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Species diversity and aboveground biomass of Mangroves species in the intertidal zone of Magallanes, Agusan Del Norte, Philippines

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Abstract

Mangrove forests are constantly subjected to unsustainable anthropogenic activities, making them vulnerable to climate change impacts, such as sea-level rise, which inevitably contributes to ecosystem deterioration. This loss adds to the dramatic decline in forest biomass, contributing significantly to the dangerously high atmospheric CO_2 levels. Although the Philippines is one of the world's mangrove-rich countries, little is known about the exact quantity of biomass contained in the coastal flora. This study was undertaken to determine the species diversity and aboveground biomass of natural mangrove stands in Magallanes, Agusan del Norte, the Philippines, as well as their potential for carbon sequestration. Fifteen (10m × 10m) plots were laid, and all mangrove species in the quadrant were identified and measured. The Shannon-Weiner diversity of the community was determined using PAST statistical software, while the aboveground biomass was calculated using a non-destructive method. Result showed that there were 8 mangrove species found in the area. Species diversity was found to fall on a low scale of 2.009. Magallanes' dominant value is attributed to the presence and quantity of *E. agallocha* and *B. gymnorrhiza*. The sampled region had a high evenness value of 0.9399. Aboveground biomass was low and ranged from 1.66 ton/ha to 39.52 tons/ha. Biomass examination revealed that the mangrove vegetation in the area has the potential for carbon sequestration, although it falls short on the diversity scale. It is recommended that the area requires reforestation activities.

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Introduction

The Philippine Islands are among the world's top biodiversity 'hotspots', home to 1.9 percent of the world's indigenous plant and animal species (Myers *et al.*, 2000). According to Calumpong and Menez (1997), the Philippines are one of the world's most diverse coastal plant communities, including mangroves. Mangroves are woody dicotyledonous shrubs or trees almost exclusively found in the tropics. Mangrove forests provide ecological services, such as bioprotection from littoral erosion (Naylor *et al.*, 2002), natural breakwaters, attenuation of wave and tsunami energy, and protection from cyclonic storms, in addition to many ecosystem products and services to coastal residents (Alongi, 2002).

The ability of mangrove forests to absorb large amounts of CO_2 from the atmosphere and store it as biomass has recently been highlighted (Suwa *et al.*, 2009; Chen *et al.*, 2012). In addition, the economic significance of this coastal ecosystem, referred to as blue carbon sink, has drawn significant attention from the global community (Lawrence, 2012). However, mangrove forests are constantly subjected to unsustainable anthropogenic activities, which, in addition to making them vulnerable to climate change impacts, such as sea-level rise, inevitably contribute to ecosystem deterioration. This loss adds to the dramatic decline in forest biomass, contributing significantly to the dangerously high atmospheric CO_2 levels. Although the Philippines is one of the world's mangrove-rich countries, little is known about the exact quantity of biomass contained in the coastal flora. Therefore, the goal of this study was to determine the species diversity and biomass, as well as the potential for carbon sequestration, of natural mangrove stands in Magallanes, Agusan del Norte, Philippines.

Materials and methods

Study site

Magallanes is a coastal municipality found in the province of Agusan del Norte, Philippines. The municipality has a land area of 4,431 ha, constituting 1.62% of 273,024 hectares. The topography of the land is mostly flat, rolling, and is surrounded by mountainous areas. Swamps characterized much of the landscape situated at the mouth of the two major rivers in the province, the Agusan and Baug Rivers. The elevation of most of lands is 0.61 meters below sea level. The sampling area is shown in Fig. 1.

