

## ESTIMATION OF MANGROVE CARBON STOCK ABOVEGROUND IN TANJUNG API-API, SOUTH SUMATERA

### ESTIMASI STOK KARBON MANGROVE ABOVEGROUND DI TANJUNG API-API, SUMATERA SELATAN

**Anna Ida Sunaryo Purwiyanto\* dan Fitri Agustriani**  
Marine Science Department, Sriwijaya University, Palembang  
\*E-mail: [anna\\_is\\_purwiyanto@unsri.ac.id](mailto:anna_is_purwiyanto@unsri.ac.id)

#### ABSTRACT

The rapid development of infrastructure that occurred in the area of Tanjung Api-api resulted in changes in the function of mangrove land along the coast. Directly, this also impacts on the sustainability of ecological functions of mangroves. This study aims to estimate changes (prior to infrastructure development and current conditions) of aboveground carbon reserves stored in mangrove forests in Tanjung Api-api. This research was conducted in June-August 2016. Carbon stocks in mangrove along Tanjung Api-api were conducted by surveying the mangrove species and density, and then calculating biomass and carbon stock using allometric equation. While changes in carbon stocks are calculated by converting changes in mangrove area before and after infrastructure development to carbon stock value. The change of mangrove area was done by doing image data processing in 2005 and 2016. The results showed that mangrove Tanjung Api-api has 9 species of mangrove with total mangrove aboveground biomass of Tanjung Api-api is 1.1498 Mg.ha<sup>-1</sup> and stored carbon of 0.5235 MgC.ha<sup>-1</sup> and able to absorb CO<sub>2</sub> of 1.1921 MgC.ha<sup>-1</sup>. The result of satellite image processing shows that there is a reduction of mangrove land of 1056.6 ha during the last 11 years from 9741.15 ha in 2005 (before development) to 8684.55 ha in 2016. Thus, there is a decrease of mangrove biomass by 1214.894 Mg, carbon stock is reduced by 553.090 MgC and CO<sub>2</sub> uptake is reduced by 2029.84 MgC.

**Keywords :** aboveground, CO<sub>2</sub>, mangrove, Tanjung Api-api

#### ABSTRAK

Pesatnya pembangunan infrastruktur yang terjadi di kawasan Tanjung Api-api mengakibatkan perubahan fungsi lahan mangrove di sepanjang pesisir. Secara langsung, hal ini juga berimbas pada keberlangsungan fungsi ekologis mangrove. Penelitian ini bertujuan untuk mengestimasi perubahan (sebelum pembangunan infrastruktur dan kondisi terbaru) cadangan karbon above ground yang tersimpan dalam hutan mangrove di Tanjung Api-api. Penelitian ini dilakukan pada Juni-Agustus 2016. Cadangan karbon di mangrove sepanjang Tanjung Api-api dilakukan dengan melakukan survei jenis dan kerapatan mangrove, dan kemudian dilakukan penghitungan biomassa dan cadangan karbon menggunakan persamaan alometrik. Perubahan cadangan karbon dihitung dengan mengkonversi perubahan luas areal mangrove sebelum dan sesudah pembangunan infrastruktur terhadap nilai cadangan karbon. Perubahan luas areal mangrove dilakukan dengan melakukan pengolahan data citra tahun 2005 dan 2016. Hasil penelitian menunjukkan bahwa mangrove Tanjung Api-api memiliki 9 jenis mangrove dengan total biomassa mangrove di atas permukaan tanah di pesisir Tanjung Api-api adalah sebesar 1.1498 Mg.ha<sup>-1</sup> dan karbon tersimpan 0.5235 MgC.ha<sup>-1</sup> dan mampu menyerap CO<sub>2</sub> sebesar 1.1921 MgC.ha<sup>-1</sup>. Hasil pengolahan citra satelit menunjukkan adanya pengurangan lahan mangrove sebesar 1056,6 ha selama 11 tahun terakhir, yaitu dari 9741,15 ha pada tahun 2005 (sebelum pembangunan) menjadi 8684,55 ha pada tahun 2016. Sehingga, terjadi penurunan biomassa mangrove sebesar 1214.894 Mg. Karbon tersimpan berkurang sebesar 553.090 MgC dan serapan CO<sub>2</sub> berkurang sebesar 2029.84 MgC.

**Kata kunci :** aboveground, mangrove, CO<sub>2</sub>, Tanjung Api-api

## I. INTRODUCTION

Mangrove forest is a tropical and sub-tropical vegetation community that is able to grow and develop in tidal areas of sea water. The typical root system is a way of adapting to a particular habitat (Bengen, 2000). Similar to the forest ecosystem in general, mangrove forest ecosystems also have a role as an absorber of carbon dioxide (CO<sub>2</sub>) so that mangrove is very important and relevant to climate change. About 50% of the total forest carbon is stored in mangrove forest vegetation. The carbon stocks are stored both in the aboveground, such as leaves and stems, as well as on belowground, such as roots and litter that have fallen to the ground. Nevertheless, carbon deposits by aboveground of mangrove will be larger than the belowground, reaching 88.26% above the ground and only 14.08% at belowground (Mashaly *et al.*, 2016). The calculation of carbon stock can be done by knowing the amount of mangrove biomass itself and using allometry for the calculation of carbon stock. Mangrove biomass can be done by mangrove logging in the sample area. But of course, this is hard to do and even becomes illegal because one of the consequence is just the increase in the amount of carbon in the atmosphere. Therefore, a method of allometry was developed using stem diameter, height of mangrove and wood density for consideration of calculation (Komiya *et al.*, 2008; Medeiros and Sampaio, 2008; Fu and Wu, 2011).

