Species Diversity and Soil Carbon Sequestration Potential of Mangrove Species at Katunggan It Ibajay (KII) Eco-Park in Aklan, Philippines

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ABSTRACT

The Katunggan It Ibajay (KII) Eco-Park (44.22 ha) in Bugtongbato, Ibajay, Aklan, Philippines was selected in this study to determine the species diversity and to quantify the soil carbon sequestration potential of mangrove species. In identifying and recording the trees in the area, five (5) plots measuring 20mx20m were laid-out using quadrat sampling technique. Diversity index and carbon density equations were utilized to determine species diversity and carbon stocks in the soil. The diversity index (H’=1.760) was very low having a total of thirteen species belonging to four (4) recorded families namely Avicenniaceae, Acanthaceae, Rhizophoraceae, and Sonneratiaceae. The soil pH ranged from acidic to slightly acidic. Despite its lean diversity, this mangrove forest which was dominated largely by species that belong to family Rhizophoraceae was still regarded for its great potential to sequester and store a substantial amount of carbon in the upper layer of the soil. Average stored Carbon in the soil was 82.12 tons C ha⁻¹ equivalent to 301.38 tons CO₂e ha⁻¹. Hence, sustainable management strategies and collective efforts should be made to protect and preserve this naturally-grown ecosystem.

Keywords: carbon stock, carbon dioxide equivalent, diversity index, Katunggan It Ibajay (KII), mangroves, species diversity, Aklan, Philippines.

INTRODUCTION

Climate change is one of the primary concerns of humanity today threatening sustainable development. Several pieces of research were conducted to show the effects of greenhouse gas emissions such as carbon dioxide (CO₂) (IPCC, 2001) from human activities on the world’s climate. The increasing problem of greenhouse gas (GHG) emission has brought significant attention to people who contribute to the worsening of climate change considering the vital role of the forest ecosystem in assimilating CO₂ through photosynthesis or sequester carbon in biomass and soil. Previous studies (Murdiyarso et al., 2009; Chen et al., 2012; Kauffman & Donato, 2012; Abino et al., 2014) confirmed that among these ecosystems, the mangrove forest was highly regarded to have great potential in the up-taking of a vast amount of CO₂ in its biomass. Around the world, the global cover of mangrove forest is approximately 0.7% (roughly 140,000 km²) and can store up to 20 billion t C from the atmosphere and ocean; it is comparable to the annual global
CO₂ emission and carbon stock (C-stock) of other forest ecosystems in the world (Donato et al., 2011; Abino et al., 2014).

The mangrove ecosystem also offers coastal protection through wave attenuation and erosion prevention (Gedan et al., 2011). The distinct ability of mangrove forest to provide coastal protection was found evident during the aftermath of some major catastrophes in different parts of the world. Among these disasters are the Indian Ocean tsunami (December 2004), the super typhoon Haiyan (Yolanda, in November 2013) which hit the eastern part of the Philippines, and the extremely severe and destructive tropical cyclone Larry (in March 2006) which hit the eastern Australian coast 60 km south of the city of Cairns in north Queensland (Carnell, 2015; Tibbetts, 2006; Williams et al., 2007; Das & Vincent, 2009). These systems also regulate water quality, serve as critical habitats for many fish and shellfish species, provide wood and other products to local populations, and host a diverse array of rare and endangered species (Barbier et al., 2011). However, the range of services of mangrove ecosystem also dwindled due to significant anthropogenic activities. Recent reports found that the destruction of mangrove forest worldwide is roughly 340,000 to 980,000 hectares (67%) mangrove forest each year which far exceeds the range of heavy losses in other coastal ecosystems like tidal salt marshes (35%) and seagrass beds (29%). Thus, further uncontrolled human destruction would eventually lead mangrove ecosystem in danger of complete collapse (Murray et al., 2011; Pendleton et al., 2012).

Meanwhile, the continuous decline of mangrove forest is also a typical occurrence in the Philippine context. Recent statistics showed that mangrove forest in the country has significantly declined to around 10.5% from 1990-2010. Comparison of estimates produced from the study with selected historical mangrove area estimates revealed that total mangrove area decreased by approximately half (51.8%) from 1918 to 2010 which suggest a significant loss of biodiversity and biomass (Long et al., 2014). Notably, Lasco and Pulhin as cited by Abino et al. (2014) reported that the estimated mean biomass of mangrove forests in the country is around 409 t ha⁻¹ with a corresponding stored carbon of 184 t C ha⁻¹.

