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Estimation of biomass and carbon stored in trees in the Sisimeni Sanam Forest Area, Timor Island, Indonesia

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Abstract. *Dako FX, Kleruk FEI, Selanno FM, Gare KFS, Nopemnanu HM. 2025. Estimation of biomass and carbon stored in trees in the Sisimeni Sanam Forest Area, Timor Island, Indonesia. Biodiversitas 26: 5324-5333.* Forests are crucial in human life, particularly in preventing global warming caused by climate change. The Sisimeni Sanam Forest Area, located in the western part of Timor Island, Indonesia, contributes significantly to climate regulation and hence requires proper management. This study quantified above-ground biomass, carbon stock, and CO_2 sequestration in Sisimeni Sanam to provide a baseline for conservation and climate mitigation strategies. Systematic sampling was applied in the field using the Line Plot method. With a sampling intensity of 1%, the total sampled area covered 4.97 ha. A total of 124 measurement plots, each measuring 20 × 20 meters, were established to assess biomass potential and carbon reserves. The analyses showed content, total carbon reserves, and carbon sequestration of 815.73 tons/ha, 383.39 tons/ha, and 1,200.08 tons/ha, respectively. The type of vegetation with the highest biomass, carbon reserves, and carbon sequestration is teak (*Tectona grandis*), with 249.79 tons/ha, 117.40 tons/ha, and 430.86 tons/ha, respectively. In contrast, pulai (*Alstonia scholaris*) recorded the lowest values, at 4.07 tons/ha, 1.91 tons/ha, and 7.01 tons/ha, respectively. These results indicate that Sisimeni Sanam functions as a significant carbon reservoir within Timor's dry tropical landscape. Therefore, maintenance and preservation of the area are needed for proper functioning as a carbon absorber rather than a producer.

Keywords: Biomass, forest, sequestration carbon, Sisimeni Sanam, trees

INTRODUCTION

The forest is a key ecosystem with an essential role in the sustainability of human life and other living things. In addition to serving as a habitat for various species, it provides environmental services, including climate regulation, clean water supply, and sources of food and fuel (Li et al. 2019). Forest provides direct and indirect benefits for human life (Pasaribu et al. 2021). Direct benefits include providing wood for building materials and fuel, as well as a source of food and clean water (Marimpan et al. 2022), while indirect benefits are delivered through ecosystem services such as carbon storage and sequestration (Chu et al. 2019; Purwanto et al. 2021). Scientifically, forests act as a natural buffer against climate change due to their ability to absorb carbon dioxide (CO_2) from the atmosphere, thereby reducing the impact of greenhouse gases responsible for global warming.

The primary driver of global warming is the increasing concentration of greenhouse gas, specifically CO_2, from human activities such as fossil fuel combustion and deforestation. Forest encroachment, logging, fires, livestock release, and shifting cultivation are factors that can also trigger increased CO_2 emissions (Marimpan et al. 2022). Ongoing ecosystem destruction reduces their ability to absorb carbon (McNicol et al. 2018; Chen et al. 2019; Liu et al. 2021). Windarni et al. (2018) reduced forest cover significantly impairs the natural ability to absorb CO_2, leading to atmospheric accumulation and accelerated global temperature rise. The absorption ability of forests is affirmed through the process of photosynthesis in various types of plants and vegetation. During this process, plants use solar energy to convert CO_2 and water into glucose and oxygen (Heagy 2018). Trees in the active growth phase can absorb more CO_2 than mature forests, whose capacity tends to decrease due to limited nutrients, specifically nitrogen (Jiang et al. 2020). Although the sequestration capacity declines with age, mature forest continues to make a significant contribution to the overall carbon stock storage (Tuah et al. 2017).

