrica*. Based on the mangrove pattern analysis, it was known that mangrove in Ratai Bay tends to avoid the natural mangrove distribution pattern. For example, *Rhizophora apiculata* and *Bruguiera cylindrica* which supposed to be located in the middle part of mangrove forest and tends to head towards the mainland, but in Ratai Bay they were mostly found in the coastline heading to the beach.

NDVI value (derived from Sentinel 2A) were in the range of 0.48—0.84 (n=25, mean=0.75, median=0.79, SD=0.09). The normality of NDVI data was tested with Kolmogorov Smirnov and the dmax value was 0.179. The EVI value (also derived from Sentinel 2A) were in the range of 2.65—3.23 (n=25, mean=3.12, median=3.17, SD=0.13). The normality of EVI data was also tested with Kolmogorov Smirnov, the dmax value obtained was 0.187. The threshold value in critical testing table was 0.338, based on this value it was known that both, NDVI and EVI data, were distributed normally.

Correlation analysis indicated strong correlation between NDVI and EVI with the LAI field measurement result. Correlation value between NDVI and EVI was 0.983391 therefore they were strongly correlated. Correlation value between NDVI and LAI field measurement result was 0.779, EVI and LAI field measurement result was 0.762.

LAI estimation modeling was conducted by linear regression, where the result was shown in Table 1. The linear regression equation used was based on equation (1).

$$y = ax + b$$

The dependent variable was from LAI field measurement data model samples and the independent variable was from vegetation index (in this case NDVI and EVI).

**Table 1.** The result of regression equation

| Vegetation index | Regression equation result | $R^2$ |
|------------------|-----------------------------|-------|
| NDVI             | $y = 2.1472x + 0.658$       | 0.60  |
| EVI              | $y = 1.3397x + 3.222$       | 0.58  |

The result of equation indicated that 60% of LAI value from field measurement result can be explained by NDVI and 58% of LAI value from field measurement result can be explained by EVI.
Accuracy of the estimation result was tested with Standard Error Estimate (SEE) and 1:1 plot by using field measurement data. The SEE obtained a result with the maximum accuracy value of 79.8% with NDVI and 78.78% with EVI. The difference between NDVI and EVI estimation model was not significant, but NDVI model was considered to be better than EVI model statistically. This can be observed by the statistics summary in Table 2. SEE Calculation. The models were also tested with 1:1 plot to determine the accuracy of the LAI estimation.

Similar with estimation result with EVI model, overestimate result was obtained. This can be observed from the point distribution which were mainly located in the upper part of 1:1 plot line (Figure 6. 1:1 Plot). The point referred to the estimation of LAI value by using each model.

Table 2. Standard Error Estimate Calculation

|                | EVI             | NDVI            |
|----------------|-----------------|-----------------|
| SEM            | 0.395591813     | 0.357134937     |
| SEM            | 0.049448977     | 0.044641867     |
| Mean           | 0.90000000000   | 0.90000000000   |
| Standard deviation | 0.239165215   | 0.239165215   |
| Confidence Level 95% | 0.148233412     | 0.148233412     |
| upper range    | 1.04823341207   | 1.04823341207   |
| lower range    | 0.75176658793   | 0.75176658793   |
| maximum error  | 29.57982733     | 28.1052955      |
| minimum error  | 21.21390676     | 20.15640968     |
| maximum accuracy | 78.78609324     | 79.84359032     |
| minimum accuracy | 70.42017267     | 71.8947045      |
Overestimate can be caused by the photo exposure which was overly obscure, therefore Can-Eye software indicated many leaf structures than it should be. Furthermore, inequality of samples distribution also affects this estimation result. It is difficult to obtain prevalent sample distribution in mangrove area because the condition of mangrove forest is hard to access.

The accuracy of LAI estimation that have been tested statistically was subsequently compared to the visual analysis. This visual analysis was conducted by comparing the mangrove density in Sentinel 2A imagery (recorded in 21st September 2016) with the estimation result by using NDVI and EVI index (shown in Figure 7). Based on this visual analysis, estimation pattern with EVI model is more similar with mangrove density in imagery.

By observing the mangrove density distribution pattern, it can be seen in the Sentinel imagery that mostly, high mangrove density has no strict boundary and was not massive in nature like the pattern of LAI estimation by using NDVI model. For example, mangrove in the middle-northern pattern of the river indicated that high-density mangrove was not massive and it has no strict boundary. Different with the estimation by using NDVI, in that location, the mangrove seems to be highly massive and have a strict boundary.

**Figure 6.** 1:1 Plot between EVI with LAI model and NDVI with LAI model.

**Figure 7.** Comparison between mangrove density in Sentinel-2A, and LAI estimation result using NDVI and EVI.
The comparison by using density value approach considered to be quite representative. Based on the data analysis by using Can-Eye and statistical analysis, there were strong correlation between the canopy mangrove densities with LAI, moreover, it is impossible to obtain the LAI value by visual interpretation in satellite imagery.

Statistically the NDVI value was considered better than EVI to represent the LAI value, but in the high mangrove canopy density, the NDVI model has undergone saturations. Because of the saturation, NDVI lacks of sensitivity to differentiate the LAI value in high density of mangrove. In addition, the inequality field measurement samples also caused the samples to be less representative. Therefore, the EVI model was considered to be more representative to estimate the mangrove LAI value in Ratai Bay because the mangrove was highly dense.

4. Conclusion
The best model to estimate LAI mangrove was by using EVI vegetation index because it was considered to be more compatible with the mangrove density pattern in imagery and mangrove real condition in Ratai Bay. The NDVI vegetation index was considered inappropriate due to the saturation that occurred in the high-density mangrove.

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