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Floristic composition and carbon stock estimation under restored mangrove area in Bagan Serdang, North Sumatra, Indonesia

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Abstract. *Harefa MS, Nasution Z, Tuhono E, Susilowati A. 2023. Floristic composition and carbon stock estimation under restored mangrove area in Bagan Serdang, North Sumatra, Indonesia. Biodiversitas 24: 2037-2044.* Mangrove forests play an important role in the surrounding ecosystem, providing various complex ecosystem services such as coastal protection, food and medicine provision, water quality improvement, and habitat for various terrestrial and aquatic biota. However, forest degradation and conversion have destroyed the majority of mangrove habitats. Monoculture restoration of mangroves with local species has been carried out in various areas, including Bagan Serdang village in North Sumatra, to restore the degraded area. However, fewer studies have been conducted to assess the floristic diversity of monoculture restoration areas and their carbon stock storage estimation, especially in North Sumatra. This research aims to analyze vegetation diversity and estimate carbon stocks in a restoration area dominated by *Avicennia marina* (Forssk.) Vierh. species in Bagan Serdang village, North Sumatra, Indonesia. Purposive sampling was employed to identify species and measure tree diameter at breast height by creating plot lines that filled the observation area with 10 x 10 plots. Therefore, the Shannon Wiener diversity index (H') and allometric equations were used to determine mangrove diversity and biomass. The study's findings revealed that *A. marina* had the highest Importance Value Index (IVI) at all growth stages, including seedlings, saplings, and trees, with values of 89.12, 190.91, and 263.14%, respectively. The seedling stages had the highest diversity, with a value of 1.241. The total amount of CO_2 absorbed is 200.67 tons/ha, and the total amount of carbon stored is 54.67MgC H^{-1}.

Keywords: *Avicennia marina*, biomass, carbon, restoration

INTRODUCTION

Mangrove forests are unique and valuable coastal wetlands in the transition zone between land and sea. Mangrove ecosystems are unique, including terrestrial, marine, and wetland ecosystems (Brander et al. 2012; Malik et al. 2015). Mangroves are the planet's most productive natural marine ecosystems, with the highest carbon stocks per unit area of any typical coastal ecosystem. Mangroves are also contiguous land and ocean environments with high salinity, high temperatures, strong winds and tides, silty sediments, and anaerobic soils (Lee et al. 2014; Huxham et al. 2017; Zu Ermgassen et al. 2021). Ecologically, mangroves protect against storms and tsunamis, regulate water systems, and provide a habitat for a wide diversity of fish and other animals. Another important function of mangrove forests is their role in climate mitigation, with a much stronger carbon sunk than terrestrial forests in the tropics (Atwood et al. 2017; Hamilton and Friess 2018), which better in-store and release carbon (Lovelock and Duarte 2019).

The mangroves are carbon-rich ecosystems that deserve to be preserved and restored because they capture and store significant amounts of carbon (C), there called the "blue carbon" (Lovelock and Duarte 2019). Thereby mitigating anthropogenic greenhouse gas emissions (Mcleod et al. 2011; Siikamaki et al. 2012; Kauffman et al. 2017; Kauffman et al. 2020). Despite the numerous socioeconomic and ecological benefits to the ecosystem, mangrove populations have been declining for decades at about 90% in developing countries (Carugati et al. 2018). Mangrove forests are disappearing due to many factors: urbanization, agricultural land reclamation, industrialization, timber and charcoal production, coastal landfills, and decaying due to the indirect effects of upstream land use and pollution (Valiela et al. 2001; Alongi 2002). Their biodiversity will likely be significantly reduced, as the number of species in mangrove plants is directly proportional to their forest extent (Duke et al. 1998).

