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ESTIMATION OF CARBON STOCK AND BIOMASS OF MANGROVE IN PANGKAL BABU VILLAGE TANJUNG JABUNG BARAT

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ABSTRACT

Mangrove ecosystems play a critical role as blue carbon sinks, yet quantitative data on carbon stocks in many coastal villages of Jambi Province remain scarce. This study estimated above- and belowground biomass and carbon stocks in the mangrove ecosystem of Pangkal Babu Village, Tungkal Ilir District, Tanjung Jabung Barat Regency, Jambi Province, Indonesia. A non-destructive inventory method was employed across three stations, with a total of eighteen 10 × 10 m sample plots. Tree diameter at breast height (DBH) was measured for all individuals with DBH ≥ 4 cm, and biomass was computed using the generic allometric equation of Komiyama et al. (2005). Six mangrove species were recorded: *Sonneratia alba*, *Avicennia alba*, *A.marina*, *Rhizophora apiculata*, *R. mucronata*, and *Bruguiera gymnorrhiza*, with a total of 246 individual trees. Mean total biomass was 189.29 ± 69.91 Mg/ha and mean carbon stock was 88.96 ± 32.88 Mg C/ha, equivalent to 326.50 ± 120.70 Mg CO_2e/ha. Station 2 exhibited the highest carbon stock (127.88 Mg C/ha), dominated by *Avicennia alba* with the highest importance value index (IVI = 97.65). These results confirm that the mangrove ecosystem of Pangkal Babu Village serves as a substantial carbon reservoir and should be prioritized for conservation and rehabilitation programs.

Keywords: Allometric equation, Blue carbon, Carbon stock, Mangrove, Tanjung Jabung Barat

1. INTRODUCTION

Mangrove forests are among the most productive and carbon-dense ecosystems on Earth, storing considerable amounts of organic carbon in their biomass and sediments, often referred to as "blue carbon"[1]. Globally, mangroves are estimated to store 4–20 Mg C/ha/yr and sequester 20–120 Mg C/ha in aboveground biomass alone[2]. In addition to their role as carbon sinks, mangroves provide crucial ecosystem services including coastal protection, nursery habitat for fisheries, and livelihood support for coastal communities[3].

Indonesia holds approximately 3.31 million hectares of mangroves, or about 20–23% of the world's total, making it the largest mangrove-holding country in the world[4]. Jambi Province, including Tanjung Jabung Barat Regency on the eastern coast of Sumatra, harbours extensive mangrove ecosystems along its tidal rivers and estuaries. Pangkal Babu Village in Tungkal Ilir District is situated at the mouth of the Tungkal River and is flanked by tidal wetlands dominated by mangrove vegetation. Despite their ecological and climatic significance, the mangroves of this area remain poorly characterised in terms of species composition, stand structure, and carbon storage potential.

Quantification of mangrove biomass and carbon stocks is essential for national greenhouse gas (GHG) inventories, REDD+ reporting, and evidence-based coastal management[5]. Non-destructive allometric

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methods based on stem diameter measurements have become the standard approach for such assessments, with the generic pantropical allometric equation of Komiyama et al.[6] widely applied across Southeast Asian mangroves.

This study therefore aimed to (1) characterise the species composition and stand density of the mangrove ecosystem in Pangkal Babu Village across three ecologically distinct stations; (2) quantify above- and belowground biomass using allometric equations; and (3) estimate the carbon stock and CO_2 equivalent storage, thereby providing baseline data for local conservation planning and GHG accounting. Furthermore, no previous studies have been conducted in Pangkal Babu Village, and carbon stock data for West Tanjung Jabung Regency are not yet included in the national inventory.

2. RESEARCH METHOD

Time and Place

This research was conducted in the mangrove ecosystem of Pangkal Babu Village, Tungkal Ilir District, Tanjung Jabung Barat Regency, Jambi Province, Indonesia. Geographically, Pangkal Babu Village is located at coordinates 0°49'34.8"S to 103°32'30.7"E. Three sampling stations were established based on differences in vegetation physiognomy, tidal influence, and land-use proximity: Station 1 (riverine fringe zone dominated by large-diameter trees), Station 2 (mixed-species transitional zone of higher stand density), and Station 3 (degraded-margin zone with mixed pioneer regeneration). Field data were collected between December to January, 2025.

Method

A total of eighteen 10 m × 10 m (100 m²) permanent sample plots were established: six plots each at Station (total sampled area = 600 m² each). Within each plot, all mangrove trees with a stem diameter at breast height (DBH, measured at 1.3 m above ground or above pneumatophores) ≥ 4 cm were identified to species level and their stem circumference measured using a measuring tape, from which diameter was derived as D = C/π, where C is circumference in centimetres[7].

Data Analysis

Community Structure

Species diversity was described using the Importance Value Index (IVI), calculated as the sum of Relative Density (RD), Relative Dominance (RDom, based on basal area), and Relative Frequency (RF) for each species. Basal area (BA) of each tree was computed as $BA = \pi(D/2)^2$, expressed in m²/ha.

