Mangrove Mapping Using SPOT 6 at East Lombok Indonesia

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Abstract. Accumulated biomass estimation in mangrove forest is important for assessing its productivity and sustainability. It is also important on revealing the potential amount of carbon that can be emitted in the form of carbon dioxide when deforestation took place. Mangrove as a part of the coastal ecosystem is related to Blue Carbon, especially in controlling climate change. This is due to its ability in utilizing carbon dioxide for photosynthesis and store it in stock biomass and sediment. This study addressed to estimate the mangrove extent at East Lombok as a part of One Map Mangrove Bali – Nusa Tenggara, and also trying to estimate its above ground biomass (AGB). Those are indispensable, especially for eastern part of Lombok which has the greatest mangroves area and mostly in good condition such as Gili Lawang and Gili Sulat. Forest biomass can be estimated through combination of field measurement and remote sensing - GIS methods. SPOT 6 and another high resolution-imagery were used as primary remotely sensed data. On screen digitation using RGB-NIR bands and Normalized Difference Vegetation Index (NDVI) image transformation are applied for the initial canopy density classification. For field measurement at 2016, plot sample sized 10 m x 10 m were used for mangrove parameter inventory. Non-destructive biomass estimation applied in this research which is applicable for mangrove ecosystems, using allometric equations. AGB estimation model also applied in mangrove area at two small islands. Bruguiera sp. and Rhizophora sp. dominated in East Lombok. While, Sonneratia sp. and Avicennia sp dominantly appeared in seaward zone of mangrove zonation. The spatial analysis resulted mangrove area in East Lombok is 1759.5778 ha. The estimation results of above ground biomass (trees and saplings) using 12 sample plots in East Lombok is 12,667.316 kg, while there are 881,677 kg of AGB of mangrove in Gili Lawang and Gili Sulat based on the AGBs model applied.

Keywords: Mangrove, Above Ground Biomass, SPOT 6

1. Backgrounds

Mangrove as one of the essential ecosystems on coastal are facing many threats[1], [2]. High degradation level, due to its utilization as a source of timber and land cover change becoming the primary cause[3], [4]. In line with that, for sustainable development and coastal spatial planning purpose, information of mangrove extent becoming very essential. In spatial term, Mangrove monitoring can be done using a
combination of remote sensing and field surveys. Remotely sensed data still becoming one of the best sources that can reveal mangrove forest condition. Its advantages such as synoptic coverage, provide information for the inaccessible area, historical and near real-time data has brought lots of benefit in short time data processing[5]–[7]. Thus, it is compelling to support land management, spatial planning, rehabilitation, and monitoring of coastal area [7]–[10]. In term of sustainable coastal management, mangrove biomass characteristics are necessary [11]. Biomass estimation has become one crucial step to lead another action such as deforestation deterrence, agroforestry, and forest management [12].

Lombok as one of tourism destination in Indonesia has mangrove as its natural resources that should be preserved. Gili Lawang and Gili Sulat as marine conservation area becoming potency for East Lombok. Some research of mangrove in East Lombok has been done. Sidik and Kusuma [13] have carried study using Formosat to classify mangrove density in Gili Lawang and Gili Sulat. Budhiman et al. [14] have estimated the rate of mangrove forest degradation in Lombok Island using Landsat-TM. Utilizing SPOT 6 imageries, this study aims to map the mangrove extent and its canopy density distribution, and also estimate the aboveground biomass (AGB) map using remote sensing data. Further, mangrove AGB estimation model was produced using vegetation index [11]. Several studies show the estimation of mangrove AGB using remote sensing data such as high-resolution imagery (Worldview-2, GeoEye-1)[15], [16], medium resolution ASTER elevation data[16], and L-band ALOS PALSAR[17]. Along with Anaya et al.[18] that implemented enhanced vegetation index (EVI) to estimate aboveground biomass in grassland, primary forest, and secondary forest. This paper explored the possibility of estimate aboveground biomass in a densely vegetated mangrove area using normalized difference vegetation index (NDVI) computed from SPOT 6 imagery. This study was initiated as a step to enrich the mangrove mapping information in Indonesia. Also, field data used in this study were part of Bali – Nusa Tenggara’ sampling points for mangrove mapping in 2016.

2. Methodology
Mangrove mapping using remote sensing technology assisted with ground truth or mangrove validation become the major step in this study. Methods of image interpretation were varied depending on the image datasets condition. Visual and digital interpretation are the two primary methods that applied for interpreting the SPOT 6 images.