The Sisimeni Sanam Forest Area, covering 497.37 hectares in the western part of Timor Island, Indonesia, is known to be rich in biodiversity. In addition to serving as a habitat for animals and flora, it is a source of livelihood for local communities who depend on forest resources. However, the area faces various threats such as deforestation, land conversion, natural disasters, and climate change. The Sisimeni Sanam forest is located within the Timor and Wetar deciduous forest ecoregion, which is globally recognized as Critically Endangered, with only about 7% of its total area under formal protection. Meanwhile, roughly half of the unprotected territory remains forested (Dinerstein et al. 2017). Vegetation cover in the Sisimeni Sanam Forest Area has been significantly degraded, with one of the most prominent impacts being the loss of teak stands, driven by illegal logging, land conversion, wildfires, and landslides. These disturbances cause changes in the structure of vegetation and reduce the capacity of the forest to absorb and retain carbon (Misra and Jha 2021). As a result, increased greenhouse gas emissions accelerate global climate change, which causes a rising average temperature of the Earth, unstable weather patterns, sea-level rise, and more frequent extreme climate events (Kim et al. 2022). This situation threatens the survival of humans and all living things on Earth. Beyond its ecological role, the forest acts as a substantial carbon sink at the regional level (Pan et al. 2024). Therefore, assessing biomass and carbon storage in this forest is urgent to inform conservation planning, climate change mitigation, and sustainable forest management strategies.

Climate change is a major global challenge, intensified by forest destruction as a source of carbon emissions. Uncontrolled human activities often cause major climate changes (Liu et al. 2021), characterized by increasingly uncontrolled global warming (Olorunfemi et al. 2019; Peñaranda et al. 2019). When massive deforestation occurs, the capacity to absorb and store carbon decreases drastically, increasing the concentration of CO_2 in the atmosphere. This increase plays a major role in the occurrence of various global environmental problems (Rajashekar et al. 2018; Yin et al. 2022). Climate change mitigation efforts can be conducted through various strategies, namely increasing carbon absorption and reducing emissions. The method aimed to maintain and strengthen existing carbon stocks through sustainable forest management, including biodiversity conservation and vegetation preservation. This management is important to maintain the ecosystem function as a buffer against climate change. Therefore, the role of humans, specifically forest carbon control by local communities, needs to be monitored appropriately (Benjaminsen and Kaarhus 2018; Etemesi et al. 2018; Gu et al. 2022).

Based on the complexity of the dynamics occurring in this area, an in-depth study is needed on biomass and carbon storage potential in trees. At present, comprehensive data on tree carbon stocks in the Sisimeni Sanam Forest Area remain unavailable. Therefore, this study aims to estimate biomass and carbon potential stored in trees. The results are expected to improve understanding of the storage capacity and the impact of human activities on the ecosystem. The data obtained will be the basis for compiling recommendations for more effective forest management, in order to support climate change mitigation efforts and ensure the sustainability of the forest ecosystem.

MATERIALS AND METHODS

Study area

This study was conducted in the Sisimeni Sanam Forest Area located in Oesusu Village and Takari Village, Fatuleu Sub-district, Kupang District, East Nusa Tenggara, Indonesia (Figure 1). Covering approximately 497.37 hectares, the forest supports biodiversity and provides ecosystem services, such as carbon sequestration, habitat protection, and natural resource conservation. Fieldwork was conducted for 5 months, from May to October 2024. Geographically, the forest area was located at coordinates 9°59'0" S to 10°1'0" S and 124°0'0" E to 124°4'30" E, approximately 25 km east of the capital city of Kupang District. Annual rainfall in the study area ranges from 400-2500 mm. The topographic conditions in the area consist of two primary landforms based on the type of soil. Renzina had a sloping terrace topography, while the Kambisol soil type had a hilly topography. Renzina soils covered approximately 77.07 hectares (15.5%), and Kambisol soils accounted for 420.23 hectares (84.5%). Slope classification in the study area included rather steep (31.68%), gentle (24.16%), flat (22.8%), steep (20.60%), and very steep (1.28%). Critical land classification showed that 64.73, 35.10, and 0.17% were not critical, moderately critical, and potentially critical, respectively.