Tanjung Api-api is administratively a part of coastal area of South Sumatra which has an important function. The inauguration of Tanjung Api-api area as a special economic area resulted in the development of South Sumatra much focused in Tanjung Api-api area, ranging from port development to industry. This makes Tanjung Api-api area a strategic area in infrastructure change. The development of adequate infrastructure for the achievement of government goals in developing Tanjung Api-api area will of

course lead to changes in the ecosystem in the form of reduction of mangrove area. Continuously, this will lead to changes in mangrove function, especially with regard to ongoing global warming (IPCC, 2002). Van der Werf *et al.* (2009) suggests that deforestation and degradation of mangrove ecosystems cause CO<sub>2</sub> emissions to atmosphere into the second largest after fuel combustion.

Research on carbon stocks in the area of Tanjung Api-api has been done before, but still only on the estuary that faces the sea. Total carbon stored in mangrove (above and belowground) reached 6000 MgC.ha<sup>-1</sup> (Melki and Isnaini, 2014). The value was large enough to support mangrove function in absorbing atmospheric carbon. Especially considering generally, aboveground mangrove biomass in tropical wetlands was 0.099 Mg of dry matter.ha<sup>-1</sup> (Ajonina, 2008 in Mashaly, 2016). Therefore, this study aims to estimate the changes (prior to infrastructure development and the latest condition) of above ground carbon reserves stored in mangrove forests in Tanjung Api-api.

## II. METHODS

The research was conducted along the Tanjung Api-api area from June to August 2016. Sampling was conducted on 5 stations representing each coastal area in Tanjung Api-api. Tanjung Api-api has a fairly thick mangrove area, but this research was focused on the area along the coast, considering the change of mangrove area concentrated in the coastal area. Map of research location can be seen in Figure 1.

### 2.1. Research Methods

#### 2.1.1. Image Processing

The image data used include image data prior to the construction of ports and industry, and the latest image data. Image processed through image recovery procedure, image enhancement, geometric and radiometric correction, classification and determination of the extent of mangrove.

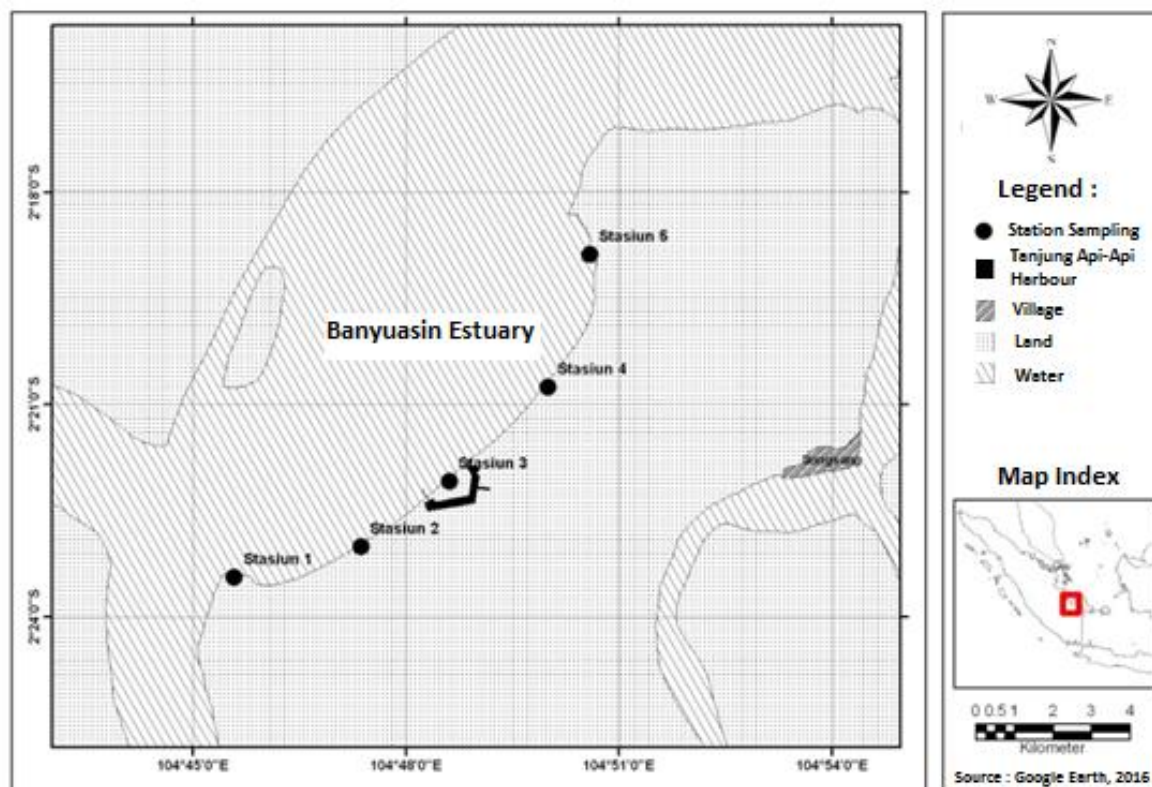


Figure 1. Research location.