Nevertheless, the Katunggan it Ibajay (KII) Eco Park in the town of Ibajay in Aklan, Philippines is home to one of the most diverse mangrove forests in the country. It is a 44.22 ha⁻¹ protected park which boasts a total of 28 true mangrove species or 80% out of the total 35 Philippine mangrove species (Primavera, Sadaba, Lebata, & Altamirano, 2004). The forest is also home to some species of birds and other wildlife like mud lobsters, fiddler crabs, mudskippers and other fauna. Recent studies conducted in the area include the identification of mollusk species, tree species, behaviors and activities of fiddler crabs. However, there has not been a published study regarding species diversity and carbon sequestration potential of mangrove species at the KII Eco Park.

Therefore, the present study is set out to evaluate the diversity of mangrove species in the area and its carbon sequestration potential. Mainly, it aimed to determine the population structure which has a dense cluster of naturally-grown mangrove stands. The study also sought to quantify the amount of carbon stored in the soil and its carbon dioxide equivalent while considering the vital role of mangroves to help mitigate impacts of climate change (Fourqurean et al., 2014). The researchers believed that the result of the present study would serve as the basis for more sustainable management strategies to protect this pristine ecosystem.
Materials and Methods

Study Site

The study was conducted at *Katunggan It Ibajay* (KII) Eco-Park (Figure 1) located in Barangays Naisud-Bugtongbato (11.8047°N, 122.2094°E), Ibajay, Aklan, Philippines. It is 36 km north of the capital town of Kalibo and 1 km away from the National Highway. The KII has a total land area of 44.22 hectares with a diverse 28 mangrove species grown in its natural habitat. It has a 1 km wooden pathway which has been built for visitors visiting the area. Also, the crown jewel of this locality is the magnificent stand of century-old mangrove tree locally known as *bungalon* or *api-api* (*Avicennia rumphiana*) (Figure 2) with a girth of 8m (26ft) and 20 m (66ft) tall (Primavera et al., 2004).

A reconnaissance survey revealed that this area is in a healthy condition because of the active protection conducted by the LGU and Peoples’ Organization of Ibajay, namely the Naisud Mangrove and Aquatic Organization (NAMAO) and Bugtongbato Fisherfolks Association (BFA) from timber poaching activities and fishpond conversion. Mangroves in the area grow mostly in clustered populations dominated by climax forest of large, old *Avicennia rumphiana/Avicennia officinalis* surrounded by zones of *Ceriops decandra*, *mixed Avicennia spp.*, *Avicennia marina*, *Bruguiera sexangula*, and planted *Ceriops tagal* (Lebata et al., 2009). In addition, a rich canopy is also evident as lianas and epiphytes thrive well in the branches of mangrove trees (Figures 2 & 3).
Species Diversity and Soil Carbon Stock Assessment

Experimental Design. This study adopted the protocols developed by Kauffman and Donato (2012) in carbon stock assessment of mangrove forests. Using a meter tape and strings, five (5) plots measuring 20 x 20 meters (400m²) each were distributed in the area using line transect method with reference to the sea (Figure 1). The plots were inside each plot, three (3) smaller plots (as replicates), arranged diagonally measuring 1 x 1 (1m²), were established to collect soil samples as basis for quantifying soil bulk densities and carbon content in the area (Figure 4). All identified species were sequentially recorded and accounted according to its growth structure such as mangrove seedlings, saplings and matured.

Data Analysis. Species diversity was computed using Shannon-Weiner Index (Shannon & Weaver, 1963), which measured the distribution and evenness of mangrove species in the area. The difference values for Shannon-Weiner were classified based on the scale developed by Fernando as cited by Gevaña and Pampolina (2010) presented in Table 1. Several studies (see Lumbres et al., 2014; and Abino et al., 2014) also cited this method. Diversity index was calculated using the following formula:

$$H' = -\sum p_i \ln p_i$$

where $H'$ is the diversity index, $p_i$ is the proportion of $i^{th}$ species individuals to total species individuals, and $\ln$ is natural logarithm. The relative values to determine the index of diversity are as follows:

Table 1. Categories of diversity index values.

