Carbon Estimation in the Tanjung Leban Peat Revegetation Area, Bengkalis Regency to Support Folu Net Sink 2030

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Abstract. Peatland ecological restoration aims to overcome damage to the peat ecosystem caused by human activities, both directly and indirectly. This damage often triggers various problems, such as land fires. Tanjung Leban Village is one of the areas with a high fire rate, especially in 2012, 2013, and 2015. Many of the fire-scarred areas have been left idle, thereby increasing the risk of fires due to a lack of management. In 2015, the people of Tanjung Leban Village began to realize the importance of restoring the peatland ecosystem. Restoration efforts were carried out on 14.7 hectares of community-owned land, with a total of 14,381 plants divided into two categories: natural wood plants and fruit plants. The research site covers only 3 ha, where the planted trees have developed into forest vegetation. This research aims to measure the carbon reserves available in the restoration area as part of efforts to support the achievement of FOLU Net Sink 2030. The research results for carbon reserves in the vegetation area are 96.07 t ha-1, with a tree density of 235 ind/ha, a pole density of 45 ind/ha, and a sampling of 76 ind/ha.

1 Introduction

Over the past decade, a series of forest and land fires have occurred in Indonesia, including widespread peat fires in most areas of Riau Province. Riau's strategic position not only makes it the economic center of western Indonesia, but also a source of haze in Southeast Asia. Therefore, the use of peatlands for plantations in Riau Province has recently become a serious concern, given that peatland fires have caused the haze disaster that has lasted for 18 years in Indonesia.

Peatland fires are a complex issue influenced by various factors, including land ownership issues related to management and utilization. Land, mostly owned by parties outside the village and managed by workers from outside the area, is often poorly monitored, so fires can occur at any time without adequate prevention. As a solution, the government is implementing a comprehensive peatland restoration program. Therefore, it is interesting to study the dynamics of peatland use, fires, and restoration efforts, especially through case studies in areas that have implemented such restoration programs.

Tanjung Leban Village is one of the areas with a high rate of peatland fires, especially in 2012, 2013, and 2015. Many of the burned lands were left abandoned, becoming idle land vulnerable to repeated fires due to a lack of supervision. In 2015, the people of Tanjung Leban Village began to realize the impact of peatland damage and initiated ecological restoration efforts through revegetation. This activity was carried out using the mentoring method by the village facilitator on duty in Tanjung Leban Village. The process begins with socialization, forming groups, procuring seeds, clearing land, and planting. This revegetation program involves communities that are members of the Peat Care Community Group (MPG), covering an area of 14.7 hectares and totaling 14,381 plants. These plants fall into two main types: natural wood plants and fruit plants [1].

Peat restoration is an effort to restore degraded peat ecosystems, restoring their hydrological conditions, structure, and function. Through peat restoration, degraded peat ecosystems can be restored to a condition with improved hydrological conditions, structure, and function (Peat Restoration Agency, 2017). The results of research [2] show that the management and use of peatlands have contributed to the economy, even as the main source of livelihood for coastal communities. Utilization of peatlands in line with local wisdom can help preserve the peat ecosystem.

Tropical peatland areas are among the most important carbon reservoirs in terrestrial ecosystems, as they are capable of storing very large amounts of carbon, both in aboveground biomass such as vegetation and in subsurface peat layers through tree biomass and other types of vegetation [3]. The government has issued a policy requiring peatland use to align with the Sustainable Development Goals [2]. Riau Province, which is around 56% covered with peatland, is very vulnerable to haze disasters caused by peatland fires. Peatlands are fragile ecosystems formed over thousands of years by the dense accumulation of wet plant material [4]. Regarding the phenomenon of peat damage and land fires, serious efforts are needed to address it. The comprehensive solution chosen by the government is peatland restoration, as outlined in Presidential Regulation Number 1 of 2016 concerning the Peat Restoration Agency (BRG). The main task and function of BRG is to coordinate and strengthen policies for implementing peat restoration across 2 million hectares in 2016-2020.

There is a government program to save critical land and carbon storage through the Sustainable Land Restoration program on Critical Land to support FOLU Net Sink 2030. FOLU Net Sink 2030 is a condition to be achieved through mitigation actions to reduce greenhouse gas (GHG) emissions from the forestry and land sectors, in conditions where absorption levels are already higher than emissions in 2030. The peatland restoration area implemented by the Tanjung Leban community is part of the FOLU Net Sink 2030 initiative. Estimating carbon potential in the Tanjung Leban peatland restoration area is feasible because the area already has forest vegetation. The aims of this research are: to estimate the total amount of carbon contained in the peatland revegetation area of Tanjung Leban Village, Bengkalis Regency.

2 Methodology

The peatland restoration forest area owned by the Masyarakat Peduli Gambut (MPG) group covers 14.7 hectares; however, the research sample consists of the revegetation area at the Rumah Runding Restorasi Gambut Mangrove (R3GM), a successful example of revegetation land measuring 3 hectares. Carbon stock calculation is conducted only for plants that were planted after the 2015 oil palm plantation fire and replanted with forest species in 2016

The plot sampling locations were selected using purposive sampling with a random start, with plots randomly placed within the designated area and spaced 100 meters apart in a zig-zag pattern. The shape, size, and distribution of the plots can be seen in **Fig. 1**. The area for each plot is 20 m × 20 m = 400 m² [5].