Following the national technique guidance: Head of Indonesia Geospatial Information Agency Regulation No. 3 2014 about Collecting and Processing of Geospatial Data of Mangrove. Image interpretation of mangrove was varied due to image condition. Mostly, visual interpretation using both of true color (RGB) and false color composite (Green – Red – NIR bands) were occupied to determine the mangrove edges. Canopy density determination was based on NDVI results. Using image enhancement with true and false color composite, made canopy density classes can be easily differentiated[19]. In order to estimate Above Ground Biomass in the mangrove area, allometric equation as cited in national guidance were used [12], [20]. Further, in this paper, AGB also estimated using vegetation index (NDVI) [11]. As part of One Map Mangrove Bali – Nusa Tenggara, several notes that should be noticed in this paper as for the amount and distribution of sampling plots. Brief and clear workflow of the mangrove mapping in East Lombok were captured in Figure 1.

2.1. Study Area
As mention in introduction subtitle, this paper utilizes data from Bali – Nusa Tenggara Mangrove Mapping Project that held in 2016 (Figure 2). As for initial work of AGB estimation using NDVI, East Lombok chose as a study area. Administratively, Lombok Island divided into Mataram City, Lombok Tengah, Lombok Timur, Lombok Utara, and Lombok Barat. Figure 3 shows the study area of mangrove mapping, with focused in two areas of East Lombok (Red boxes), and the distribution of survey plots.
Figure 1. Flowchart of Mangrove Mapping

Figure 2. Area of Bali – Nusa Tenggara Mangrove Mapping Project
2.2. Materials and Methods
Base map used for image geo-rectification was Indonesia topographic map scale of 1:25.000. Satellite images used in this study are SPOT 6 imageries acquired varied from February 2015 to March 2016, with 6 m of multispectral and 1.5 m panchromatic bands spatial resolution. Those imageries are used for NDVI transformation and also visual interpretation.

2.3. Vegetation Index
Classification of canopy density resulted from NDVI image transformation referred to the national standard for Mangrove Surveying and Mapping (SNI 7717: 2011) scale of 1:25.000. The canopy density classes would be: Very dense (5), dense (4), moderate (3), rare (2), and very rare (1). Many vegetation index has been used for vegetation analysis[7], [11], and NDVI can be used for mangrove canopy density mapping [8], [19]. NDVI yielded better correlation between vegetation index and vegetation presentation using ALOS/AVNIR-2 data [21].

\[
NDVI = \frac{\text{Band (NIR)} - \text{Band (R)}}{\text{Band (NIR)} + \text{Band (R)}}
\]

Where:
NIR : Near Infrared
R : (visible) Red
Range of NDVI : -1 to 1

Figure 3. Study area (A: North; B: South)
2.4. Field survey
The field survey is carried to validate the sample points and polygons as the result of image interpretation. First thing in field survey is validation form of existing mangrove which needed to verify the results of image interpretation. This step is essential to clarify the information derived from the image with cloud existence or other disturbance. Next, inventory of mangrove stands parameters such as trees density, canopy density, value index, and mangrove species (dominance). For 180° view of mangrove canopy, Fisheye lens is used. The percentage of canopies open derived from the photo captured by fisheye lens then it can be calculated to find the percentage of mangrove canopy cover. Secondary data also needed to fit up.

Since this study is part of Bali - Nusa Tenggara Mangrove Mapping Project, survey plots arrangement (number and distribution) are based on the extent of mangrove area along Bali - Nusa Tenggara which divided into 189 map index (NLP). The number of sampling points throughout Bali - Nusa Tenggara was calculated for accuracy assessment. Technically, validation and mangrove parameters measurement carried on a plot sampling (PS) sized 10 x 10 m². And fewer parameters acquired in point sampling (TS) sized 5 x 5 m², only canopy density, and species dominance. On average, up to 2 PS distributed in each map index. For Bali - Nusa Tenggara, it resulted in 285 PS and 150 TS (Table 1) laying along the coastal, and only 12 PS plotted in in East Lombok, Gili Sulat and Gili Lawang which occupied for AGB estimation based on NDVI (Figure 3).

