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Seedling Growth Evaluation of Rehabilitated Mangrove and Carbon Estimation of Two Types of Mangroves in Perlis, Langkat, North Sumatra

Ahmad Hisyam Pulungan[1], Mohammad Basyuni[*1,2], Rizka Amelia[1,2], Irvan[3], Astrid Fauzia Dewinta[4], Julia Syahriani Hasibuan[4], Itchika Sivaipram[5]

[1] *Faculty of Forestry, Universitas Sumatera Utara, Kampus USU 2 Bekala, Pancur Batu, Deli Serdang, 20353, North Sumatra, Indonesia*

[2] *Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan 20155, North Sumatra, Indonesia*

[3] *Faculty of Engineering, Universitas Sumatera, Utara. Medan, 20155, North Sumatra, Indonesia*

[4] *Faculty of Agriculture, Universitas Sumatera Utara, Medan 20155, North Sumatra, Indonesia*

[5] *Faculty of Science, Chulalongkorn University, 10330, Bangkok, Thailand*

[*]Corresponding Author: m.basyuni@usu.ac.id

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ABSTRACT

Perlis Village is around the mangrove forest in Langkat Regency, North Sumatra, Indonesia. This village has several barren lands potentially planted with mangroves. They were considering that the livelihoods of most of the people were fishermen and mangrove crab catchers. It is necessary to plant and rehabilitate damaged mangrove forests to restore and repair the ecosystem in Perlis Village. Planting activities were carried out in locations considered suitable for planting 200 seedlings. Three transects were made to obtain vegetation analysis data and carbon content. Each transect consists of six plots in natural forest and restoration forest. When the seedlings at the planting location were 3 months old, observations were carried out again, and of the 135 plants, approximately 67.16 percent were still alive from a total of 200 seedlings planted. Carbon storage in natural forests is 69 Mg ha^{-1} and 41.64 Mg ha^{-1} in restoration forests. By enriching the methods and estimating the potential carbon stocks of natural and rehabilitated mangroves in Perlis village in the context of Indonesia's climate change mitigation strategy, it is hoped that this information has the potential to help the blue carbon research community and policymakers.

Keyword: Blue Carbon, Carbon Stock, Mangrove Forest, Perlis Village, Restoration

1. Introduction

Mangroves are a unique and distinctive form of the forest ecosystem that lives in tidal areas between land and sea along tropical and subtropical coastlines, has great economic and ecological value, but is very vulnerable to damage if not managed wisely [1], [2]. Mangroves are believed to support the economy of coastal communities because they are a source of income for fishermen [3]. Mangrove forests provide ecosystem services, including preventing coastal erosion and seawater intrusion, nurturing, spawning, and feeding grounds for a variety of marine biota, and for direct use (such as firewood, charcoal, and construction materials) [4], [5]. Mangroves are one of the successful ecosystems in coastal areas. They act as a link between land and sea. This area is influenced by sea level height [6]. Mangrove forests have an important function in mitigating climate change, including their ability to absorb and store carbon [7], [8]. The capacity of mangrove forests to store CO_2 is four times greater than tropical forests [9].

Mangrove forests have the extraordinary ability to absorb carbon dioxide from the atmosphere, thereby reducing its presence. Rahman et al. [10] emphasized the important role of mangrove biomass and carbon sinks in this process because both effectively absorb and store carbon, thereby reducing CO_2 levels in the atmosphere. Mangrove areas, therefore require special attention, not only from the government, but especially from people who live around mangrove areas and people who care about the environment (NGOs). One effort that can be made to overcome this is through rehabilitation efforts. It is hoped that this activity will be able to restore the important function of mangroves in coastal areas. In order for rehabilitation goals to be achieved, active involvement of the local community is also needed [11]. One effective way to combat global warming is to utilize existing forests. Understanding the carbon storage capacity of mangroves adds depth and significance to their distinctive characteristics. The accumulation of carbon in the atmosphere contributes to global warming. The essence of maintaining oxygen and carbon dioxide levels in the ecosystem, from micro to macro scales, lies in the important function of mangrove leaves in producing oxygen and absorbing carbon dioxide [12].

