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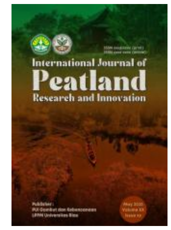


# Estimating Biomass and Carbon Stock Potential in the Imbo Putui Customary Forest Ecosystem, Riau

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## ABSTRACT

Climate change is one of the most widely discussed environmental issues. Climate change is caused by forest degradation and deforestation. Efforts are made to reduce the impact of climate change by controlling carbon concentration through carbon sinks. Data is needed on the carbon content stored in forest biomass. One of the forest areas that has the potential to store carbon is the Imbo Putui customary forest. This study aimed to calculate the carbon stock potential of forest carbon sources in the Imbo Putui customary forest, Kampar Regency. The research method used was destructive sampling and non-destructive sampling. Data collection was carried out by making sample plots using the systematic sampling method with random start. The results of the research in the Imbo Putui customary forest have a total carbon stock potential of 179.65 tons/ha and a total biomass stock potential of 382.21 tons/ha. Details of carbon stock potential in five carbon sources are 86.46 tons/ha of surface carbon stock, 32.00 tons/ha of subsurface carbon stock, 2.20 tons/ha of litter carbon, 4.73 tons/ha of necromass carbon, 54.26 tons/ha of soil carbon. The substantial carbon stock indicates that the Imbo Putui Customary Forest serves as an important carbon sink, playing a crucial role in reducing atmospheric $CO_2$ concentrations and supporting Indonesia's commitment to achieving Net Zero Emission (NZE).

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## 1. Introduction

Climate change has become one of the most widely discussed environmental issues worldwide. According to data from the Indonesian Meteorology, Climatology, and Geophysics Agency (BMKG), the year 2024 was recorded as the hottest year on record, with the global average temperature reaching 1.55 °C above the pre-industrial baseline (1850–1900). In Indonesia, 2024 was also recorded as the warmest year since observations began in 1981, with temperatures averaging 0.8 °C higher than the 1991–2020 normal. Climate change is largely driven by forest degradation and deforestation caused by encroachment, forest fires, illegal logging, and the conversion of forests for settlements, plantations, agriculture, and other uses that disregard sustainable forest management principles [1].

Controlling carbon concentrations through carbon sinks is one of the key strategies for mitigating the impacts of climate change. A carbon sink refers to vegetation or trees within forests that function as reservoirs for storing and sequestering carbon [2]. Data on carbon stocks stored in forest biomass are essential for the development of carbon sink programs [1]. Forest biomass provides critical information for estimating biomass at various stand ages, which can then be used to assess forest productivity levels [3].

One forest area with significant potential for carbon stock is the Imbo Putui customary forest, located in Riau Province, Indonesia. This forest is managed by local Indigenous communities who apply customary laws that have been passed down through generations to maintain the forest's sustainability and ecological integrity [4]. Further research is required to quantify the potential carbon biomass stored within the Imbo Putui customary forest. The objective of this study is to estimate the carbon stock potential from forest carbon sources in the Imbo Putui Customary Forest, Kampar Regency.

## 2. Research Significance

This study provides both scientific and practical contributions to the field of forest carbon dynamics. Scientifically, it establishes baseline data on the carbon stock potential of the Imbo Putui Customary Forest—an area that has not been previously quantified. The findings enhance current understanding of the role of community-managed tropical forests as effective carbon sinks, thereby contributing to global climate change mitigation efforts. Furthermore, the quantified carbon stock value offers a useful reference for comparative studies across different forest types and agroforestry systems in Indonesia.

From a practical standpoint, this research supports the implementation of sustainable forest management and provides empirical evidence that can inform local policy and conservation planning. The results also highlight the potential for integrating the Imbo Putui Customary Forest into carbon-based incentive schemes such as REDD+ and Payment for Environmental Services (PES). Overall, the study underscores the ecological importance of this forest as the last remaining natural forest in Petapahan Village, emphasizing its crucial role in biodiversity conservation and long-term carbon sequestration.

# 3. Methods

## Study Area and Period

This study was conducted in the Imbo Putui Customary Forest area, located in Petapahan Village, Tapung Subdistrict, Kampar Regency, Riau Province, Indonesia. The research was carried out from June to October 2024. The research location map is presented in Figure 1.