This processing is intended to obtain the areas of mangrove Tanjung Api-api overall, including changes in the mangrove area. The imagery used is the 2005 image that represents the condition of mangrove before the infrastructure development and the latest mangrove condition in 2016.

## 2.2. Field Sampling

Samples mangrove were taken including the sample stems, twigs, and leaves. Sampling was done by making a mangrove plot refers to the simple sampling methods according to Manuri *et al.* (2011). Simple sampling is one of the common sampling techniques performed on mangrove carbon analysis. This method is used in areas where initial data on estimates of carbon stock distribution are not available. This method does not classify sample populations based on certain considerations so that the variation between plots becomes larger (Manuri *et al.*, 2011). The mangroves observed for analyzed

carbon stocks in this study, focused on mangroves having stem diameters (DBH)  $\geq 5$  cm in accordance with Komiyama *et al.* (2005). Therefore, in the sampling method, using 4 subplots representing mangrove size (2 m x 2 m for seedlings, 5 m x 5 m for saplings, 10 m x 10 m for pole and 20 m x 20 m for tree). The grouping was performed in accordance with Lugina *et al.* (2011), Manuri *et al.* (2011) and SNI No. 7724 of 2011 to facilitate the recording of data in the field.

## 2.3. Data Analysis

Data analysis includes calculation of community structure, mangrove biomass, carbon stock estimation, carbon uptake estimation by mangrove and estimated changes in carbon stock. Calculation of mangrove community structure was done to know the distribution of mangrove species and density as carbon absorber. Calculations were performed using the Shannon-Wiener Index which includes relative density (RD<sub>i</sub>),

relative frequency (RFi), relative basal area (RBA) and important value (IV). The equations used are as follows (Ati *et al.*, 2014):

$$RDi = \frac{ni}{\sum n} \times 100 \%$$

$$RFi = \frac{Fi}{\sum F} \times 100 \% \text{ dengan } Fi = \frac{pi}{\sum p}$$

$$RBA = \frac{Ci}{\sum C} \times 100 \% \text{ dengan } Ci = \frac{BA}{A}$$

$$IV = RDi + RFi + RCi \dots \dots \dots (1)$$

Keterangan : ni = number of species i; n = total number of species; pi = number of species i in the observed plot; BA = basal area type; A = area unit width.

Calculation of mangrove biomass was carried out by using equation Komiyama *et al.* (2005):

$$W_{top} = 0.251 \rho D^{2.46} \dots \dots \dots (2)$$

Keterangan: Wtop = biomass on the surface (kg), D = diameter (cm), and ρ = density of wood (g.cm<sup>-3</sup>).

The density value of the wood following the research results Komiyama *et al.* (2005), Kauffman and Donato (2012) and are presented in Table 1.

Table 1. Wood density of mangroves.

Species	Wood Density (gcm <sup>-3</sup> )
<i>Rhizophora apiculata</i>	0.770
<i>Bruguiera gymnorrhiza</i>	0.699
<i>Avicennia alba</i>	0.506
<i>Xylocarpus granatum</i>	0.528
<i>Avicennia marina</i>	0.670
<i>Avicennia officinalis</i>	0.670
<i>Excoecaria agallocha</i>	0.450
<i>Sonneratia alba</i>	0.475
<i>Sonneratia caseolaris</i>	0.340

Carbon content value is obtained using the data and calculated the total biomass with SNI 7724-2011 equation:

$$C_b = 0.47 \times B \dots \dots \dots (3)$$

Notes: C<sub>b</sub> = the carbon content from biomass (kg); B = total biomass (kg)

The uptake of CO<sub>2</sub> was calculated using Brown (1997) equation:

$$CO_2 = 3,67 \times \text{Kandungan Karbon} \dots \dots \dots (4)$$

### III. RESULT AND DISCUSSION

#### 3.1. Mangrove Community Structure

Mangrove vegetation that becomes the object of research is in the size of the mangrove saplings, poles and trees. The size of the grouping criteria is based on the size of the trunk diameter obtained by Teddy *et al.* (2015). Mangrove individuals who have less than 5 cm in diameter are not taken into account in the study. Along Tanjung Api-api found 9 true mangrove species, namely *Avicennia alba*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Rhizophora apiculata*, *Sonneratia alba*, *Sonneratia caseolaris*, *Xylocarpus granatum*. Numbers of mangrove species in Tanjung Api-api were more than mangrove species found in Sembilang National Park. Manuri *et al.* (2011) stated that in Sembilang National Park, only found six species of mangroves with dominance on the type of *Rhizophora apiculata* and *Bruguiera gymnorrhiza*. The distribution of individual distribution of mangroves on the station are presented in Table 2.