Perlis is a village located in West Brandan District, Langkat Regency, Indonesia which has an area of 611 ha with a height of 4 meters above sea level. The rehabilitation program was implemented in September 2022 on land that experienced abrasion by planting *Rhizophora apiculata* propagules using the enrichment method. Every country that has mangrove forests must mandate the creation of protected mangrove areas and the rehabilitation of degraded mangroves. Over time, the motivation behind mangrove restoration has evolved from mere profit (timber industry, charcoal, and aquaculture) to recognition of mangroves as valuable riparian habitats [13]. This study aimed to evaluate the rehabilitation activity on degraded mangroves with enrichment method and to estimate the potential of carbon stock on natural and rehabilitated mangroves in Perlis.

2. Method

2.1 Location and Time of Research

The research was conducted in October-December 2022 in mangrove forest of Perlis Village, West Brandan District, Langkat Regency, North Sumatra (Figure 1). Perlis Village is located at 04º 02' 11"- 98º 16' 29" - North Latitude, and between 98º 14' 57.92"- 98º 18' 37.87 " - East Longitude. This study uses the enrichment method in the degreded mangrove area.

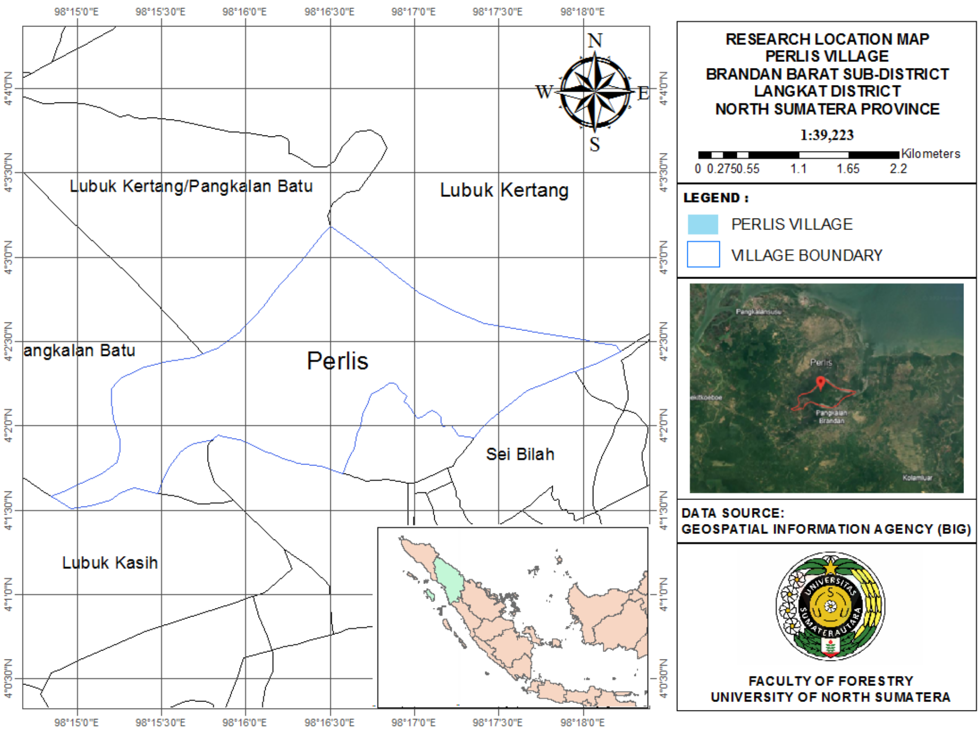

Figure 1. Perlis Village, West Brandan District, Langkat Regency, North Sumatra

2.2 Method of Research

2.2.1 Plant growth evaluation measurement

The plants used in land restoration were 200 *Rhizophora apiculata* propagules. The planting process was carried out by planting them into parts of barren mangrove land, which were marked with numbered transects. The propagules were planted and observed two times to measure total plant height. The initial observation was conducted in October and the final in December 2022. The Haga meter was a tool to measure plant height, measuring the total height from the ground surface to the tip of the tallest plant shoot. Two observations were made on 200 plants resulting from mangrove rehabilitation measuring the diameter of plant stems. The tool used in measuring the diameter of plant stems is a caliper to get more accurate results and for measuring stem diameter is a caliper with an accuracy level of 0.05 mm for measuring stem diameter was carried out at 10 cm from the tip of the propagules where the shoots growing.

2.2.2 Forest structure and composition

This study used a non-destructive sampling technique by measuring the diameter of the tree at a height of 130 cm above ground level diameter at breast height (DBH). The height and name of the tree species were measured and recorded. Forest structure surveys were performed in the form of transects and plots.