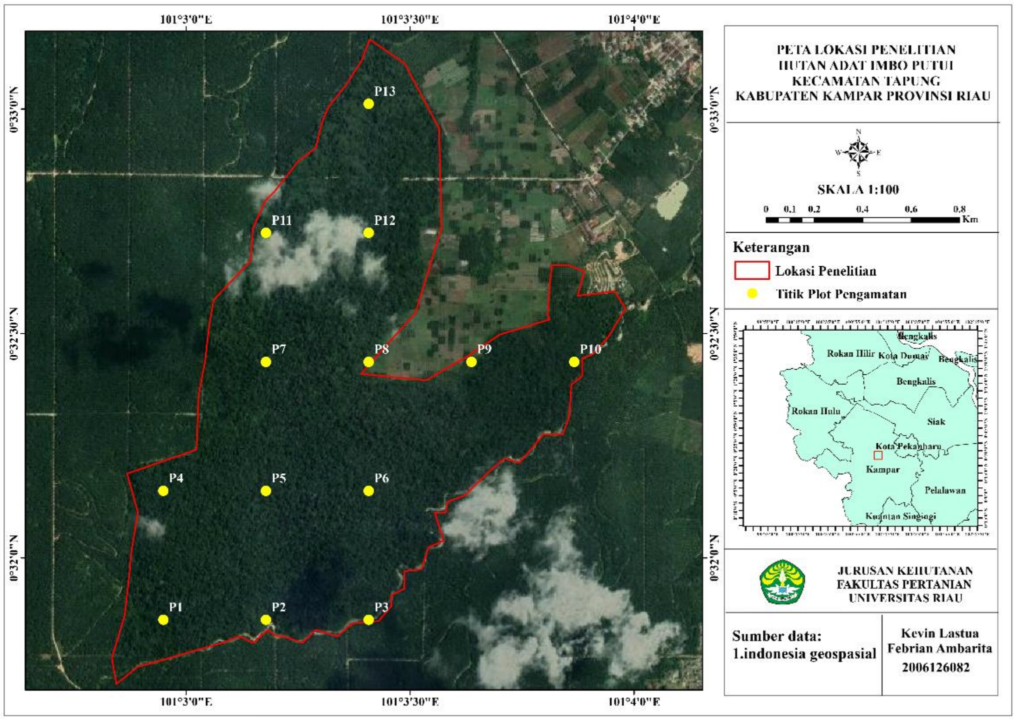


**Fig 1**. Research Location Map

## Materials and Equipment

The materials used in this study included vegetation, understory plants, litter, necromass, and soil samples collected from the Imbo Putui Customary Forest. The equipment utilized comprised a camera, stationery, hoe, measuring tape, phiband, raffia string, scissors, compass, machete, plastic bags, meter stick, a 1.3 m wooden pole, Avenza Maps application, weighing scale, label paper, rubber bands, marker, ring sampler, and an oven.

## Research Methods

The research employed both destructive sampling and non-destructive sampling methods. The destructive sampling method was applied to seedlings, understory vegetation, litter, and soil, while the non-destructive sampling method was used to measure the biomass of roots, saplings, poles, trees, and dead trees.

Data collection was carried out by establishing sample plots using the Systematic Sampling with Random Start method. A sampling intensity of 1% was applied to the total research area of 251 ha, resulting in a total observation area of approximately 2.5 ha. Based on this sampling intensity, 13 transects were established, with an interval distance of 500 m between transects.

## Research Implementation

### *Establishment of Sample Plots*

Sample plots measuring 2 m × 2 m were established for the seedling, understory, and litter layers. Plots measuring 5 m × 5 m were used for the sapling layer, 10 m × 10 m for the pole layer, and 20 m × 20 m for the tree layer. The plots were arranged longitudinally from north to south to account for the influence of sunlight on different vegetation types. The north–south orientation provides a more representative depiction of vegetation composition and structure [5].

