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SPECIES DIVERSITY AND CARBON STOCK OF MANGROVE IN GUIUAN, EASTERN SAMAR, PHILIPPINES

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ABSTRACT

Mangrove forests sequester substantial amounts of atmospheric carbon dioxide, store carbon in their biomass, and have the highest carbon pool of any forest. The Philippines is one of the mangrove-rich countries, with almost 1.9% of the global mangroves. No current published works on mangroves exist in Guiuan, Eastern Samar, Philippines. This study utilized a non-destructive technique through quadrat sampling to identify and measure mangroves' biodiversity and carbon stock. The allometric equation was applied to quantify the carbon stock and Shannon-Wiener diversity index to determine the biodiversity. Twelve species were identified from the 36 sampling plot with 10 × 10 meter. Results showed the mean species evenness of 0.28 and the Shannon-Wiener diversity value of 0.92, indicating very low diversity. The overall aboveground, belowground, total carbon stock, and CO_2 sequestration of 209 t/ha, 76 t/ha, 157 t/ha, and 575 CO_2 t/ha, respectively. The test revealed that comparing the six barangays regarding species diversity and carbon stocks gives no statistically significant difference of 0.032 and 0.046, respectively. Considering the estimated carbon stock and CO_2 equivalent accounted from the tree biomass, the mangrove stands in Guiuan have the potential to store and sequester a large amount of carbon dioxide.

Keywords: Aboveground carbon stocks, belowground carbon stocks, carbon dioxide sequestration, conservation status, mangrove diversity indices.

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INTRODUCTION

Mangrove forests are a biologically essential ecosystem that grows along tropical and subtropical coastlines. They are vital to socioeconomic development because most of the population living along the coast relies heavily on local resources for income (Pototan et al., 2017; Kathiresan, 2012). It provides ecosystem services like habitat, food production, and waste processing. It can also be a source of nutrients for other inshore marine habitats like coral reefs and seagrass beds (Abantao et al., 2015). It also protects coastlines from the catastrophic effects of storm surges, floods, and erosion and filters the water (Chaudhuri et al., 2019).

Moreover, despite its socioeconomic benefits, mangroves are identified as the most threatened habitat. The cleaning and degradation of mangrove forests are due to population growth, aquaculture, urbanization, salt-pond construction, and water diversion (Heenkenda et al., 2014). The Philippines has one of the most mega-diverse mangrove ecosystems worldwide and has at least 50% of known mangrove species and threatened species noted as vulnerable and endangered (Pototan et al., 2021). According to a study by Samson & Rollon (2011), the Philippine mangroves have the most significant number of species - about 42 species belonging to 18 families out of 70 mangrove species around the world. Moreover, the country is also internationally ranked 16th out of the most mangrove-rich countries having an area of 259,600 hectares, almost 1.9% of the global mangrove (Siikamäki et al., 2012).

In the study of Camacho et al. (2011), the mangrove in Banacon, Bohol province, Philippines, is in a healthy condition of storing a large amount of carbon. The researchers used a standard sampling technique and allometric equations to measure the carbon storage of the mangroves. According to the data gathered, a 40-year-old plantation has the most extensive carbon stock, followed by a 15-year-old plantation, then a 20-year-old plantation, and the natural stand.

The Philippines, which lies within the Pacific Typhoon Belt and Pacific Ring of Fire, is one of the world's most disaster-prone countries, with Guiuan being one of the most vulnerable areas. The 2013 super typhoon Yolanda (Haiyan) first landed in Guiuan and annihilated all plantations of many kinds. The mangrove ecosystem was severely disturbed because of the storm surge causing uprooting, stem breakage, leaf defoliation, and mortality (Carlos et al., 2015). The 206 ha plantation of mangroves in barangay Campoyong and Bungtod in Guiuan were unable to grow back six months after it was hit by the typhoon (Alura et al., 2015). With the assistance of Philippine government agencies and NGOs, various livelihood programs on mangrove plantations were established.