Three transects were formed. Each transect had six circular plots made perpendicular to the sea-mangrove ecotone, and the first plot of each transect was made 15 m inland from the ecotone. This fieldwork was done using large circular plots with a radius of 7 m for trees ≥ 5 cm dbh, as well as providing the estimates of seedling biomass composition and structure. The design also allowed for inspection connections between tidal gradients and elevation. The advantage of this design was that the linear plot arrangement captures much of the change in mangrove forest along the sea slope to the plateau [14].

2.2.3 Soil sampling

Soil sampling was carried out to measure the C-organic and Nitrogen (N) content using a purposive sampling method by taking soil samples of 0.5 kg each on three transects representing soil in natural forests and rehabilitated mangroves. Soil samples were taken to determine the organic carbon content by collecting subsamples at a distance of 5 cm from the center point of the extracted core at distances of 0–15 cm, 20–30 cm, 30–50 cm, and 50–100 cm a Russian peat borer [14]. Soil samples were dried at a temperature of 70º C until their weight was constant and ground before being weighed and sent to the laboratory for analysis of organic carbon concentration and nitrogen content.

2.2.4 Carbon stock calculation

The estimation of the increase in aboveground biomass in this study uses the mangrove forest allometric equation which was previously developed by Komiyama et al. [11]. Data from stem diameter measurements was analyzed using the allometric formula in Table 1. Table 1 shows a summary of aboveground biomass equations for various species using different predictors.

Table 1. Equality allometric various mangroves based on DBH (cm) [11].

Aboveground biomass (W kg)	**Biomass below ground level (W R kg)**
Avicennia marina W above = 0.308DBH 2.11 r^2 = 0.97, n = 22, D max = 35 cm *Rhizophora apiculata* W above = 0.235DBH 2.42 r^2= 0.98, n = 57, D max = 28cm *Bruguiera gymnorrhiza* W above = 0.186DBH 2.31 r^2 = 0.99, n =17, D max = 25 cm Common equation W above = $0.251pD^{2.46}$ r^2 = 0.98, n = 104, Dmax = 49 cm	*Avicennia marina* WR = 1.28DBH 1.17 r^2 = 0.80, n = 14, D max = 35 cm, Bruguiera spp. WR = 0.0188 (D 2 h) 0.909 r^2: No is known, n = 11, D max = 33 cm, *Rhizophora apiculata* WR = 0.00698DBH 2.61 r^2 = 0.99, n = 11, D max = 28 cm, *Rhizophora stylosa* WR = 0.261DBH 1.86 r^2 = 0.92, n = 5, D max = 15 cm, *Rhizophora* spp. WR = 0.00974 (D 2H) 1.05 r^2: No is known, n = 16, D max = 40 cm, Common equation WR = $0.200p^{0.899}D^{2.22}$ r^2 = 0.95, n = 26, Dmax = 45 cm,

Calculation of carbon from biomass uses the formula: C=B x % organic C.

C is the carbon content of the biomass, expressed in Megagrams (Mg) having previously been converted from kg; B = total biomass, expressed in (Mg)/ha: % organic C is the percentage value of carbon content assuming the carbon content in plants is 50%. Data analysis To relate our analysis to the existing data set, regression analysis was used to assess the relationship between height, diameter, aboveground biomass, belowground biomass, number of leaves, and leaf thickness. Statistical analysis was performed using Microsoft Excel.

3. Result and Discussion

Planting activities are carried out in two ways. They are the direct seedling method and indirect planting using polybag seedlings. Based on the criteria for the material to be planted, planting mangroves can be done in two ways namely direct planting using fruit/propagules and indirect planting, i.e. seedlings made from nurseries [23]. This research was carried out using indirect planting which are seedlings planted in polybags were planted in the rehabilitation area.

Figure 2. Vegetation analysis data collection in Perlis Village

Planting is done by planting in an empty area on the land to be rehabilitated. Mangrove planting activities are said to be successful when mangroves thrive as indicated by leaves that look fresh green and by the growth of new leaf shoots, and vice versa. Mangrove planting activities are said to fail if the planted mangroves die [24]. Mangrove death is indicated by leaves and stems that dry, or turn yellow, partially wither, and do not show new shoot growth.

Evaluation of growth in *Rhizophora apiculata* seedlings at the rehabilitation site was carried out in October 2022. It can be evaluated through several factors, namely growth rate, measurement of growth in height, measurement of growth in diameter, and increase in number of leaves.