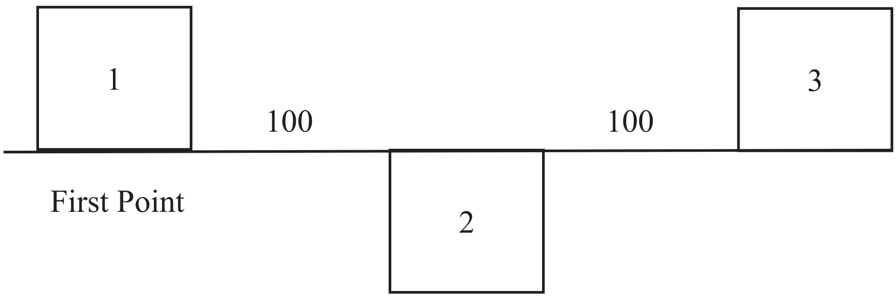
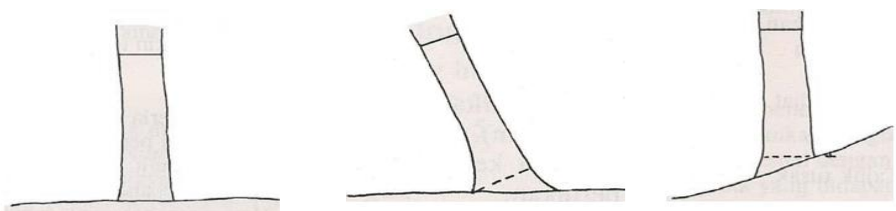


Fig. 1. Distribution plot

Vegetation measurements were carried out at various stages, including seedlings, stakes, poles, trees, and litter. A total of 10 plots were established with the criteria of dense tree canopies. The survey was conducted in March 2025, with sample collection coordinates at 1°28'13.50" N 101°41'02.60. Biomass measurements were conducted by measuring the diameter of vegetation (poles and trees) at breast height (1.3 meters from the base), across various vegetation conditions, as shown in **Fig. 2**.



a) Normal tree : For upright trees growing on level ground, DBH is measured exactly 1.3 m above the ground. This represents the standard and most common measurement condition.

b) Leaning tree : When a tree is leaning, the DBH measurement is still taken at 1.3 m along the stem axis, not vertically from the ground. This ensures that the measurement point reflects the true stem diameter and avoids bias caused by the tree's inclination.

c) Tree on sloping ground: For trees growing on uneven or sloped terrain, DBH is measured 1.3 m from the uphill side of the stem. Measuring from the upper slope prevents overestimation of diameter due to elevation differences at the base of the tree.

Fig. 2. Diameter at breast height (DBH) measurement guidelines in various tree conditions

Woody vegetation measurements were carried out at various levels: seedlings, saplings, poles, trees, and litter. Data collected includes vegetation diameter, understory plant samples, and litter. The field data collection process has followed the Indonesian National Standard (SNI 7724:2019), which is used to measure and calculate carbon stocks [6].

The Allometric Equations for Seedlings, Poles, Trees, and Forest Necromass are calculated based on allometric equations as shown in **Table 1**.

Table 1. Allometric Relationship for Biomass Estimation [7]

Rainfall area zone (mm/year)	Allometric Equations
Dry (<1500 mm)	$Y = 0{,}139D^{2{,}32}$
Humid (1500 – 4000 mm)	$Y = 42{,}69 - 12{,}8D + 1{,}24D^2$ $Y = 0{,}118D^{2{,}53}$
Wet (>4000 mm)	$Y = 21{,}3 - 6{,}95D + 0{,}74D^2$ $Y = 0{,}03D^{1{,}89}H$

Note: Y: Biomass (kg); D: Diameter (cm); H: Height (m)

Once the biomass value is known, it can be used to estimate the potential for carbon stored in forest vegetation. Converting biomass calculation results to carbon (kg) by multiplying the biomass value by a conversion factor. The estimated carbon content calculation according to [8] uses an assumption of 50% of the biomass weight.

3 Results & Discussion

Carbon estimation research was conducted in Tanjung Leban Village on a peatland that underwent revegetation following forest and land fires from 2015 to 2018, with a total affected area of 14.7 ha [9]. Peatland restoration activities were carried out by the Peat Care Community Group (MPG). The main objectives were to rewet dry peatlands, replant degraded peatlands (revegetation), and strengthen the community's economy through livelihood revitalization. Sampling for this study was conducted in the most successful restoration area on the peat restoration-negotiated plot owned by Mr. Jauhari. Planting began in 2015 over approximately ±3 ha with species including jelutung (*Dyera polyphylla*), spices (*Dillenia spp.*), meranti (*Shorea leprosula*), bintangur (*Calophyllum dioscuri*), and several fruit species such as rambutan (*Nephelium lappaceum* L.), petai (*Parkia speciosa*), and jengkol (*Pithecellobium jiringa*). Based on the field survey, vegetation density and diameter data were obtained as shown in **Table 2**.