Table 1. Mapping index and number of samples

| Areas/ Province          | Σ Index | Number of PS | Number of TS |
|--------------------------|---------|--------------|--------------|
| Bali                     |         | 25           | 8            |
| Nusa Tenggara Barat (NTB)| 189 NLP | 89           | 47           |
| Nusa Tenggara Timur (NTT)|         | 181          | 104          |
| TOTAL                    |         | 295          | 159          |

Of course, in mapping, accuracy assessment must be done to test the confidence level of the product. Accuracy assessment is required because of another land cover around the mangrove area on the image interpretation results, thus allowing for a less precise or mixing border between mangrove and non-mangrove. Also, interpreting the mangrove area of the image will not always result in accuracy, this may be due to the date of acquisition of the old image irrelevant to the actual land cover conditions. Thus, it is necessary to do the field validation. The assessment of the image interpretation accuracy was calculated using the matrix accuracy developed by Short in 1982:

\[
\text{Overall Accuracy} = \left(\sum_{i=1}^{n} X_{ii}/N\right) \times 100\%
\] (2)

where:
\(X_{ii} = \text{diagonal matrix}\)
\(N = \text{sample}\)

2.5. Biomass Estimation
One of biomass estimation method without extraction is sampling. By measuring several parameters such as height (H), diameter at breast height (DBH), diameter (D), and distinguishing between tree and saplings, allometric equations can be applied to extrapolate the above ground biomass [12]. Different allometric equations applied based on range of DBH value. Mangroves with DBH ≥ 10 cm, general allometric equation built by [20] and \(\rho\) value by Simpson (1996) cited in the national technical guidance of mangrove mapping was applied. Another general allometric equation used for mangroves with DBH
< 10 cm [12]. Beside using allometric equation, above-ground biomass estimation model also implemented using NDVI result [11], but only in Gili Sulat and Gili Lawang which has almost homogeneity land cover. The AGBs estimation model was built by field measurements in Segara Anakan, Cilacap and yielded $R^2 > 80\%$, and claimed that the higher the NDVI will resulted biomass increasing in logistic correlation.

The AGBs estimation model[11]:

$$\frac{(30.97183 - (56.898258 \times \text{NDVI}))}{(1 + (3.952476 \times \text{NDVI}) - (9.567301 \times (\text{NDVI}^2)))}$$

3. Results and Discussion

The strands of Bali – Nusa Tenggara islands often referred as the "Sunda Kecil". Consisting of three provinces, namely Bali, West Nusa Tenggara, and East Nusa Tenggara, those have different mangrove variations. Bali - Nusa Tenggara Mangrove mapping project was made to support One Map Mangrove Indonesia in 2016.

In Bali, mangroves are found in large areas, especially in Perancak, Bali Barat National Park (Menjangan Island), and Benoa. *Rhizophora* (*R. apiculata* and *R. mucronata*) becoming the dominant genera of mangrove. By the profile, the area with the most mangrove species is Buleleng Regency. *Avicennia* sp., *Sonneratia* sp., *Rhizophora* sp., *Bruguiera* sp., and *Ceriops* sp. inhabited the coastal, sequence from seaward to landward zone. The most extensive mangrove area found at Badung Regency, it is 574.38 ha, while mangrove area based on canopy cover classification in whole Bali province is contained in Table 2. The canopy cover class which is dominant in Bali is “dense” class.

Some of the new species found in West Bali National Park (TNBB) include *Rhizophora lamarckii* (a mixture of *Rhizophora apiculata* species with *Rhizophora stylosa*), *Acanthus ebracteatus*, *Cerbera odollam*, *Dolichandrone spathacea*, *Xylocarpus moluccensis*, *Xylocarpus granatum*, *Aegiceras floridum*, *Heritiera littoralis*, and *Ceriops australis*. Associated with the substrate, the result of grain size substrate test in TNBB area shows that the dominance of silt and clay with percentage is 88.18%. The substrate type is suitable as the habitat of *Rhizophora* sp.

Mangrove observed in the province of NTB spreading on the main island of Lombok and Sumbawa, and also in many small islands “Gili” around Lombok Island. Meanwhile, the mangrove area located on Sumbawa Island is Alas Moyo, Saleh Bay, Seteluk-Taliwang, Lunyuk-Labangka, Teluk Sanggar, Cempi Bay, Waworada Bay, Bima Bay, and Sape Bay. Based on the interpretation result using SPOT 6 image, the mangrove area in NTB province is about 10,667.19 ha, with canopy density class "moderate" having the most extensive area (Table 2). In the vegetation phase of trees, the dominant species are *Sonneratia alba*, while in the sapling and seedling phase *R. apiculata* dominated. The grain size test results from the five substrate sample locations of mangrove scattered in NTB showed mostly mangrove substrate is by silt and clay (90%).