3.1 Evaluation of Seedling Growth

Based on the results of evaluating the growth rate of planting seedlings in the land rehabilitation area, it can be said that it was successful due to the high percentage of plant growth, which was 67.16% of a total of 201 seedlings planted in the rehabilitation area. From these results it can be found that the highest mortality rate was in line 1A where 15 seedlings were found to die and the lowest was in line 2B where 2 seedlings were found to have died (Figure 3). The cause of the mortality rate of the seeds planted is the result of several seeds being trampled by the surrounding community while installing and taking crab traps and one of the biggest impacts of these deaths is the length of the ebb and flow of water that occurs at the place where the planting activity is carried out.

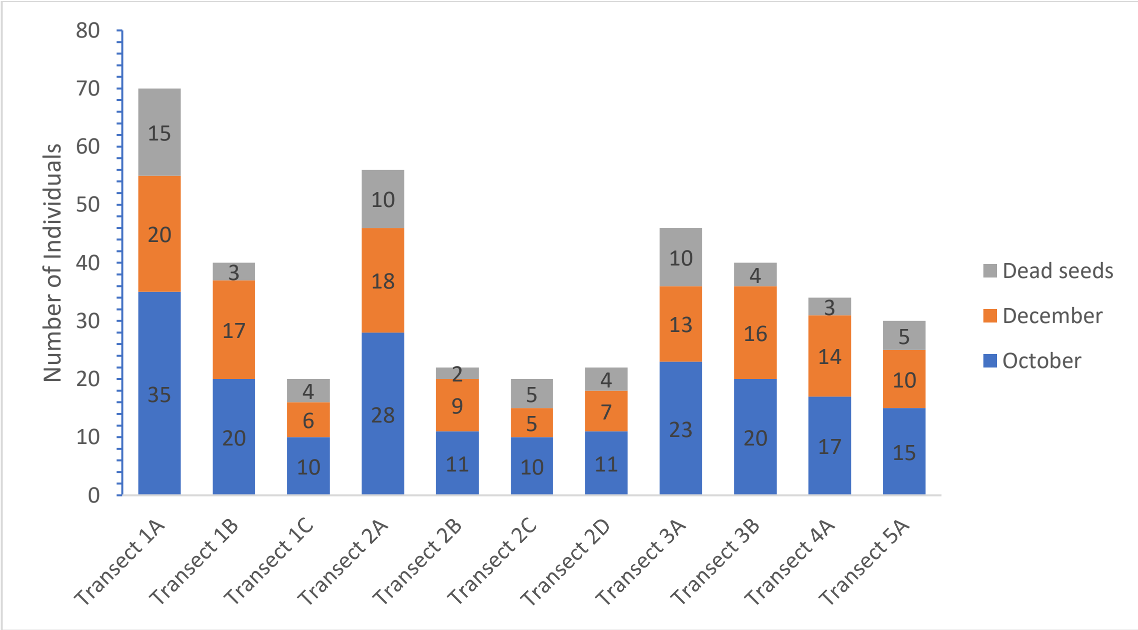

Figure 3. Results of Evaluation of Growth Success of *R. apiculata* in October and December 2022

The results obtained in this study as listed in Table 2 and Table 3 for natural forest locations were found to be the most common and frequently encountered species, namely the *Rhiphora apiculata* which found as many as 258 ind/ha and the least found was *Scyphiphora hydrophyllacea* which was 10 ind/ha. Meanwhile, in restoration forest locations, the most common species was *Scyphiphora hydrophyllacea* with 235 ind/ha and the least encountered was *Acacia leptocarpa* where only 5 individuals/hectare were found. In natural forest areas, *Rhizophora apiculata* is more common because this type has fast-growing characteristics and is easy to adapt to its environment, which makes it easy for this type to survive and quickly enter the tree group. *Rhizopora apiculata* has one advantage, namely in terms of adapting to the aquatic environment [14].