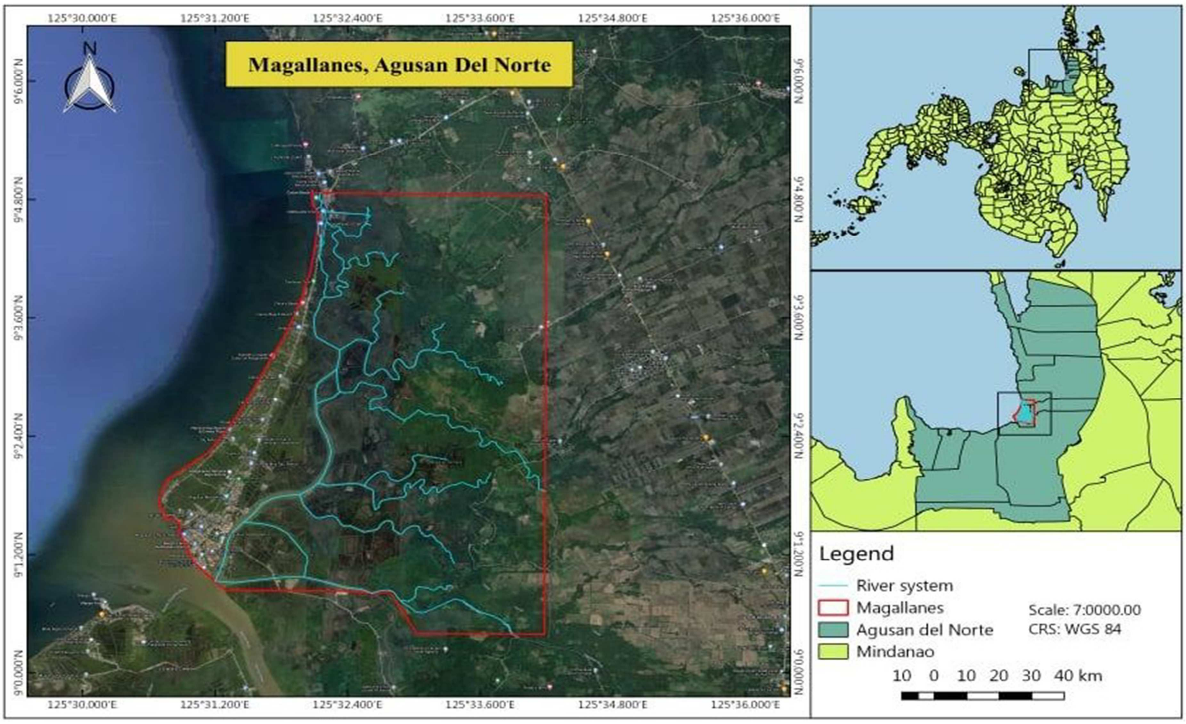

Fig. 1. Map showing the region of interest of the study.

Sampling method

Fifteen (10m × 10m) plots were laid out, all the mangrove species present in the quadrant were identified, and their diameter at breast height (DBH), total height, and basal area were estimated using the standard methodology (Species Diversity Index) (Cintron & Schaeffer-Novelli 1984). Species diversity (Shannon Wiener index, H′), dominance (Simpson's index, Cd), and evenness (Pielou's index, e) were calculated independently for each location using all the species present (Pielou 1966; Shannon & Weaver 1963; Simpson 1949). Necessary secondary data were obtained from the Municipal Environment and Natural Resources Office (MENRO). The amount of aboveground biomass was estimated using a non-destructive formula as a product of tree volume and wood density (Briggs, 1997).

Data Analysis

Species Diversity and Vegetation Structure Analysis

The data gathered were analyzed based on the vegetation structure analysis formula given by Cheng (2004). That is,

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

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

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

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

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

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

Species importance values (SIV) = Relative density + Relative Frequency + Relative Dominance

Diversity indices, such as the Shannon-Weiner diversity index, species dominance, taxonomy, and evenness were calculated using the Paleontological Statistical Software Package (PAST). The PAST software is a free program that many academics use to inventory flora and animals, including mangroves (Hammer *et al.*, 2001). A modified scale was used to classify Shannon-Weiner indices. The diversity values for Shannon-Weiner were classified based on the scale developed by Fernando (1998) (see Table 1).