Over the last two decades, various parties have highlighted the global importance of mangrove forests and their carbon stocks, prompting significant conservation and restoration for degraded mangrove areas (Taillardat et al. 2018; Lee et al. 2019). However, despite widespread mangrove restoration, their success rates remain dismally low (Balke and Friess 2016). The failure to select the most suitable species for the right site is arguably one of the most common problems during mangrove restoration (Worthington and Spalding 2018). Furthermore, mangrove species have varying tolerance to environmental factors such as temperature (Chen et al. 2017), salinity (Barik et al. 2018), and elevation (Leong et al. 2018). *Avicennia marina* (Forssk.) Vierh. is frequently used to restore mangrove areas, including those in Bagan Serdang Village, Deli Serdang District, North Sumatra. *A. marina* has a high tolerance to salinity (Chowdhury et al. 2016), and the flexibility of its growth pattern, so this species is adaptable to a wide latitude range. The species is also frequently found to dominate in a mangrove forest area, as stated by Windusari et al. (2014), who discovered that *A. marina* was the dominant species and was found at all growth stages in their research. Thatoi et al. (2016) also stated that the *Avicennia* genus was the dominant group of pioneering plants.

The success of mangrove restoration activities can be achieved by assessing the floristic diversity in the restored areas. The information regarding the floristic composition also can describe the potential carbon stocks in those locations. Numerous carbon stocks have been estimated in mangrove areas, mainly composed of various species, concerning carbon cycles and sequestration (Liu et al. 2014; Dung et al. 2016; Bindu et al. 2020). Furthermore, the estimation of floristic composition in various restoration areas has been revealed. However, estimates of vegetation carbon stocks and floristic diversity of monospecies in the restoration areas, particularly for *A. marina* species in North Sumatera, are fewer to be studied. With the application of monoculture systems in restoration activities, we suspect distinct characteristics of the ecosystems formed along with the carbon stocks stored. Therefore, the aim of this study was to analyze vegetation diversity and estimate carbon stocks in a restoration area dominated by *A. marina* species in Bagan Serdang village, North Sumatra, Indonesia. The research results are expected to be useful in conserving and selecting the appropriate species for long-term conservation.

MATERIALS AND METHODS

Study area

The study was conducted in Bagan Serdang Village, Deli Serdang District, North Sumatra province (Figure 1). The study site is a restoration area dominated by *A. marina* species, located approximately 50 meters from the shoreline and subjected to tides. In addition, the research area includes river bank areas that receive direct tidal influences from offshore. The site size is 1.5 Ha and has less than seven years old vegetation.

Vegetation analysis

The transect method was used to collect data, separating transects by 50 meters. The number of plots is determined by maximizing the total area of the restoration area. The observation plots consisted of three different sizes, where in a plot measuring 10 x 10 m², subplots were made measuring 5 x 5 m² for the sapling stage (2-10 cm in diameter) and 2 x 2 m² for the seedling stage (diameter < 2 cm). Diameter at Breast Height (DBH) was measured as primary data along with the species and the number of vegetation found in the observation plots. Species identification was conducted using the latest botanical classifications. Data analysis was performed in this study to obtain an Importance Value Index (IVI) developed by several researchers, including Curtis and Mclntosh (1950), Misra (1968), and Sharma (2003). This IVI parameter determines biological success and dominance found in research sites, which can be obtained using the following formula to calculate the vegetation's relative density, frequency, and basal area.