Mangrove forests sequester significant amounts of atmospheric carbon dioxide store carbon in their biomass, and have the highest carbon pool of any forest, with nearly half of all absorbed by the mangrove returning to the atmosphere through below- and aboveground-biomass (Abino et al., 2014; Alongi, 2012). Philippine mangrove has a biomass of around 401.8 tons, with approximately 176.8 tons of carbon stored (Camacho et al., 2011). However, climate change and land use are threatening mangrove forests. Thus far, no existing studies or published works related to mangroves in Guiuan. Hence, this study aims to assess mangroves' biodiversity and carbon stock in Guiuan, Eastern Samar.

MATERIALS AND METHODS

Study Site

The study was conducted in the six Barangays - Bungtod, Dalaragan, Sulangan, Pagnamitas, Bucao, and Baras of Guiuan, Eastern Samar, Philippines (Fig. 1). The selection of sites is primarily based on the mangrove stands. The Guiuan peninsula is a northwest-southwest trending landmass on the island of Samar's southern tip covering 175.5 km². The town has flat terrain with no high ground that could be referred to as Extension Mountains. Numerous islands, islets, and coves surround and protect the municipality's southernmost portion (GMRPLS, 2012). Guiuan has a Type II climate category (PAGASA, 2014).

Data Collection

A non-destructive quadrat sampling technique was used to establish 36 sampling plot with 10 × 10 meter to determine the study's species diversity and C stocks. First, a transect line was established that runs 300–500 m from the shoreline point until the end of mangrove vegetation. Then, the plots were laid with a 50-meter distance between plots. Next, mangrove species were identified using plant taxonomy classification. Primavera's (2009) Field Guide to Philippine Mangroves was used to further guide in identifying the mangrove species. For further re-verification, the species were sent to the Department of Environment and Natural Resources Office, Guiaun, Eastern Samar, Philippines. Next, the aboveground biomass was estimated by measuring each mangrove tree's trunk diameter at breast height (dbh 1.3 m) (Kusmana et al., 2019). Dwarf and shrub mangroves that did not reach 1.3 m were included in the computation, where the dbh was recorded at 0.5 m above the ground. A diameter tape and a vernier calliper were used to determine the diameter at breast height (dbh).

