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Floral composition and carbon stock estimation of monospecies restoration area in Pasar Rawa, North Sumatra

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ABSTRACT

Mangrove forests are important in climate mitigation, particularly for their greatest carbon storage. *Rhizophora apiculata*, a mangrove species with numerous advantages, is frequently employed in restoration activities. Monoscpecies restoration activities are well known, although information on floristic composition and carbon uptake must be available. The objective of this research was to investigate the floristic composition and carbon stock of *R. apiculata* in the Pasar Rawa Village restoration area, Langkat Regency, North Sumatra Province. This study employed the vegetation analysis approach and carbon estimates based on diameter breast height (DBH) and total vegetation height. The study's findings indicate low floristic diversity in the research area. At the seedling stages, the greatest IVI (113.68%) was discovered in *Achanthus ilicifolius*, and the only species found in the sapling stage with an IVI value of 200% was *R. apiculata*. The study of diversity indices revealed very low values at the seedling stage (H'= 0.806) and no diversity at the sapling stage. The total carbon stored estimation in *R. apiculata* stands relatively low, at 8.56 tonnes/ha. The absorbed carbon produced by *R. apiculata* is 31.42 tons/ha with a CO_2 absorption of 3.141 g/m^2 and is classified as relatively low.

Keyword*:* Carbon, Monospecies, Restoration, *Rhizophora apiculata,*

1. Introduction

Mangroves are salt-tolerant woody plants that are usually found in the intertidal zone in tropical and subtropical regions. Mangroves can adapt to the harsh intertidal zone environment through morphological, physiological, and reproductive changes [1]. This environment reveals typical mangrove morphological and ecophysiological traits such as pneumatophores, viviparous embryos, tidal dispersal of propagules, a lack of undergrowth, the ability to survive in high water salinity, as well as effective nutrient retention mechanisms [2]. Mangrove forests provide important ecosystem goods and services, particularly to coastal communities and marine ecosystems, such as fish breeding and nesting areas, coastal erosion, foraging habitats, breeding grounds, storms, tsunamis, sea level rise protection, water purification, and ecotourism. Another significant role of recently revealed mangroves is their considerable ability to absorb and store carbon [3].

Mangroves are one of the most efficient ecosystems for fixing carbon dioxide in the atmosphere and storing it in biomass and sediment compared to all coastal and terrestrial ecosystems [1]-[2]. These are globally important habitats, together with seagrass beds and salt marsh ecosystems known as blue carbon, since they absorb enormous quantities of carbon compared to other ecosystems [3]-[4]. Changes in land use and land cover (LULCC) significantly impact ecosystems, including their ability to absorb carbon. This is a human-caused change to the terrestrial environment [5]. Mangrove forests, notably in Southeast Asia, have been exposed to land conversion and degradation [6]-[7]. Deforestation and land conversion have produced significant carbon emissions [8]-[9].

Mangrove forests can be found in various districts in North Sumatra, including Asahan, Tanjung Balai, Batubara, Deli Serdang, Labuhan Batu, Serdang Bedagai, and Langkat [10]. The documented area of mangroves in 1990 was 34,742.12 ha, which had decreased to 16,765.96 ha in 2015, and land conversion into oil palm plantations and aquaculture was recognized as the cause of deforestation in Langkat Regency [10]. The rehabilitation of degraded mangrove areas is becoming more of an agenda every year. Regarding target species, some promote utilizing a single species to achieve rapid mangrove restoration and development results and restore some ecosystem structure and function [11]. The success of monospecies restoration activities and creating mangrove succession was also stated by [12]-[14], but more information on *R. apiculata* needs to be. As known, Rhizopora is the most common species utilized for mangrove rehabilitation programs, particularly in Indonesia. *R. apiculata* is a fast-growing mangrove with a high pattern of adaptation to environmental conditions such as substrate type, salinity fluctuations, sea tides, organic matter content, temperature, and pH, allowing this species to thrive for an extended period. This species is found in all mangrove forest zones, from coastal to river banks [15].

