Mangrove canopy density analysis using Sentinel-2A imagery satellite data

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Abstract. Teluk Jor has alluvium surface sediment that came from volcanic materials. Sea wave that relatively calm and the closed beach shape support the existence of mangrove forest at Teluk Jor. Sentinel-2A imagery has a good spatial and spectral resolution for mangrove density study. The regression between samples and the NDVI values of Sentinel-2A used to analyze the mangrove canopy density. Mangrove canopy density was identified using field survey with transect method. The regression analysis shows field data and NDVI value has correlation $R=0.7739$ and coefficient of determination $R^2=0.5989$. The result of the analysis shows area of low density $397,900 \text{ m}^2$, moderate density $336,200 \text{ m}^2$, the high density has $110,300 \text{ m}^2$ and very high density has $500 \text{ m}^2$. This research also found that mangrove genus in Teluk Jor consists of Rhizophora, Ceriops, Aegiceras and Sonneratia.

1. Introduction
The balance of coastal ecosystems influenced by the organisms that grow and develop around the coast such as mangrove, estuary, meadow/seagrass, coral reefs, small islands, and the deep sea. The length of Indonesia’s shoreline with its physical condition can support mangroves to grow, thus Indonesia has 3.5 million ha of mangrove area [1], had been the largest in the world (18-23 %), after Brazil (1.3 million ha), Nigeria (1.1 million ha), and Australia (0.97 million ha) [1].

Mangrove is a coastal vegetation that grow in tidal areas with muddy shore. The mangrove forest is one of the tropical and subtropical forest that grow along the coast or a river that is affected by the tide. The mangrove forest is able to provide considerable benefits for the balance of nature, especially the coastal areas and coastal communities. Mangrove forest is a transition ecosystem between land and sea with the complex interactions between the physical and biological properties. Mangroves are found along the coastal area and can grow in tidal area according to their tolerance to salinities, flooded area, substrates, and coastal morphology [2].

Mangrove forest has some advantages and functions for human life. Mangrove could be used for fuel, building materials, fisheries, textiles, agriculture, papers, home equipment, foods and beverages [1]. Mangrove has an important role in coastal protection of currents, winds, and storms. For fishery, mangrove keeps the life cycle of fishes, shrimps, and molluscs, keeps the fertility of coastal area, and also become organic matter supplier [1]. Forest canopy density is the most useful considered parameter for implementation in planning and environmental rehabilitation [3]. One of the methods to measure canopy density is from canopy cover. Canopy cover is the ground area that covered by vertical projection.
of vegetation canopy or tree crown. Measuring canopy cover use remote sensing data nowadays became more often because the remote sensing data has ability to observe the earth surface.

Remote sensing is the science and art of obtaining information about the object, area, or phenomenon by analyzing data obtained using instruments without direct contact with the objects [5]. Sentinel-2A imagery has a high spatial resolution and can be downloaded for free. Sentinel-2A is a program of the Global Monitoring and Environmental Security (GMES) and the initiation of the European Commission (EC) and European Space Agency (ESA). This satellite was launched in June 2016. Studies that use Sentinel-2A imagery is still very rare, especially for mangrove forests study. Sentinel-2A imagery has a great potential in mangrove research because it has a high spatial resolution about 10 meters for visible and near-infrared bands.

Teluk Jor (located in Lombok Timur Regency) has a physical condition that allows mangroves to grow. Teluk Jor has alluvium surface sediment that came from volcanic materials. Sea wave that relatively calm and the closed beach shape support the existence of mangrove forest. Vegetation structure is related to ecological conditions, thus it is important to know the environment conditions. This study is to find out the application of Sentinel-2A in the study of mangrove canopy density at Teluk Jor.

2. Methodology

2.1 Data used and Pre Processing

Mangrove canopy density analysis is carried out with remote sensing data and field survey. Sentinel-2A was launched in June 23rd 2015 and was prepared for providing earth observation for environmental, agriculture and security monitoring. Sentinel-2A satellite data that recorded on 16 January 2016 is used in this study, has various spatial and spectral resolution with 13 bands consists of 4 bands with 10 meters spatial resolution, 6 bands with 20 meters, and 3 bands with 60 meters. This research uses visible and near infrared data (band 2, 3, 4 and 8) for data modelling.

Sentinel-2A data is pre-processed with radiometric, atmospheric correction and finished with image transformation before can be applied for canopy density modelling. Radiometric correction retrieved by calibrating Digital Number (DN) divided by default quantification value that provided in metadata. Atmospheric correction uses Dark of Pixel (DOP) method to decrease the atmospheric effect on reflectance value. Image transformation method has done with Normalized Difference Vegetation Index (NDVI) to shows the information about vegetation density.