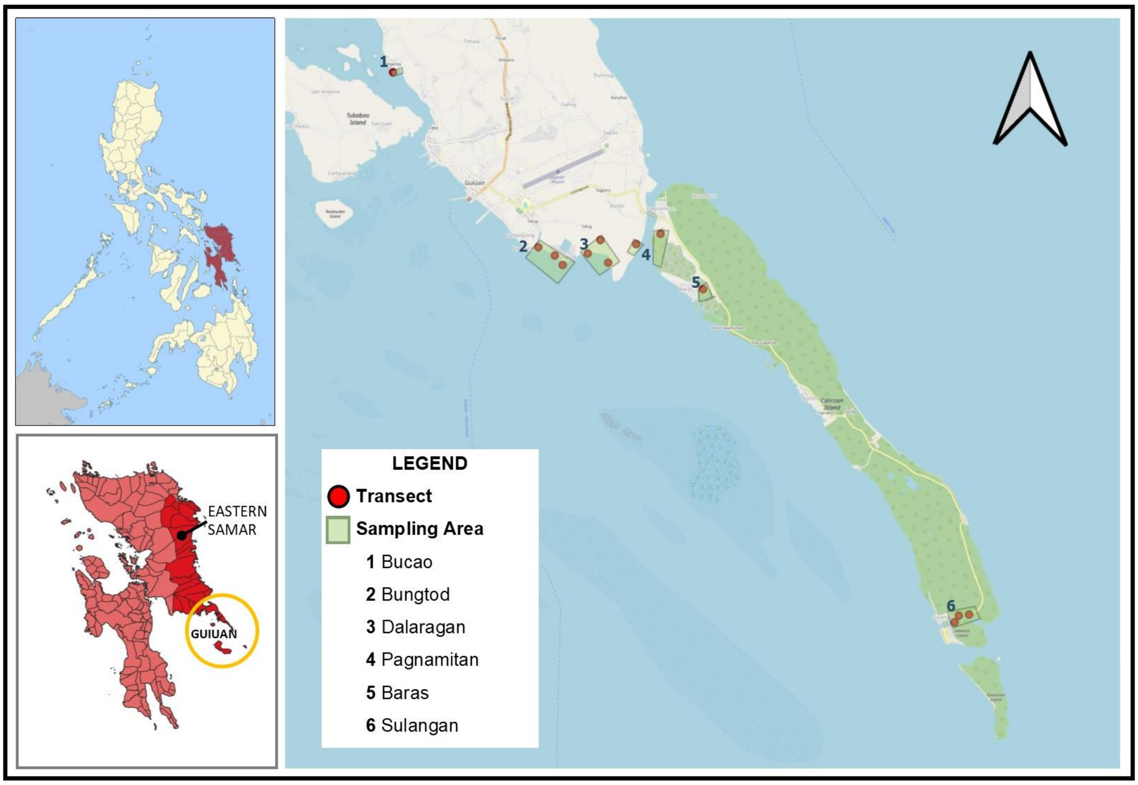

Figure 1. Location map of the study site in Guiuan, Eastern Samar, Philippines

Data Analysis

The diversity index of the Mangrove species was measured using the species abundance, relative abundance, and Shannon-Wiener Diversity Index (Abino et al., 2014). This statistical tool is suitable and has been used in measuring the diversity of species that combines species richness and evenness. Several studies used this species diversity index, which was calculated using the formula:

$$H' = -\sum_{i=1}^{S} Pi \times \ln(Pi)$$

Where: H′ is the diversity index; Pi is the proportion of the total sample represented by species i; and ln is a natural logarithm.

$$\text{Species abundance} = \text{Total no. of individual species found in the area}$$

$$\text{Relative abundance} = \frac{\text{Total no. of species A}}{\text{Total no. of individual of all species recorded}} \times 100$$

$$E = \frac{H'}{\ln(S)}$$

Where: E is the species evenness; H′ is the Shannon-Wiener index; and S is the number of species.

In quantifying stored carbon and estimating the aboveground and belowground biomass of the mangroves based on the diameter at breast height (dbh), the allometric equation (Abino et al., 2014) was used. The following allometric equations were used: aboveground biomass $W_{agb} = 0.25\rho D^{2.46}$; belowground biomass $W_{agb} = 0.199p^{0.899}D^{2.22}$; C – stock = $(W_{agb} - W_{bgb}) \times .55$ (Alemayehu et al., 2014); and CO_2 equivalent = C – stock × 3.67 (Bobon-Carnice & Lina, 2017; Bobon-Carnice et al., 2021). One-way analysis of variance (ANOVA) was used to determine the significant difference in the species diversity of mangroves among the selected barangays. Further, one-way multivariate analysis of variance (one-way MANOVA) and Scheffé's Post Hoc multivariate analysis were used to assess whether there are any differences in aboveground, belowground, and total C stocks among the selected barangays.

RESULTS AND DISCUSSION

Species Diversity

A total of 2,072 mangrove individuals have been recorded from 36 (10 × 10 m) samplings plots from the six selected barangays in Guiuan; 12 species were identified belonging to seven mangrove families, namely; *Aegiceras floridum (14), Avicennia marina (54), Bruguiera gymnorrhiza (13), Bruguiera sexangula (1), Ceriops decandra (2), Pemphis acidula (1), Rhizophora apiculata (1083), Rhizophora mucronata (68), Rhizophora stylosa (758), Scyphiphora hydrophyllacea (4), Sonneratia alba (71),* and *Xylocarpus granatum (3). Rhizophora apiculata, Rhizophora stylosa*, and *Rhizophora mucronata* were the top species found and were widely distributed from the six barangays.