The success of the restoration program can be identified using floristic diversity in the restoration area [16]. Monitoring floristic diversity can be used as the initial step for determining the success of restoration programs [17]. The vegetation composition in the restoration area may indicate the potential stored carbon at that location. Carbon estimation in multispecies mangrove ecosystems has been extensively investigated [18]-[20]. However, there are still limited studies on restoring monospecies ecosystems, especially in North Sumatra. Therefore, we are to determine the floristic composition and carbon stock of *R. apiculata* in the restoration area of Pasar Rawa Village, Langkat Regency, North Sumatra Province.

2. Method

2.1. Research location

This research was conducted in Pasar Rawa Village, Langkat Regency, North Sumatra province (Figure 1). The research location is on the bank of a river which receives direct tides. The research location has a substrate in the form of sticky mud and is quite deep.

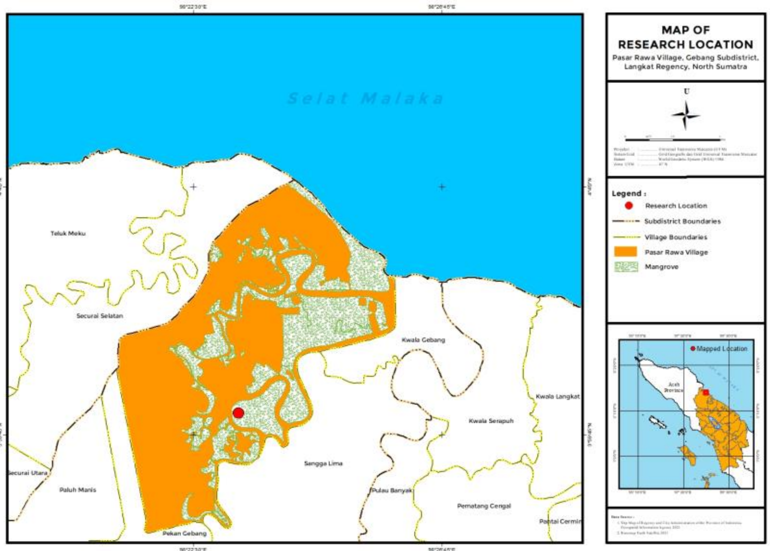

Figure 1. Research site in Pasar Rawa Village.

2.2. Data analysis

The purposive sampling method was used in this research to obtain information regarding vegetation diversity and estimates of vegetation carbon based on diameter breast height (DBH) diameter. Plots of 10 m x

10 m are made on transect lines estimated according to the restoration area. To measure the juvenile stage of plants (seedling and sapling stages), subplots of different sizes were created in plots measuring 10 m x 10 m, where observations of vegetation at the seedling and understory levels were carried out in plots measuring 2 m x 2 m and vegetation at the sapling stage were observed in a plot measuring 5 m x 5 m. Meanwhile, vegetation at the tree level was observed in the plot with the largest size, 10 m x 10 m. Meanwhile, all individual trees with DBH of 5 cm or more are identified and recorded as vegetation whose carbon uptake will be estimated. In addition to diameter, the estimated total height of trees included in each observation plot is also taken into account.

In this research, data analysis was carried out to obtain an important value index developed by several researchers, including [21]-[23], where this parameter was used to determine biological success and dominance at the research location. The important value index is a quantitative parameter used to determine the condition of a species in a plant community. The importance value index (IVI) is obtained using the following formula:

$$IVI = \text{Relative Density} + \text{Relative Frequency (seedling and sapling)} \quad (1)$$

$$IVI = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Basal Area (for tree)} \quad (2)$$

Species diversity and uniformity indices were carried out using the Shannon-Wienner Diversity Index (H') and the Shannon-Wienner Evenness Index (E) [24]. The tree basal area was calculated with an allometric equation referring to [25] for various mangrove species, where the estimated biomass of *R. apiculata* was calculated using a formula referring to [26]. To determine the carbon value using the preferred units, the biomass value is then converted using a formula referring to [27].

3. Result and Discussion

3.1. Floristic composition

The research on the relationship between diversity and yield (notably [28]-[30]) has revealed that species richness has a positive and consistent effect on agricultural productivity. The results showed that the *R. apiculata* restoration area had a low floristic composition, with only three plant species present at the seedling and sapling stages, each with a different IVI value (Table 1).

