Abstract—The research mainly studied the carbon stocks of wetland areas of Indonesia especially Papua, started from the west to the east areas based on the long term surveys. The field study was carried out for 26 days in the field of September 2011. The collected information will be very useful in developing the baseline data of wetlands, especially in selected mangrove ecosystem, soil properties and its carbon stocks. The Objective of research was to measure the amount of carbon stocks including its distribution, and also to monitor C-pools of the mangrove forest in the south of Papua. The representative location of carbon stock sampling was chosen base on differences landform (mangroves) areal from west to east in the south of Papua. There were 3 locations for carbon stocks sampling in Papua, i.e. : 1) Teminabuan - South Sorong as region of West Papua Province, 2) Bintuni as region of West Papua Province, and 3) Timika as region of Papua Province. Five up to six transects were laid in each determined mangroves land. The Field Procedure was based Protocols for Measurement Carbon Stocks in Mangrove Forest. The result showed that the total carbon storage in the mangrove ecosystems ranged from 853.23 to 1311.61 Mg.ha$^{-1}$ with the highest value was located at the mangrove forest in Bintuni. These total carbon stock were exceptionally higher compared to the same forest type of mangrove located around the world. This study pointed out that mangroves in Bintuni is the most significant ecosystems in storing large number of carbon. These imply that the mangrove ecosystem should be considered among strategies for climate change mitigation.

Keywords— C-Stocks, mitigation, wetlands papua.
B. Sampling and Analysis

The Field Procedure was based Protocols for Measurements Carbon Stocks in Mangrove Forest [3], [4], [5]. To determine the biomass of tree of each plot, the measured parameters were main stem diameter (dbh), type of species, and tree height. The values of measured parameters were used in the published allometric equations [2], [6]. Down wood volume was calculated from line intercept data using scaling equations [1], [9].

In each sampled mangrove ecosystem, a transect was laid perpendicular from the river or coast shoreline with no prior knowledge of forest composition or structure. Six transects were laid parallel to each other of each site (or perpendicular to the fringe of water) on representative location. Six plots were established along each transect at 25 m intervals. Measurements and collection of C-Stocks sampling were conducted as described below.

Aboveground pools
- Trees : > 1.3 m height :
  a. Dead
  b. Live by species (in DBH)
     > 100 cm, 50 - 100 cm, 30 - 50 cm, 10 - 30 cm,
     0 - 10 cm
- Palms
- Shrub and Dwarf Mangroves
- Seedling, herbs, litter, pneumatophores
- Downed wood (diameter in cm)
  0.67 cm
  0.67 - 2.54 cm
  2.54 - 7.6 cm
  > 7.6 cm

Belowground pools
- Roots
- Soils (Depth in cm)
  0 - 15 cm, 15 - 30 cm, 30 - 50 cm, 50 - 100 cm,
  > 100 cm

Fig 2. Schematic of plot layout for Mangroves

Analyses of chemical and physical characteristics of the soil samples were carried out at the Laboratory IPB - Bogor. The methods of analyses for soil samples are shown in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Total C (%)</td>
<td>Dry Combustion</td>
</tr>
<tr>
<td>2.</td>
<td>Total N (%)</td>
<td>Kjeldahl</td>
</tr>
<tr>
<td>3.</td>
<td>Bulk Density (g/cm³)</td>
<td>Ring Sample, Drying 60 °C (Oven)</td>
</tr>
</tbody>
</table>

Total Carbon Stock or the Total Ecosystem Carbon Pool

The total carbon stock or pool (carbon density) was estimated by adding all of the component pools, as follow:

a. Each component pool was averaged across all plots (e.g., trees, soil, etc),

b. These average values were then summed together to obtain the total.

(a) Equation for total carbon stock or pool:

\[
\text{Total C stock (Mg/ha) of the sampled stand} = C_{\text{treeAG}} + C_{\text{treeBG}} + C_{\text{dead-tree}} + C_{\text{sap/seed}} + C_{\text{sap/seedBG}} + C_{\text{deadsap/seed}} + C_{\text{nontreeveg}} + C_{\text{woodydebris}} + C_{\text{soil}}
\]

\[C_{\text{treeAG}} = \text{aboveground carbon pools of trees, } C_{\text{treeBG}} = \text{belowground tree carbon pool, } C_{\text{dead-tree}} = \text{the dead tree pool, } C_{\text{sap/seed}} = \text{saplings and seedling carbon pools, } C_{\text{nontreeveg}} = \text{non-tree vegetation carbon pools,}
\]
C_{woodydebris} = \text{downed wood carbon pool}, C_{soil} = \text{the soil carbon pool}.

(b) Equation for total carbon stock of a given project area;  
Total C stock of project area (Mg) = Total C (Mg/ha) \times \text{Area (ha)}

IV. RESULT AND DISCUSSION

A. Distribution of C pools and total C in Mangrove Ecosystems

Above and Belowground C-stocks

The C-stocks of mangrove forest areas ranged from 853.2 to 1311.6 Mg ha$^{-1}$ (Table 2; Fig. 2) and the overall mean of C-stock across these three study areas was 655.9 Mg C ha$^{-1}$. Based on the study of [8], the C stock in upland tropical forest is ranged from 150 to 500 Mg C ha$^{-1}$, therefore this mangrove forest of Bintuni, Timika, and Teminabuan had significantly higher C stock compared to the upland tropical forest. Among these three mangrove forests, Bintuni mangrove contained the largest mean C stock of 1311.6 Mg C ha$^{-1}$, followed by Timika mangrove at 1243.8 Mg C ha$^{-1}$ and Teminabuan mangrove at 853.2 Mg C ha$^{-1}$. The site dominance of each mangrove was also varied whereas Teminabuan areas has more diverse of mangrove species compared to Bintuni and Timika.