Table 2. Mangrove area at Bali – Nusa Tenggara

| No | Region | Canopy Density Class | Area (ha) |
|----|--------|----------------------|-----------|
| 1  | Bali   | Very Dense           | 417.17    |
|    |        | Dense                | 822.39    |
|    |        | Moderate             | 472.27    |
|    |        | Rare                 | 197.42    |
|    |        | Very Rare            | 108.60    |
| 2  | NTB    | Very Dense           | 155.42    |
|    |        | Dense                | 3.078.83  |
|    |        | Moderate             | 3.756.67  |
|    |        | Rare                 | 2.320.14  |
|    |        | Very Rare            | 1.356.12  |
| 3  | NTT    | Very Dense           | 473.91    |
|    |        | Dense                | 5.580.00  |
Aegialitis annulata found as an endemic species in the province of East Nusa Tenggara, especially in East Sumba, with 1.5 - 3 meter (bonsai) trees height. Mangrove area with extent 22,147.39 ha found throughout the NTT region, where the species of Sonneratia alba predominate in the tree-growing phase. In the region of Sabu Raijua and Rote Ndao many Lumnitzera sp found, which is a type of mangrove that lies somewhat away from the coastline and is only flooded at the highest tide that occurs just a few days a month. This area is characterized by substrate conditions that tend to be dry and dense. Grain size test of nine substrate samples spread over NTT showed that three of them were dominated by muddy sand with a composition of 3.24% gravel; 58.91% sand; and 37.85% silt and clay, and the remaining six were dominated by mud and clay with a composition of 0.77% gravel; 10.59% sand; and 88.64% silt and clay. By grain size, the substrate composition has not been able to characterize the zonation of a particular species mangrove directly. The composition of the substrate is the general composition of mangrove habitat for all species. In fact, almost all types of mangroves can grow on both types of substrate dominance. Substrate characteristics will be typical when combined with the tides where the substrate slope difference will control the high tidal and puddle frequency at a location which will automatically also control the salinity level at that location.

Mangrove mapping of Bali - Nusa Tenggara region yielded > 85% for the accuracy of above 85% is obtained for mangrove land cover interpretation and canopy cover classification based on NDVI (Table 3). Some of the technical things that can affect the achievement of such accuracy are, first, the spatial resolution of SPOT 6 where the distinction of mangrove and non-mangrove can be made quite clear. According to Tobler (1987) in Head of Indonesia Geospatial Information Agency Regulation No. 3 2014, the determination of the equivalent image resolution for a certain scale mapping is half the number of map-scale denominators divided by 1000. Since SPOT 6 image has 6 meters for spatial resolution (multispectral), it meets the accuracy rules of using image resolutions on a 1: 25,000 scale mapping. Second, the image used is relatively up-to-date. Date of image acquisition time varied on February 2015 - March 2016 while the field survey was carried on August 2016. Third, the location of PS in the field survey. As has been done, the determination of plot samples (PS) taken in the middle of a polygon interpreted as a mangrove where NDVI values tend to be homogeneous [19]. Four, the delineation process refers to the many SPOT 6 imageries available. It is intended to cover each other the weakness of the image used. Where in one of the cloud-covered imagery, the information can be obtained from another image with the same location and the adjacent time. The process is carried back and forth between the main image and the supporting image. For canopy density, the result of NDVI is tracked back with the green band [19]. Five, Coastal condition of Bali - Nusa Tenggara supports the interpretation of mangrove and non-mangrove areas. Mangroves grow at specific locations, especially the bay. Also, the coastal steepness reliefs in the Nusa Tenggara area and land use conditions in coastal regions consisting of ponds, tourist lands, villas, or garden plots, also bolster the interpretation step.

### 3.1 Mangrove of East Lombok

Geographically, the mangrove habitat in NTB lays on delta system with an ecosystem width of more than 1 km inland. Mangrove meets the coastal space like the former ponds. Different condition on small islands near Lombok Island, Gili Lawang and Gili Sulat that covered almost 80% with mangrove. Gili Lawang and Gili Sulat are appointed as marine conservation area, and mangrove grows well at those place. Figure 3 shows mangrove mapping results in East Lombok. In the mainland, mangrove grew in the delta, spread like patches in specific coastal. Mangrove's extents based on canopy density slicing are listed in (Table 4), where the largest categorized at dense class (4) with 756,0154 ha of mangrove area. Using Formosat image, Sidik and Kusuma [13] state that “Dense class” was also found as the largest area (4,409,024 m²) based on canopy density using NDVI in Gili Sulat and Gili Lawang, East Lombok.
Escalation of mangrove extent had been noticed, where in 2009, only 1,492.56ha mangrove area of East Lombok were recorded [8].