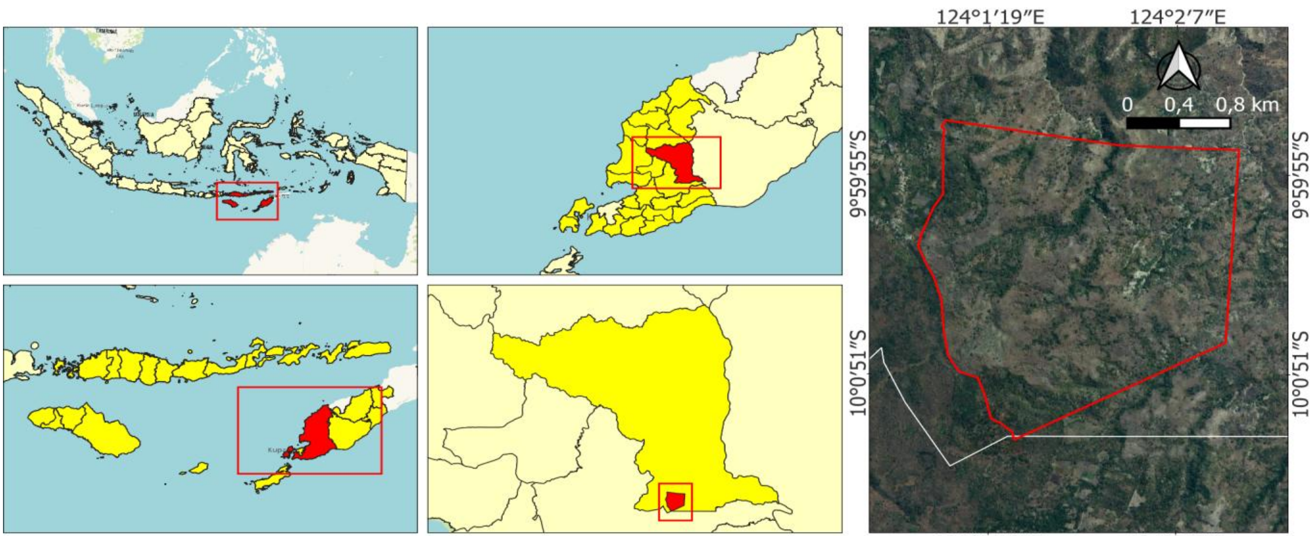

Figure 1. Research location map in the Sisimeni Sanam Forest Area in Oesusu Village and Takari Village, Fatuleu Sub-district, Kupang District, East Nusa Tenggara, Indonesia

Forest inventory

Forest inventory was conducted in the Sisimeni Sanam Forest Area under the Forest Management Unit of Kupang District. The tools used were a phiband, roll meter, stakes, paint, raffia rope, brush, handheld Abney water level, and Global Positioning System (GPS). Furthermore, the method applied was systematic sampling with the placement of measurement plots using the line plot technique. A sampling intensity of 1% was used, leading to a total sample area of 4.97 Ha, distributed across 124 plots, each measuring 20 m × 20 m, in accordance with Indonesian National Standards (BSN 2011) for carbon stock estimation.

The area was established by pulling a rope 20 meters to the north and 20 meters to the east, and the points were tied in a square to a stake (Hairiah et al. 2001; Marimpan et al. 2022). Trees on the outer boundary were included in the measurement plot when more than 50% of the stem diameter fell in the plot. All trees in the study site were numbered with yellow paint, while the belt with a diameter of 1.3 m at breast height was painted red to facilitate measurement when necessary (Marimpan et al. 2022). Various parameters were also measured, including the number of trees in each plot, average diameter, average height, and total carbon (Bentsi-Enchill et al. 2022).

Tree biomass data analysis, carbon content, and carbon estimation

Measurements were conducted to estimate tree biomass, carbon content, and estimated CO_2 uptake. Biomass was calculated using an allometric equation based on the method by Krisnawati et al. (2012) and Selano et al. (2021). This method was chosen because it provides accurate estimates and is widely used in various types of tropical forests in Indonesia. In addition, due to the limitations of methods specific to local locations, a general method was used in accordance with the ground-based forest carbon accounting guidelines (BSN 2011). The allometric equation is as follows:

$$B = BV \times BEF_{standing} \qquad [1]$$

Where, B: Total Biomassa (ton/ha), BV: Biomassa Volume (ton/ha), BEF: Biomass Expansion Factor