<table>
<thead>
<tr>
<th>Relative values*</th>
<th>$H'$- Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>&gt; 3.5000</td>
</tr>
<tr>
<td>High</td>
<td>3.0000 – 3.4999</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.5000 – 2.9999</td>
</tr>
<tr>
<td>Low</td>
<td>2.0000 – 2.4999</td>
</tr>
<tr>
<td>Very low</td>
<td>&lt; 1.9999</td>
</tr>
</tbody>
</table>

*Source: Gevaña & Pampolina (2009).

Organic Carbon in the soil was determined by collecting 1 kilogram of soil samples in each plot at a depth of 30 cm. The samples were air-dried and sent immediately to the Bureau of Soil and Water Management (BSWM) in Diliman, Quezon City, Philippines for Organic Matter (OM) content and soil carbon analysis. They were analyzed following the methods of Walkley and Black/Loss of Ignition Method. Soil pH from each plot was also determined using a Digital pH meter (Model: OAKLON).

In determining the bulk density of each plot, three (3) soil samples were collected using metal cylinders of known volume (100 cm³). A cylinder was carefully driven into the upper 5-cm layer of the undisturbed spot inside the 1 m² plot. The extracted sediment core samples were then immediately placed in sealed plastic bags with labels. The gathered samples were immediately
transported to the Soil Laboratory of the College of Agriculture, Forestry and Environmental Sciences (CAFES) of Aklan State University – Banga, Aklan for analysis. The undisturbed cores were weighed and oven-dried at 105°C for two days. Bulk density \((g \text{ cm}^{-3})\) was computed as the ratio of the dry weight \((g)\) of soil sample over its fresh volume \((\text{cm}^3)\) as shown in the formula:

\[
1) \text{BD} \left( \frac{g}{\text{cm}^3} \right) = \frac{\text{Oven Dry Weight}}{\text{Volume of Cylinder}}
\]

On the other hand, the Soil C-stock for each sampling plots were calculated using the two methods of calculation following Donovan (2013):

\[
2) C_T = C_F \times D \times V
\]

where \(C_T\) is total carbon for the layer in metric tons obtained as the product of \(C_F\) (fraction of carbon (percentage carbon divided by 100), \(D\) (bulk density, \(g \text{ cm}^{-3}\)), and \(V\) (volume of the soil layer, \(g \text{ cm}^{-3}\)).

Another shortcut equation giving tons of carbon per hectare was computed as the product of \(T_{\text{cm}}\) (thickness of the sampled layer, cm), \(D\) (density, \(g \text{ cm}^{-3}\)), and \(C\) (%), the percentage of carbon:

\[
3) T = T_{\text{cm}} \times D \times C\ (%)
\]

Further, results obtained from carbon density calculation were then converted to its total carbon dioxide equivalent expressed in tons per hectare (tons ha\(^{-1}\)) to quantify the amount of carbon that will be released into the atmosphere when this ecosystem is left unprotected. It was obtained by multiplying tons of Carbon by 3.67 to get tons of Carbon dioxide \((\text{CO}_2)\) based on the conversion equivalent suggested by Donovan (2013). Furthermore, Soil C stocks (tons ha\(^{-1}\)) were added together to get the total soil C stock; while the amount of carbon that the forest sequesters annually was calculated by dividing the total soil C stock by 12.

**Statistical analysis.** Descriptive statistics such as frequency count, percentage, mean and standard deviation (Laolu & Aremu, 2016) was employed to determine the population structure and soil C-stock for each sampling plots.

**RESULTS**

**Population Structure and Diversity**

Table 2a summarizes the structure & composition of species recorded in the study. Gleaned from the results, Plot 5 has the most abundant number of mangrove individuals dominated by species of C. tagal, C. decandra, and C. philippinensis. The record shows a total of 8,053 (38.76%) individuals resolved into 7,303 seedlings, 287 saplings, and 463 matured mangrove trees. Plot 2 had the least in the count with a total of 822 (3.96%) with 532 seedlings, 184 saplings, and 106 mangrove trees (Figure 5).