### *Above-Ground Biomass Measurement*

The measurement of seedling and understory biomass followed the procedures outlined in SNI 7724:2019, with the following steps:

1. Cut all parts of understory vegetation above the soil surface and seedlings or saplings with a diameter of < 2.5 cm, excluding the roots, within the 2 m × 2 m plots using scissors or machetes.
2. Weigh the total fresh biomass within the sample plots.
3. Collect and weigh approximately 300 grams of fresh biomass as a subsample.
4. Oven-dry the subsamples in the laboratory at 105 °C for 24 hours until a constant weight is achieved.
5. Weigh the dried biomass to determine the dry weight of the understory vegetation.

Data collection for saplings, poles, and trees was conducted using non-destructive sampling. Diameter at breast height (DBH) was measured at approximately 1.3 m above the ground surface using a phiband. DBH measurements were adjusted according to the various tree forms encountered in the field.

DBH data and species names were then used to estimate biomass through species-specific allometric equations, depending on the vegetation type. The allometric equations used are presented in Table 1.

Table 1. Allometric equations for vegetation biomass

| Tree species group | Allometric equation | Source |
|---|---|---|
| Artocarpus, Macaranga, Mallotus, Rhodamnia | $W = 26.475\ D^{0.055}$ | [6] |
| Calophyllum | $W = -0.972 + 2.078 \ln(D)$ | [7] |
| Palaquium, Diospyros | $W = 0.153108\ D^{2.40}$ | [8] |
| Tectona grandis | $W = 0.153\ D^{2.39}$ | [8] |
| Dipterocarpaceae | $W = 0.141\ D^{2.525}\ \rho^{0.231}$ | [9] |
| Other tree species | $W = 0.11\ \rho\ D^{2.62}$ | [10] |

*Notes:* W = total biomass, D = diameter at breast height (DBH), ρ = wood density.

### *Litter Biomass Measurement*

The measurement of litter biomass followed the procedures outlined in SNI 7724:2019, with the following steps:

1. Litter was collected from the 2 m × 2 m measurement plots.
2. The total fresh weight of the litter was measured.
3. A subsample of approximately 300 grams was taken and weighed.
4. The subsample was oven-dried at 105 °C for 24 hours until a constant weight was achieved.
5. The dry weight of the litter was then recorded.

### *Necromass Biomass Measurement*

The measurement of dead tree necromass followed SNI 7724:2019, with the following steps:

1. The DBH of dead trees was measured.
2. The degree of decomposition (or tree intactness level) of each dead tree was determined. The classification of dead tree intactness levels is shown in Figure 3.
3. The necromass of dead trees was estimated using allometric equations, multiplied by a correction factor based on the tree intactness level.

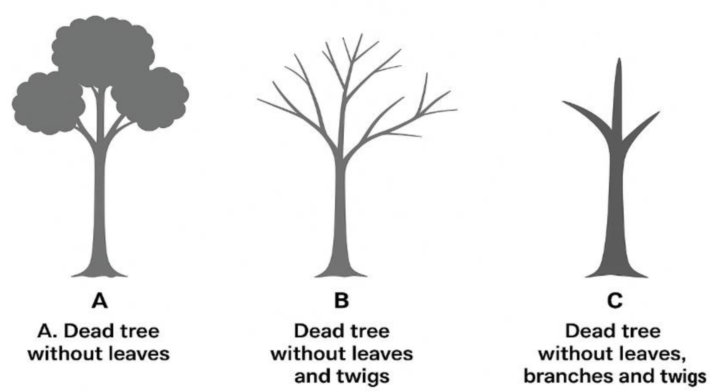


**Fig 2.** Levels of dead tree intactness
*(Source: BSN, 2019 [11])*

### *Soil Sampling*

Soil samples were collected to a depth of 30 cm from the ground surface. Sampling was conducted for each soil horizon (0–5 cm, 5–10 cm, 10–20 cm, and 20–30 cm) using a ring sampler.