Table 1. Biodiversity Scale (Fernando, 1998).

Relative Interpretation	Shannon's (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

Volume and above-ground biomass

The volume and aboveground biomass were calculated using the formula of Alongi (2012) and Briggs (1997), respectively. That is, *volume* = $[\pi D^2/12) \times h^3/(h-b)^2$. where b = 1.3 m (constant), D is the diameter (m) at 1.3 m (constant), and h is the plant height (m). For biomass, it is calculated using the formula, *Biomass = V x wood density* (Briggs, 1997). where V is the volume and uses the wood density for Rhizophora= 0.92, Bruguiera= 0.91, Avicennia=0.74, Sonneratia and Excoecaria = 0.74, Ceriops= 0.85, Lumnitzera = 0.88 (Alongi, 2012).

Results and discussion

Species Composition and Distribution of Mangroves

There are 8 species were identified in the intertidal sampling area, namely, *Avicennia alba*, *Sonneratia alba, Rhizophora mucronata, Rhizophora apiculata, Bruguiera gymnorrhiza, Bruguiera parviflora, Sonneratia caseolaris, and Excoecaria agallocha.* These species belong to four families: Avicenniaceae, Rhizophoraceae, Sonneratiaceae, and Euphorbiaceae. The species that dominate the area are *Bruguiera gymnorrhiza* and *Excoecaria agallocha*. The results showed that the Magallanes intertidal zone has a low number of species. This study found that mangrove areas rapidly disappear around the world as they are cleared for coastal development and aquaculture, as well as for lumber and fuel production (2010). These concepts were supported by the reality in the selected sampling locations, which have seen considerable land conversion for a variety of economic reasons.

The municipality of Magallanes has a low number of mangrove species because of anthropogenic disturbances. These activities have changed the soil type from swampy to sandy mud soil, which has contributed to sudden changes in the environment to the true mangroves (Goloran *et al.*, 2020). Additionally, the recently occurring typhoon Rai aggravated the species loss.

The relative frequency, density, and dominance of each mangrove tree species are presented in Table 2. *R. mucronata* had the highest relative frequency (19.19%), followed by *E. agallocha* and *S. caseolaris* (15.99%), whereas *R. apiculata* had the lowest (8.53%). The highest relative density was observed in *E. agallocha* (13.04%), followed by *S. caseolaris* (11.59%), and the lowest was observed in *A. alba* and *B. gymnorrhiza* (6.85%) for relative dominance.

R. mucronata and *E. agallocha* have a high relative frequency and relative density in trees because of their greater adaptability to environmental factors, which promotes optimal growth in comparison to other species. This species' highest relative dominance is also caused by its ability to obtain more nutrients to ensure that the stem volume is large enough and the canopy is wide enough, resulting in its dominance over other types, as well as muddy substrates, and tolerance to high salt levels (Nurdin *et al.*, 2015; Urrego *et al.*, 2014).

Table 2. Relative Frequency (FR), Relative Density (KR), Relative Dominance (DR) and Species Importance Value (SIV) of trees of mangrove species in Magallanes Agusan del Norte.

Species	FR%	KR%	DR%	SIV
B. parviflora	12.79	10.87	12.33	59.65
S. alba	12.79	10.87	12.33	59.65
E. agallocha	15.99	13.04	17.81	46.84
S. caseolaris	15.99	11.59	16.44	44.02
R. mucronata	19.19	7.24	12.33	38.76
B. gymnorrhiza	9.69	7.97	6.85	34.2
R. apiculata	8.53	10.87	8.22	27.62
A. alba	9.69	7.97	6.85	24.51
Total	100	100	100	335.25

All identified mangrove species decreased in terms of population and stability. More than 35% of the world's mangroves have already gone and 50% in countries such as India, the Philippines, and Vietnam. Rapid changes in the mangrove environment clearly affect the species in many ways and are considered to be one of the world's most threatened tropical ecosystems (Numbere, 2018).