Generally, all the plots had a very low diversity index values following a decreasing trend: Plot 2 > Plot 3 > Plot 4 > Plot 5 > Plot 1 (Figure 6). Plot 1 had the lowest index value \((H' = 0.840)\) with only four (4) identified species lower compared to Plots 4 \((H' = 0.947)\) and 5 \((H' = 0.896)\) even with only three (3) species recorded. The result may be due to the number of seedlings present in these plots comparable to Plot 1. The highest index was found in Plot 2 with a diversity index value of \(H' = 1.410\) because of its number of species recorded equivalent to six (6) even it had the lowest total abundance.

On the other hand, the total number of species identified in all sampling plots was thirteen dominated by four (4) families namely: *Avicenniaceae*, *Acanthaceae*, *Rhizophoraceae*, *Barrientos, Apolonio*.
and Sonneratiaceae with a very low diversity index ($H' = 1.760$). Among all the species, *C. decandra* dominated the area of KII with a total of 7,444 (35.84%) individuals (Table 2b).

**Table 2a.** Population structure and diversity per sampling plots.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Species*</th>
<th>Population Structure</th>
<th>Total</th>
<th>$H'$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Seedling</td>
<td>Sapling</td>
<td>Matured</td>
</tr>
<tr>
<td>1</td>
<td>Ai, Ar, Bg, Ct, Nf</td>
<td>1,303</td>
<td>1,501</td>
<td>38</td>
</tr>
<tr>
<td>2</td>
<td>Nf, Rm, Rs, Cd, Bp, Cp</td>
<td>532</td>
<td>184</td>
<td>106</td>
</tr>
<tr>
<td>3</td>
<td>Aa, Ao, Cd, Cp</td>
<td>1,922</td>
<td>667</td>
<td>952</td>
</tr>
<tr>
<td>4</td>
<td>Sa, Cd, Cp</td>
<td>2,981</td>
<td>169</td>
<td>2,414</td>
</tr>
<tr>
<td>5</td>
<td>Ct, Cp, Cd</td>
<td>7,303</td>
<td>287</td>
<td>463</td>
</tr>
</tbody>
</table>


**Table 2b.** Species diversity of mangroves in the area.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>$N$</th>
<th>Percent (%)</th>
<th>$H'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avicenniaceae</td>
<td><em>A. alba</em></td>
<td>767</td>
<td>3.69</td>
<td>-0.122</td>
</tr>
<tr>
<td></td>
<td><em>A. officinalis</em></td>
<td>764</td>
<td>3.68</td>
<td>-0.121</td>
</tr>
<tr>
<td></td>
<td><em>A. rumphiana</em></td>
<td>114</td>
<td>0.55</td>
<td>-0.029</td>
</tr>
<tr>
<td>Acanthaceae</td>
<td><em>A. illicifolius</em></td>
<td>1</td>
<td>0.005</td>
<td>-0.368</td>
</tr>
<tr>
<td>Rhizophoraceae</td>
<td><em>C. decandra</em></td>
<td>7,444</td>
<td>35.84</td>
<td>-0.149</td>
</tr>
<tr>
<td></td>
<td><em>C. tagal</em></td>
<td>1,032</td>
<td>4.97</td>
<td>-0.149</td>
</tr>
<tr>
<td></td>
<td><em>C. philippinensis</em></td>
<td>6,376</td>
<td>30.70</td>
<td>-0.363</td>
</tr>
<tr>
<td></td>
<td><em>N. fruticans</em></td>
<td>1,474</td>
<td>7.10</td>
<td>-0.188</td>
</tr>
<tr>
<td></td>
<td><em>B. gymnorrhiza</em></td>
<td>1,282</td>
<td>6.17</td>
<td>-0.172</td>
</tr>
<tr>
<td></td>
<td><em>B. parviflora</em></td>
<td>27</td>
<td>0.13</td>
<td>-0.009</td>
</tr>
<tr>
<td></td>
<td><em>R. mucronata</em></td>
<td>364</td>
<td>1.75</td>
<td>-0.071</td>
</tr>
<tr>
<td></td>
<td><em>R. stylosa</em></td>
<td>56</td>
<td>0.27</td>
<td>-0.016</td>
</tr>
<tr>
<td>Sonneratiaceae</td>
<td><em>S. alba</em></td>
<td>1,071</td>
<td>5.16</td>
<td>-0.153</td>
</tr>
</tbody>
</table>

Total 20,772 100.00 1.760
Figure 5. Population structure of mangrove species in all sampling plots.