Where BV was the result of multiplying the stem volume (m^3/ha) and wood density (ton/m^3), a BEF value of 1.74 can be used when BV is greater than 190 tons/ha. For values less than 190 tons/ha, BEF was obtained using the equation developed by Brown and Lugo (1992), namely $BEF_{standing} = \exp\{3.213 - 0.506 \times \ln(BV)\}$ (Selano et al. 2021). The wood density or specific gravity used is the specific gravity of each vegetation. Where species-specific values were unavailable, an average value for natural forest, 0.68 g/cm^3 or 680 kg/m^3, was used (Lusiana et al. 2006; Tuah et al. 2017). The Brown and Lugo (1992) allometric model is widely applied in estimating above-ground biomass in tropical forests. This model uses stand Biomass Volume (BV) as the main predictor variable to estimate Biomass Expansion Factors (BEF), making it particularly suitable for forests where Diameter at Breast Height (DBH) and stem volume are reliable indicators of total biomass. In the context of dry tropical forests such as Sisimeni Sanam, the model is relevant because these ecosystems are dominated by hardwood species with variable diameters and relatively low canopy heights compared to humid tropical forests. The emphasis on BV as a determinant aligns well with the structural characteristics of dry forests, where tree height tends to plateau but diameter increment remains an important predictor of carbon storage.

The carbon content stored in vegetation was calculated using the formula established by the BSN (2011):

$$Cb = B \times \%\ C\ organic \qquad [2]$$

Where, Cb: Carbon content of biomass (kg), B: Total biomass (kg), % C organic: The percentage value of carbon content is 0.47

The carbon content per hectare was determined by calculating the following equation (BSN 2011):

$$Cn = \frac{Cb}{1000} \times \frac{10000}{L\ Plot} \qquad [3]$$

Where, Cn: Carbon content per hectare (ton/ha), Cb: Carbon content (kg), L plot: Plot area (m^2)

CO_2 sequestration was estimated using the following formula (Paradika et al. 2021):

$$CO_2 = Cn \times 3.67 \qquad [4]$$

Where, CO_2: Carbon dioxide sequestration (ton/ha), Cn: Carbon content per unit area (ton/ha), 3.67: Equivalent number or conversion of element carbon to CO_2

Where CO_2 is the amount of CO_2 absorption in tons/ha. Meanwhile, 3.67 was the carbon element constant obtained from the ratio of the relative atomic mass of carbon (12) to the relative molecular mass of CO_2 (44).

RESULTS AND DISCUSSION

Biomass and carbon stocks

Carbon is an essential element absorbed from the atmosphere through photosynthesis by plants and stored in the form of biomass. This process allows forests to function as natural carbon sinks, helping to reduce CO_2 levels in the atmosphere and contributing to mitigating global climate change. The rate of carbon absorption in forests was influenced by various factors, including climate, topography, land characteristics, age and density of vegetation, as well as species composition and quality of the growing place (Pan et al. 2024). The primary storage places in the forest include living biomass (consisting of upper parts such as stems, branches, twigs, leaves, flowers, and fruits, and lower parts such as roots), dead organic matter in the soil, and long-term carbon reservoirs such as harvested wood products used in construction and household materials (Mildrexler et al. 2020; Sun and Liu 2020). Scientifically, the process of photosynthesis is the primary mechanism responsible for the conversion of CO_2 from the atmosphere into organic matter in green plants. Biomass produced experience changes during its life cycle, namely additions (growth) and reductions (decomposition and combustion), thereby affecting the amount of carbon stored.

The Sisimeni Sanam Forest Area is a mixed ecosystem with a dual function, namely as carbon stock (C-Stock) storage. Based on the study results, 24 types of tree-level vegetation were identified in the area, where Teak trees dominated in 97 plots (Dako et al. 2023). Teak grows best in tropical climates with temperatures of approximately 25-30°C, sufficient rainfall, shallow to deep soil, medium to clay texture, neutral pH, and good drainage. The brown, humus-rich, light calcareous soil of the study area provided favorable conditions for Teak growth due to the water storage capacity. This is supported by the findings of Dako et al. (2023), which indicate that the dominance of teak (*Tectona grandis* L.f.) in the Sisimeni Sanam Forest Area is due to the fact that the area was originally established as a forest plantation. Moreover, teak is well adapted to tropical climates, such as those found on Timor Island. This type of diversity is an important element in ecosystem management, given the correlation with forest biomass. Various studies showed a positive relationship between species diversity and biomass volume (Vargas-Larreta et al. 2021). However, other studies suggest that forests with lower biodiversity may have the same or higher biomass, depending on the specific characteristics of the ecosystem (Yuan et al. 2019; Michalet et al. 2024).