Table 1. Mangrove species identified in the study area with their conservation status

Family	Botanical name	Local name	Conservation status (IUCN; GMRPLS*)
Primulaceae	*Aegiceras floridum*	Saging-saging	Near Threatened
Acanthaeceae	*Avicennia marina*	Bungalon	Least concern
Rhizophoraceae	*Bruguiera gymnorrhiza*	Pototan	Least concern*
Rhizophoraceae	*Bruguiera sexangula*	Pototan	Least concern
Rhizophoraceae	*Ceriops decandra*	Baras-baras	Near Threatened
Lythraceae	*Pemphis acidula*	Bantigi	Least concern
Rhizophoraceae	*Rhizophora apiculata*	Bakawan lalaki	Least concern
Rhizophoraceae	*Rhizophora mucronata*	Bakawan babaye	Least concern
Rhizophoraceae	*Rhizophora stylosa*	Bakawan bato	Least concern
Rubiaceae	*Scyphiphora hydrophyllacea*	Nilad	Least concern
Lythraceae	*Sonneratia alba*	Pagatpat	Least concern
Meliaceae	*Xylocarpus granatum*	Tabigi	Least concern

Following the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, *Aegiceras floridum*, and *Ceriops decandra* are identified as nearly threatened. In contrast, the other identified mangrove species belong to the minor concern category. However, *Bruguiera sexangula* has no record on the IUCN but was assessed by the GMRPLS as the most diminutive concern species. Table 1 presents the mangrove species with their present conservation status.

Diversity level among the Mangroves Tree Species

The analyses of the relative abundance, species evenness, and species diversity index are shown in Table 2. Relative abundance refers to the evenness of distribution of individuals among species *R. apiculata* had the highest relative abundance of 52.27%, followed by *R. stylosa* (36.58%), *Sonneratia alba* (3.43%), *Rhizophora mucronata* (3.28%), *Avicennia marina* (2.61%), *Aegiceras floridum* (0.68%), *Bruguiera gymnorrhiza* (0.63%), *Scyphiphora hydrophyllacea* (0.19%), *Xylocarpus granatum* (0.14%), *Ceriops decandra* (0.10%), and *Bruguiera sexangula* (0.05%) and *Pemphis acidula* (0.05%).

Species evenness measures how evenly the individuals in the community are distributed over the different species (Lemma & Tekalign, 2020). For example, *R. stylosa* rendered 0.06 species evenness while *R. apiculata* rendered 0.05. It was followed by *Rhizophora mucronata* and *Sonneratia alba* with 0.03. Further, *Avicennia marina* had 0.02, while *Scyphiphora hydrophyllacea*, *Bruguiera gymnorrhiza*, *Aegiceras floridum*, *Xylocarpus granatum*, and *Ceriops decandra* rendered a species evenness value of 0.01. However, *Bruguiera sexangula* and *Xylocarpus granatum* recorded no evenness at all.

The species' evenness among the species rendered 0.23, which signified no evenness. It is because there are a few species that are dominating the mangrove stands in Guiuan. The lesser the number is, the more it leans toward a taxon dominating the area (Pototan et al., 2017).

The overall diversity value among the species was H'= 1.13. Based on the scale from Gevaña and Pampolina, this signified very low diversity. It means there is a low variety of the species, although an abundant number is found in the area. The lack of species variation in the mangrove stands is the primary cause for the low diversity level. Another possible reason is planting pre-selected species during reforestation (Picardal et al., 2011).