Table 2 was seen that each station has different composition of mangrove species, especially at station 5 which is found only by *Sonneratia*. Zurba *et al.* (2017) explains the *Sonneratia* usually likes mud and sand substrate and is often found in coastal areas or estuaries that are protected from waves. Further, described by Kartawinata *et al.* (1978)

Table 2. The composition of mangroves species in Tanjung Api-api.

Station	Species	Range DBH (cm)	Average DBH (cm)	RDi	RFi	RBA	IV
1	<i>Rhizophora apiculata</i>	2.55-44.9	15.139	56.452	30	17.710	104.162
	<i>Bruguiera gymnorhiza</i>	2.55-36.62	14.566	25.806	30	16.758	72.564
	<i>Avicennia alba</i>	2.55-45.22	13.163	11.290	20	15.461	46.752
	<i>Xylocarpus granatum</i>	9.24-41.72	28.901	6.452	20	50.071	76.523
	<i>Rhizophora apiculata</i>	3.82-56.69	13.607	60.656	33.333	14.368	108.357
2	<i>Xylocarpus granatum</i>	8.28-18.79	11.253	4.918	11.111	14.808	30.837
	<i>Avicennia marina</i>	3.5-36.31	16.561	8.197	11.111	42.985	62.293
	<i>Excoecaria agallocha</i>	10.83-12.42	11.624	3.279	11.111	15.802	30.192
	<i>Avicennia alba</i>	5.73-17.2	10.146	22.951	33.333	12.038	68.322
	<i>Avicennia alba</i>	3.5-28.34	11.890	34.694	33.333	19.810	87.837
3	<i>Avicennia marina</i>	3.5-37.9	10.532	53.061	33.333	16.635	103.030
	<i>Rhizophora apiculata</i>	5.73-22.93	11.890	6.122	11.111	18.319	35.552
	<i>Avicennia officinalis</i>	3.5-32.48	10.255	6.122	22.222	45.236	73.580
	<i>Rhizophora apiculata</i>	3.5-41.72	17.407	78.261	50	61.149	189.410
4	<i>Bruguiera gymnorhiza</i>	4.14-24.84	13.340	21.739	50	38.851	110.590
	<i>Sonneratia alba</i>	3.5-23.25	12.208	60.870	50	47.260	158.129
5	<i>Sonneratia caseolaris</i>	4.46-28.98	13.041	39.130	50	52.740	141.871

Keterangan : RDi = relative density; RFi = relative frequency; RBA = relative bassal area; IV = important value.

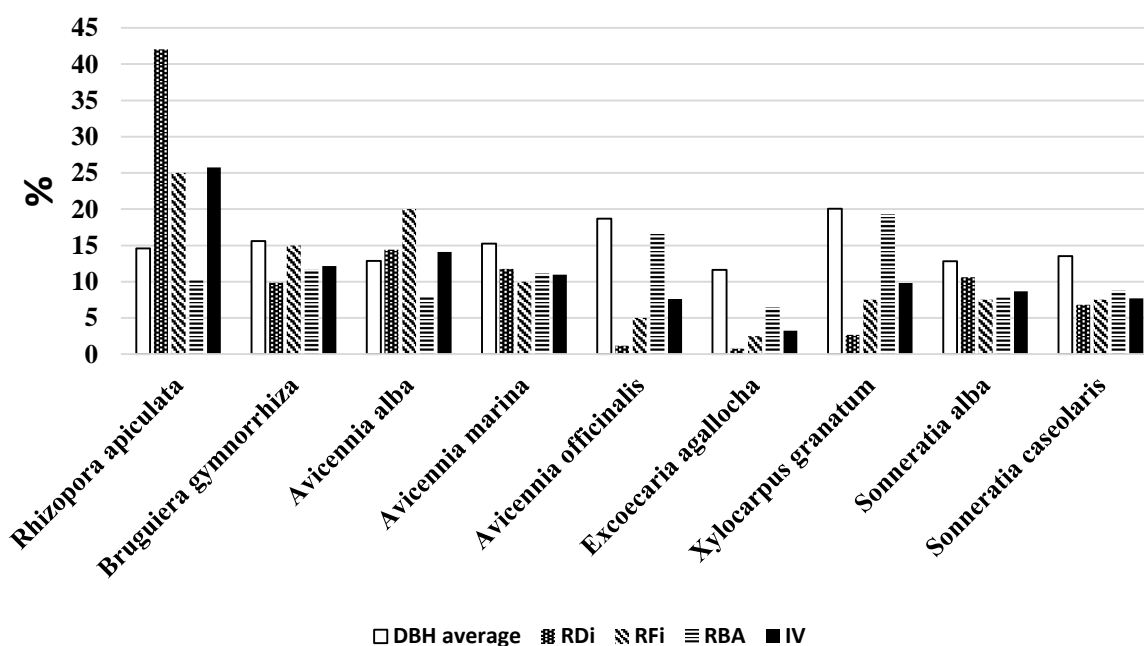


Figure 2. Percentage distribution of Shannon-Wiever Index of mangrove species.