Table 1. The IVI of species found in the *R. apiculata* restoration area

Growth stage	Species	Family	RD (%)	RF (%)	RBA (%)	IVI (%)
Seedling	*A. ilicifolius*	Acanthaceae	40.00	73.68	-	113.68
	A. aureum	Pteridaceae	3.50	23.68	-	27.18
	R. apiculata	Rhizophoraceae	56.50	2.63	-	59.13
Sapling	*R. apiculata*	Rhizophoraceae	100	100	-	200

Table 1 showed that *R. apiculata* was the only seedling species found at the research location alongside two understory species, namely *A. ilicifolius* and *A. aureum*. At the seedling stages, the highest IVI obtained was in *A. ilicifolius* with an IVI value of 113.68%, while the lowest IVI obtained was in the *A. aureum* species with an IVI value of only 27.18%. At the sapling stage, *R. apiculata* is the only species found at this location. The absence of species at tree stages and the low number of restoration species (*R. apiculata*) at the research location are thought to be caused by anthropogenic disturbance and environmental pollution.

Based on the findings of this study, we concluded that using mono species in restoration initiatives would probably be successful. This is demonstrated by the fact that the chosen species have grown and evolved and are gradually beginning to construct complex ecosystems with various new recruitment species (non-planted species). Although the findings of this study showed no vegetation at the tree stage, we believe that in the absence of anthropogenic disturbances, *R. apiculata* can grow well to the maximal growth rate (tree stage) and regenerate successfully. In line with IVI value, *R. apiculata* restoration area had a low diversity value. No vegetation was found at the tree stage, and a single species was found at the sapling stages (only *R. apiculata*), causing no diversity at the sapling and tree levels (Figure 2).

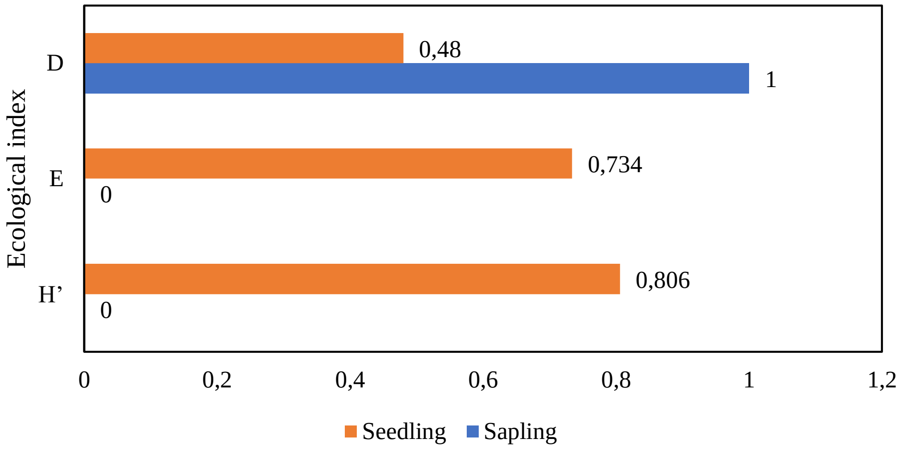

Figure 2. Vegetation ecological index in the restoration area of Pasar Rawa Village, North Sumatra

3.2. Biomass and carbon stock

Mangrove ecosystems play an important role in the global carbon cycle and the oceans and act as good CO_2 sinks (from the atmosphere) or store biomass carbon above ground, below ground, and in the soil. It is also a source of inorganic and organic carbon for the surrounding ecosystem and atmospheric CO_2 through the respiration of living creatures, forest fires, and changes in land function [31]-[32]. Based on the research results, we obtained the results that the total biomass stored in *R. apiculata* vegetation in monoculture restoration land is relatively small (Table 2).