2.2 Field Survey Method

Measurement of mangrove canopy density uses two methods, hemispherical photography and subjective density method. Hemispherical photography method usually used for canopy identification with upward photo taking or downward using wide-angle camera [6]. Hemispherical photography method has more advantages compared to other indirect methods, such as faster measurement, cheaper and permanent result. This method gives information about gap fraction distribution that can be used for forest canopy properties, for examples leaf area index, leaf angle distribution, and canopy openness [7]. Subjective density method is used for sample comparison. This method considering field canopy density and measure it based on density card. The sample data are obtained using transect method that directed from the land to the sea.

Technically, canopy cover data obtained by taking photo upward with constant height, 1 meter in every sample location. Photo taken 5 times; 1 photo on the center of plot and others on the surrounding. According to Sentinel’s pixel size (10 m) was build sample area 15 x 15 m to anticipate the effects of surrounding object and geometric error. Can Eye software is used to obtain canopy cover values. The process is usually use hemisphere camera but in this study we use pocket camera. We also analyze the horizontal structure of mangrove by observing dominant and non-dominant mangrove genus in every sample location. The leaf, flower, stream, and root of mangroves tree that found in sample location are identified and matched with mangrove genus characteristic table.
2.3 Mangrove Canopy Density Mapping
Mangrove canopy density map is established from two parameters, NDVI values of Sentinel-2A and field survey data of mangrove canopy density. The spectral transformation NDVI image gives optimal result for identify the variation of vegetation in the relation to density [8]. Statistical relationship like regression is the simplest and the most common approach for modelling ecological parameter [9]. Linear regression analysis is used for modelling mangrove forest canopy density at Teluk Jor. The independent variable is field data, and the dependent variable is NDVI values. The linear regression analysis give the equation formula to extrapolating the canopy density values in the defined area. The strong correlation between NDVI and field survey data indicates the model is good enough for estimating the mangrove canopy density at Teluk Jor. Correlation value explains the relationship; strength, direction, and the possibilities to analyze in regression. Whether or not model depends on coefficient of determination value from the regression.

![Figure 1. Mangrove Area in Teluk Jor from Sentinel-2A Satellite Data](image)

3. Results and Discussion

3.1 NDVI Result
Canopy density model is established from the regression equation between field data and NDVI value. The results of image processing Sentinel-2A indicates that NDVI imagery can clearly appearance of water, soil and vegetation in the study area. Fig.1. shows the appearance of water or rivers are shown in a low NDVI values (red color), and the appearance of vegetation are shown with high NDVI value (green color). NDVI Transformation has an ability to distinguish objects reliable in identifying vegetation density, assuming higher canopy density is also has higher NDVI value.
**Figure. 2. NDVI value at Teluk Jor**

Table 1. Field data and canopy cover model

| Sample | Coordinate | Genus | Other Genus | Subjective Density | Hemispherical Photography | Canopy Cover Model |
|--------|------------|-------|-------------|---------------------|----------------------------|-------------------|
|        | X          | Y     | Dominant    | Density (%)         |                             |                   |
| 1      | 443036     | 9026638 | Sonneratia  | -                   | 20                          | 20.93             | 31.04             |
| 2      | 443048     | 9026622 | Sonneratia  | Rhizophora          | 40                          | 68.83             | 57.15             |
| 3      | 443054     | 9026620 | Ceriops     | Sonneratia          | 20                          | 45.59             | 50.66             |
| 4      | 443061     | 9026611 | Sonneratia  | Rhizophora          | 40                          | 61.18             | 54.05             |
| 5      | 443060     | 9026596 | Sonneratia  | Rhizophora          | 25                          | 59.62             | 60.04             |
| 6      | 443069     | 9026581 | Sonneratia  | Rhizophora          | 30                          | 58.78             | 56.24             |
| 7      | 443087     | 9026550 | Sonneratia  | Rhizophora          | 25                          | 42.67             | 26.30             |
| 8      | 443061     | 9026586 | Sonneratia  | -                   | 80                          | 62.42             | 56.09             |
| 9      | 443915     | 9025540 | Ceriops     | -                   | 25                          | 10.96             | 16.94             |
| 10     | 443913     | 9025562 | Aegiceras   | -                   | 70                          | 57.56             | 40.25             |
| 11     | 443900     | 9025579 | Rhizophora  | -                   | 50                          | 44.41             | 49.85             |
| 12     | 443898     | 9025608 | Rhizophora  | Sonneratia          | 75                          | 34.50             | 26.61             |
| 13     | 443872     | 9025590 | Sonneratia  | Rhizophora          | 50                          | 59.23             | 50.82             |
| 14     | 443869     | 9025572 | Sonneratia  | Rhizophora          | 50                          | 36.15             | 52.08             |
| 15     | 443859     | 9025562 | Rhizophora  | -                   | 65                          | 43.99             | 52.42             |
| 16     | 443873     | 9025542 | Sonneratia  | Rhizophora          | 20                          | 28.95             | 38.29             |
| 17     | 443886     | 9025525 | Rhizophora  | -                   | 10                          | 8.06              | 14.32             |
3.2 Data Collection
The data was collected using transect method and produced 3 transects by 17 the number of sample plots. Transect method has chosen because of the difficulty of penetrating dense mangrove fields and muddy. Data collection could only be done on 14:00 until 17:00 because at that time, the tide was low thus the mangrove forests can be passed.