in Kushartono (2009), where this difference is allegedly caused by differences in soil properties especially organic material content. Mardiana (2005) in Nursin *et al.* (2014) also explains that one of the properties that affect the existence of mangrove land is a type of soil that has a smooth texture, low maturity level, salinity and high alkalinity, and often contain layers of acid sulfate or sulfidic materials (paint clay). In addition to differences in the species composition, the difference at each station also looked at the diameter size distribution and most important value. However, based on the diameter size, overall mangrove stakes which were in the category dominates the mangrove ecosystem in Tanjung Api-api. These conditions will further affect carbon stocks held by the mangrove.

Based on Figure 2, generally, *Rhizophora apiculata* has the highest distribution, abundance and even IV compared to other species of mangroves. Although the average diameter of *Rhizophora* is not greater than other species, but the abundance (RDi) and frequency (RFi) of *Rhizophora* were predominate. *Rhizophora* generally reached 26% of the overall IV (Figure 2). Important value (IV) shows that species which has the highest density will have the highest IV. Those results in line with mangrove research analysis in Tanjung Lesung, Banten (Ati *et al.*, 2014).

### 3.2. Biomass, Carbon Stock and CO<sub>2</sub> Uptake

Biomass is defined as the total amount of living matter that is above the surface at a tree and expressed in units of tons of weight per unit area (Kitamura *et al.*, 1997). Measurements of biomass can be performed using allometric equations based on the size of stem diameter and density of wood every species of mangrove. The results of the calculation showed that biomass can be used to determine the carbon stocks contained in plants. Kauffman *et al.* (2011) explained that the stock of carbon in mangrove forests is 46-50% of the total biomass of mangrove. Calculation of carbon stock in mangrove was done by using allometry of Komiyama *et al.* (2005). The result of the calculation of the carbon content is presented in Figure 3 and Table 3.

In Figure 3, the highest biomass and carbon stock is found in *Rhizophora apiculata*. This is suspected because the type of *Rhizophora* is the dominant mangrove species in terms of density and frequency (see Figure 2). This is consistent with Ati *et al.* (2014) which suggests that the potential of mangrove biomass is influenced by soil fertility and tree density. Similar results were also found by Hartoko *et al.* (2014) in Kemujan mangrove Parang Island Karimunjawa National Park and Demak Coastal Area, and Chandra *et al.* (2011) in Sarawak mangrove area.

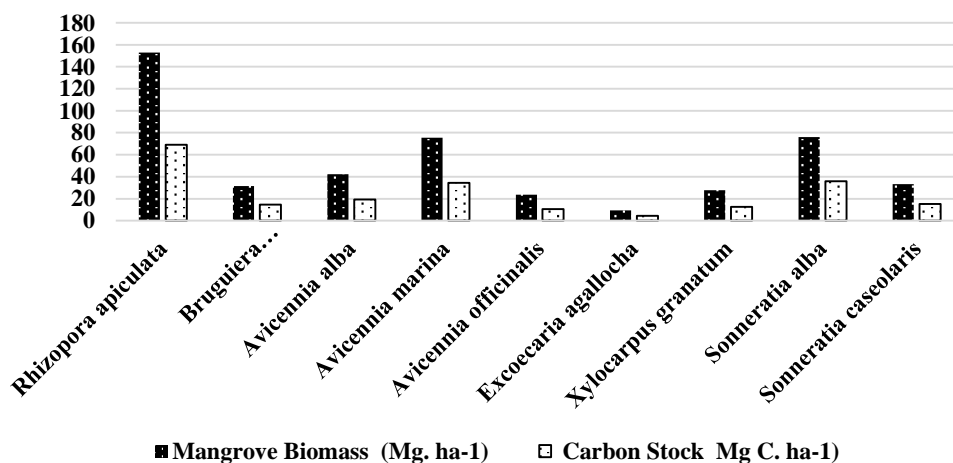


Figure 3. Biomass (Mg. ha<sup>-1</sup>) and carbon stock (MgC. ha<sup>-1</sup>) of each mangrove species.

Table 3. Aboveground biomass, carbon stock and CO<sub>2</sub> uptake by mangrove at each station.