Biomass Estimation

Above-ground biomass (AGB) of individual trees was estimated using the generic allometric equation for mangroves proposed by Komiyama et al.[6]:

$$W_{AGB} = 0.251 \times \rho \times D^{2.46}$$

where W_{AGB} is the above-ground biomass (kg), ρ is species-specific wood density (g/cm³), and D is DBH (cm). Wood densities used were: *Sonneratia alba* = 0.52 g/cm³; *Avicennia alba* = 0.52 g/cm³; *A. marina* = 0.65 g/cm³; *Rhizophora apiculata* = 0.80 g/cm³; *R. mucronata* = 0.82 g/cm³; *Bruguiera gymnorrhiza* = 0.85 g/cm³[8,9].

Below-ground biomass (BGB) was estimated using the root biomass equation of Komiyama et al.[6]: $W_{BGB} = 0.199 \times W_{AGB}^{0.899}$

Total biomass per plot was summed and expressed in megagrams per hectare (Mg/ha) after scaling to plot area. Carbon stock (Mg C/ha) was calculated by multiplying total biomass by a carbon fraction of 0.47, following the IPCC (2006) default[10]. Carbon dioxide equivalents were derived by multiplying carbon stock by 3.67 (molecular weight ratio of CO_2 to C).

3. RESULT AND DISCUSSION

Species Composition and Stand Density

A total of 246 individual trees belonging to six species from four genera were recorded across all stations (Figure 1). Station 1 was monodominant, with *S. alba* comprising 96.15% of all trees recorded (n =

25), accompanied by a single individual of *A.alba*. This pattern reflects the riverine fringe position of Station 1, where *S. alba* typically dominates as a pioneer canopy species on soft, reduced substrates at the seaward margin**Error! Reference source not found.**. Station 2 recorded the highest species richness and the greatest stand density (n = 133 trees; 4,433 ind/ha), with four species present: *A. marina* (75.94%), *A. alba* (18.80%), *R. mucronata* (3.01%), and *R. apiculata* (2.26%). Station 3 had five species and an intermediate density (n = 87 trees; 2,900 ind/ha), adding *B. gymnorrhiza* to the assemblage. The presence of *Bruguiera* and *Rhizophora* spp. at the landward stations is consistent with zonation patterns described for Sumatran mangroves, where these genera occupy higher-elevation, less frequently inundated substrates[11].

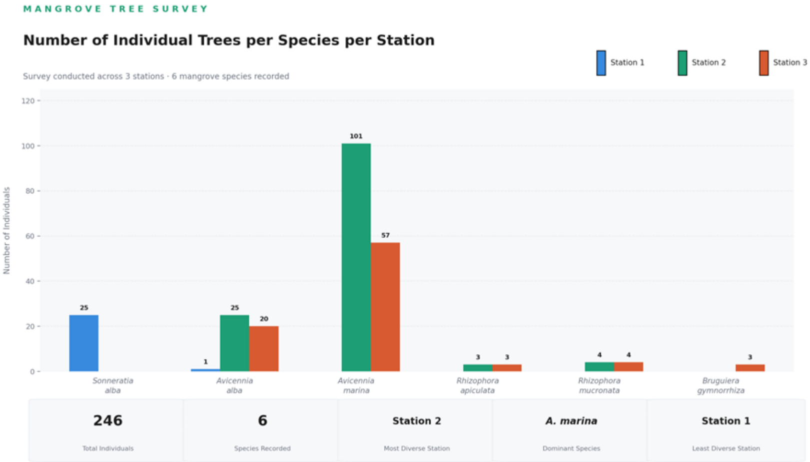

Figure 1. Number of individual trees per species per station

Table 1. Species density, relative density (RD), relative dominance (RDom), relative frequency (RF), and Importance Value Index (IVI) per station.

Species	Station	Density (ind/ha)	RD (%)	RDom (%)	RF (%)	IVI
Sonneratia alba	1	417	96.15	98.17	85.71	280.04
Avicennia alba	1	17	3.85	1.83	14.29	19.96
A. marina	2	3367	75.94	45.19	46.15	167.29
A. alba	2	833	18.80	53.85	38.46	111.11
Rhizophora mucronata	2	133	3.01	0.57	7.69	11.27
R. apiculata	2	100	2.26	0.38	7.69	10.33
A. marina	3	1900	65.52	39.73	40.00	145.24
A. alba	3	667	22.99	57.64	26.67	107.29
R. mucronata	3	133	4.60	0.89	13.33	17.40
Bruguiera gymnorrhiza	3	100	3.45	1.13	13.33	17.91
R. apiculata	3	100	3.45	0.62	6.67	12.16

Importance Value Index (IVI)

The Importance Value Index (IVI) results are presented in Table 1. At Station 1, *S. alba* attained the highest IVI (244.32), reflecting its near-complete numerical and basal area dominance. Such high IVI values for a single species are characteristic of early-successional mangrove fringes dominated by fast-growing canopy pioneers[13]. At Station 2, although *A.marina* had the highest density (3,367 ind/ha, IVI = 146.13), *A. alba* had a higher relative dominance (53.85%) because of the greater mean diameter of its individuals, yielding an IVI of 97.65. The co-dominance of two *Avicennia* species is consistent with findings from other tidal estuaries in Sumatra, where these congeners often partition the canopy niche by size-class. At Station 3, *A. marina* remained the most abundant species (IVI = 125.24). At the same time, *A. alba* dominated in terms of basal area (RDom = 57.64%, IVI = 100.62), indicating that older, larger individuals of the latter species contribute disproportionately to stand structure.