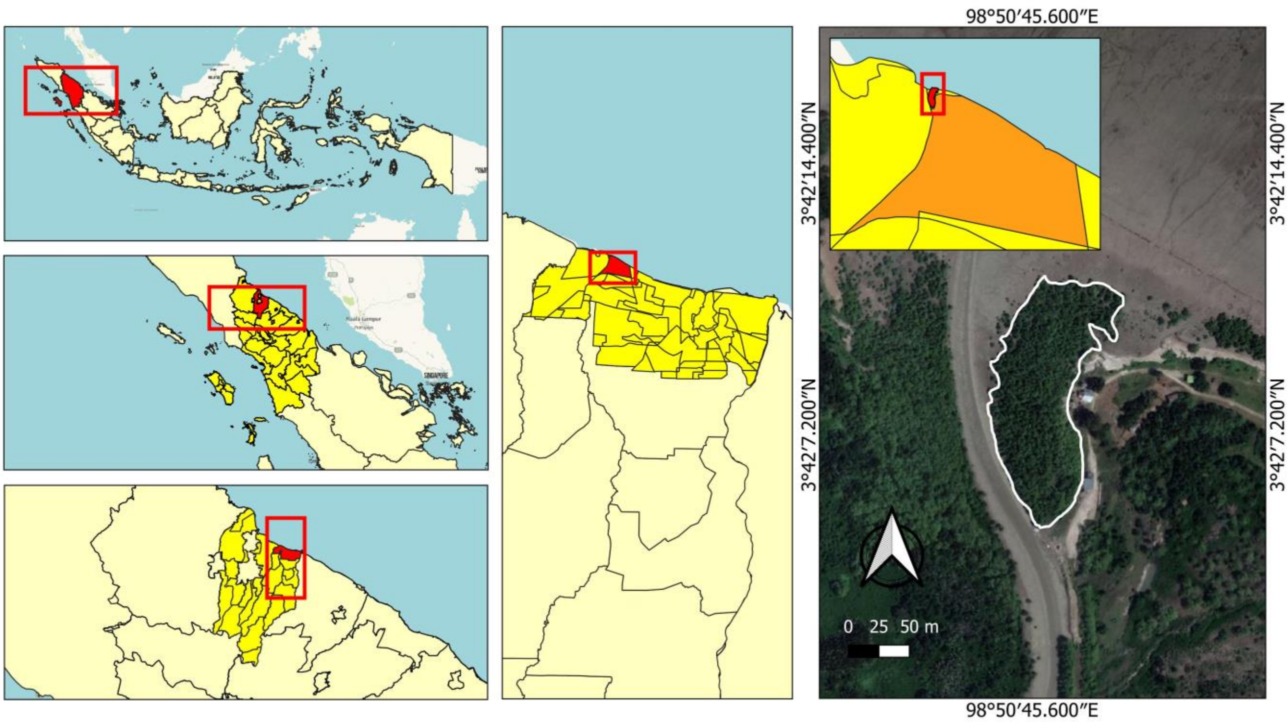

Figure 1. Research location in Bagan Serdang Village, Deli Serdang District, North Sumatra, Indonesia

Relative density

The relative density is calculated by comparing each species' density to all species' densities. The average number of individual species found at the study site is described by relative density (Sharma 2003). The following formula can be used to calculate relative density:

$$\text{Relative density of a species (RD)} = \frac{\textit{Density of a species}}{\textit{Density of all species}} \times 100\%$$

Relative frequency

The relative frequency of occurrence of individual species in a predetermined plot is used to calculate vegetation composition. Sharma (2003) defines frequency as the number of plots where a specific species is found as a percentage of all species plots made in the study. The following formula can be used to calculate relative frequency:

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

Relative basal area

Furthermore, diameter data is required to quantify dominance when calculating basal area, where basal area refers to soil cover by tree trunks (Sharma 2003). As a result, the basal area can be calculated using the formula:

$$\text{Relatif Basal Area (RBA)} = \frac{\textit{Basal area of species}}{\textit{Basal area of all species}} \times 100\%$$

The Importance Value Index (IVI) is calculated by adding relative density, frequency, and dominance (basal area) percentages at the tree level. Meanwhile, the importance value index was calculated for seedlings and saplings by adding the relative densities and relative frequencies based on the number of species discovered. The important value index is a quantitative parameter used to assess the status of a species within a plant community. The formula is used to calculate the important value index:

$$\text{IVI} = (\text{RD} + \text{RF}) \text{ (seedling and sapling)}$$
$$\text{IVI} = (\text{RD} + \text{RF} + \text{RBA}) \text{ (for tree)}$$

The Shannon-Wienner Diversity Index (H') and Uniformity Index (Indriyanto 2006) were used to calculate the species diversity and uniformity index:

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

Where: H' is the Shanon-Wiener diversity index and Pi is the ratio of the number of individuals of a species to the total number of all species. In addition to species diversity, this study examined species uniformity; the species uniformity index was calculated using the following formula (Odum 1971):

$$\text{E} = \frac{\text{H}'}{Hmaks}$$

Where: E represents the species uniformity index, H' represents the species diversity index, and Hmaks = ln S, where S represents the total number of species discovered. The results of the calculation of species uniformity can be divided into three categories: low if E ≤ 0.5, moderate if 0.5 ≤ E ≤ 0.6, and high if E > 0.6.

