

Estimation of aboveground carbon stock in PT KOJO's forest in Riau, Indonesia

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Abstract. The government of Indonesia is committed to reducing carbon emissions through the Forestry and Other Land Uses (FOLU) Net Sink scheme, e.g., by measuring and calculating potential aboveground carbon in PT KOJO's forest. This research aims to measure biomass and aboveground biomass in PT KOJO's forest, Pinggir District, Bengkalis. Non-destructive sampling was applied by making plots of 20 m × 20 m (trees), 10 m × 10 m (poles), and 5 m × 5 m (saplings). Destructive sampling was carried out in a plot of 1 m × 1 m for seedlings and understory plants. Results showed that potential carbon stock at tree, pole, sapling, seedling, understory plant, litter, and necromass levels were 160.62 tC/ha, 34.60 tC/ha, 20.88 tons/ha, 1.54 tC/ha, 11.59 tC/ha, and 1.47 tC/ha, respectively. The total carbon stock in PT KOJO's forest was 160.69 tC/ha. Carbon stock in PT KOJO's forest is classified as medium, therefore efforts are needed to increase carbon stocks and efforts to protect PT KOJO's forest area so that stored carbon is not released into the air.

1 Introduction

The Indonesian government is committed to reducing carbon and greenhouse gas (GHG) emissions, which is critical to climate change mitigation, ecosystem management, and FOLU Net-Sink 2030 Forestry and Other Land Use (FOLU) advocacy. FOLU Net-Sink 2030 is a condition where the level of carbon sequestration in FOLU sectors is equal to or exceeds the level of greenhouse gas emissions produced by the sector in 2030 [1].

Carbon sequestration in forest ecosystems has recently come to the attention of many parties due to concerns over global climate change [2, 3]. As regards land cover change in Jambi, the estimated net emission in 2009-2011 was 4.8 Mt CO₂-eq/year [4].

Climate change, mainly bred by the increasing concentration of GHG in the atmosphere, is a serious threat to the planet. In addressing the threat, we have to find effective ways to reduce carbon dioxide (CO₂) concentration in the atmosphere, such as by capitalizing on forest vegetation. The vegetation has a range of functions, e.g., producing wood, absorbing carbon from the air, utilizing it for photosynthesis, and storing it in the form of biomass. The

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more CO₂ absorbed by plants and stored in the form of biomass, the greater the adverse effects of the greenhouse effect which can be controlled [5].

Meanwhile, forests can also be a major source of CO₂ emissions through decomposition, degradation, and deforestation. Therefore, the existence of forests must be maintained and protected, allowing them to absorb and store carbon and preventing them from transforming into a source of CO₂.

Results demonstrate that the highest estimated carbon stock is found in secondary forests, with a carbon stock of 265.86 tons/ha, while agroforestry has a carbon stock of 131.31 tons/ha. Meanwhile, palm plantations come with a carbon stock of 100.89 tons/ha, and the lowest carbon stock is notable in rice fields, with a carbon stock of 70.50 tons/ha [6]. Among these ecosystems, forests have the highest carbon stocks.

Related to climate change and global warming, several efforts to maintain the ecological function of forests are to care for and maintain forest vegetation from possible damage (deforestation and recession) as forests store and absorb CO₂. Estimating carbon stocks in vegetation stands has become an urgent issue in calculating, monitoring, managing, and evaluating carbon stocks [7].

Species extinction due to global warming and carbon trading is currently a heated debate in the global community, and a variety of studies have been conducted to estimate carbon content using allometric formulas to determine potential carbon reserves in an area. Many different allometric formulas were made by various researchers, including for agroforestry land [8], secondary forests [9], and peat forests [10]. It is an opportunity for forests with urban status, such as PT KOJO's forest, one of the largest sources of carbon stock, to participate. However, the owning company has no knowledge about how the overall carbon potential there is stored, making research to calculate carbon content in PT KOJO's forest area in Bengkalis, Riau crucial.