Table 2. Biomass and carbon stock estimates per station

Species / Station	AGB (Mg/ha)	BGB (Mg/ha)	Total Biomass (Mg/ha)	Carbon Stock (Mg C/ha)	CO_2 Equiv. (Mg CO_2e/ha)
1	126.75	13.60	140.35	65.96	242.07
2	244.24	27.84	272.08	127.88	469.31
3	138.44	16.99	155.43	73.05	268.08
Mean	169.81±62.50	19.48±7.41	189.29±69.91	88.96±32.88	326.50±120.70

Table 3. Carbon stock by species and station (Mg C/ha).

Species	St. 1	St. 2	St. 3	Total (mg C/ha)
S. alba	65.02	-	-	65.02
A. alba	0.94	77.99	44.72	123.65
A. marina	-	48.99	26.57	75.56
Rhizophora apiculata	-	0.34	0.36	0.70
Rhizophora mucronata	-	0.55	0.55	1.10
Bruguiera gymnorrhiza	-	-	0.85	0.85
Total	65.96	127.88	73.05	266.89

Biomass and Carbon Stock

Estimates of above-ground biomass (AGB), below-ground biomass (BGB), total biomass, carbon stock, and CO_2 equivalent per station are presented in Tables 2 and 3. Station 2 exhibited the highest total biomass (272.08 Mg/ha) and carbon stock (127.88 Mg C/ha), driven by the large DBH of *A. alba* individuals (mean DBH up to 52.55 cm) combined with the high stem density of *A. marina*. Station 1, despite its lower stand density (417 ind/ha), had a substantial carbon stock (65.96 Mg C/ha) attributable to the large-diameter *S. alba* trees (maximum DBH = 38.22 cm) and the exponential relationship between diameter and biomass in the allometric model. Station 3 had an intermediate carbon stock of 73.05 Mg C/ha.

The mean carbon stock of 88.96 ± 32.88 Mg C/ha recorded in this study falls within the range reported for mangroves in Sumatra and Kalimantan (50–150 Mg C/ha)[15] and is comparable to values reported for mangroves in Riau Province (87–112 Mg C/ha)16. The mean CO_2 equivalent stock of 326.50 Mg CO_2e/ha underscores the significant climate-mitigation value of these mangroves and underscores the importance of preventing further deforestation.

The BGB to AGB ratios (approximately 10.7%) were consistent across all stations and aligned with the global root: shoot allometric of Komiyama et al.[6]. It should be noted that this study did not account for carbon stored in deadwood, litter, or sediment organic carbon, which can represent a large fraction of total mangrove carbon stocks up to 50–70% in old growth mangroves[17]. Therefore, the values reported here are conservative estimates of total ecosystem carbon.

Implications for Conservation and Management

The mangrove ecosystem of Pangkal Babu Village stores a mean of 88.96 Mg C/ha of carbon in living biomass alone, equivalent to approximately 326.50 Mg CO_2e/ha. Given the expanding global carbon market and Indonesia's commitment to reducing emissions through its FOLU Net Sink 2030 target, accurate local-level carbon assessments, such as this one, are a prerequisite for participation in voluntary carbon offset schemes and REDD+ programmes[18]. The relatively intact stand at Station 2, characterised by high species diversity, large-diameter *A. alba* trees, and the highest carbon density, should be prioritised for strict protection. Community based rehabilitation programmes focusing on *Avicennia* and *Rhizophora* propagation are recommended for degraded zones. Future research should incorporate sediment organic carbon measurements, satellite based mapping of mangrove extent, and long-term monitoring to track carbon dynamics and the success of rehabilitation efforts[19].

4. CONCLUSION

This study characterised the species composition, stand structure, and carbon stocks of the mangrove ecosystem in Pangkal Babu Village, Tungkal Ilir, Tanjung Jabung Barat. Six species were recorded from 246 individual trees across three stations. *A.marina* was the most abundant species at Stations 2 and 3, while *S. alba* dominated Station 1 in the riverine fringe zone. Mean total biomass was 189.29 ± 69.91 Mg/ha, with a mean carbon stock of 88.96 ± 32.88 Mg C/ha (326.50 ± 120.70 Mg CO_2e/ha). Station 2 had the highest carbon density (127.88 Mg C/ha), driven by large *A. alba* trees. These findings provide an empirical baseline for carbon accounting and should support evidence-based management, including priority protection of high-carbon stands and targeted rehabilitation of degraded areas.

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