## Data Analysis

### *Biomass Analysis of Seedlings, Understory Vegetation, and Litter*

The calculation of biomass for seedlings, understory vegetation, and litter followed the formula [11]:

$$Bo = \frac{Bks \times Bbt}{Bbs} \tag{1}$$

Where:
Bo = Biomass (kg)
Bks = Dry weight of subsample (kg)
Bbt = Total fresh weight (kg)
Bbs = Fresh weight of subsample (kg)

### *Belowground (Root) Biomass Analysis*

Belowground biomass was estimated using an indirect method in accordance with SNI 7724:2019. The following equation was applied:

$$Bbp = NAP \times Boap \tag{2}$$

Where:

Bbp = Total root biomass (kg)
NAP = Root-to-shoot ratio
Boap = Aboveground biomass (kg)

### *Necromass Biomass Analysis*

The biomass of necromass was calculated using the following equation [11]:

$$B_{okm} = V_{km} \times BJ_{km} \tag{3}$$

Where:
Bokm = Dead wood biomass (kg)
Vkm = Volume of dead wood ($m^3$)
BJkm = Wood density of dead wood ($kg/m^3$)

### *Soil Carbon Stock Analysis*

Soil carbon stock was analyzed based on the BSN (2019) method, using the following equation [11]:

$$C_{tm} = Kd \times \rho \times \%C_{organic} \tag{4}$$

Where:
Ctm = Carbon content of mineral soil ($g/cm^2$)
Kd = Depth of mineral soil sample (cm)
ρ = Bulk density ($g/cm^3$)
% C organic = Percentage of organic carbon content in mineral or peat soil, obtained from laboratory analysis.

***Carbon Stock Analysis***

Carbon content was estimated by multiplying the biomass by the carbon fraction. This analysis was applied to aboveground biomass, belowground biomass, litter, seedlings, understory vegetation, and necromass, using the following equation [11]:

$$C = B \times \%C_{organic} \quad (5)$$

Where:
C = Carbon content of biomass (ton/ha)
B = Total biomass (ton/ha)
% C organic = Carbon fraction (0.47)

## 4. Results and Discussion

### 4.1 Research Site Conditions

Petapahan Village consists of several major land cover types. Plantation and agricultural areas dominate the village, covering 5,900 ha, followed by rice fields (50 ha), wetlands (85 ha), and forest areas (251 ha). The Imbo Putui Customary Forest represents the only remaining natural forest in Petapahan Village. The topography is generally undulating with slopes ranging from 20° to 40°, and elevations between 500 and 1,000 m above sea level. This customary forest serves as the native habitat for various plant and animal species. Approximately 60 tree species have been recorded, including *Syzygium* sp., *Shorea* sp., and *Ficus* sp., as well as endemic species such as *Scorodocarpus borneensis* [12].

### 4.2 Aboveground Carbon Stock

Aboveground carbon sources consist of trees, poles, saplings, seedlings, and understory vegetation, each contributing different amounts of biomass [11]. The results are presented in Table 2.

Table 2. Aboveground Carbon Stock

| Carbon Source | Biomass (ton/ha) | Carbon (ton/ha) | Percentage (%) |
|---|---|---|---|
| Seedlings & understory | 0.61 | 0.29 | 0.34 |
| Saplings | 2.68 | 1.26 | 1.46 |
| Poles | 15.51 | 7.29 | 8.43 |
| Trees | 165.15 | 77.62 | 89.78 |
| **Total** | **183.95** | **86.46** | **100.00** |

The largest carbon pool originates from trees, which is influenced by their larger diameters compared to other vegetation types. Tree diameter plays a crucial role in determining stand biomass, as biomass increases with age and diameter [13,14]. Forest stands dominated by species with higher wood densities also store greater amounts of carbon than those dominated by lower-density species [15]. High-diameter and high-density species commonly found in the Imbo Putui Customary Forest include *Shorea* sp., *Scorodocarpus borneensis*, and *Pentace* sp.

The total aboveground carbon stock in this study area is lower than that reported for Ghimbo Pomuan Customary Forest, which reached 145.19 ton/ha for pole and tree strata [16], and lower than that of Talang Forest in Bengkalis (95.96 ton/ha) [14]. This variation is influenced by differences in stand structure, species composition, and the allometric equations applied.

### 4.3 Belowground Carbon Stock (Roots)

Belowground carbon stock is stored in plant root systems and was estimated using non-destructive methods. The results are presented in Table 3.

