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Species diversity, aboveground biomass, and carbon stock of mangrove species in coastal area of Mahaba Island, Placer, Surigao Del Norte

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Abstract

The Philippines is known worldwide for its mangrove rich ecology, which plays an essential role in ecosystem services and climate change mitigation. However, limited information on the ecology and carbon stock of mangroves in Mahaba Island, thus the study was conducted. Twenty plots of 10 m × 10 m were established using the transect line plot method to identify, measure, and record the trees. Meanwhile, aboveground biomass estimation was conducted using a non-destructive method. Based on the results, the diversity index (H' =1.5218) was very low, with a total of five true mangrove species identified. Among the five mangrove species, *Sonneratia alba* and *Rhizophora mucronata* dominated the area in terms of density, frequency, and number of individuals recorded. Mangrove vegetation analysis showed that *S. alba* has the highest importance value index of 115.78%, followed by *R. mucronata* and *Rhizophora apiculata*. The mean aboveground biomass (AGB) of mangroves in Mahaba Island was 1.064968 Mg ha^{-1} and a mean carbon stock of 0.5112 Mg ha^{-1}.

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Introduction

The increase in greenhouse gas (GHGs) concentrations in the atmosphere has become a significant environmental concern (Daba *et al.*, 1996). The current climate change crisis poses a threat to economies, while hastening the extinction of marine biodiversity and habitats (Bindoff *et al.*, 2019). The role of mangrove forests in sequestering substantial amounts of atmospheric carbon dioxide (CO2) and storing carbon in its biomass has been underscored (Suwa *et al.*, 2012; Chen *et al.*, 2012) to mitigate the effects of climate change (FAO, 2006).

Mangrove forests are among the world's most productive ecosystems (Lugo and Snedaker, 1974), thriving in intertidal areas ranging from trees, vines, and ferns to palms (Tomlinson, 1986). It plays a vital role in sustaining the balance of the shoreline ecosystem, is one of the most biologically important ecosystems in coastal areas within the tropical and subtropical regions of the world (Anderson and Chowdhury, 2014), and significantly protects coastal ecosystems. It protects communities from storms that cause deaths and injury, and property damage (Barbier, 2016) and contributes to the ecological equilibrium of an environment. The Philippines, as one of the mega diverse countries, has relatively high mangrove diversity.

It is one of the richest in the world; however, it constantly faces threats from human activities and other environmental problems (Van Lavieren *et al.*, 2012). Overexploitation, conversion of regions to diverse uses, and simultaneous logging of watersheds in the uplands were all noted by the Philippines Department of Environment and Natural Resources in 2005. In consideration of their value to the environment and coastal communities, mangrove conservation should become a priority, and efforts must be invested in finding new and successful methods for conserving the mangrove ecosystem. Assessment of mangrove species plays a critical role in the conservation and protection of the mangrove forest, thus the conduct of the study.

Materials and methods

Study site

Placer, officially the municipality of Placer, is a 4th class municipality in the province of Surigao del Norte, Philippines. The municipality has a land area of 61.29 square kilometers. Placer is in the northeast part of Mindanao Island, facing the Hinatuan Passage to the east. Its territory includes the small islands of Tinago, Banga, and Mahaba, as well as half of Masapelid Island, where barangays Ellaperal, Lakandula, and Sani-Sani are located. Its topography consists of low-rising hills that are interspersed with plains. The Municipality of Placer is approximately 9° north latitude and 125° east longitude on the island of Masapelid. Elevation at these coordinates is estimated at 8.6 meters or 28.1 feet above mean sea level (Fig. 1). This study was conducted explicitly in Mahaba, found on Masapelid Island.