Based on field survey, four mangrove genus are identified in Teluk Jor. They are *Rhizophora*, *Sonneratia*, *Ceriops* and *Aegiceras*. The most genus that can be found is *Sonneratia*. But most commonly found near the sea is *Rhizophora*. *Ceriops* and *Aegiceras* can be found in the middle of the mangrove forest, but they are not the dominant genus in Teluk Jor. Mangrove structure in Teluk Jor has irregular pattern. According to field survey, the structure of the mangrove genus does not have a distinct arrangement. For example in mangrove area that dominated by *Sonneratia*, we can also found *Ceriops* genus that grow between them.

Density value is extracted using two methods: subjective methods and hemispherical photography method. Values of subjective method shows the density ranges from 10% to 80% while the hemispherical photography method is processed using Can Eye software, and produces density ranges from 8.06 % to 68.83 %.

3.3 Regression Analysis
Vegetation density sample using subjective and hemispherical photography is analyzed using linear regression analysis to show the correlation with NDVI value of Sentinel-2A data. The best correlation between two methods will be used for modelling the mangrove canopy density in Teluk Jor. Based on regression analysis, the subjective density has very low correlation with NDVI value with $R=0.2762$ and determination coefficient $R^2=0.0763$. This result shows that the subjective density is not good enough to be modelled with NDVI value. In other hand, hemispherical photography has much better correlation with NDVI value. The result shows canopy density measured with hemispherical photography method has a correlation $R=0.7739$ and coefficient determination $R^2=0.5989$. The good correlation between canopy density and NDVI value shows the regression formula is good enough for modelling mangrove canopy density.
3.4 Mangrove Canopy Density Analysis
Mangrove canopy cover that produced by the mangrove density model has a minimum value of 0 % and a maximum value of 81.204 %. The result of the density map can be seen in Figure 4. The map shows the percent of mangrove canopy cover in result of regression equation. The 0 % value indicates the cover is not vegetation, it could be either water or bare land.

The canopy cover or density of mangrove is classified into 4 classes to simplify the analysis. The result explains mangrove vegetation with low density has an area 97,900 m$^2$, medium density has 336,200 m$^2$, the high density 110,300 m$^2$ and very high density 500 m$^2$. Qualitatively, it explains there are many high density mangrove near sea, although there is also few area of low density between the high density of mangroves and sea. There are many mangrove medium density in the middle of the forest. Low density mangrove widely located in the edge of medium density mangrove and has the highest number of extents compare to the other classes. Very high densities mangrove are only found at some point between the high density and has the smallest area with only 500 m$^2$.

This irregularly pattern of mangrove cover density depends on many factors. Some Teluk Jor mangrove sites especially on the near land is the former pond. It can be identified from the pattern looking at Sentinel-2A imagery is made some square shapes. On the former pond, the existence of mangrove is the result of planting programs. Former pond and mangrove forest is divided by mound, therefore restrict the tide.

Mangrove forest at Teluk Jor is directly adjacent with settlement and farming land. The dense settlement gives household waste supply that indirectly affects mangrove growth. Mangrove zonation could not clearly identified in the location because there is no large estuary. The largeness of estuary, and also the aridity climate at the location affects the amount of sediments that become medium of mangrove growth. Meanwhile the medium tidal amplitude also does not really flat coastal morphology at some parts affects the narrowness mangrove at Teluk Jor.
4. Conclusions

Remote sensing data give a lot of solution to model the environmental condition. Mangrove has a crucial part on environment but has fragile characteristic. Remote sensing has an ability to observe the earth condition, including mangrove forest. This paper shows Sentinel-2A satellite data has an ability to model the mangrove canopy density. The regression analysis between field canopy cover data using hemispherical photography method has a good correlation with NDVI value that computed from Sentinel-2A data. The regression analysis shows field data and NDVI value has correlation $R=0.7739$, and coefficient determination $R^2=0.5989$.

The mangrove canopy density model shows Teluk Jor mangrove forest has varies canopy density. The density exists from 0 % to 81.204 %. The largest area is low canopy density, with covering 397,900 m$^2$ of the mangrove forest, while the smallest area is high mangrove density class with only 500 m$^2$. The moderate canopy density is covering 336,200 m$^2$ and the high density covering 110,300 m$^2$. This research also found the mangrove genus at Teluk Jor consists of *Rhizophora*, *Ceriops*, *Aegiceras* and *Sonneratia*.

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