Table 2. Species Richness, Abundance, Diversity, and Evenness of Mangrove vegetation in Guiuan, Eastern Samar, Philippines

Species	Species Abundance	Relative abundance (%)	H′	Species Evenness
Aegiceras floridum	14	0.68	0.03	0.01
Avicennia marina	54	2.61	0.10	0.02
Bruguiera gymnorrhiza	13	0.63	0.03	0.01
Bruguiera sexangula	1	0.05	0.00	0.00
Ceriops decandra	2	0.10	0.01	0.01
Pemphis acidula	1	0.05	0.00	0.00
Rhizophora apiculata	1,083	52.27	0.34	0.05
Rhizophora mucronata	68	3.28	0.11	0.03
Rhizophora stylosa	758	36.58	0.37	0.06
Scyphiphora hydrophyllacea	4	0.19	0.01	0.01
Sonneratia alba	71	3.43	0.12	0.03
Xylocarpus granatum	3	0.14	0.01	0.01
TOTAL	2,072	100	1.13	0.23

Diversity level among the Selected Barangays

Barangay Sulangan rendered the highest Shannon-Wiener diversity index and species evenness (Fig. 2) of 1.56 and 0.6, respectively. Barangay Bungtod followed it with a diversity index of 1.03 and an evenness of 0.28. Barangay Bucao had a 1.01 diversity index and 0.31 species evenness. In comparison, Barangay Pagnamitan rendered a diversity index of 0.99 and evenness of 0.23. Barangay Dalaragan had a 0.83 diversity index and an evenness of 0.22. Finally, Barangay Baras recorded the most diminutive species diversity (0.12) and species evenness (0.04).

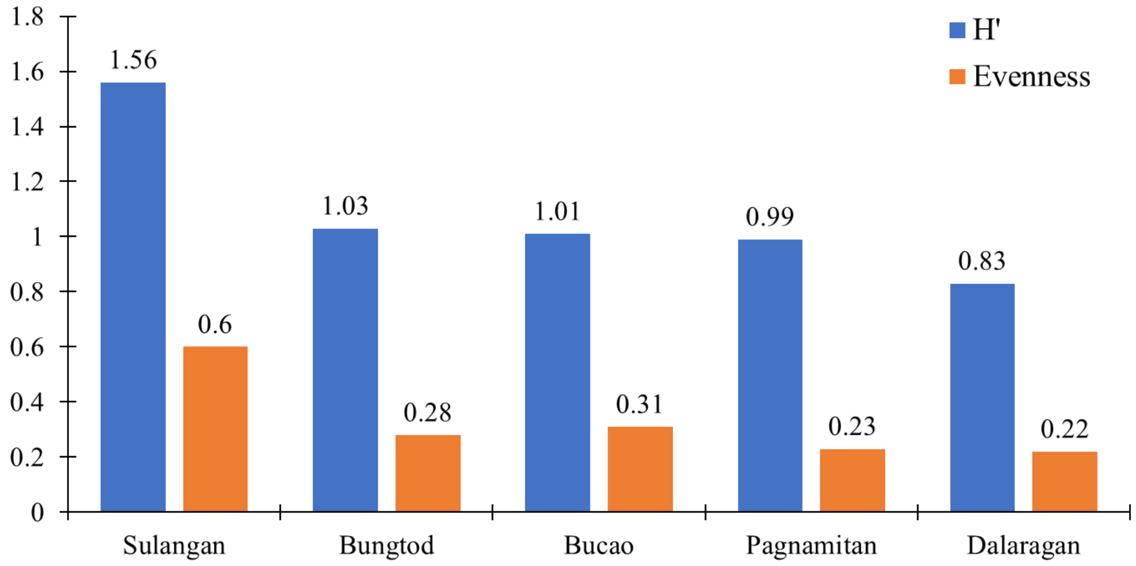

Figure 2. Species diversity and evenness of mangrove vegetation in Guiuan, Eastern Samar, Philippines

Table 3. Species Richness, Abundance, Diversity, and Evenness of Mangrove vegetation in Guiuan, Eastern Samar, Philippines

Barangay	Species Abundance	Relative abundance (%)	H′	Species Evenness
Pagnamitan	718	34.65	0.99	0.23
Bungtod	454	21.91	1.03	0.28
Dalaragan	345	16.65	0.83	0.22
Baras	296	14.29	0.12	0.04
Bucao	155	7.48	1.01	0.31
Sulangan	104	5.02	1.56	0.6
TOTAL	2,072	100		
MEAN	345	16.67	0.92	0.28