**TABLE 2**

<table>
<thead>
<tr>
<th>Ecosystem types</th>
<th>Mangrove ecosystems</th>
<th>Bintuni</th>
<th>Timika</th>
<th>Teminabuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aboveground pools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live trees</td>
<td></td>
<td>212.12</td>
<td>219.24</td>
<td>139.89</td>
</tr>
<tr>
<td>Dead trees</td>
<td></td>
<td>23.03</td>
<td>1.66</td>
<td>1.26</td>
</tr>
<tr>
<td>Down woods</td>
<td></td>
<td>11.4</td>
<td>22.11</td>
<td>13.91</td>
</tr>
<tr>
<td>Total aboveground</td>
<td></td>
<td>246.55</td>
<td>243.01</td>
<td>155.06</td>
</tr>
<tr>
<td>Belowground pools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roots</td>
<td></td>
<td>33.06</td>
<td>35.84</td>
<td>23.26</td>
</tr>
<tr>
<td>Soil</td>
<td></td>
<td>1032</td>
<td>964.9</td>
<td>674.9</td>
</tr>
<tr>
<td>Total belowground</td>
<td></td>
<td>1065.06</td>
<td>1000.74</td>
<td>698.16</td>
</tr>
<tr>
<td>Total Ecosystem C</td>
<td>Stock</td>
<td>1311.61</td>
<td>1243.75</td>
<td>853.22</td>
</tr>
</tbody>
</table>

Most of the aboveground C storage dominated by trees and down wood which contained up to 246.6 Mg C ha$^{-1}$, however belowground pools comprised the largest of C pools which ranged from 698.2 to 1065.1 Mg C ha$^{-1}$ (Table 1). The highest C storage at above and below ground pools was in the Bintuni mangrove and the lowest in Teminabuan mangrove.

Regarding the soil depths, most of the C storage ranged from 10 cm to about 2 m. The C storage in the soil was tended to be higher from the topsoil. This pattern was found in all soil depths of all study areas of mangrove ecosystem. The highest C storage was found in the soil depths of >100 cm. In other words, that the more the soil depth, more of the C storage. Figure 2 shows the C pools and C stocks both in above and below ground of Mangrove Areas of Bintuni, Timika, and Teminabuan sites. Belowground pools of roots and soils had significantly contributed the majority of C storage in this ecosystem.

**Fig 2. Above and belowground carbon pools in Mangrove Areas of Bintuni, Timika, and Teminabuan**

B. The Characteristics of Soil in Mangrove Ecosystems

Soil organic carbon (SOC) is one of the important soil chemistry characteristics in mangrove ecosystems. These soil properties can also be used to estimate the organic matter content in the soil. SOC was also determined according to the soil depth at each study site of Bintuni, Teminabuan and Timika. Figure 3 shows the SOC content at each transects of the mangrove ecosystem in Bintuni (BTN), Teminabuan (TMB) and Timika (TMK) sites. In addition, the SOC content of Teminabuan sites was slightly higher than Bintuni and Timika sites. Regarding to the soil depth, the highest SOC content for these three sites was in the depth of 0-100 cm from the soil surface and it tends to be lower on the depth of >100 cm. This indicated that mangrove areas of Teminabuan and Timika have a high potential of C stocks of belowground especially in the depth of 0-100 cm.

The total N content in the soil of mangrove areas is shown in the Figure 4. Total N content in the soil of mangrove areas of Aranday site ranged from 0.19 to 0.41 %, 0.09 to 0.46% in Timika, and 0.02 to 0.43% in Teminabuan, respectively. Regarding to the soil depth, total N content was also higher in the depth of 0-100 cm from soil surface, and it tends to be lower when the soil depth was greater than 100 cm. In general, both soil organic carbon and soil total nitrogen have been identified as factors that are important to soil fertility in both managed and natural ecosystems (7).

V. CONCLUSION

The data presented in this study show that mangrove ecosystems stored exceptional high carbon comparing to other ecosystem in the tropics. The result showed that the total carbon storage in the mangrove ecosystems ranged from 853.23 to 1311.61 Mg ha$^{-1}$ with the highest value was located at the mangrove forest in Bintuni. These total carbon stock were exceptionally higher compared to the same forest type of mangrove located around the world. This study pointed out that mangroves in Bintuni is the most significant ecosystems in storing large number of carbon. These imply that the mangrove ecosystem should be considered among strategies for climate change mitigation.
ACKNOWLEDGMENT

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REFERENCES


![Fig 3. Carbon content (%) in Mangrove Ecosystems](image1)

![Fig 4. Nitrogen content (%) in Mangrove Ecosystems](image2)