Station	Total above ground biomass (Mg.ha <sup>-1</sup> )	Total above ground C-stock (Mg C.ha <sup>-1</sup> )	Total aboveground CO <sub>2</sub> uptake (Mg C.ha <sup>-1</sup> )
1	0.3223	0.1466	0.5382
2	0.3462	0.1571	0.5764
3	0.1646	0.0751	0.2756
4	0.2073	0.0935	0.3430
5	0.1095	0.0512	0.1879
Total	1.1498	0.5235	1.9211

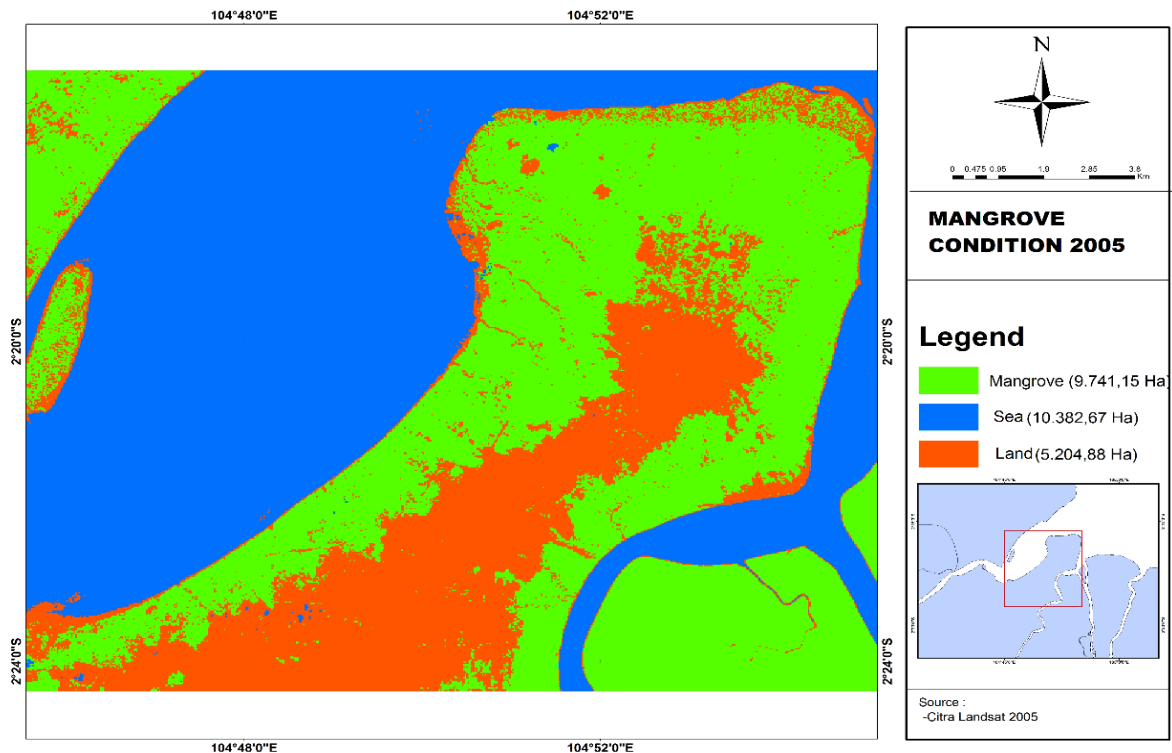
Table 3 shows the total above ground biomass of mangrove in Tanjung Api-api was 1.1498 Mg. ha<sup>-1</sup>. The highest biomass contained at station 2 and the smallest at station 5. Station 1 which had an individual number of almost the same as station 2 but had a smaller biomass value even though the average diameter of the stem was larger. This was because at station 2, found more types of mangroves. Allometric calculations were based on the wood density and stem diameter of each species, so that although the stem diameter was larger but the number of species will have a role in the calculation of biomass. This is evidenced by the correlation value (r) obtained, where the relationship between stem diameter and biomass was 0.813, the relationship between biomass and mangrove density was 0.925 and the relationship between biomass and mangrove species was 0.738. Each correlation indicates a strong relationship, so the causation of the three needs to be considered that will affect the mangrove biomass. In addition, Chandra *et al.* (2011) also confirmed that the variation of mangrove biomass is one of them caused by species. Similar results were also found by Cahyaningrum *et al.* (2014), where the higher number of trees does not necessarily have higher biomass. Based on Table 3, the ability of mangrove Tanjung Api-api was large enough to store carbon, which amounted to 0.5235 MgC. ha<sup>-1</sup> and its able to absorb CO<sub>2</sub> of 1.9211 MgC. ha<sup>-1</sup>. The carbon content was lower when compared to the

mangrove Sembilang National Park which store carbon at 141.0 MgC. ha<sup>-1</sup> (Manuri *et al.*, 2011). However, those ability was higher than the carbon content of mangrove in Segara Anakan which were only able to store carbon by 0.0416 MgC. ha<sup>-1</sup> (Aziz *et al.*, 2013) and mangrove in Dumai Bandar which capable of storing carbon 0.0579 MgC. ha<sup>-1</sup> (Mandarin *et al.*, 2016). This difference is thought to be caused by various factors, such as mangrove species composition, mangrove density, mangrove conservation level, and sediment conditions of mangrove habitat (Sitoe *et al.*, 2014).