The mean species evenness of the six barangays rendered a comparable value of 0.28 (Table 3) to the mean evenness value of 0.23 obtained by species. This implies that there are unequal numbers of individuals in each species. Some species are more abundant than others, reflecting species diversity in each barangay. The species evenness in each barangay depends on the number of species found in that area - the mean overall Shannon-Wiener diversity value of the selected barangays rendered 0.92. According to the scale used by Gevaña & Pampolina (2009) and the Modified Fernando Biodiversity Scale (Fernando, 1998), as cited by Aureo et al. (2020), this is considered very low. These values are considered low compared to the diversity level in Imelada, Dinagat Island (Aye et al., 2022), where its evenness rendered a value of 0.64 and obtained a Shannon diversity of 1.86. However, based on the classification that was given by Fernando (1998), this value was considered very low diversity.

Mangrove Biomass and Carbon Stock Estimation

The total aboveground and belowground biomass from the six mangrove stands in Guiuan rendered a total of 209 t ha^{-1} and 76 t ha^{-1}, respectively, where the total amount of C stocks in the mangrove area rendered 157 t ha^{-1} which is equivalent to 575 CO_2 t ha^{-1}, (Fig. 4). The belowground and aboveground biomass ratio (B: A Ratio) is 0.36. Barangay Sulangan rendered the highest total carbon stock of 397 t ha^{-1} where aboveground contributed more compared to the below. It was followed by Barangay Bucao and Barangay Bungtod with 210 t ha^{-1} and 120 t ha^{-1} carbon storage, respectively. The belowground biomass of Barangay Sulangan (171 t ha^{-1}) rendered highest and Baranggay Baras as the lowest (52 t ha^{-1}). Figure 3 presents the selected barangays' aboveground, belowground, and c-stock. Barangay Pagnamitan and Barangay Baras had the least total carbon stock from among the selected barangays. Relatively, the average biomass of the natural mangrove stand in Botoc, Pinabacdao, Samar has a very high value with 401.07 mg/t and a c-stock of 188.50 t/ha there was a considerable similarity of the species identified where six out of its eight identified species were the also recorded in the mangrove stand in Guiuan (Albino et al., 2014). Meanwhile, in Demta Bay, Papua province, Indonesia the average biomass of 134.6 mg/ha and a c-stocks of 58.6 mg/ha which is lower than the total average and c-stocks of the mangrove stand in Guiuan (Indrayani et al., 2021).

The accounted aboveground biomass of the study site can be credited to the three species: *S. alba*, *R. apiculata*, *R. stylosa*, and *A. marina* that garnered 30,293.99 kg m^{-2}, 16,000.28 kg m^{-2}, 9,924.81 kg m^{-2}, and 6,475.59 kg m^{-2}, respectively. The basal area of S. *alba* and *A. marina* is relatively higher among other mangrove species (Mahenge, 2022). Among the four species, *S. alba*, commonly known as Pagatpat, was noted as a significant contributor to the overall biomass due to its stem diameter. Although the species only occurred in some established plots, *S. alba* species with the largest basal area can be attributed to large dbh (Sreelekshmi et al., 2020). Moreover, this species has been recognized to have a relatively larger basal area than the other species found in several mangrove ecosystems in the country (Alimbon & Manseguiao, 2021). However, as they live close to their tolerance limits, they are particularly vulnerable to anthropogenic disturbances (Geneva & Pampolina, 2009). In this study, the aboveground accounted for 73 percent of the total, with the roots accounting for the remaining 27 percent.

To determine if there is a significant difference in the diversity levels of mangroves among the selected barangay, Analysis of Variance (ANOVA) was used. The computed p-value of 0.005 of species diversity among the six selected barangays showed a significant difference. This study also determines the significant difference between the aboveground, belowground, and carbon stock of mangroves in the six barangays. The one-way MANOVA was used to obtain the comparison results. The carbon stock of mangroves differed statistically among the aboveground, belowground, and total carbon stock in selected barangays, $F = 2.033$, p 0.046; Wilks' Lambda = 0.548.