Table 3. Belowground Carbon Stock (Roots)

| **Carbon Source** | **Carbon (ton/ha)** | **Percentage (%)** |
|---|---|---|
| Seedlings & understory | 0.11 | 0.34 |
| Saplings | 0.47 | 1.47 |
| Poles | 2.70 | 8.44 |
| Trees | 28.72 | 89.75 |
| Total | 32.00 | 100 |

The belowground carbon values were lower than those of aboveground pools due to the smaller root volumes [17]. A large proportion of plant biomass, approximately 60%, is stored in stems [18]. Direct root measurements are often challenging because fine roots are difficult to separate from surrounding vegetation [19].

The belowground carbon value recorded in this study is higher than that of Sorong agroforestry systems (0.184 ton/ha) [20] and eucalyptus industrial plantations (6.15 ton/ha) [22]. This is likely due to the higher tree density and biomass typically found in natural forests [21].

### 4.4 Litter Carbon Stock

The total litter carbon stock was 2.20 ton/ha, with a corresponding biomass of 4.68 ton/ha. This relatively small value reflects the advanced stage of decomposition typical of litter layers. This value is higher than that recorded in Talang Forest, Bengkalis (1.20 ton/ha) [14], secondary forests in Samarinda (3.13 ton/ha) [23], and mangrove forests in Pulau Cawan (0.10 ton/ha) [24]. Litter accumulation is strongly influenced by canopy cover and tree age; dense canopies tend to increase litterfall [25].

### 4.5 Necromass Carbon Stock

The necromass carbon stock reached 4.73 ton/ha. This value is lower than that observed in Rumbio Customary Forest (8.27 ton/ha) [26], but higher than that in Rowosari agroforestry systems in Jember (0.40 ton/ha). Accumulation of necromass is influenced by natural disturbances such as pest outbreaks, disease, and lightning strikes [17].

### 4.6 Soil Carbon Stock

Soil represents one of the largest carbon pools. The analysis results are shown in Table 4.

Table 4. Soil Carbon Stock

| Depth (cm) | Bulk Density (g/cm³) | Organic C (%) | Carbon Stock (ton/ha) |
|---|---|---|---|
| 0–5 | 0.90 | 0.05 | 16.34 |
| 5–10 | 0.94 | 0.02 | 10.51 |
| 10–20 | 0.97 | 0.02 | 14.39 |
| 20–30 | 1.09 | 0.01 | 13.02 |
| Total | — | — | 54.26 |

Soil carbon stock is influenced by soil organic carbon content, bulk density, and depth [28,29]. The soil carbon value recorded in this study is higher than that of the Senaru Forest Education and Training Area (42.7 ton/ha) [30] and post-coal mining reclamation sites at PT Borneo Indobara (53.76 ton/ha) [32], but lower than that of the Maribaya Forest Management Unit (74.9 ton/ha) [31]. Mineral soils generally have lower carbon stock capacities compared to peat soils, which can store up to ten times more carbon [33].

### 4.7 Total Carbon Stock

Total carbon stock is the sum of all five carbon pools. The results are presented in Table 5.

Table 5. Total Carbon Stock

| Carbon Source | Biomass (ton/ha) | Carbon (ton/ha) | Percentage (%) |
|---|---|---|---|
| Aboveground | 183.95 | 86.46 | 48.13 |
| Belowground | 68.06 | 32.00 | 17.81 |
| Soil | 115.46 | 54.26 | 30.21 |
| Necromass | 10.06 | 4.73 | 2.63 |
| Litter | 4.68 | 2.20 | 1.22 |
| Total | 382.21 | 179.65 | 100 |

The largest proportion of carbon is stored in aboveground vegetation (48.13%), while the smallest contribution comes from litter (1.22%). Litter carbon is rapidly released back into the atmosphere through decomposition processes [36]. The total carbon stock of 179.65 ton/ha is higher than that of Talang Forest (99.56 ton/ha) [14], but lower than that of complex agroforestry systems (166.55 ton/ha) and simple agroforestry systems (58.86 ton/ha). Variations in carbon stocks are largely influenced by stand composition and tree diameter distributions.