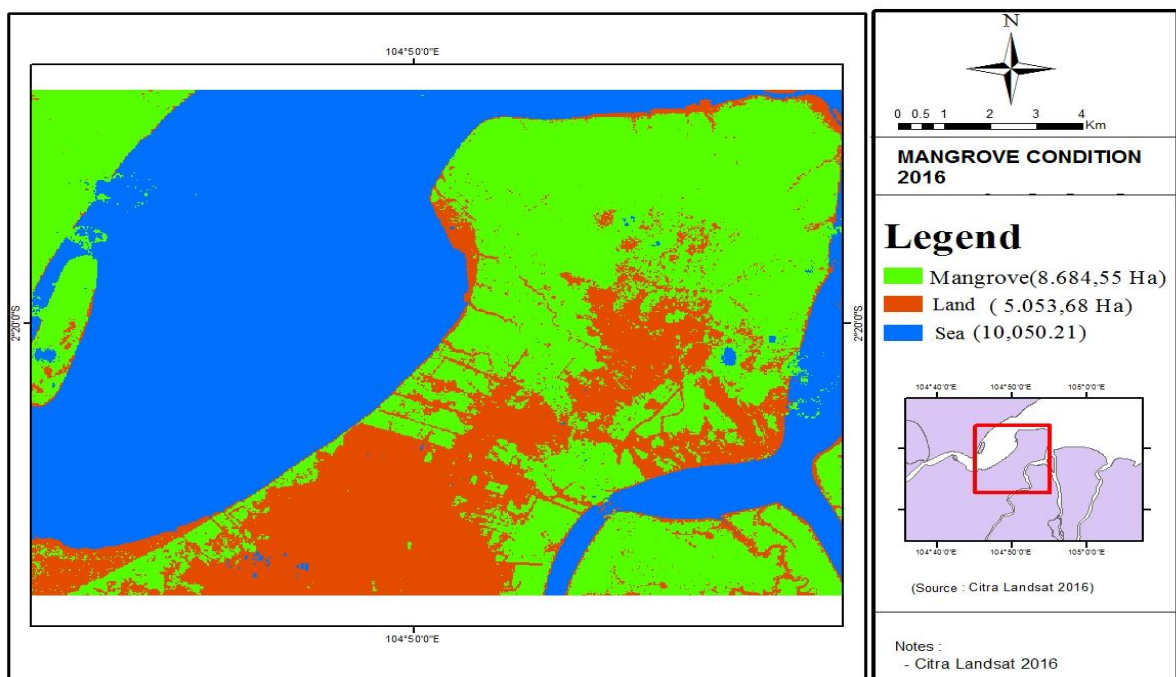
### 3.3. Estimation of Alteration in Carbon Stock and Absorption

Estimation of changes in carbon stocks in mangrove Tanjung Api-api performed by processing image data. Image processing resulted in 2005 and 2016 showed the magnitude changes in the area of mangrove which of course will have an impact on the carbon content changes. The image processing results is shown in Figure 3.

Figure 4 showed the change in the function of the mangrove area of Tanjung Api-api, i.e. the change on green color areas. In 2005, the mangrove area of Tanjung Api-api was 9741.15 ha, and in 2016 was reduced to 8684.550 ha. Or we can say that in 11-year period, the extent of mangrove area of Tanjung Api-api reduced by 10.85%. Changes in the area of mangrove areas, which will directly impact on the change in the amount



(a)



(b)

Figure 3. Results of Image Processing (a). 2005; (b). 2016.

of carbon and CO<sub>2</sub> can be stored. In 2005, with an area of 9741.15 ha, the mangrove areas Tanjung Api-api has above ground

biomass of 11200.516 Mg. That biomass was capable to store amounting to 5099.120 Mg carbon and capable of absorbing CO<sub>2</sub> by



18713.8 Mg. But in 2016, the reduced area of mangrove resulted in above ground biomass also experienced a reduction becomes 9985.622 Mg. The carbon content in the mangrove was also reduced to 4546.03 Mg C and 16683.9 Mg of CO<sub>2</sub> uptake.

Decrease the amount of carbon stocks and CO<sub>2</sub> absorption capability is not only caused by a reduction in the mangrove area, but the conditions were more dominated by mangrove stakes also affects the ability of mangrove plants in absorbing and storing carbon. It was described by Sutaryo (2009), that the largest proportion of carbon stocks will be found in plants that have a large diameter.

#### IV. CONCLUSION

Mangrove area of Tanjung Api-api has 9 species of mangroves with above-ground biomass 1.149Mg. ha<sup>-1</sup>. It supported mangrove ability to store large amounts of carbon, which was about 0.524MgC. ha<sup>-1</sup> and absorb CO<sub>2</sub> of 1.921 MgC. ha<sup>-1</sup>. Nevertheless, the development of infrastructure in Tanjung Api-api resulted in a reduction in the mangrove area of 1056.6 ha or 10.85% in the las 11 years. This reduction resulted in a decrease of 553.090 MgC in aboveground carbon stock and a decrease in mangrove CO<sub>2</sub> uptake of 2029.84 MgC.