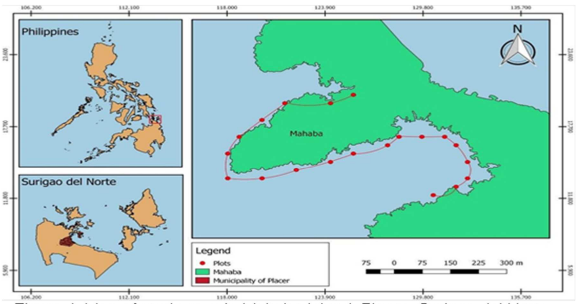

Figure 1. Map of study area in Mahaba Island, Placer, Surigao del Norte

Fig. 1. Map of study area in Mahaba Island, Placer, Surigao del Norte

Sampling technique

Mangrove assessment standard protocol was adapted from English *et al.* (1994) with modifications following Cañizares and Seronay (2016). This study was limited to rapid diversity assessment and did not include the zonation patterns of the mangrove forests. It utilized the transect line plots method to quantitatively describe species diversity, stand structure, and biomass of man- groves (English *et al.*, 1997).

The first transect location started just above the high tide mark. A hand-bearing compass was used to ensure that the transect was perpendicular to the shore pass. Random sampling allows the researcher to quickly determine the composition of mangroves and their type of species because individuals are rarely evenly distributed within an area; it is vital to sample randomly to ensure that it accurately represents the Mangrove population. The Global Positioning System (GPS) used to mark the locations of transects and sampling plots. Unfortunately, there was no size estimate for Mahaba Island.

The plots are fashioned by measuring 10 meters by 10 meters (English *et al.*, 1997) with an interval of 100 m. A 30.48-centimeter wood stake designates each corner, and the section is cordoned with hemp rope. Individual trees' diameter at breast height (DBH) is recorded using a tree caliper (Haglof Mantax). All mangrove species inside the plot were subsequently analyzed. However, saplings and seedlings were not included in this rapid mangrove assessment. Mangrove field guide by Primavera and Dianala (2009) was used to identify the mangrove species inside the plots. Mangroves were identified through their fruits, flowers, leaves, and overall structure.

Species diversity

To assess the floral biodiversity of the said area, Species diversity (Shannon-Wiener index, H′), dominance (Simpson's index, Cd), and evenness (Pielou's index, e) were determined by calculating independently for each location using all species present. Using Paleontological Statistical Software Pack- age (PAST) developed by Hammer *et al.*, 2001 the Shannon-Weiner diversity index, species richness, relative abundance, and evenness were calculated. PAST software is the freeware widely used by many researchers for flora and fauna inventory, including mangroves. Furthermore, generating an abundance curve visually represented the species richness and evenness. The diversity index is determined in this study using the Shannon-Weiner's Index (Shannon and Weaver, 1963) indicates the quantitative description of mangrove habitat in terms of species distribution and evenness. This species diversity index was used in several studies (Gevana and Pampolina, 2009) as shown in Table 1 and calculated, using the following formula.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where: H'= Shannon-Weiner index, S= total individuals of the population sampled, In= the natural logarithm, Pi = total number of individuals belonging to i species

Table 1. Biodiversity scale (Gevana and Pampolina, 2009)

Relative Interpretation	Shannon (H') Index	Evenness Index
Very High	>3.5	0.75-1.00
High	3.00-3.49	0.50-0.74
Moderate	2.50-2.99	0.25-0.49
Low	2.00-2.49	0.15-0.24
Very Low	<1.99	0.05-0.14

Species community structure analysis

Relative density, frequency, dominance, and importance values were calculated for each site to analyze the community structure of the species identified (Netto *et al.*, 2015). Relative density determines which species have the highest count per unit area. Relative frequency establishes which species occur most in the location. Relative dominance identifies the species that constitute the most significant part of the biomass of the mangrove area. Importance value designates which component species are relatively acclimated to Mahaba Island. The importance value index (IVI), which indicates the structural importance of each species in the community, was obtained by adding the percentage values of relative frequency (RF), relative dominance (RDom), and relative density (RD).