**Table 3. Overall accuracy (%) for land cover and canopy density interpretation**

| Land cover | Canopy Density |
|------------|----------------|
| Bali       | 89.33%         |
| Nusa Tenggara Barat (NTB) | 85.26%         |
| Nusa Tenggara Timur (NTT) |                |

| Canopy Density | Very Rare | Rare | Moderate | Dense | Very Dense | Total | Comm. | PA (%) |
|----------------|-----------|------|----------|-------|------------|-------|-------|--------|
| Very Rare      | 25        | 2    | 2        | 1     | 30         | 83.33 |
| Rare           | 4         | 43   | 3        | 3     | 53         | 81.13 |
| Moderate       | 1         | 2    | 64       | 10    | 78         | 82.05 |
| Dense          | 6         | 79   | 2        | 32    | 87         | 90.80 |
| Very Dense     | 1         | 4    | 32       |       | 37         | 86.49 |

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| Survey  | 30 | 47 | 76 | 97 | 35 | 285 |
|---------|----|----|----|----|----|-----|
| Omission| 16.67 | 8.51 | 15.79 | 18.56 | 8.57 | 85.26 |

| UA (%) | 83.33 | 91.49 | 84.21 | 81.44 | 91.43 | 85.26 |

| Land cover | A | B | C | D | E | F | G | H | Total | Comm. | PA (%) |
|------------|---|---|---|---|---|---|---|---|-------|-------|--------|
| A          | 105 | 4 | 1 | 1 | 2 | 1 |   |   | 114 | 7.89 | 92.11  |
| B          | 3  | 1 |   |   |   |   |   |   | 4   | 25.00 | 75.00  |
| C          | 7  |   | 1 |   |   |   |   |   | 8   | 12.50 | 87.50  |
| D          | 4  |   | 1 |   |   | 1 |   |   | 5   | 20.00 | 80.00  |
| E          | 4  |   |   |   |   | 4 |   |   | 4   | 0.00  | 100.00 |
| F          |   |   |   |   |   |   |   |   | -    | -     | -      |
| G          | 1  | 1 | 1 | 8 |   |   |   |   | 11  | 27.27 | 72.73  |
| H          | 1  |   | 3 |   |   |   |   | 4 | 25.00 | 75.00  |

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| Survey  | 106 | 7  | 9  | 6  | 6  | 2  | 10 | 4   | 150 |
|---------|-----|----|----|----|----|----|----|-----|-----|
| Omission| 0.94 | 57.14 | 22.22 | 33.33 | 33.33 | 100.00 | 20.00 | 25.00 |

| UA (%) | 99.06 | 42.86 | 77.78 | 66.67 | 66.67 | 0.00 | 80.00 | 75.00 | 89.33 |

* A = Mangrove; B = Forest; C = Plantation; D = Field; E = Settlement; F = Open field; G = Shrubs; H = Ponds
Table 4. Mangrove Area (ha)

| No | Code | Class       | Area (ha)  |
|----|------|-------------|------------|
| 1  | 5    | Very Dense  | 76.4251    |
| 2  | 4    | Dense       | 756.0154   |
| 3  | 3    | Moderate    | 466.9573   |
| 4  | 2    | Rare        | 199.9951   |
| 5  | 1    | Very Rare   | 237.3041   |
|    |      | Total       | 1736.6970  |

East Lombok Regency is one of the regencies with the most mangrove species, and the mangrove crossing profile is initiated by Sonneratia sp. followed by *Avicennia* sp., *Rhizophora* sp., and *Bruguiera* sp. In mapping process, the combination of visual interpretation and utilizing vegetation index (Figure 4) resulted in the slight difference of mangrove class area.

Canopy density mapping using SPOT 6 with spatial resolution 6 meter provides detail information in terms of canopy separation of individual vegetation. Compare to 30 meter of Sentinel image [22] which has low correlation to canopy density, finer spatial resolution (4 – 8 m) delivers mangrove spatial structure from double tree crown to community [23]. However, another benefit of using multispectral images is spectral resolution. Canopy density is also can be identified by optimizing spectral characteristic of the image. NDVI is chosen to enhance the vegetation parameters and it is perfect indices to canopy density mapping in different environmental settings [24]. Most of NDVI applications are to provide ‘greenness’ information of vegetation which is closely related to canopy density.

3.2 Above Ground Biomass Estimation
This study utilizes field data from One Map Mangrove Bali - Nusa Tenggara, which aims to achieve mapping accuracy. In East Lombok, there are 12 sample plots (sized 10 m x 10 m) applying vegetation analysis, including DBH measurement. The mangrove vegetation found in 12 sample plots consisted of *Sonneratia alba*, *Rhizophora mucronata*, *Rhizophora stylosa*, *Rhizophora apiculata*, *Bruguiera gymnorrhiza*, and *Ceriops tagal*. All these species are the primary mangrove plants commonly found in the mangrove area. In 6 sample plots, there were only saplings data to estimate the biomass (Table 5). Allometric equation applied to estimate the above ground biomass in 12 plots and resulted in 12667.3158 kgs of mangrove above ground biomass. However, it had noted that using published allometric standard equation could yield significant error in estimating biomass, due to variation of location and species.