Biomass estimation

Komiyama et al. (2008) developed the allometric equation method to estimate stand biomass. First, each plot identified an individual with a stem diameter of 5 cm or greater. Next, the Diameter at Breast Height (DBH) and total individual height estimation were performed as measurement parameters for each individual encountered. Then, tree biomass was calculated using the number, basal area, and total height of trees found in those observation plots. The following formula was used by Ellenberg and Muller-Dombois (1974) to calculate the basal area of tree stems:

$$\text{ba} = \left(\frac{1}{2}D\right)2\pi$$

Where: Ba denotes the basal area, D denotes the Diameter at Breast Height (DBH), and is a constant of 3.14. The measurement of tree biomass is done non-destructively. Mangrove species use different allometric calculations to measure the value of biomass. The formula for calculating a species' biomass is chosen based on the species found in the research location. The aboveground biomass and belowground biomass are calculated using Comley and McGuinness (2005) for *A. marina* and Poedjirahajoe et al. (2017) for *Avicennia alba* Blume, which is as follows:

Aboveground biomass (AGB)

A. marina : $\text{Wtop} = 0.308(\text{DBH})^{2.11}$
A. alba : $\text{Wtop} = 0.079211(\text{DBH})^{2.470895}$

$r^2 = 0.97$, n = 22, D max = 35 cm.

Belowground biomass (BGB)

In this study, the estimation of underground biomass was calculated based on the estimation of vegetation roots on the DBH of individual trees. The estimation of underground biomass in *A. marina* species was quantified using a formula based on Komiyama et al. (2008), while the estimation of underground biomass in *A. alba* species was quantified using an equation formula referring to Komiyama et al. (2005) where the formula used is as follows:

A. marina : $\text{Wr} = 1.28\text{DBH}^{1.17}$
A. alba : $\text{Wr} = 0.199 * \rho^{0.899} * \text{DBH}^{2.22}$

Those results are then converted to the biomass value using the following formula to obtain the carbon value in the desired unit:

$$\text{C} = \text{B} \times \%\ \text{C Organic}$$

Where: C denotes the carbon content of the biomass in kilograms (kg), B denotes the total biomass in kilograms/hectare (kg/ha), and % C organic denotes the percentage value of carbon content, assuming that the carbon content in plants is 50% (Komiyama et al. 2008). In this case, carbon stocks can be calculated as total slow-tree biomass (Tons/ha) x 0.50. In this study, we also consider CO_2 absorption using a formula from Murdiyarso (1999):

$$W\ CO_2 = C \times FK\ CO_2$$

Where: W CO_2 is the amount of CO_2 absorbed (tons/ha), and C is the carbon (tons/ha). FK CO_2 is the carbon (C) to CO_2 conversion factor with a value of 3.67 included in the equivalent number or conversion of element C to CO_2 with an atomic mass of C being 12 and O being 16. The obtained formula is CO_2 → (1x12)+(2x16) = 44; conversion → (44:12) = 3,67).

RESULTS AND DISCUSSION

Floristic composition

The research found six species in the research area: *Cynodon dactylon* (L.) Pers., *A. marina*, *Acanthus ilicifolius* L., *Nypa fruticans* Wurmb, *Rhizophora mucronata* Lam, and *A. alba* (Table 1). Regarding the number of species, the seedling stages have the highest (4 species), while the tree stage has the fewest (2 species). Based on IVI, *A. marina* has the highest IVI value at each growth stage. The high IVI value indicated that *A. marina* dominated and has grown well in the restoration area. The selection of *A. marina* species as a monoculture-planted species in the Bagan Serdang Village restoration area greatly contributed to the high number of individuals and the resulting high IVI value. Furthermore, because of its high adaptability to the environment, this species has grown and developed rapidly, allowing for adequate regeneration at each stage of development. Moore et al. (2015) stated that *A. marina* is a salt-tolerant mangrove species that can withstand twice the salinity of seawater. *A. marina* is also the only species with highly developed morphological, biological, physiological, and ecological adaptations to varying environmental conditions (Das et al. 2016).