Based on the data in Table 1, the total biomass and carbon stock were 815.73 tons/ha and 383.39 tons/ha, respectively. These values are significantly higher compared to the results of previous studies. For example, Karmila et al. (2020) used Normalized Difference Vegetation Index (NDVI) analysis and obtained an average biomass of 15.66 tons/ha at KHDTK, Universitas Lambung Mangkurat, Indonesia, while Paradika et al. (2021) reported 61 tons/ha along the KHDTK River in the same region. This showed variability depending on ecosystem conditions and land cover characteristics. According to Waleed et al. (2024), carbon conversion for various land cover classes varied, where forest had an above-ground carbon content of 54 Mg/ha.

The carbon storage potential of various levels of vegetation was influenced by factors such as wood density, stem diameter, and height of trees. As the tree ages, the diameter and height often increase, leading to higher carbon storage capacity as most of the biomass and carbon are stored in the trunk (Chave et al. 2005). The larger the diameter and height, specifically in mature trees, the greater the capacity to store carbon. That was because the volume and biomass of the trunk increased quadratically and cubically with respect to diameter and height (Chave et al. 2005). In contrast, the seedling and sapling stages, despite the higher numbers, contributed relatively small amounts to total carbon stocks due to the smaller size and lower biomass. The results of biomass and carbon stock measurements are presented in Table 1 and Figure 2.

Table 1. Biomass and carbon stocks in the Sisimeni Sanam Forest Area, Timor Island, Indonesia

Species name	Type name	Biomass (ton/ha)	Carbon stock (ton/ha)
Aegle marmelos (L.) Corrêa	*Maja*	8.64	4.06
Aleurites moluccana (L.) Willd.	*Kemiri*	8.74	4.11
Alstonia scholaris (L.) R.Br.	*Pulai*	4.07	1.91
Bauhinia purpurea L.	*Tayuman*	22.78	10.71
Cassia javanica L.	*Trengguli*	9.01	4.24
Cassia senna siamea (Lam.) H.S.Irwin & Barneby	*Johar*	37.08	17.43
Ceiba pentandra (L.) Gaertn.	*Kapuk hutan*	16.20	7.61
Cocos nucifera L.	*Kelapa*	13.04	6.13
Cordia dichotoma G.Forst.	*Nunang*	35.35	16.61
Eucalyptus Alba Reinw. ex Blume	*Kayu putih*	25.25	11.87
Hibiscus similis Blume	*Waru gunung*	12.74	5.99
Leucaena leucocephala (Lam.) de Wit	*Lamtoro*	7.37	3.47
Melia azedarach L.	*Mindi*	10.59	4.98
Mimosa leucophloea (Roxb.) Benth.	*Pilang putih*	51.84	24.36
Mimusops elengi L.	*Tanjung*	8.29	3.89
Falcataria moluccana (Miq.) Barneby & J.W.Grimes	*Sengon*	8.11	3.81
Pterocarpus indicus Willd.	*Kayu merah*	29.02	13.64
Schleichera oleosa (Lour.) Oken	*Kesambi*	7.65	3.59
Spondias pinnata (L.fil.) Kurz	*Kedondong hutan*	5.95	2.80
Swietenia macrophylla G.King	*Mahoni*	40.83	19.19
Tamarindus indica L.	*Asam*	150.22	70.60
Tectona grandis L.f.	*Jati*	249.79	117.40
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	*Pilang*	42.56	20.00
Ziziphus mauritiana Lam.	*Bidara*	10.63	5.00
Total		815.73	383.39

Note: Data source from primary data processing (2024)