Table 2. Number of individuals with tree species found in natural forest in Perlis Village

No	Family	Type	Ind/ha
1	Rhizoporaceae	*Rhizophora apiculata*	258
2	Rhizoporaceae	*Rhizophora stylosa*	52
3	Rubiaceae	*Scyphiphora hydrophyllacea*	10
4	Lythraceae	*Sonneratia alba*	136
		Total	456

Table 3. Number of individuals with tree species found in restoration forest locations in Perlis Village

No	Family	Type	Ind/ha
1	Fabaceae	*Acacia leptocarpa*	5
2	Rhizoporaceae	*Rhizophora apiculata*	60
3	Rhizoporaceae	*Rhizophora stylosa*	31
4	Rubiaceae	*Scyphiphora hydrophyllacea*	235
5	Lythraceae	*Sonneratia alba*	17
6.	Nypoideae	*Nypa fruticans*	17
		Total	348

Table 4 shows the results after observation, namely where the diameter of the largest was found at the research location, namely the species, namely 7.10 cm and the highest, namely the type *Sonneratia alba* and for the smallest diameter, it was found in the type *Rhizopora apiculata* with a diameter of 5.53 cm and for the highest type, namely the type of *Sonneratia alba* with a height of 6.15 m and for the smallest type for the height, namely the type of *Scyphiphora hydrophyllacea* of 4.15 m.

Table 4. The vegetation structure of mangrove forests in natural forest locations in Perlis Village

No	Type	Diameter (cm)	Height (m)
1	*Rhizophora apiculata*	5.53	4.41
2	*Rhizophora stylosa*	6.01	4.78
3	*Scyphiphora hydrophyllacea*	7,10	4.15
4	*Sonneratia alba*	7.02	6.15

The results of diameter and height in the restoration forest are found in Table 5. The largest diameter was for the *Acacia leptocarpa* species 8.30 cm. The smallest diameter was for the *Scyphiphora species hydrophyllacea* which is 6.22 cm. The species with the highest height, namely *Nypa fruticans* (9.06 m). The smallest height comes from the *Scyphiphora hydrophyllacea* (4.39 m).

Table 5. Vegetation structure of the mangrove forest at the restoration forest location in Perlis Village

No	Type	Diameter (cm)	Height (m)
1	*Acacia leptocarpa*	8.30	7.60
2	*Rhizophora apiculata*	6.24	4.70
3	*Nypa fruticans*	8.25	9.06
4	*Rhizophora stylosa*	7.48	5.95
5	*Scyphiphora hydrophyllacea*	6.22	4.39
6	*Sonneratia alba*	8.00	6.33

3.2 Estimation of Carbon Stocks in The Mangrove Forest of Perlis Village

Mangroves are one of the most carbon-rich biomes, mangroves only contribute about 1% of carbon sequestration by the world's forests, but as coastal habitats, they contribute 14% of carbon sequestration by the oceans [25]. Table 6 shows that the highest carbon storage is found in natural forests, namely 57.63 Mg ha-1 above ground level and 12.07 Mg ha−1 below ground level.

Table 6. Vegetation structure of the mangrove forest at the restoration forest location in Perlis Village

Type	Biomass (kg/m^2)		Carbon Stock (Mg ha^{-1})		Total carbon (Mg ha^{-1})
	Above ground	Below gorund	Above ground	Below gorund	
Natural Forest	3851.45	972.27	57.63	12.07	69.70
Restoration	2171.97	736.41	32.50	9.14	41.64
Total	**6,023.43**	**1,708.68**	**90.13**	**21.22**	**111.35**

The carbon content of the restoration forest in Perlis Village is 32.50 Mg ha^{-1} for aboveground carbon and 9.14 Mg ha^{-1} for belowground carbon for a total of 41.64 mg/ha. The results of this study are not much different from previous research conducted by Amelia et al 2023 [26], the total carbon storage of biomass stored by 7-year-old plants using propagules is 51.18 Mg ha^{-1}, while the carbon storage by planting seedlings using seedlings is 56.79 Mg ha^{-1}. The rate of increase of tree biomass such as the age of the stand, the history of vegetation development, the composition of the stand, and the structure of the vegetation affect the biomass of the forest stand [27], [28].

4. Conclusion

There are 135 seedlings survived (67.16%) of the 200 seedlings planted in the mangrove forest of Perlis Village. The number of individual mangrove plants in the natural forest was 456 ind/ha and 348 ind/ha in the restoration forest. Overall, the carbon stock of the mangrove forest in Perlis Village was 111.35 Mg ha^{-1}. Our results show that carbon stocks in mangrove forests can be increased by selecting species with high carbon density for reforestation and stand improvement. By enriching the method and estimating the potential carbon stocks of natural and rehabilitated mangroves in Perlis Village in the context of Indonesia's climate change mitigation strategy, it is hoped that this information has the potential to help the blue carbon research community and policymakers.

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