2 Methodology

This research was undertaken in PT KOJO's forest in Pinggir District, Bengkalis, Riau (Figure 1) in 2022. The tools used were a map, Phi band, GPS (Global Positioning System), stationery, oven, envelope, 50 m meter, 1.3 m long wooden stick, scissors, plastic bags, scales, soil drill, raffia rope, and tally sheet. The research material was PT KOJO's forest stand.

Non-destructive and destructive sampling methods were implemented; the first was applied for sapling, pole, tree, and necromass levels, while the latter was for seedling, understory, and litter levels.

Non-destructive sampling method activities were measuring the Diameter at Breast Height (DBH) and using allometric equations to calculate biomass. The non-destructive sampling method was more widely used because of its ease and lower cost for research design and application and its high level of accuracy. We developed sampling techniques and allometric equations from the latter method. This research mostly referred to SNI Carbon Measurement [11].

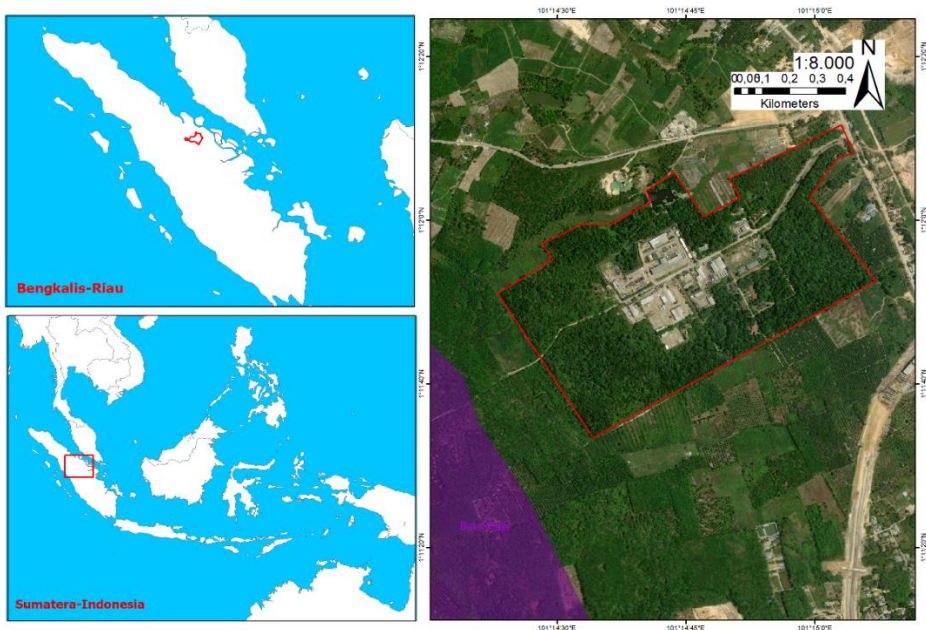


Fig. 1. PT KOJO’s forest.

The plot shape used in carbon content measurement was square [12], considering that compared to a circular one, a square plot was easier to ascertain which trees were included in the plot.

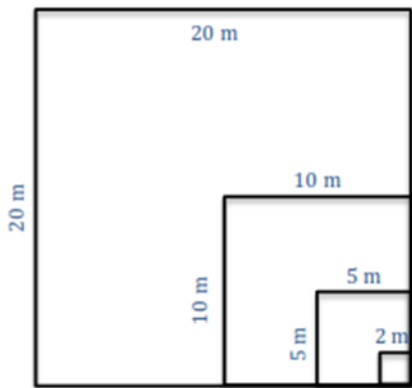


Fig. 2. Measurement plot design with four subplots.