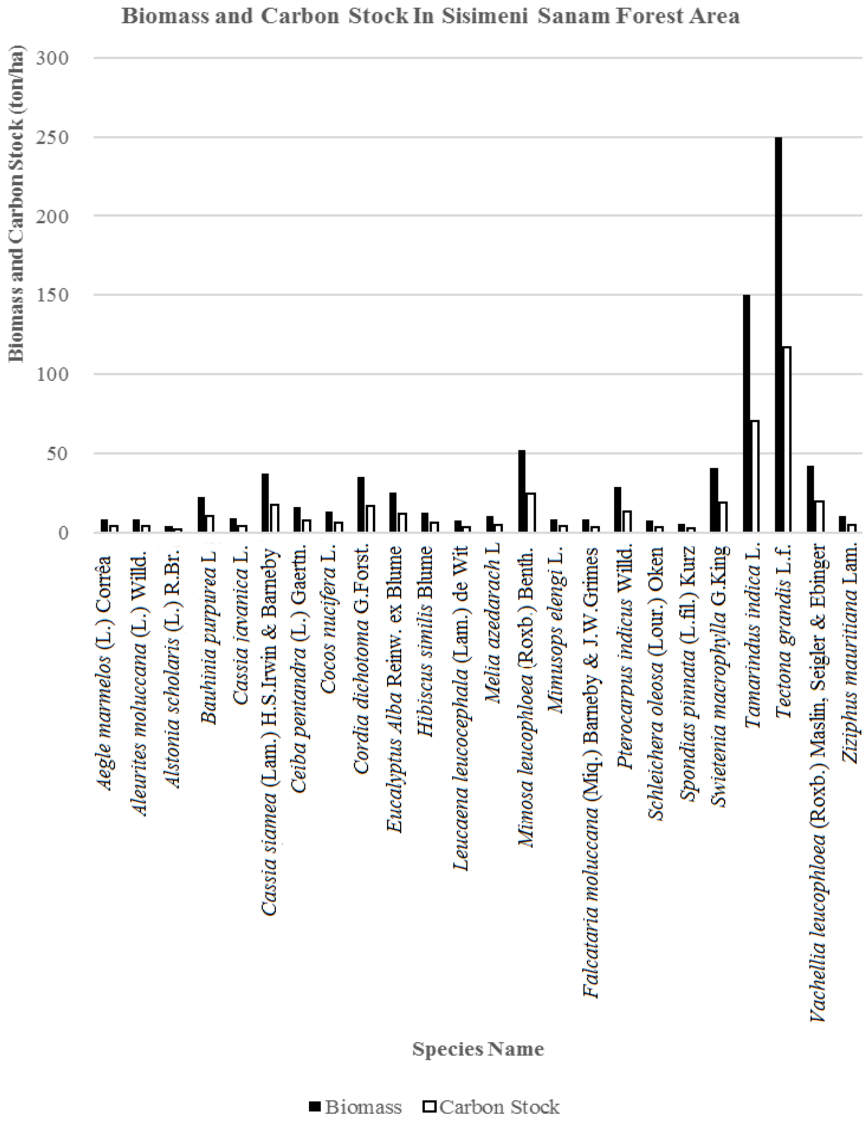

Figure 2. Biomass and carbon stocks in the Sisimeni Sanam Forest Area, Timor Island, Indonesia

Vegetation with high density values often showed high biomass accumulation. The density, defined as the number of trees per unit area, directly affected the total biomass production, as a higher tree count corresponded to increased organic matter. Scientifically, biomass refers to the total mass of organic matter produced by trees, including trunks, branches, leaves, and other parts, which function as carbon storage (He et al. 2025).

As presented in Table 1, direct measurements in the Sisimeni Sanam Forest Area showed that *T. grandis* trees had the highest biomass value of 249.79 tons/ha. This value corresponded to substantial carbon reserves and CO_2 absorption capacity of 117.40 tons/ha and 430.86 tons/ha, respectively. The high biomass potential is primarily attributed to the large trunk diameter and rapid growth, which increased the volume of organic material capable of storing carbon (He et al. 2018). Greater trunk diameter directly correlates with a larger storage volume, resulting in increased carbon retention.