From Table 5, it can be inferred that the amount of mangrove found in a plot affected the amount of biomass. In PS 41, only nine trees and one sapling of *Rhizophora mucronata* recorded, but allometric equation gives a surprising number of aboveground biomass (5531.751kgs in 100 m2) compared with other plot samples. DBH of mangrove trees inside PS 41 is ranged between 20.701 cm – 28.025 cm and are the largest value of DBH than others. The high-density condition does not mean it has higher biomass than low density because it is determined by the observable size of the existing tree in the field. Thus, an observation plot with a small number of big trees can have larger biomass than a plot with a lot of trees. In general, the largest tree biomass is obtained in trees with the largest diameter as well. According to Kusmana et al.[25], the magnitude of biomass determined by diameter, plant height, wood density, and soil fertility. Moreover, this will affect the amount of carbon that can be absorbed even increases. This is due to biomass is closely related to the process of photosynthesis, where biomass will increase if plants absorb CO2 from the air and convert it into organic compounds from photosynthesis process and resulted in plants growth.
**Figure 4.** Mangrove area at East Lombok (left: northern part, right: southern part).

**Table 5.** Above ground biomass (ton) from 12 sample plots at East Lombok

| ID   | Phase | Genera/Species | Diameter (cm) | Quantity | AGB (kg) | Total AGB (kg/100m²) | Total AGB (kg/m²) | AGBs Estimation Model (kg/m²) |
|------|-------|----------------|---------------|----------|----------|----------------------|------------------|-----------------------------|
| PS 32 | Tree  | Sonneratia alba | 10.032 – 17.197 | 10       | 1041.915 | 1059.741             | 10.597           | 0.491                       |
|       | Sapling | Sonneratia alba | 2.87 – 5.41    | 5        | 17.827   |                      |                  |                             |
| PS 33 | Tree  | Rhizophora apiculata | 3.3439 – 6.051 | 11       | 24.041   |                      |                  |                             |
|       | Sapling | Rhizophora apiculata | 2.5478 – 7.3248 | 10       | 38.587   |                      |                  |                             |
| PS 34 | Tree  | Rhizophora mucronata; Sonneratia alba | 11.306 – 16.561 | 5        | 673.936  |                      |                  |                             |
|       | Sapling | Rhizophora mucronata; Sonneratia alba | 5.7325 – 8.5987 | 10       | 73.695   |                      |                  |                             |
| PS 35 | Tree  | Ceriops tagal; Rhizophora apiculata | 2.2293 – 5.0955 | 11       | 21.514   | 21.514               | 0.215            | 0.033                       |
| PS 37 | Tree  |                 |               |          |          |                      |                  |                             |
|       | Sapling |                 |               |          |          |                      |                  |                             |
Biomass approach from vegetation is the result of rationing green index using red band and near-infrared (NIR) band. Since red and NIR band have different characteristic when interacting with leaf due to chlorophyll absorption. The red band is weakly reflected. The vegetation index values are in the range of -1 - 1, where the negative value or below 0 correlated with no vegetation. The NDVI results in Gili Lawang and Gili Sulat are shown in Figure 5. Manually divided into five classes based on the data distribution form, the canopy grade range based on NDVI on the island area are:

Table 6. NDVI Index reclassification

| NDVI     | Canopy Density  |
|----------|-----------------|
| < 0.001  | Non vegetation  |
| 0.0014 - 0.2745 | Very Rare       |
| 0.2745 - 0.3578 | Rare            |
| 0.3578 - 0.4448 | Moderate        |
| 0.4448 - 0.5323 | Dense           |
| 0.5323 - 0.6326 | Very Dense      |
The AGB estimation model implementation results are attached in Table 5. There are only 12 results that depicted from the models due to cloud cover on the imagery used. Based on Table 6, NDV index found in five PS at Gili Sulat and Gili Lawang are ranged between moderate until very dense category (0.393621 – 0.578368). On the purpose of revealing the spatial information of above-ground biomass in a large mangrove area such as Gili Lawang and Gili Sulat, AGBs Estimation Model built by Chandra was implemented. This step is a preliminary trial of an existing model that require NDVI data. The reason of model [11] implementation instead of own build model are:
- Little amount of field data, particularly on Gili Sulat and Gili Lawang
- The size of plot sample in field measurement did not meet the extent required in producing training area with SPOT 6 imagery (spatial resolution 6m x 6m)
- To estimate aboveground biomass for mangrove area in Gili Sulat and Gili Lawang based on the model that built in the tropical area, particularly southern part of Indonesia and had similar genera variation for mangrove. Further, to avoid extrapolating AGB content from the field into the mangrove area.