The vegetation structure analysis was based on the formula given by Cheng (2004). That is,

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of individuals of all species in the area sampled}}$$

$$\text{Frequency} = \frac{\text{Total number of quadrats in which the species occurred}}{\text{Total number oTotal number of occurrences in the study}}$$

$$\text{Dominance} = \frac{\text{Total basal area of each tree of a species from all plots}}{\text{Total area of all the measured plots}}$$

$$\text{Relative Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative Frequency (\%)} = \frac{\text{Frequency of Species}}{\text{Frequency of all species}} \times 100$$

$$\text{Relative Dominance} = \frac{\text{Total basal area of species}}{\text{Basal area of all species}} \times 100$$

$$\text{Species Importance Value (SIV)} = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Dominace}$$

Aboveground biomass

The volume and aboveground biomass were calculated using the formula of Alongi (2012) and Briggs (1997), respectively, as cited by Puzon *et al.*, 2022. That is, *Volume (V) =* $[\pi D^2/12) \times h^3/(h-b)^2$, where: b = 1.3 m (constant), D is the diameter (m) at 1.3 m (constant), and h is the plant height (m). For above ground biomass (AGB), it is calculated using the formula by Briggs (1997), that is, *AGB = V x wood density*, where *V* is the volume, and uses the wood density for Rhizophora= 0.92, Bruguiera= 0.91, Avicennia=0.74, Sonneratia 0.74, (Alongi, 2012).

Carbon stock

The amount of standing organic matter per unit area is defined as the amount of carbon stored in each tree, represented as the weight of mangrove trees. To estimate carbon stock, the above-ground biomass value is multiplied by a factor of 0.48 (Kauffman and Donato 2012; Howard *et al.*, 2014; Alavaisha and Mangora 2016). Conversion factors are used to convert biomass to carbon. The Carbon equation is *C (kg/tree) = AGB * CF*, where *C* is the carbon stock in kilograms per tree, *ABG* is the aboveground biomass (kg/tree), and Carbon Fraction (CF) of (0.48).

Results and discussion

Species diversity

The total number of individuals in 20 plots is 175, and composed of the species namely: *Sonneratia alba, Rhizophora apiculata, Rhizophora mucronata, Aegiceras corniculatum,* and *Bruguiera parviflora* under four genera of four families as classified by Primavera (2009) were recorded at the natural mangrove stand of Mahaba Island (Table 2).

Among the species recorded in the mangrove stand, *S. alba* was found dominating the mangrove forest with an importance value index of 115.78%. It was followed by *R. mucronata* (63.67 %) and *R. apiculata* (55.03%). The species with the highest importance value belonged to the family Sonneratiacea. The total relative frequency of mangrove species was 100.00, meaning these species occur most in the location (Table 3).

All of the species recorded in the natural mangrove forest of Mahaba Island are among the 42 true mangrove species thriving in the Philippines (Samson and Rollon, 2011). According to FAO (2007), true mangrove species grow only in a mangrove environment. These mangrove species are morphologically, physiologically, and reproductively adapted to saline, waterlogged, and anaerobic condi tions. They are only found in tropical intertidal habitats. They do not extend into terrestrial plant communities (Anon 2007; Polidoro *et al.*, 2010). The DBH of mangroves ranges from 5.0 cm to 45 cm, with a total height varying between 4.0 m to 10.0 m**.** *S. alba* registered the largest DBH and tallest height.

All identified species in the study site, though with decreasing population trend based on the most recent assessment, are of Least Concern conservation status according to International Union for Conservation of Natural List of Threatened Philippine Plants and their Categories (*see DENR Administrative Nos. 2007-01 and 2017-11*). The calculated diversity index (Shannon-Weiner's in- dex), as shown in Table 2, was *H'*= 1.5128, which was very low based on the diversity scale used by Gevana and Pampolina (2009). This could be due to the dominance of a few species in terms of frequency, basal area (dominance), and density over other species.