## 5. Conclusions

The Imbo Putui Customary Forest has a total carbon stock potential of **179.65 ton/ha**, with total biomass reaching **382.21 ton/ha**. This includes aboveground carbon (86.46 ton/ha), belowground carbon (32.00 ton/ha), litter (2.20 ton/ha), necromass (4.73 ton/ha), and soil (54.26 ton/ha). The implications of this finding are highly significant for both environmental management and climate change mitigation. The substantial carbon stock indicates that the Imbo Putui Customary Forest serves as an important carbon sink, playing a crucial role in reducing atmospheric $CO_2$ concentrations and supporting Indonesia's commitment to achieving Net Zero Emission (NZE). The large biomass and carbon reserves reflect a relatively healthy and stable forest ecosystem, emphasizing the ecological importance of conserving customary forests as part of sustainable forest management practices.

## References

[1] L. Kurniarahma, L. T. Laut, and P. K. Prasetyanto, "Analisis Faktor-Faktor yang Mempengaruhi Emisi CO2 di Indonesia," pp. 368–385, 2020.

[2] W. D. P. A. Sardi, R. P. Kainde, and W. Nurmawan, "Cadangan Karbon pada Pohon di Taman Hutan Raya Gunung Tumpa H. V. Worang," *COCOS*, vol. 14, no. 3, 2022.

[3] A. I. Passal, G. Mardiatmoko, and F. Latumahina, "Hubungan Volume Tegakan Dengan Kandungan Biomassa Tersimpan Skala Plot Pada Areal Agroforestry Dusung di Dusun Toisapu Kota Ambon," *Jurnal Hutan Pulau-Pulau Kecil*, vol. 3, no. 1, pp. 40–54, 2019, doi: 10.30598/jhppk.2019.3.1.40.

[4] R. Lestari, "Pengelolaan Hutan Adat Imbo Putui untuk Meningkatkan Ekonomi Masyarakat Hukum Adat Kabupaten Kampar," *Jurnal Magister Hukum Udayana*, vol. 11, no. 3, pp. 691–709, 2022, doi: 10.24843/JMHU.2022.v11.i03.

[5] Pebriandi, O. Rusdiana, and M. B. Saleh, "Tipe Komunitas Hutan Lahan Kering Di Hutan Lindung Sentajo, Kabupaten Kuantan Singingi, Riau," *Jurnal Silvikultur Tropika*, vol. 08, no. 2, pp. 103–109, 2017.

[6] Karyati, Karmini, and K. Y. Widiati, "The allometric equations for estimating above-ground biomass in a 50 years-old secondary forest in East Kalimantan, Indonesia," *Biodiversitas*, vol. 24, no. 3, 2023, doi: 10.13057/biodiv/d240318.

[7] T. M. Basuki *et al.*, "Allometric Equations for the Biomass Estimation of Calophyllum inophyllum L. in Java, Indonesia," *Forests*, vol. 13, no. 7, p. 1057, 2022, doi: 10.3390/f13071057.

[8] N. A. E. Widyasari, B. H. Saharjo, Solichin, and Istomo, "Pendugaan biomassa dan potensi karbon terikat di atas permukaan tanah pada hutan rawa gambut bekas terbakar di Sumatera Selatan," *Jurnal Ilmu Pertanian Indonesia*, vol. 15, no. 1, pp. 41–49, 2010.

[9] Kurniatun. Hairiah, Andree. Ekadinata, R. Ratna. Sari, and Subekti. Rahayu, *Pengukuran cadangan karbon : dari tingkat lahan ke bentang lahan*. World Agroforestry Centre (ICRAF), 2011.

[10] S. Manuri *et al.*, "Tree biomass equations for tropical peat swamp forest ecosystems in Indonesia," *For Ecol Manage*, vol. 334, pp. 241–253, 2014, doi: 10.1016/j.foreco.2014.08.031.

[11] Q. M. Ketterings, R. Coe, M. van Noordwijk, Y. Ambagau', and C. A. Palm, "Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass

in mixed secondary forests," *For Ecol Manage*, vol. 146, no. 1–3, pp. 199–209, 2001, doi: 10.1016/S0378-1127(00)00460-6.

[12] H. Firmanda, "Hukum Adat Masyarakat Petapahan dalam Pengelolaan Lingkungan Sebagai Upaya Pemenuhan Hak Masyarakat Adat," *Fikri : Jurnal Kajian Agama, Sosial dan Budaya*, vol. 2, no. 1, pp. 1–26, 2017, doi: 10.25217/jf.v2i1.