Figure 6.1. Diversity indices in all sampling plots.

Soil physico-chemical properties

Figure 6 presents the physico-chemical properties of the soil in Katunggan It Ibajay Eco-Park. The soils of the area were slightly acidic with an average pH value of 6.09. Among all sampling plots, the lowest pH was 5.79 in Plot 3 (soil under the dominance of *Avicennia* spp); whereas, the highest pH was 6.51 recorded in Plot 5 under the dominance of *C. decandra*.

On the other hand, bulk densities of the soil in the area varied slightly in all sampling plots. Highest bulk density recorded was 2.12 g cm\(^{-3}\) found in Plot 2 while Plot 5 has a density of 1.40 g cm\(^{-3}\). The result may be affected by the soil texture and compaction of the soil in different sampling plots. It also suggests that there were only specific species of mangroves that thrive with a required bulk density in soil. Hence, this finding confirmed the assertion of Sitoe et al. (2014) in Sofala Bay Mangrove Forests that mangrove soils usually have bulk densities ranging from 1.12 g cm\(^{-3}\) to 1.05 g cm\(^{-3}\), in 0–30, 30–60, and 60–100cm depth intervals. Respectively, it did not differ significantly (\(p=0.40\)) across depths.

Soil Carbon Stock

Table 3 presents the results of the analysis of soil gathered in KII. The finding reveals that the amount of Carbon (C) concentrated in the area varies from every sampling plots which follows an increasing trend: Plot 1 > Plot 2 > Plot 3 > Plot 4 > Plot 5. Among the plots, the highest percentage of organic Carbon stored in the soil is Plot 5 (2.16%). The result was significantly affected by the amount of bulk density (1.40 g/cm\(^3\)) and the acidity (6.51) of the soil which was confirmed by Abino et al. (2014). They asserted that the lower the bulk density of the soil, the higher the organic matter content (percent of Organic Carbon (OC) and other nutrients). Likewise, the result may be due to the dominance of *C. decandra* species found in this plot.

On the other hand, Plots 3 and 4 had Carbon concentrations of 1.65% and 1.99%, respectively. This result may be because of the abundance of *C. philippinensis* that thrives on this plot. Meanwhile, plot 2 dominated mostly by *Rhizophora mucronata* (Bakhaw babae) had 1.21% organic carbon concentration in the soil. Plot 1, on the other hand, had the lowest organic
Carbon concentration of 0.94% relative to the growth and abundance of *Nypa fruticans* (Nipa) and *Bruguiera gymnorrhiza* (Pototan) species.

Consequently, we noted that the computed carbon density and carbon dioxide equivalents varied closely in each sampling plot following the sequence: Plot 4 > Plot 5 > Plot 3 > Plot 2 > Plot 1 (Figure 7a-b). The highest carbon stored in the soil was found in Plot 4 amounting to 96.71 tons ha\(^{-1}\) or equivalent to 354.94 tons CO\(_2\)e ha\(^{-1}\) among others. This finding was particularly affected by the amount of bulk density of the soil in this plot which was higher than Plot 5. Comparably, the amount of carbon stored in Plots 3 and 5 was found nearly similar amounting to 90.72% tons ha\(^{-1}\) (332.94 tons CO\(_2\)e ha\(^{-1}\)) and 90.09 tons C ha\(^{-1}\) (330.63 tons CO\(_2\)e ha\(^{-1}\)), respectively. Hence, the computed result was affected by the amount of bulk densities and concentration of soil carbon.

However, the plot (Plot# 2) dominated by *Rhizophora spp.* was found to have contributed on the sequestration of carbon in the upper layer of the soil to about 76.96 tons C ha\(^{-1}\) (282.43 tons CO\(_2\)e ha\(^{-1}\)). But Plot 1 roughly dominated by *Nipa* palms (*Nypa fruticans*) had the lowest stored carbon at a rate of 56.12 tons C ha\(^{-1}\) (205.95 tons CO\(_2\)e ha\(^{-1}\)).