Four species were founded at the study site at the seedling stage, with *C. dactylon* having the lowest IVI (16.45%). Three species were found at the sapling stages, with *R. mucronata* and *N. fruticans* having the lowest IVI of 4.54%. Finally, *A. alba* received the lowest value at the tree stage, with an IVI value of 36.85%. Despite its low IVI value, these new species' appearance indicates that the ecosystem's complexity in the restoration area is being revealed.

According to Irsadi et al. (2019), environmental factors in the mangrove ecosystem support the planting program's success. The observations showed that the observed environmental parameters produced values that were not much different at the three observation times and even found the same values for several parameters (Table 2). The observed values remain within the range of Minister of Environment Decree No. 51 of 2004 concerning seawater quality standards for marine biota, with the pH standard for mangroves being 7-8.5 and the salinity standard being 34 ppt. As a result, the mangroves in this study can grow to their maximum capabilities. The average temperature in this location ranges from 27.2°C to 30°C. This temperature is suitable for mangrove habitats and corresponds to the temperature standard for mangroves. Another important factor in the development of mangroves is salinity. Salinity and *A. marina* growth have a positive correlation where increasing salinity will stimulate Avicennia growth (Ball 2002). The best salinity for the growth of *A. marina* is 5 - 30%.

Biomass and carbon stock estimation

The dominant genus of mangrove trees in a particular stand determines wood density and tree morphology, which may be a predictor of biomass C stock efficiency (Donato et al. 2011). According to the research findings, the value of stored biomass and carbon in the Bagan Serdang Village restoration forest is divided into aboveground and belowground biomass (Table 3). According to the biomass allometric equation, the maximum diameter data obtained is 49 cm. Hairiah et al. (2011) stated that tree biomass content is the sum of the biomass content of each tree organ, representing the total organic matter from photosynthesis. Thus, aboveground biomass includes the main stem, branches, twigs, leaves, flowers, and fruit, while belowground biomass includes roots.

Table 1. Floristic composition of a restored area in Bagan Serdang Village, Deli Serdang District, North Sumatera, Indonesia

Growth stage	Species	Family	RD (%)	RF (%)	RBA (%)	IVI (%)	H'	E
Seedling	*Cynodon dactylon*	Poaceae	13.33	3.12	-	16.45	1.241	0.895
	Avicennia marina	Avicenniaceae	36	53.14	-	89.14		
	Acanthus ilicifolius	Acanthaceae	40	21.87	-	61.87		
	Nypa fruticans	Arecaceae	10.66	21.87	-	32.54		
Sapling	*Avicennia marina*	Avicenniaceae	98. 92	92	-	190.92	0.067	0.061
	Rhizophora mucronata	Rhizophoraceae	0.54	4	-	4.54		
	Nypa fruticans	Arecaceae	0.54	4	-	4.54		
Tree	*Avicennia marina*	Avicenniaceae	96.296	93.75	73.11	263.15	0.158	0.228
	Avicennia alba	Avicenniaceae	3.703	6.25	26.90	36.85		

The total biomass of *A. marina* obtained was 25,152.15 kg, with 16,851.81 kg for AGB and 8,300.35 kg for BGB (Table 3). On the other hand, Manna et al. (2014) demonstrated different results in Sundarban, with the maximum AGB value resulting from planting *Avicennia* spp being 122.29 MgC H^{-1}. This Sundarban exceeds the findings in this study, where the total carbon produced is only 54.67 Mg C H^{-1}. The difference in biomass value and carbon content stored in various ecosystems depends on the diversity and density of plants and the management of these ecosystems. According to Manafe (2016), differences in stored carbon stocks are due to differences in diameter between stands. The larger diameter of composed trees in an area, the greater the weight of tree biomass on that land. Therefore, the weight of biomass will affect the amount of carbon stock in an area. However, given that the area is narrow and has less dense vegetation, the carbon value produced in this study is quite large. That follows the findings of Hairiah et al. (2011), who assume that aboveground tree biomass contains the greatest carbon stocks.