[13] Z. Uthbah, E. Sudiana, and E. Yani, "Analisis Biomasa dan Cadangan Karbon pada Berbagai Umur Tegakan Damar (Agathis dammara (Lamb.) Rich.) di KPH Banyumas Timur," *Scripta Biologica*, vol. 4, no. 2, pp. 119–124, 2017, doi: 10.20884/1.sb.2017.4.2.404.

[14] Pebriandi *et al.*, "Potensi Simpanan Karbon di Hutan Talang Kecamatan Pinggir, Kabupaten Bengkalis, Provinsi Riau," *Jurnal Ilmu-Ilmu Kehutanan*, vol. 7, no. 2, pp. 85–91, 2023.

[15] S. I. Maulana, "Pendugaan Densitas Karbon Tegakan Hutan Alam di Kabupaten Jayapura, Papua," *Jurnal Penelitian Sosial dan Ekonomi Kehutanan*, vol. 7, no. 4, pp. 261–274, 2009.

[16] A. T. Ratnaningsih, S. Aisyah, T. Warningsih, Z. Saam, Zulkarnaini, and A. Syahza, "Valuasi Ekonomi Karbon padaTegakan Tingkat Tiang dan Pohon di Hutan Adat Ghimbo Pomuan Kabupaten Kampar Provinsi Riau," *Wahana Forestra: Jurnal Kehutanan*, vol. 18, no. 2, pp. 163–175, 2023, doi: 10.31849/forestra.v18i2.14075.

[17] S. Ramadhanti, B. Wasis, and I. Hilwan, "Pendugaan Simpanan Karbon pada Bagian Atas dan Bawah Permukaan Tanah di Taman Hutan Raya Banten," *Jurnal Penelitian Hutan Tanaman*, vol. 20, no. 1, pp. 19–36, 2023, doi: 10.59465/jpht.v20i1.160.

[18] F. Rulianti, R. Devi, R. Mela, and M. Hidayat, "Estimasi Biomassa (Estimasi Stok Karbon) pada Pohon di Kawasan Hutan Primer Pegunungan Deudap Pulo Aceh Kabupaten Aceh Besar," in *Prosiding Seminar Nasional Biotik*, Universitas Islam Negeri Ar-Raniry, 2018, pp. 246–258.

[19] D. Sutaryo, *PENGHITUNGAN BIOMASSA: Sebuah pengantar untuk studi karbon dan perdagangan karbon*. Bogor: Wetlands International Indonesia Programme, 2009.

[20] S. Ohorella, R. H. Siburian, and I. Febriadi, "Biomasa Karbon Below Ground Paraserianthes Falcataria (L.) Nielsen pada Lahan Agroforestri Tradisional di Distrik Aimas, Sorong," *Median : Jurnal Ilmu Ilmu Eksakta*, vol. 16, no. 3, pp. 144–154, 2024, doi: 10.33506/md.v16i3.4176.

[21] Istomo and N. E. Farida, "Potensi Simpanan Karbon di Atas Permukaan Tanah Tegakan Acacia nilotica L. (Willd) ex. Del. di Taman Nasional Baluran, Jawa Timur," *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*, vol. 7, no. 2, pp. 155–162, 2017.

[22] Y. W. Yolanda, Ilyas, and Sufardi, "Potensi Karbon Biomassa pada Beberapa Tipe Penggunaan Lahan di Kecamatan Blang Bintang Kabupaten Aceh Besar," *Jurnal Ilmiah Mahasiswa Pertanian*, vol. 6, no. 3, pp. 201–209, 2021.

[23] Z. Azham, "Estimasi Cadangan Karbon Pada Tutupan Lahan Hutan Sekunder, Semak Dan Belukar Di Kota Samarinda," *Agrifor : Jurnal Ilmu Pertanian dan Kehutanan*, vol. 14, no. 2, pp. 325–338, 2015.

[24] T. Emrinelson and T. Warningsih, "Estimasi Simpanan Karbon Hutan Mangrove di Pesisir Utara Pulau Cawan, Indragiri Hilir," *Prosiding Seminar Nasional Fakultas Pertanian dan Perikanan Universitas Muhammadiyah Purwokerto*, vol. 5, no. 1, pp. 58–68, 2023, doi: 10.30595/pspfs.v5i.704.