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#### REFERENCE

- Ati, R.N.A, A. Rustam, T.L. Kepel, N. Sudirman, M. Astrid, A. Daulat, D.D. Suryono, Y. Puspitaningsih, P. Mang-  
 indaan, and A. Hutahaean. 2014. Karbon stok dan struktur komunitas mangrove sebagai blue carbon di Tanjung Lesung, Banten. *J. Segara*, 10(2):119-127.
- Azizah, M., E.R. Ardli, and E. Sudiana. 2013. Analisis stok karbon hutan mangrove pada berbagai tingkat kerusakan di Segara Anakan Cilacap. *J. Sains Natural Universitas Nusa Bangsa*, 3(2):161–172.
- Brown, S. 1997. Estimating biomass and biomass change of tropical forest. FAO. USA. 134p.
- Bengen, D.G. 2000. Ekosistem dan sumberdaya alam pesisir. Pusat Kajian Sumberdaya Pesisir dan Lautan. Bogor. 62hlm.
- Cahyaningrum, S.T., A. Hartoko, and Suryanti. 2014. Biomassa karbon mangrove pada kawasan mangrove Pulau Kemujan Taman Nasional Karimunjawa. *Diponegoro J. of Maquares*, 3(3):34-42.
- Chandra, I.A., G. Seca, and A. Hena. 2011. Aboveground biomass production of *Rhizophora apiculata* Blume in Sarawak mangrove forest. *American J. of Agr and Bio Sci*, 6(4):469-474
- Fu, W. and Y. Wu. 2011. Estimation of aboveground biomass of different mangrove trees based on caopy diameter and tree height. *Procedia Environ. Sci.*, 10:2189-2194.
- Hartoko, A., S. Chayaningrum, D.A. Febrianti, D. Ariyanto, and Suryanti. 2014. Carbon biomass algorithms development for mangrove vegetation in Kemujan, Parang Island Karimunjawa National Park and Demak Coastal Area – Indonesia. *Procedia Environ. Sci.*, 23:39 – 47.
- Kauffman, J.B., C. Heider, T.G. Cole, K.A. Dwire, and D.C. Donato. 2011. Ecosystem carbon stocks of micronesian mangrove forest. *Wetlands*, 31:343 – 452.

- Kauffman, J.B. and D.C. Donato. 2012. Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. CIFOR, Bogor. 50p.
- Kitamura, S., C. Anwar, A. Chaniago, and S. Baba. 1997. Handbook of mangrove in Indonesia: Bali and Lombok. International society for mangrove ecosystem. Denpasar. 51p.
- Komiyama, A., S. Pongpan, and S. Kato. 2005. "Common allometric equations for estimating the tree weight of mangroves. *J. of Tropical Ecology* 21:471-477. doi:10.1017/S0266467405002476.
- Kushartono, E.K. 2009. Beberapa aspek biofisik kimia tanah di daerah mangrove Desa Pasar Banggi Kabupaten Rembang. *J. Ilmu Kelautan*, 14(2):76-83.
- Lugina, M., K.L. Ginoga, A. Wibowo, A. Bainnura, dan T. Partiani. 2011. Prosedur operasi standar untuk pengukuran dan perhitungan stok karbon di kawasan konservasi. Pusat Penelitian dan Pengembangan Perubahan Iklim dan Kebijakan. Badan Penelitian dan Pengembangan Kehutanan. Bogor. 34hlm.
- Mandari, D.Z., H. Gunawan, dan M.N. Isda. 2016. Penaksiran biomassa dan karbon tersimpan pada ekosistem hutan mangrove di Kawasan Bandar Bakau Dumai. *J. Riau Biologia*, 1(3):17-23.
- Manuri, S., J. Purbopuspito, and M.W. Warren. 2011. C-stock assessment of mangrove ecosystem at Sembilang National Park, South Sumatra, Indonesia. Technical Report. <https://www.researchgate.net/publication/267512031>. doi:10.13140/2.1.3600.8965
- Mashaly, I.A., A.K. Hegazy, M.A. Aal, and S.A. El-Hussieny. 2016. Habitat-based estimate of carbon content in mangrove *Avicennia marina* (Forssk.) Vierh. of South Sinai, Egypt. *IOSR-J. of Environ, Sci, Toxicol, and Food Tech*, 10(11):8-14.
- Medeiros, T.C.C. and E. Sampaio. 2008. Allometry of aboveground biomass in mangrove species in Itamaracá, Pernambuco, Brazil. *Wetlands Ecol. and Management*, 16:323-330
- Sitoe, A.A., L.J.C. Mandlate, and B.S. Guedes. 2014. Biomass and carbon stocks of Sofala Bay mangrove forests. *Forests*, 5:1967-1981. doi: 10.3390/f5081967.
- Sutaryo. D. 2009. Perhitungan biomassa (sebuah pengantar untuk studi karbon dan perdagangan karbon). Wetlands International Indonesia Programme. Bogor. 48p.
- Teddy, R., T. Tiryana, dan J. Purwanto. 2015. Panduan survei cadangan karbon dan keanekaragaman hayati di Sumatera Selatan. Final Report. German International Cooperation (GIZ) dan Kementerian Lingkungan Hidup dan Kehutanan. Dinas Kehutanan Provinsi Sumatera Selatan. 80p.
- Zurba, N., H. Effendi, and Yonvitner. 2017. Pengelolaan potensi ekosistem mangrove di Kuala Langsa, Aceh. *J. Ilmu dan Teknologi Kelautan Tropis*, 9(1):281-300.

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