Other tree species with high biomass and carbon stock potential values at the study area were *T. indica*, at 150.22 and 70.60 tons/ha, as well as *Mimosa leucophloea* (Roxb.) Benth., at 51.84 and 24.36 tons/ha, respectively. These values were influenced by the diameter of the trunk, which served as the primary indicator of the volume and mass of tree biomass. According to He et al. (2018), a larger diameter allowed trees to store more biomass and carbon. The diameter of the trees and species abundance greatly influenced the magnitude of the variables.

The results of this study show that *T. grandis* trees had the largest number of individuals, totalling 821, followed by *M. leucophloea* trees and *Swietenia macrophylla* G.King with 33 and 28, respectively. The number of individuals was statistically closely related to the total biomass and carbon stock per area. A greater number of trees led to a higher volume of organic material to store carbon. Consequently, an increased population of a species enhances the carbon sequestration potential of a forested area (Safitri et al. 2017).

Several types of trees had low biomass and carbon stock potential. *Alstonia scholaris* (L.) R.Br. tree species showed biomass and carbon stock of 4.07 tons/ha and 1.91 tons/ha, respectively. *Spondias pinnata* (L.fil.) Kurz had a biomass of 5.95 tons/ha and a carbon stock of 2.80 tons/ha, while *Leucaena leucocephala* (Lam.) de Wit recorded 7.37 tons/ha and 3.47 tons/ha, respectively. These low values were influenced by the small stem diameter and fewer individuals. The highest and lowest biomass and carbon stock values were observed in *T. grandis* trees and *A. scholaris*, respectively. This was in accordance with the report that trees with large diameters and a high number of individuals tend to store more carbon, due to greater biomass volume and mass (Köhl et al. 2017).

Tree biomass is an important source of carbon in forest ecosystems, accounting for the largest proportion of carbon storage on land. The value is not only influenced by tree density and diameter, but also by the species, height, soil fertility, and wood density (Esteves et al. 2023). It is directly proportional to the carbon storage capacity because the volume and mass of organic matter increase with growth (Mildrexler et al. 2020). An increase followed every increase in biomass value in carbon stock (Funes et al. 2022). Biomass is a reliable proxy for assessing carbon storage potential, as carbon stock values are influenced not only by individual density (Erly et al. 2019; Pragasan 2022), diversity, and plant density (Köhl et al. 2017), but also by the age of trees, environmental quality, and genetics.

The dominance of *T. grandis* in the study area reflects its history as a former industrial plantation, illustrating how land-use legacies influence present-day forest composition (Dako et al. 2023). *Tectona grandis* is highly adapted to Timor's dry climate and calcareous soils, giving it a competitive advantage over native species. That contributes to a simplified forest structure where a few species dominate biomass accumulation, potentially reducing resilience to environmental disturbances (Michalet et al. 2024). Vegetation stratification is evident, with *T. grandis* and other large-diameter species occupying the canopy layer, while smaller trees such as *L. leucocephala* and *S. pinnata* persist in the understory. Such stratification highlights functional differentiation in light capture, water use, and growth strategies (Vargas-Larreta et al. 2021). Topographic variation further influences biomass distribution, with steeper slopes and shallow soils supporting lower biomass compared to gentler terrain. Anthropogenic disturbances, including logging and grazing, exacerbate structural heterogeneity by facilitating the spread of fast-growing pioneer species such as *Senna siamea* (Lam.) H.S.Irwin & Barneby, which are more abundant in disturbed sites (Bentsi-Enchill et al. 2022). While overall biomass and carbon stocks are high, this reliance on a narrow set of dominant species raises concerns for long-term ecological stability.

As trees mature, carbon reserves increase due to changes in structural dimensions, particularly diameter and height (Köhl et al. 2017). Among these factors, diameter played a critical role, as larger trunks stored more biomass, resulting from the ongoing absorption and conversion of atmospheric CO_2 into organic matter. This process contributed to an increase in both biomass and carbon storage. The trunk served as the primary reservoir of photosynthate used for plant growth, making it a crucial component of carbon accumulation (Furze et al. 2018). In forest ecosystems, tree biomass is the main source of stored carbon and is scientifically positively correlated with the storage capacity. Factors such as diameter, number of individuals, and age of trees greatly influenced the value of carbon reserves. Therefore, the conservation management of large and healthy trees is very important to increase the carbon absorption capacity in forest areas. Estimating carbon reserves also provides valuable insight into the amount of CO_2 absorbed (Bhaskara et al. 2018).