Above ground biomass estimation using model derived from the medium resolution of optical image data adopted from Budi [11] found to be low accurate. The high difference of spatial image resolution used between model [11] and this study can be the main reason for the difference of resulted AGB as well. And, less biophysical parameters used to predict AGB also caused inaccurate prediction. A previous study [16] mapped AGB using important ecological attributes such as elevation as a predictor in the model. The regression equation offered biomass simulation and revealed pattern of organic matter that differs due to latitude [26]. Nevertheless, there are some limitations in the model. The model was built based on SPOT XS image with 20 m x 20 m spatial resolution, and it was not the best model to explain the relationship between biomass and vegetation index. The best relation had shown by estimating biomass using Infrared Index between NIR and MIR (Krieger et al. in [11]). The unavailability of MIR band in this research became one of data shortcoming. Employing the AGBs estimation model using NDVI in Figure 5 yielded 0.00198 kg/m2 of aboveground biomass for all mangroves area at Gili Lawang and Gili Sulat, similar to 881,677 kg of biomass in the whole region.

Figure 5. The NDVI result (left) and AGBs estimation using model (right) for Gili Sulat and Gili Lawang, East Lombok
However, the AGB estimation between using allometric equation and model did not show the same value. The result from allometric equation seemed higher than those predicted from AGB model. It could not conclude that the model does not accurately yield above-ground biomass information since there was no sufficient data for validation.

4. Conclusions
Remote sensing data has been widely used to map biophysical characteristics of mangrove. This study demonstrate that SPOT 6 can be used to extract mangrove canopy density and above ground biomass information. Optical remote sensing data has proven effectively to map mangrove canopy density [24]. Likewise, although it is limited in field data points, this research provide evidence of SPOT 6 data application for mangrove canopy density mapping (accuracy> 85%). And, using this advantage, prediction of above ground biomass can be done as well

NDVI provides better greenness information, however this parameter is not good predictor for AGB mapping. Based on PS 40 point, showed that high NDVI value and canopy density on field survey did not actually represent high AGB. That was different from other PS points which tend to have high AGB with high NDVI value. Mangrove biophysical information extraction using remote sensing data processing needs to be developed. Integration using other geospatial data can be powerful to increase the accuracy of resulted AGB estimation.

5. Suggestions
Due to some of feebleness found in this paper, we suggest to build a survey design that can accommodate both of mapping accuracy and ecological purpose. It is important to digging more information of mangrove or another mapping object while generating spatial accuracy. For AGB estimation, another model based on vegetation index could be implemented to see the comparison.

References
[1] C Giri, E Ochieng, L L Tieszen, Z Zhu, A Singh, T Loveland, J Masek and N Duke 2011 Status and distribution of mangrove forests of the world using earth observation satellite data Glob. Ecol. Biogeogr, vol. 20, no. 1, pp. 154–159
[2] FAO The world’s mangroves 1980-2005 FAO For. Pap., vol. 153, p. 89, 2007.
[3] B Nurkin 1994 Degradation of mangrove forests in South Sulawesi, Indonesia Hydrobiologia, vol. 285, no. 1–3, pp. 271–276
[4] B A Polidoro, K E Carpenter, L Collins, N C Duke, A M Ellison, J C Ellison, E J Farnsworth, E S Fernando, K Kathiresan, N E Koedam, S R Livingstone, T Miyagi, G E Moore, V N Nam, J E Ong, J H Primavera, S G Salmo, J C Sanchezco, S Sukardjo, Y Wang and J W H Yong 2010 The loss of species: Mangrove extinction risk and geographic areas of global concern PLoS One, vol. 5, no. 4
[5] C Kuenzer, A Bluemel, S Gebhardt, T V Quoc and S Dech 2011 Remote sensing of mangrove ecosystems: A review,” Remote Sensing, vol. 3, no. 5, pp. 878–928
[6] R A A L M Agris and R A B Arreto 2010 Mapping and assessment of protection of mangrove habitats in Brazil Panam. J. Aquat. Sci., vol. 5, no. Ong 1995, pp. 546–556
[7] S P Sari and D Rosalina 2016 Mapping and monitoring of mangrove density changes on tin mining area. Procedia Environ. Sci., vol. 33, pp. 436–442
[8] S Hartini, G B Saputro, M Yulianto and Suprajaka 2010 Assessing the used of remotely sensed data for mapping mangroves Indonesia, in 10th WSEAS/IASME International Conference on Electric Power Systems, High Voltages, Electric Machines, POWER’10, 6th WSEAS International Conference on Remote Sensing, REMOTE’10, 2010, pp. 210–215.
[9] J Long, D Napton, C Giri and J Graesser 2014 A Mapping and Monitoring Assessment of the Philippines’ Mangrove Forests from 1990 to 2010. J. Coast. Res., vol. 294, no. 2, pp. 260–271
[10] A Aslan, A F Rahman, M W Warren and S M Robeson 2016 Mapping spatial distribution and biomass of coastal wetland vegetation in Indonesian Papua by combining active and passive
remotely sensed data. Remote Sens. Environ., vol. 183, no. September, pp. 65–81