The species planted in the Bagan Serdang village restoration forest was *A. marina*, but upon further investigation, another species, *A. alba*, was also discovered. That can be impacted by tides, which carry propagules that fall to the ground and are washed away by the tides (Peterson and Bell 2012). *A. marina*, however, remained the dominant species in the study area as the selected species. The results revealed that the dominant species at the study site (*A. marina*) had the highest carbon absorption value (Table 4).

The total CO_2 absorption at the study site was 200.67 CO_2 Mg H^{-1}, which was quite high. CO_2 uptake in *A. marina* is estimated to be 199.99 Mg H^{-1}. Zulhalifah et al. (2021) found that *A. marina* produced a carbon absorption of only 67.38 tonnes/ha in their research in Lombok, Indonesia. These findings are significantly lower than those obtained in the *A. marina* in this study. The higher amount of carbon stock in *A. marina* than other mangrove species, such as *R. mucronata* is thought to be related to *A. marina* root morphology. *A. marina* has a pencil and finer roots. These root characteristics increase *A. marina* productivity when combined with an anoxic environment and a low decomposition rate, which play an important role in carbon sequestration. Furthermore, *A. marina* has an extensive and complex underground main root system (cable root) and a pneumatophore to maximize carbon sequestration (Manafe 2016). In addition, the high carbon uptake generated at the study site is thought to be caused by monoculture planting. Monoculture planting increases species dominance in an area, directly increasing CO_2 uptake by these species. Meanwhile, Zulhalifah et al. (2021) stated the diverse species composition had divided the land and resulted in smaller carbon uptake for each species.

Discussion

In some ecosystems, species composition may affect the structure and distribution of plants (Susilowati et al. 2021). Species diversity and composition also can reflect the stability of plant communities (Hooper et al. (2012). Therefore, to quantify the species diversity of an area, three components were calculated: diversity, uniformity, and dominance. Our result found six mangrove species belonging to five families: Poaceae, Rhizophoraceae, Acanthaceae, Arecaceae, and Avicenniaceae. In addition, several new species, including *C. dactylon*, *A. ilicifolius*, *N. fruticans*, *R. mucronata*, and *A. alba*, were discovered in previously planted areas with *A. marina*. The new seedling recruitment in the *A. marina* restoration area also has been stated by Tamin et al. (2011). The new recruitment on restoration areas dominated by *A. marina* and *R. stylosa* are thought to have originated from mother trees in the nearby forest. The root growth characteristic is thought to have trapped more sediment and transported seeds, attracting more wild seeds each fruiting season. Many factors contribute to the presence of new recruitment of species in the mangrove ecosystem. Water dispersal of seeds is thought to be one of the most important contributors to species diversity in the study area. The restoration area's history as a natural forest has left a variety of natural species that are quite diverse and provide mother trees that still produce seeds naturally around them. Peterson and Bell (2012) proposed water dispersal of propagules stating that high water events, such as storm tides, have facilitated propagule dispersal over large mangrove vegetation expanses.

Table 2. Results of environmental parameter measurements in the *A. marina* restoration area in Bagan Serdang Village, North Sumatra, Indonesia

Environment parameter	Morning	Noon	Afternoon
Substrate moisture (%)	10	10	10
pH	7	7	7
Temperature (°C)	27,2	30,3	30
Salinity (Ppt)	20	20	20

Table 3. The potential of stored carbon and carbon sequestration of forest restoration in Bagan Serdang Village, North Sumatra, Indonesia

Parameter	Bagan Serdang restoration forest	Total (MgC H^{-1})
Aboveground biomass (AGB) (kg)	16851.81	25,152.15
Biomass belowground level (BGB) (kg)	8300.35	
Carbon aboveground level (AGC) (MgC H^{-1})	36.63	54.67
Carbon belowground level (BGC) (MgC H^{-1})	18.04	

Table 4. Carbon dioxide (CO_2) absorption of restoration forest in Bagan Serdang Village, North Sumatra, Indonesia

Species	CO_2 absorption (Mg H^{-1})
Avicennia marina	199.99
Avicennia alba	0.68
Total	200.67