Between Groups (mangrove species and the selected barangays) sum of squares value is the sum square (SS) of the difference of the overall mean of each group, which is MST = 21.27 at 1 degree of freedom (df). Within Groups, (mangrove species) sum of squares value is the sum square of the deviation of each observation from its group mean, which is 18.59 at 11 degrees of freedom. The F value 12.59 is the ratio between groups and within groups mean squares. The Sig or p-value is

0.005, which is less than 0.05, which means that there is a significant difference in the species diversity of mangroves among the selected barangays. The carbon stock differs from each barangay and its identified mangrove species. The findings of this study confirm that biomass and carbon stock vary with the size of the mangrove's dbh. CO_2.

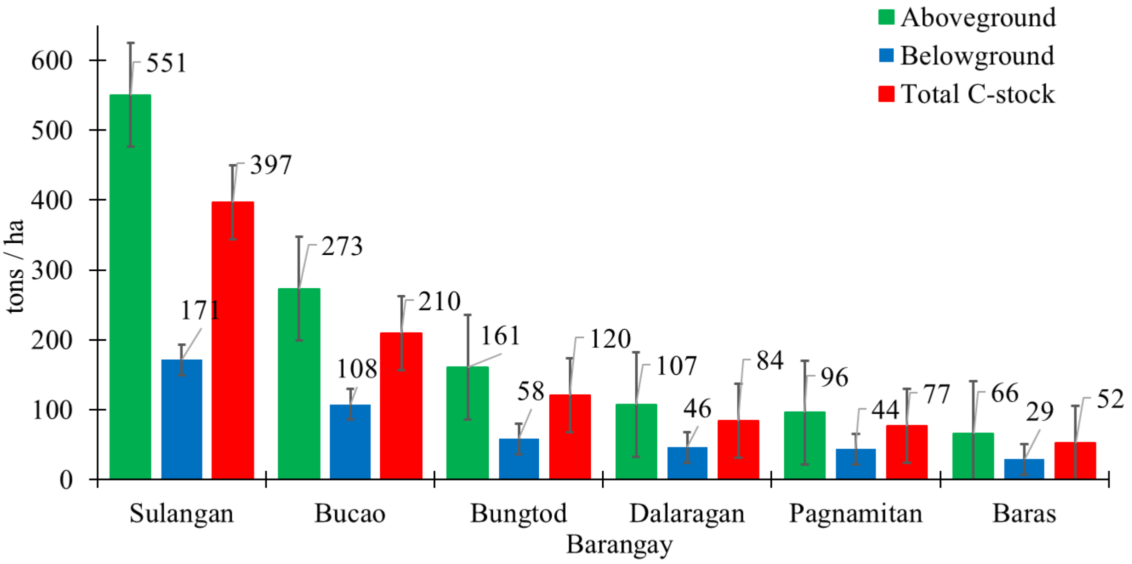

Figure 3. Aboveground, belowground, and total C stocks of mangrove vegetation in Guiuan, Eastern Samar, Philippines