In contrast to other tropical forest ecosystems, some studies determined that mangroves have very low diversity indices due to their distinctive stand development (Gevana and Pampolina, 2009; Stanley & Lewis, 2009; Kovacs *et al.*, 2011). It is also primarily due to the lack of species variation in the mangrove stands. Several studies coincidentally concluded that the mangroves had very low diversity indices due to their unique stand formation compared to other tropical forest ecosystems (Lu *et al.*, 1998).

Table 2. Species composition and community structure of mangroves in Mahaba Island, Placer, Surigao del Norte

Plot No.	No. of trees	Species	Height				DBH			
			Mean	Min.	Max.	SD	Mean	Min.	Max.	SD
1	14	P, BL, BB, SS, L	7.693	5	11	2.023	11.929	5	29	6.911
2	10	P, BB, SS, L	5.9	5	9	1.287	15	7	25	5.558
3	14	P, BL, BB, SS L	6.571	4	10	1.828	13.429	5	28	6.936
4	8	P, BB, SS, L	7.75	5	10	1.982	14.875	7	23	6.058
5	13	P, BB, SS, L	6.923	5	10	1.553	16.692	6	30	7.889
6	7	P, BL, SS	5.714	4	9	1.704	19.429	8	30	8.791
7	10	P, BB, SS, L	6.5	5	9	1.581	18.6	7	30	8.922
8	8	P, BL, BB	6.25	4	8	1.389	15.5	7	30	7.464
9	8	P, BB, SS	7.5	6	10	1.414	13.875	7	23	6.402
10	13	P, BL, BB, L	8	5	10	1.581	15.692	5	45	12.175
11	7	P, BL, SS, L	6.286	5	8	1.113	14.143	10	30	7.313
12	7	P, BB, SS, L	7.571	5	10	2.149	14.286	10	21	4.386
13	8	P, BL, L	7.375	5	9	1.598	16.375	10	24	5.208
14	6	P, BL, BB	5.667	4	9	1.751	19	5	57	19.586
15	6	P, BL, L	7.167	6	8	0.983	15.5	5	19	5.357
16	5	P, BB, L	5.6	5	6	0.548	22.2	13	41	11.52
17	7	P, BL, BB, SS	6.571	5	9	1.618	18.714	5	33	9.912
18	11	P, BL, BB, SS	7.455	6	10	1.44	18.909	6	52	13.464
19	8	P, BL, L	7	5	10	2.268	26.125	8	64	21.905
20	5	P, BL, BB	7.8	6	9	1.304	21	9	39	15.556

Note*:* P= *Sonneratia alba*, BL = *Rhizophora apiculata*, BB = *Rhizophora mucronata*, SS= *Aegiceras cornilatum*, L=*Bruguiera parviflora*

Table 3. Analyses of importance value and Shannon-Weiner diversity index of man groves in Mahaba Island, Placer, Surigao del Norte.

Species	No. of individual	RF (%)	RDom (%)	RD (%)	IVI (%)	*H'*
Sonneratia alba	59	27.40	54.67	33.71	115.78	0.3666
Rhizophora apiculata	34	17.81	17.79	19.43	55.03	0.3183
Rhizophora mucronata	42	20.55	19.12	24.00	63.67	0.3425
Aegiceras corniculatum	14	16.44	3.29	8.00	27.73	0.2021
Bruguiera parviflora	26	17.81	5.12	14.86	37.79	0.2833
Total	175	100.00	100.00	100.00	300.00	1.5128

Note*:* RF=relative frequency, RDom=relative dominance, RD=relative density, IVI=importance Value Index, *H'*=diversity index

Aboveground biomass and carbon stock

Aboveground biomass measurement is a prerequisite for carbon stock estimation, and so is the latter for calculating carbon dioxide sequestration potential (Intergovernmental Panel on Climate Change 2013; Howard *et al.*, 2014). The trunk diameter, or DBH, is utilized as an independent variable in determining mangrove biomass. In comparison to recorded densities in several coastal habitats in the Philippines, such as San Juan, Batangas (Gevaa and Pampolina, 2009), and Banacon, Bohol, the estimated mean above-ground biomass and C-stock in the Mahaba Island mangrove was similarly high (Camacho *et al.*, 2011).