- Description:
- A. Seedlings, litter, and understory (2 m × 2 m)
 - B. Saplings (5 m × 5 m)
 - C. Poles (10 m × 10 m)
 - D. Trees (20 m × 20 m)

The plot shape and size (Fig. 2) were adjusted to that by the Indonesian National Standard (SNI 7724:2019) for each vegetation growth level [11]. The random sampling technique was implemented to determine plots randomly and avoid plot placement in uniform locations.

Determining zone/stratification in PT KOJO’s forest was based on canopy density grouping for data accuracy in sampling. Crown density was divided into dense, medium, and sparse crown density.

The DBH 1.3 m above ground level was measured using a technique adjusted to the general conditions of the location and the tree to be measured. Data on DBH and specific gravity were tabulated and analyzed using Microsoft Excel. Primary field data on DBH and tree species names were used to estimate biomass content. The formula used was Ketterings’ allometric equation for secondary forest $W = 0.11 \rho D^{2.62}$ [9] (W = Biomass (kg), D = Diameter (cm), ρ = Specific gravity of the tree).

Biomass measurements of seedlings, understory, and litter were conducted on a 2 × 2 m plot. Seedlings and understory plants were cut from the crown and weighed for their wet weight, while litter was collected and weighed for its wet weight in the field. Seedling, understory, and litter samples were taken 300 grams to be baked at 105°C for 24 hours. Calculation of litter and understory organic matter used the following formula [11]:

$$B = \frac{BA \times BC}{BD} \tag{1}$$

- Description:
- B = weight of organic matter (kg);
 - BA = dry weight of the sample (kg);
 - BC = total wet weight (kg);
 - BD = wet weight of the sample (kg)

Dead tree biomass was measured on a plot of 20 × 20 m. The criterion for both standing and fallen dead trees was having a diameter of > 5 cm. The DBH of dead trees was measured, and the level of integrity of dead trees was determined. Necromass was calculated using the allometric equation by SNI:7724. The carbon stock was calculated as proposed by [11], [13], [14] below:

$$C = 0.47 BC \tag{2}$$

- Description:
- C = Carbon content (kg)
 - B = Tree’s dry biomass (kg)

3 Results and Discussion

3.1 General situation of the research location

PT KOJO’s forest, a tropical rainforest in Bengkalis, had an A climate with medium rainfall. The mineral soil forest had a flat to undulating topography and a temperature range of 25°C -33°C with humidity of 79%-85%. The forest was directly adjacent to community plantations, namely rubber (*Hevea brasiliensis*) and oil palm (*Elaeis quinensis*) plantations, and community settlements.

3.2 Carbon stock based on canopy classification

Canopy classification was essential in maintaining forest ecosystem stability, conserving biodiversity, and buoying valuable natural resources. It was part of the forest system which contributed to the sequestration and stock of carbon from the atmosphere, enabling the

reduction of carbon dioxide concentration in the atmosphere and mitigating global climate change. Carbon measurement output based on canopy classification is indicated in Table 1.

Table 1. Carbon stock based on canopy classification.

No.	Carbon Pools	Canopy Classification (Ton/Ha)		
		High	Medium	Low
1	Trees	95.98	24.64	0.00
2	Poles	10.19	14.19	10.22
3	Saplings	8.15	6.88	5.86
4	Seedlings and understories	0.92	0.41	0.22
5	Litters	6.65	4.41	0.53
6	Necromass	1.47	0.00	0.00
	Total	123.35	50.52	16.82

PT KOJO’s forest area, associated with carbon calculation, was divided into three land covers, which were high, medium, and low canopies, each of which was sampled to determine the amount of carbon contained in the area. We chose and undertook purposive sampling, a sampling technique with certain considerations concerning the type of land cover and the different ecosystem conditions in the field. Carbon content in high, medium, and low canopies would successively decrease.

The amount of carbon stocks in each location varied, depending on land characteristics, diversity, and density of existing plants. Different densities and types of vegetation would illustrate the amount of CO₂ which plants could absorb in an ecosystem, helping us to identify the degree of contribution given by land in various ecosystems as a carbon stock store. The amount of carbon stock is supported by the density of vegetation and the absorption of CO₂ gas absorption capacity [15]. Areas that are dominated by trees have higher carbon stocks.