Overall, the carbon density values obtained

<table>
<thead>
<tr>
<th>Plot</th>
<th>OM* (%)</th>
<th>OC* (%)</th>
<th>C(_t^*) (tons ha(^{-1}))</th>
<th>CO(_2)e* (tons ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.62</td>
<td>0.94</td>
<td>56.12</td>
<td>205.95</td>
</tr>
<tr>
<td>2</td>
<td>2.08</td>
<td>1.21</td>
<td>76.96</td>
<td>282.43</td>
</tr>
<tr>
<td>3</td>
<td>2.84</td>
<td>1.65</td>
<td>90.09</td>
<td>330.63</td>
</tr>
<tr>
<td>4</td>
<td>3.42</td>
<td>1.99</td>
<td>96.71</td>
<td>354.94</td>
</tr>
<tr>
<td>5</td>
<td>3.72</td>
<td>2.16</td>
<td>90.72</td>
<td>332.94</td>
</tr>
<tr>
<td>Total</td>
<td>13.68</td>
<td>7.95</td>
<td>410.6</td>
<td>1,506.89</td>
</tr>
<tr>
<td>Mean</td>
<td>2.74</td>
<td>1.59</td>
<td>82.12</td>
<td>301.38</td>
</tr>
<tr>
<td>SD</td>
<td>0.84</td>
<td>0.51</td>
<td>16.22</td>
<td>59.55</td>
</tr>
</tbody>
</table>

*aOM – Organic Matter; OC – Organic Carbon; C\(_t\) – Total Carbon; CO\(_2\)e – Carbon dioxide equivalent.*

**Figure 7a.** Soil C-stock in *Kattunggan It Ibajay* Eco Park.

**Figure 7b.** Total CO\(_2\) equivalent in *Kattunggan It Ibajay* Eco Park.
in the present study summed up to 410.60 tons C ha\(^{-1}\) (1,506.89 tons CO\(_2\)e ha\(^{-1}\)) equivalent to 410.60 Mg C ha\(^{-1}\) carbon stock. Even though this study bears some restrictions due to natural variation in an attempt to compare the soil organic carbon pool of mangrove ecosystem, still, the estimated mean carbon stock was 82.12 tons C ha\(^{-1}\).

DISCUSSION

It can be concluded from the review that this intertidal forest (mangrove forest) is an important sink of CO\(_2\). Therefore, the conduct of this study was pushed through to determine the potential of this naturally-grown mangrove forest of Ibajay, Aklan in sequestering CO\(_2\) in the soil. Likewise, the diversity of mangrove species that thrives in the area made the researchers infer that it can contribute to reducing the amount of increased carbon released into the soil and the atmosphere. This study also explores the variation of carbon concentrations in the soil exhibited by different mangrove species in the area.

Comparably, the result of this study was found higher than the recorded species reported by Gevaña and Pampolina (2010) in Verde Passage Corridor in the province of Batangas, Philippines. This observation suggested a unique formation of mangrove stands wherein only a few number of species particularly those that belong to Family Rhizophoraceae tend to dominate. A similar finding reported on the mangroves of Pagbilao and Padre Burgos, Quezon by ENFOR (2004) and Gevaña et al. (2010) that observed a very low diversity in the bakawan and Avicennia (piapi) vegetations of the area. This observation may be due to some factors that affect the growth of other species regarding the physical (texture, porosity, bulk density, etc.) and chemical (pH, OM, moisture content) properties of the soil, high salinity, tidal inundation, and weather condition. While some authors (Stanley & Lewis, 2009; Kovacs et al., 201; Abino et al., 2014) claimed that low diversity indices of mangroves are due to its unique stand formation compared to other tropical forest ecosystems.

Meanwhile, the average pH value of this mangrove forest was found higher than the findings reported by Arianto et al., (2015) in Awat-Awat Mangrove Forest in Sarawak, Malaysia. The result of this study also confirmed the findings of Sukardjo as cited by Arianto et al. (2015) who reported that species of Avicennia thrive in mangrove soils with a pH ranging from 4.35 to 5.29.

On the other hand, the mean organic Carbon concentration of the area was 1.59% which was considered significant as to the amount of organic matter content of the soil in the area (BSWM, 2016). Several studies conducted (Perie & Ouimet, 2008; Hossain et al., 2012, Gevaña & Pampolina, 2010) also affirmed that soil OM contains about 58% of Organic Carbon; hence, providing enough nutrients to the growth of mangrove trees. However, the total C-stock of this study was found lower than that of the findings of Gevaña and Pampolina (2009) estimating the mean above-ground layer of mangrove forest in Verde Passage, San Juan Batangas at around 103.50 tons C ha\(^{-1}\), as well as of the result found by Abino et al. (2014) in Bahile mangrove forest in Palawan which was estimated to 529.9 tons C ha\(^{-1}\).