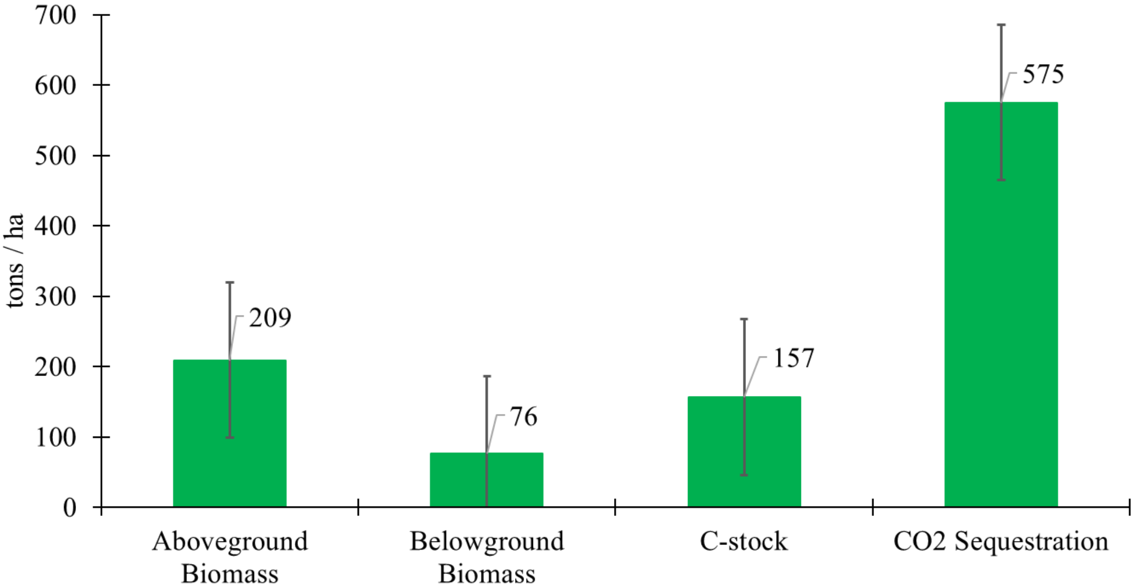

Figure 4. Overall computation of the aboveground, belowground, total C stock, and CO_2 sequestration of mangroves in Guiuan, Eastern Samar

The significant difference in the carbon stock of the mangroves was also computed using Scheffe's Post Hoc multivariate test. The carbon stock of mangroves differed statistically among the aboveground, belowground, and total carbon stock in selected barangays, $F = 2.033$, p 0.046; Wilks' Lambda =548. The test revealed that the comparison among the six barangays gives a statistically significant difference. The carbon stock differs from each barangay and its identified mangrove species. The findings of this study confirm that biomass and carbon stock vary with the size of the mangrove's dbh. The difference in the carbon stocks in the biomass of the mangrove ecosystem in different barangays may be attributed to the type of mangrove species that stand in the plot (Harishma et al., 2020).

In comparison, mangroves in C stocks of Pongara National Park, Gabon, have 644 to 943 Mg C ha^{-1} (Trettin et al., 2021), while mangroves of Kerala, southwest coast of India has 139.82 t/ha (Harishma et al., 2020), which are both lower compared to Guiuan's mangrove C stocks vegetations. Given mangroves' high carbon sequestration capacity, it is crucial to efficiently manage these ecosystems to preserve the vegetation and ensure their full carbon sequestration potential is achieved. It can be accomplished in several ways, including protecting mangroves from deforestation and degradation, regenerating degraded mangrove forests, and employing sustainable management strategies. It further indicates that the mangroves should be well-managed to conserve the vegetation, as this could be included in the Philippine C stocks estimate.

CONCLUSION

The carbon stock and species diversity of mangrove stand in Guiuan, Eastern Samar, were assessed in the study. Generally, the species diversity observed was considered low even with the number of species recorded; among the others, a few belonging to the Rhizophoraceae family were observed as abundant and dominant. Relatively, findings showed that the mean diversity level of selected barangay has rendered a very low diversity value. Considering the estimated carbon stock and CO_0 equivalent accounted from the tree biomass, the mangrove stands in Guiuan have the potential to store and sequester a large amount of carbon dioxide. Moreover, the findings showed that the species diversity and mangroves' carbon stock significantly differ among the selected barangays. There are only a few species that are considered near threatened by IUCN, most are of less concern. Regardless, the survival of these mangroves could still be threatened, and they are vulnerable to anthropogenic activities and climate change. As a result, conservation management and protection efforts must be stepped up. Furthermore, mangrove stands are known for their ecological function and offer ecosystem services, and they are one of the prominent climate change mitigation strategies.

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