Table 2. Plant Density and Diameter at Various Levels

Vegetation Level	Density (ind ha^{-1})	Average Diameter (cm)
Stake	45	7.5
Pole	76	16.8
Tree	325	26.6

As shown in **Table 2**, sapling-level vegetation has the lowest density (45 individuals/ha). This is due to the dense tree canopy, which limits light penetration to the forest floor and affects natural regeneration in this secondary forest, which was intentionally planted for peatland restoration. Vegetation density generally decreases as plant morphological dimensions increase. As explained by [10], this pattern is caused by increased competition among plants for growing space, light, and nutrients—allowing only the most adaptive species to survive. The study area is dominated by tree species, which significantly increases potential carbon reserves, as higher vegetation density contributes to greater carbon sequestration [11].

The distribution of tree species found in the revegetation area is illustrated in **Fig. 3**, which presents the dominant species planted during restoration, including jelutung, meranti, bintangur, dillenia, and several fruit trees. These species were selected because they are well adapted to peatland ecosystems and contribute significantly to long-term biomass accumulation.

Fig. 3. Names of tree species in the revegetation area

The larger tree diameter compared with other vegetation types reinforces the understanding that trees are the primary contributors to carbon storage. This is because tree trunks can store approximately 34% of carbon produced from photosynthesis—the highest proportion among plant organs [12, 13].

Fig. 4. Tree stands, poles, and saplings in the peatland revegetation area of Tanjung Leban.

The structural conditions of vegetation at different growth levels—trees, poles, and saplings—are shown in **Fig. 4**. This figure illustrates the vertical stratification of vegetation in the peatland revegetation area, highlighting the dominance of mature trees and the relatively limited sapling layer due to canopy shading. This structural composition contributes to differences in biomass and carbon storage potential among vegetation strata. Based on measurements obtained in the revegetation area, the potential carbon stock is shown in **Table 3**.

Table 3. Potential Carbon Savings

Vegetation Level	**Carbon saving (t ha^{-1})**	
	Biomass	**Carbon**
Tree	255.2	127.6
Pole	69.6	34.8
Stake	42.5	26.2
Litter	0.43	2.6

Biomass conversion from the field resulted in an estimated carbon stock of 96.07 t ha^{-1}, categorized as medium. This indicates that the vegetation is well-maintained but still has relatively small average tree diameters (26.6 cm), partly because selected species are not fast-growing [14]. For peatland revegetation, species selection must match peatland characteristics, including acidity, water availability, and depth. Endemic peatland species—jelutung, ramin, pulai rawa, gaharu, and meranti—are recommended due to their ecological resilience.

The greater the diameter of the vegetation, the greater the biomass [15]. The findings align with [16], which reported that peatland revegetation in Kalimantan (planted in 2016) had carbon reserves of 65.90 t ha-1, lower than those of primary forest due to CO_2 release from fires. The results study assess carbon stock losses following fire and post-fire recovery, showing that peatland fires cause substantial carbon losses and that vegetation recovery requires a long period to approach primary forest carbon stocks [17]. Understory and litter carbon stocks were much lower (0.24 and 2.6 t ha^{-1}, respectively) due to limited sapling numbers, small diameters, and the dominance of low-biomass species such as ferns [5]. Meanwhile, litter shows higher biomass due to slower evaporation under a dense canopy.

The peatland revegetation area of Tanjung Leban has substantial potential to support the FOLU Net Sink 2030 target. This national program aims to achieve net-zero emissions in the forestry and land-use sectors by 2030 [18]. Carbon stock levels are influenced by vegetation diversity, soil type, and land management practices [19]. Forest biomass typically contains approximately 50% carbon [20], which can be released during fires and contributes significantly to atmospheric CO_2.

The carbon stock estimate of 96.07 t ha^{-1} indicates strong potential for contributing to national emission-reduction efforts. Strengthened monitoring, reporting, and verification (MRV) systems at the district level are essential for optimizing carbon management and accelerating progress toward Indonesia's forestry net-emission target under FOLU Net Sink 2030.

4 Conclusion

Revegetation of peatlands affected by the 2013–2015 fires in Tanjung Leban Village, Bengkalis Regency—using Jelutung (*Dyera polyphylla*), rempah-rempah (*Dillenia* spp.), meranti (*Shorea leprosula*), bintangur (*Calophyllum dioscuri*), and several fruit trees such as rambutan (*Nephelium lappaceum* L.), petai (*Parkia speciosa*), and jengkol (*Pithecellobium jiringa*)—produced an estimated carbon stock of 96.07 t/ha. This value indicates that the revegetation area is in a well-maintained condition and has begun to recover its ecological function as a carbon sink. The findings also highlight the importance of selecting peat-adapted species and maintaining vegetation structure to support long-term carbon accumulation and contribute to regional climate mitigation efforts.

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