In this study, we estimated the mean soil C–stock of KII Eco-park to 82.12 tons C ha\(^{-1}\). This result is much higher than the results reported in North Sulawesi - 61.4 tons ha\(^{-1}\) (Murdiyarso et al., 2009); Okinawa Japan - 80.50 tons ha\(^{-1}\) (Khan et al., 2009); Bengal, India - 60.0 tons ha\(^{-1}\), (Kathiressan et al., 2013); and Southern China - 55.0 tons C ha\(^{-1}\) (Chen et al., 2012). This finding focuses on the high carbon content as most carbon–pool mangrove forests have 703 Mg C ha\(^{-1}\) (Jardine & Siikamaki, 2014). Meanwhile, the assertion of
Fahey et al. (2010) confirms the results of the present study because a massive carbon deposit was found to be stored apparently on the two sources of mangrove forest ecosystem: the living tree biomass and soil organic matter.

Hence, this natural mangrove stand needs to be preserved and protected. The substantial amount of carbon stock in the soil found in the present study is a significant contribution to environmental conservation primarily in an attempt to mitigate the impacts of climate change. Nevertheless, human encroachment is still evident in the area, and some residents neglect the importance of mangroves and regard this area as sewage disposal sites. With the knowledge of its ecological value, the result of this study will serve as basis for action by the following entities: the Local Government Unit of Ibajay, Peoples’ Organization and residents, and other stakeholders to create sustainable programs; the intensification campaign for protection of the area thru information, education, communication (IEC) development; the conduct of training and seminars; and enforcement of legal actions coupled with enough manpower, resources and political will to realize these goals.

Although this study employed various procedures and techniques in determining the species diversity and quantification of stored carbon in the soil, we recommend a further validation of the results to be conducted in the same location. The sampling methodologies of this study could be improved by adding more quadrants and other tools or inventory methods like using Geographic Information System (GIS) Mapping to account the species diversity of the whole area. Moreover, the estimated carbon stock in the area needs further validation following methods employed by other authors (Gevaña and Pampolina, 2010; Abino et al., 2014) in calculating carbon stock in mangroves. Further studies may also be conducted in the same area such as assessing the carbon stock in the below-ground layer of the soil and factors affecting the distribution of soil carbon stock in the area.

CONCLUSION

Mangroves play a significant role in sequestering carbon and reducing greenhouse gases. Despite the very low diversity index recorded from this natural mangrove forest, which covers 44.22 hectares, the researcher grasps its potential to sequester and store a substantial quantity of 410.60 tons C ha\(^{-1}\) (34.22 tons C ha\(^{-1}\) per year). Taking into account the amount of CO\(_2\) equivalent, this much above-ground carbon stock which amounted to 1,506.89 tons CO\(_2\) e ha\(^{-1}\) (125.59 tons CO\(_2\) e ha\(^{-1}\) per year) is a significant amount to manage. If this mangrove forest is exposed to deforestation or any other anthropogenic (human) activities, the area has the potential to release this much CO\(_2\) back into the atmosphere, increasing the high level of atmospheric Greenhouse Gases (GHGs) and eventually aggravating and worsening the impact of climate change.

Therefore, considering the numerous benefits that people can get from this intertidal forest, this study would lead to more efficient and sustainable management strategies for climate change mitigation and continuously conserve mangrove ecosystems for sustainable livelihood among coastal inhabitants who largely depend on it (Abino et al., 2014). It is also vital to explore activities and strategies eligible under Verified Carbon Standard (VCS) such as Reducing Emissions from Deforestation and forest Degradation (REDD+) (www.edf.org), the Reforestation and Revegetation Activities (ARR), the Wetlands Restoration or Conservation (WRC), or combinations of these, to provide maximum flexibility and at the same time protect the benefits from these ecosystems.
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REFERENCES


Fourquarean, J., Johnson, B., Kauffman, J. B., Kennedy, H., Lovelock, C., Alongi, D. M.,...