[11] C Budi 2000 Model Penduga Biomassa dan Indeks Luas Daun menggunakan Data Landsat TM dan SPOT Multispektral (XS) di Hutan Mangrove (Studi Kasus Segara Anakan, Cilacap),” Institut Pertanian Bogor

[12] D Sutaryo 2009 Penghitungan Biomassa: Sebuah pengantar untuk studi karbon dan perdagangan karbon. Bogor: Wetlands International Indonesia Programme

[13] F Sidik and D W Kusuma 2006 Formosat Imagery Formangrove Density Identification In Gili Sulat-Gili Lawangmangrove Forest, East Lombok, Bali

[14] S Budhiman, R Dewanti, C Kusmana and N Puspaningsih 2001 Kerusakan Hutan Mangrove Di Pulau Lombok Menggunakan Data Landsat-TM Dan Sistem Informasi Geografis ( SIG ),” Warta LAPAN, Jakarta, p. 12

[15] O Mutanga, E Adam and M A Cho 2012 High density biomass estimation for wetland vegetation using worldview-2 imagery and random forest regression algorithm Int. J. Appl. Earth Obs. Geoinf., vol. 18, no. 1, pp. 399–406

[16] N R A Jachowski, M S Y Quak, D A Friess, D Duangnamon, E L Webb and A D Ziegler 2013 Mangrove biomass estimation in Southwestern Thailand using machine learning Appl. Geogr., vol. 45, pp. 311–321

[17] O Hamdan, H Khali Aziz and I Mohd Hasmadi 2014 L-band ALOS PAL SAR for biomass estimation of Matang Mangroves, Malaysia Remote Sens. Environ., vol. 155, pp. 69–78

[18] J A Anaya, E Chuvieco and A Palacios-Orueta 2009 Aboveground biomass assessment in Colombia: A remote sensing approach For. Ecol. Manage., vol. 257, no. 4, pp. 1237–1246

[19] A W Rudiastuti, D M Yuwono, Niendyawati, G H Pramono and B. D. Rahmanto 2016 Overview of National Thematic Data Integration (An Experience on One Map Mangrove Sulawesi) IOP Conf. Ser. Earth Environ. Sci., vol. 47, no. 1, p. 12012

[20] A Komiyama, J Eong and S Pourangp 2008 Allometry , biomass , and productivity of mangrove forests : A review, ” Aquat. Bot., vol. 89, pp. 128–137

[21] A R As-syakur and I W S Adnyana 2009 Analisis Indeks Vegetasi Menggunakan Citra Alos/Avnir-2 Dan Sistem Informasi Geografi ( Sig ). J. Bumi Lestari, vol. 9, pp. 1–11

[22] M Wachid, R Hapsara, R Cahyo, G Wahyu, A Syarif, D Umarhadi, N Fitriani, D Ramadhanningrum and W Widyatmanti 2017 Mangrove canopy density analysis using Sentinel- 2A imagery satellite data Mangrove canopy density analysis using Sentinel-2A imagery satellite data IOP Conf. Ser. Earth Environ. Sci., vol. 70

[23] M Kamal, S Phinn and K Johansen 2014 Characterizing the spatial structure of Mangrove features for optimizing image-based mangrove mapping Remote Sens., vol. 6, no. 2, pp. 984–1006

[24] D D Torio 2007 Modelling Canopy Density Variations from Remotely Sensed Data: Implication on Monitoring Floristic and Macro-benthic Properties of Mangrove Ecosystems Dante International Institute for Geo-Information Science and Earth Observation

[25] C Kusmana, S Sabiham, K Abe and H. WATANABE 1992 An Estimation of Above Ground Tree Biomass of a Mangrove Forest in East Sumatra, Indonesia. Tropics, vol. 1, no. 4, pp. 243–257

[26] P Saenger and S C Snedaker 1993 Pantropical Trends in Mangrove Aboveground Biomass and Annual Litterfall Oecologia, vol. 96, no. 3, pp. 293–299

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