As shown in Fig. 2, the mean living aboveground biomass (AGB) of mangroves in Mahaba Island was 1.064968 Mg ha^{-1} with the mean carbon stock of 0.5112 Mg ha^{-1}. Notably, the accounted aboveground living biomass of the study site can only be attributed to five species: *S. alba, R. apiculata, R. mucronata, A. corniculatum,* and *B. parviflora,* due to its big stem density, the most critical species had the most contribution. On the stand level, the mangroves forest in Mahaba Island has a total biomass of 186.36942 Mg ha^{-1}**.** In detail, the aboveground biomass ranged from 5.748609 Mg ha^{-1} to 102.57361 Mg ha^{-1} with the mean of 1.03497 Mg ha^{-1} and mean Carbon stock of

0.51118 Mg ha^{-1}. Among the established sample plots, vast quantities of biomass and stored carbon were estimated in those plots with large tree girths.

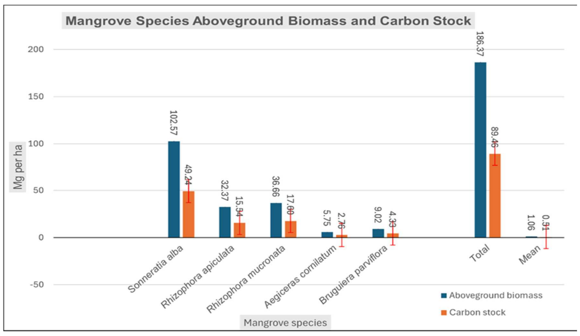

Fig. 2. Aboveground biomass and carbon stock (Mg per ha) of Mangrove species in Mahaba Island, Placer, Surigao del Norte

The biomass estimates acquired in this study are worth comparing to the studies undertaken in different parts of Asia and the Pacific region. The mean aboveground biomass in this study was lower than that of North Sulawesi (Murdiyarso *et al.*, 2009), Okinawa, Japan (Khan *et al.*, 2009), and Sarawak Mangrove Forest in Malaysia (Chandra *et al.*, 2011). The findings in Mahaba Island were also relatively lower than that of Micronesian coastal fringe of Yap (363.0 Mg ha^{-1}) and Palau (225.0 Mg ha^{-1}) (Kauffman *et al.*, 2011).

Conclusion

Based on the results and findings of the study, it was concluded that the mangrove areas of Mahaba Island, Tagana-an, and Surigao del Norte fall under very low biodiversity. The area has a total number of five mangrove species in four families. Among the five mangrove species, *S. alba* and *R. mucronata* dominated the area in terms of density, frequency and number of individuals recorded. It means that the area experienced very low disturbances from anthropogenic activity. Mangrove vegetation analysis showed that *S. alba* had the highest value in terms of relative frequency, relative density, relative dominance, and species importance value, followed by *R. mucronata* and *R. apiculata,* respectively. The mean aboveground biomass living biomass (AGB) of mangroves in Mahaba Island is 1.064968 Mg ha^{-1} with the mean carbon stock of 0.5112 Mg ha^{-1}.

Recommendation

With the presented result, mangroves play a significant role in maintaining an ecological balance between living and nonliving organisms. Conservation effort must be considered knowing that the area has several threatened species and experience anthropogenic damages. Investigating long-term funding and practical incentive systems is critical to reconciling mangrove protection with sustainable lifestyles for coastal residents. Thus, conservation and protection efforts should be continued. Periodic monitoring of this aspect of mangrove ecology and estimation of carbon in the other pools are recommended as this information is equally helpful in mangrove conservation and management. Moreover, further study on developing a biomass equation for different Philippine mangroves species applicable to comprehensive DBH classes is also necessary. For Future studies, it is highly recommended to have a thorough assessment of soil and water analysis along the mangroves area of Mahaba Island, Tagana-an, Surigao del Norte.

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