The new species recruitment contributes to the study area's diversity. The results revealed that the seedling stage had the highest diversity (H'= 1.241), while the sapling stage had the lowest diversity (0.067). The emergence of various new species significantly impacts the acquisition of diversity values in research locations. The environmental conditions at the study site are thought to have contributed greatly to the emergence of various species. The environmental parameter measurements (Table 2) show that environmental parameter values, especially salinity, and pH, are within the appropriate range for mangrove species, especially for *A. marina*, as the species planted in the restoration program. Furthermore, Fichtner et al. (2018) and Forrester and Bauhus (2016) stated that plants and environmental factors were related to their diversity and productivity. According to Cruz (2008), *A. marina* is a mangrove species with a wide range of physiological tolerance that creates an ideal environment for forming other mangrove species. This reinforces the assumption that the high number of *A. marina* individuals at the study site is supported by superior species characteristics and the high number of individuals planted to implement the monospecies system. As a result, this species is recommended for monoculture restoration programs in degraded mangrove areas.

The dominance of *A. marina* in the Bagan Serdang restoration area also influences the research location's carbon stock, as carbon in the atmosphere is higher than carbon in the ground. The presence of carbon, an organic material composed of stem cell walls, causes a high carbon content above the soil surface, particularly in the stems, known that wood is generally composed of cellulose, lignin, and extractive materials. The majority of which are composed of carbon elements (Hilmi 2003). Aboveground biomass is related to basal area (Ruiz-Jaen and Potvin 2010). Larger-diameter trees have a larger basal area and more carbon stored, particularly in the stem (Rahman et al. 2015). In this study, the value of AGB was higher compared to BGB. Organic carbon stored in tree parts is generally greater than in roots (Howard et al. 2014). As the underground carbon conversion factor, the carbon content of mangrove roots ranges from 36% to 42%, with a median of 39%. (Jaramillo et al. 2003). Meanwhile, the percentage of aboveground carbon stored in various mangrove tree parts is close to 46% on average, which is higher than underground carbon (Kauffman et al. 2011). Donato et al. (2011) state that the contribution of above-soil carbon stocks in the Indo-Pacific marine and estuarine areas is greater in overall mangrove carbon stocks than underground carbon stocks.

Carbon stocks increase with increasing biomass, which is affected by the diameter and number of trees. Because of their large capacity for carbon storage and sequestration over long time scales, mangroves, and other coastal wetlands, such as mudflats and seagrass beds, are called 'blue carbon ecosystems' (Sasmito et al. 2022). Murdiyarso et al. (1999) calculate the potential for absorption of carbon dioxide gas (CO_2) by multiplying the carbon content by the amount of carbon dioxide (CO_2) absorption. Mangrove ecosystems are very effective and efficient at reducing the concentration of carbon dioxide (CO_2) in the atmosphere because mangroves can absorb CO_2 through photosynthesis by stomata diffusion and then store carbon as biomass (Windardi 2014). The density of mangrove stands is thought to be very important in determining biomass value, carbon content, and ability to absorb CO_2 gas. The higher the density value of mangrove stands, the higher the biomass value, which influences the carbon content and ability to absorb carbon. However, as long as it is not disturbed, this restoration site has great potential. Therefore, it is desired that this restoration forest will be able to resume its role as a natural forest, serving as a medium for carbon storage, CO_2 absorption, and ecological, physical, and economic functions for the surrounding community.

The research pointed out that the Bagan Serdang restoration area has proved the ecosystem's complexity through the emergence of new species. At this location, two true mangrove species were found those were *A. marina* and *A. alba*. *A. marina* remains dominant in the study location as indicated by the highest IVI value in each growth stage. The new recruitment in the seedling stage exhibited the greatest diversity, with a diversity index of 1.241. The total amount of carbon stored is 54.67MgC H^{-1}, and the total amount of CO_2 absorbed is 200.67 tons/ha. This study also shows that restoration activities using a monoculture system and appropriate environmental conditions can create suitable habitats for the new species recruitment, thereby enriching the diversity of species in the study location, which has implications for carbon stocks in a location.

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