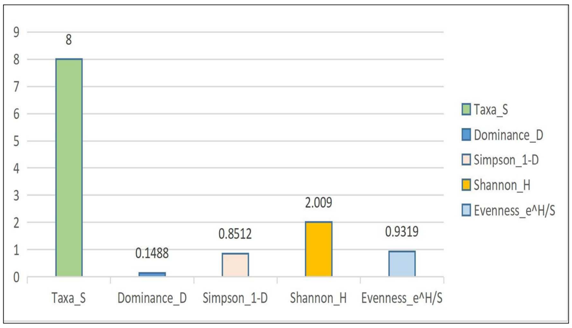

Fig. 2. Species diversity, dominance, abundance, and evenness of the area.

In terms of diversity, it obtained a result of 2.009, which falls under the low diversity scale. This means that the mangrove ecosystem requires further rehabilitation, protection, and conservation. Magallanes' dominant value was attributed to the existence and quantity of *E. agallocha* and *B. gymnorhizza*. The importance of these mangrove species in this area is indicated by their high dominance. The sampled region had a high evenness value of 0.9399. When examining species diversity, evenness and richness were both beneficial.

The number of mangrove species in all selected areas was mostly influenced by anthropogenic factors. Among these include incorrect solid waste disposal, wastewater problems, kaingin, human consumption, illegal housing, land conversion, coastline conversion, and development, to name a few. These findings are consistent with previous research indicating that mangrove habitats are rapidly deteriorating owing to direct anthropogenic influences and global change (Polidoro *et al.*, 2010).

Volume and above ground Biomass of Mangrove Species

The results of the aboveground biomass study are shown in Table 3, where *B. gymnorriza* has the highest volume and aboveground biomass with 4.34 m^3/ha) and 39.52 tons/ha, respectively while *E. agallocha* has the lowest volume and ABG of 0.2 (tons/ha) and 1.66 m^3/ha, respectively. B. gymnorriza had the highest biomass because of its height and diameter. As a result, the larger the tree biomass is, the more carbon is absorbed. The tree density for *R. apiculata* was the highest. Stand density, stand composition and structure, and the quality of mangrove growth sites all influence the increase in the biomass and carbon content of mangrove trees.

Table 3. Volume per hectare and aboveground mangrove species in Magallanes, Agusan del Norte, Philippines.

Species	Volume per hectare (m^3/ha)	Aboveground biomass (ton/ha)
Bruguiera gymnorrhiza	4.34	39.52
Bruguiera parviflora	1.93	17.52
Soneratia alba	1.6	11.85
Rhizophora mucronata	1.14	10.52
Soneratia caseolaris	1.32	9.79
Aegiceras alba	1.02	7.52
Excoecaria agallocha	0.2	1.66
Rhizophora apiculata	12.61	1.37
Rhizophora apiculata	12.61	1.37
Total	12.92	110.99

The ability of mangroves to store carbon can help reduce the increase in natural carbon emissions (Alongi, 2020; Dinilhuda *et al.* 2018; Turner *et al.*, 2009). Mangroves store four times more carbon per hectare than do other tropical forests worldwide. Mangrove forests can moderate climate change by absorbing CO2 from the atmosphere and oceans at a significantly higher rate than terrestrial forests (McLeod *et al.*, 2011). As a result, mangrove forests are a natural resource that must be protected to minimize the impact of climate change.

Conclusion

Species diversity in the intertidal zone of Magallanes falls under a low scale according to the Shannon-Weiner diversity index. The sampled region had a high evenness value of 0.9399. The results of the aboveground biomass study showed that *B. gymnorrhiza* had the highest above-ground biomass.

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Conflict of interest

The authors declare no conflicts of interest regarding the publication of this manuscript.

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