[25] Rositah, R. Herawatiningsih, and G. Hardiansyah, "Pendugaan Biomassa Karbon Serasah dan Tanah pada Hutan Tanaman (Shorea Leprosula Miq) Sistem TPTII PT. Suka Jaya Makmur," *Jurnal Hutan Lestari*, vol. 1, no. 3, pp. 358–366, 2013.

[26] S. Wulandari, Y. Fauziah, and Irfan, "Analisis Potensi Cadangan Carbon Nekromasa di Hutan Larangan Adat Kenagarian Rumbio Kecamatan Kampar Provinsi Riau," *Dinamika Lingkungan Indonesia*, vol. 9, no. 2, pp. 118–123, 2022.

[27] K. W. Lestari and D. N. Dewi, "Potensi Simpanan Karbon pada Beberapa Tipe Agroforestri Berbasis Kopi Robusta di Desa Rowosari, Jember," *Journal of Tropical Silviculture*, vol. 14, no. 2, pp. 150–157, 2023.

[28] A. Purnama, Mariaty, and N. Wijayanti, "Potensi Simpanan Karbon Tanah pada Ruang Terbuka Hijau Kampus: Studi Kasus di Kampus II Universitas Muhammadiyah Palangkaraya," *Jurnal Kehutanan Indonesia Celebica*, vol. 5, no. 2, pp. 376–390, 2024, [Online]. Available: http://ojs.uho.ac.id/index.php/CELEBICA

[29] W. I. Apriliana, F. Purwanti, and N. Latifah, "Estimasi Kandungan Biomassa dan Simpanan Karbon Hutan Mangrove, Mangunharjo, Semarang," *Life Science*, vol. 10, no. 2, pp. 162–172, 2021.

[30] M. H. Idris, S. Latifah, I. M. L. Aji, E. Wahyuningsih, Indriyatno, and R. V. Ningsih, "Studi Vegetasi dan Cadangan Karbon di Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Senaru, Bayan Lombok Utara," *Jurnal Ilmu Kehutanan*, vol. 7, no. 1, pp. 25–36, 2013.

[31] H. H. Siringoringo, "Potensi Sekuestrasi Karbon Organik Tanah pada Pembangunan Hutan Tanaman Acacia Mangium Willd," *Jurnal Penelitian Hutan dan Konservasi Alam*, vol. 10, no. 2, pp. 193–213, 2013.

[32] M. S. Noor, Hafizianoor, and Suyanto, "Analisis Cadangan Karbon pada Tanaman Reklamasi Lahan Bekas Pertambangan Batubara di PT. Borneo Indobara," *Jurnal Hutan Tropis*, vol. 8, no. 1, pp. 99–108, 2020.

[33] M. Irfan, I. Ilyas, and S. Sufardi, "Potensi dan Cadangan Karbon pada Beberapa Tipe Penggunaan Lahan di Kecamatan Pasie Raya Kabupaten Aceh Jaya," *Jurnal Ilmiah Mahasiswa Pertanian*, vol. 8, no. 4, pp. 748–757, 2023, [Online]. Available: www.jim.usk.ac.id/JFP

[34] Sukarman and U. Haryati, "Tanah Gambut dan Estimasi Cadangan Karbon di Kabupaten Kutai Kartanegara, Kalimantan Timur," *Jurnal Agroekoteknologi Tropika Lembab*, vol. 4, no. 1, pp. 20–28, 2021.

[35] W. S. Utami, R. Juliani, Z. Abidin, S. Santoso, A. D. Rahayu, and N. Ankhoviyya, "Potensi Simpanan Karbon dan Serapan CO2 Mahoni (Swietenia Macrophylla) di Taman

Keanekaragaman Hayati PT Tirta Investama, Kabupaten Subang," *Gorontalo Journal of Forestry Research*, vol. 7, no. 1, pp. 13–23, 2024.

[36] C. Windarni, A. Setiawan, and Rusita, "Estimasi Karbon Tersimpan Pada Hutan Mangrove Di Desa Margasari Kecamatan Labuhan Maringgai Kabupaten Lampung Timur," *Jurnal Sylva Lestari*, vol. 6, no. 1, pp. 66–74, 2018.