Table 2. Potential of stored carbon and carbon sequestration of Pasar Rawa village restoration forest

	Pasar Rawa Village Restoration Forest	Total
Above ground biomass (AGB) (kg)	4,598.89	4,793.81
Biomass below ground level (BGB) (kg)	194.92	
Carbon above ground level (AGC) (Ton/Ha)	8.21	8.56
Carbon below ground level (BGC) (Ton/Ha)	0.35	

The results show that the total *R. apiculata* biomass obtained was 4,793.81 kg, consisting of 4,598.89 kg of AGB and 194.92 kg of BGB. The high above-ground biomass was also revealed by [33], which states that the largest proportion of carbon reserves is found in above-ground tree biomass. According to the Intergovernmental Panel on Climate Change [34], above-ground tree biomass consists of main stems, branches, twigs, leaves, flowers, and fruit. Furthermore, [33] added that tree biomass content is the sum of the biomass content of each tree organ, which is a picture of the total organic material from photosynthesis.

Still related to the age of the vegetation, the low total biomass stored in *R. apiculata* is thought to be caused by many factors, including vegetation ages. In addition to the vegetation factor itself, environmental factors are known to influence the biomass in vegetation. According to [35], mangrove biomass can vary greatly depending on several edaphic factors related to the dominance of tides, rainfall, dominance of waves, and rivers. The total aboveground biomass per hectare also varies according to the age of the stand. Table 3 shows that the potential for carbon storage in the restoration forest of Pasar Rawa Village is 8.56 tons/ha. Carbon above ground is higher than carbon below ground. The high carbon content above the soil surface, especially in stems, is caused by carbon elements and organic materials that make stem cell walls. In contrary, wood is generally composed of cellulose, lignin, and extractive materials, mostly carbon elements [36]. Aboveground biomass depends on the basal area [37]; larger diameter trees will have greater basal area and will contain more carbon stored, especially in the trunk [38].

Despite the relatively low result, the total carbon obtained in the *R. apiculata* stands at the study site has a greater value than the total carbon stored in one of the restoration areas with the same species. Research by [39] showed lower result of *R. apiculata* in logged areas in West Borneo. In the data presented, the total carbon uptake increases as the plant ages. In stands that are five years old, *R. apiculata* is known to have a total carbon of 7,240 tons/ha, which is smaller than the total carbon in the study location, which is 8.56 tons/ha. This result strengthens the assumption that the age of the stand greatly affects the total carbon in vegetation. The age of the plants in the study sites, which were ± 4-5 years old, showed significantly different results. However, other factors such as the number of plants, substrate condition, and others are believed to influence the carbon stored significantly. Not much different from the estimation of total carbon stocks, the study's results also showed that CO_2 absorption at the study sites tended to be low, which was 31.42 tonnes/ha (Table 3). The low carbon uptake is also indicated by the acquisition of a relatively low basal area with a small diameter so that the carbon produced is also low.

Table 3. Carbon dioxide (CO_2) absorption of the restoration forest of Pasar Rawa village

Species	CO_2 absorption (tons/ha)	CO_2 uptake (g/m^2)
Rhizophora apiculata	31.42	3,141.65

The low carbon absorption value obtained is closely related to vegetation density in the study area. Vegetation that is not too dense indicates a lower number of vegetation and relatively small size. The age of the plant is automatically suspected as the main reason for this to happen. Not only that, the area of restoration also needs to be considered in determining the size of carbon absorption and carbon storage in an area. Mangrove ecosystems are very effective and efficient in reducing the concentration of carbon dioxide (CO_2) in the atmosphere because mangroves can absorb CO_2 through photosynthesis through diffusion through the stomata and then store carbon in the form of biomass [40]. Based on this, it is hoped that the restoration area under study can grow and develop to increase carbon storage as a climate mitigation effort over time. At the same time, more complex ecosystems are expected to form over time and improve the welfare of the surrounding community.

4. Conclusion

The research results show that floral diversity at the research location tends to be low. *A. ilicifolius* was the species that obtained the highest IVI at the seedling stages (113.68%) and *R. apiculata* was the only species found at the sapling with an IVI value of 200%. Diversity analysis showed very low values at the seedling stage (H'= 0.806) and no diversity at the sapling stage. The total carbon stored in *R. apiculata* monospecies restoration is relatively low (8.56 tonnes/ha). The amount of absorbed carbon produced by *R. apiculata* is 31.42 tons/ha with a CO_2 absorption of 3.141 g/m^2 and is relatively low.

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