3.3 Total carbon in PT KOJO’s forest based on carbon pools

Trees, as the main constituent of forests, played an important role in carbon stock, while poles and piles, also forest constituents, could absorb much carbon in the air. The different roles were because the growth usually slowed down at the tree growth level, while at the pole and pile ones, meristematic tissues were actively dividing. Trees were effective carbon sinks and could inhibit CO₂ effects in the atmosphere [16]. Carbon biomass measurement output in PT KOJO’s forest is pointed out in Table 2.

Table 2. Total carbon stock based on carbon pools.

No.	Carbon Pools	Total (Ton/ha)	Percent (%)
1	Trees	120.62	63.25
2	Poles	34.60	18.15
3	Saplings	20.88	10.95
4	Seedlings and understories	1.54	0.81
5	Litters	11.59	6.08
6	Necromass	1.47	0.77
	Total	190.69	100.00

As presented in Table 2, with carbon stored amounting to 120.62 tons/ha or 63.25% of the total carbon stock, trees had the highest amount of carbon stock in comparison with other carbon stock pools. Based on previous research, the proportion of tree carbon biomass was 85.16% of the total carbon biomass stored in Dramaga Research Forest, Bogor [17]. High and low carbon stocks in a location or plot were germane to the vegetation density of the plot,

and the larger the trees’ diameter and the older the trees’ ages in a forest area., the higher the biomass and carbon stocks there [18]. However, when trees with large diameters could store large amounts of carbon, the larger the diameters, the fewer the individuals in the natural forest [19].

Analyses of 30 tree samples showed that the largest carbon stock allocation (93%) was in the trunk, followed by branches (5%) and leaves (2%) [2]. Seedlings and understory plants had the lowest carbon stores. Measuring seedlings and understory plants using destructive sampling methods and the carbon they contained was considered insignificant to change the grouping results or not worth the time and effort required to survey them [20].

3.4 Total carbon stock of PT KOJO’s forest

Different carbon content in each forest area was a result of different stand compositions and tree diameters in the areas. Total belowground biomass (BGB) was 32% of aboveground biomass (AGB) [21]. The total carbon stock of PT KOJO’s forest is suggested in Table 3.

Table 3. Total carbon stock of PT KOJO’s forest.

No.	Canopy Classification	Area (Ha)	Carbon (Ton/Ha)	Total (Ton)
1	High	61.67	123.35	7606.75
2	Medium	3.74	50.52	188.94
3	Low	0.76	16.82	12.84
	Total	66.17	190.69	7,808.53

The total aboveground carbon stock in PT KOJO’s forest was 190.69 tons/ha. Carbon content in PT KOJO’s forest was higher relative to that in the secondary forest in Pelalawan, with a carbon content of 83.49 tons/ha [22]. However, PT KOJO’s forest had a lower content than the aboveground carbon potential in Sentajo Protected Forest, which was 223.17 tons/ha [23]. The amount of carbon stocked in a forest stand depends on the age and productivity of the forest [24], [25]. The result of extrapolation to the total area of the study site was 7,808.53 tons of carbon.

4 Conclusion

The potential carbon stock at tree, pole, sapling, seedling, understory plant, litter, and necromass levels were 160.62 tC/ha, 34.60 tC/ha, 20.88 tons/ha, 1.54 tC/ha, 11.59 tC/ha, and 1.47 tC/Ha, respectively. The aboveground carbon stock of PT KOJO’s forest was 190.69 tons/ha, and the total aboveground carbon stock potential was 7,808.53 tons of carbon. Carbon stock in PT KOJO's forest is classified as medium, therefore efforts are needed to increase carbon stocks and efforts to protect PT KOJO’s forest area so that stored carbon is not released into the air.

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