Carbon sequestration

CO_2 sequestration occurs through the stomata pores located primarily on the surface of leaves. The pores functioned as the main pathway for gases to enter and exit the leaves. This allowed plants to regulate the gas exchange needed in the process of photosynthesis. The efficiency of stomata function directly affects the ability to absorb CO_2. This positive impact on the capacity to store carbon contributes to reducing CO_2 levels in the air (Ding et al. 2024). According to Thompson et al. (2017), absorbed CO_2 is used in the process of photosynthesis to produce energy and organic matter. This process occurs in the chloroplasts of leaves and produces glucose as well as oxygen as by-products. The glucose functioned as a source of energy and building material for plants, while oxygen was released into the atmosphere. Therefore, photosynthesis played a major role in the global carbon cycle and reduces CO_2 pollution. Determining the mass of carbohydrates produced during photosynthesis provided a reliable method for estimating the mass of CO_2 absorbed by plants (Thompson et al. 2017). Scientifically, the greater the mass of carbohydrates formed, the more CO_2 was absorbed and converted into organic matter. Purnomo et al. (2022) found that differences in carbohydrate mass indicate the absorption of carbon dioxide in plants during photosynthesis.

Trees absorb more carbon than other types of vegetation, with the large stem contributing to greater capacity for storage. That implies that the storage potential of vegetation is directly proportional to the absorption ability. Based on observation, vegetation or plants absorb carbon through the stomata on the leaves (Paradika et al. 2021). Table 2 and Figure 3 present the calculated carbon stored due to the photosynthesis process.

According to the results, the ability of tree vegetation in the Sisimeni Sanam Forest Area to absorb carbon reached approximately 1,200.08 tons/ha. The value showed that trees were able to absorb large amounts of CO_2 from the atmosphere. This is an important process in reducing greenhouse gas emissions and supporting environmental sustainability. Carbon sequestration by vegetation occurs when trees are subjected to photosynthesis, a biological process that allows plants to convert CO_2 into organic matter through chemical reactions in the leaves' chloroplasts. When compared to the ability to store a total of 383.39 tons/ha of carbon, this value is quite large and shows the efficiency of trees. The value reflects that most of the carbon absorbed through photosynthesis is stored in biomass and other vegetation structures in the area. Scientifically, the process confirms the role of tree vegetation as a large store that contributes significantly to reducing carbon in the atmosphere and mitigating climate change.

Tectona grandis recorded the highest carbon sequestration in the Sisimeni Sanam forest, reaching 430.86 tons/ha. This capacity resulted from rapid growth and a large stem diameter, which led to high biomass accumulation and substantial carbon storage. *Tectona grandis* played a central role in strengthening the area's carbon sequestration potential and supporting climate change mitigation.

In contrast, *A. scholaris* had the lowest value at 7.01 tons/ha, influenced by slower growth, smaller stem size, and lower abundance. The ability of trees to absorb and retain carbon depended on physiological and ecological traits, especially growth rate and structural features. The difference between *T. grandis* and *A. scholaris* reflected the variation in carbon sequestration among tree species in the area. *Tectona grandis* contributed significantly to conservation and restoration strategies aimed at enhancing carbon sequestration. While *A. scholaris* contribution remained modest, the ecological value supported biodiversity and other forest functions.

Paradika et al. (2021) reported that limited uptake occurred in species with small and sparse leaves. Since photosynthesis relies on stomata, a low stomatal count reduces carbon fixation. *Tectona grandis*, with broad leaves, absorbed more carbon in the forest. This advantage, alongside population density, increased the overall contribution. Sequestration capacity varied across plant types, influenced by leaf area, thickness, stomatal density, plant age, and environmental factors (Daud et al. 2021).

The Sisimeni Sanam forest, particularly through trunk storage, acted as a carbon sink. A portion is slated for designation as a Special Purpose Forest Area managed by the Politeknik Pertanian Negeri Kupang for education and training. The area supports carbon regulation and atmospheric CO_2 stabilization. To maintain this role, managers need to address anthropogenic threats, including illegal logging, forest burning, and cattle grazing. Dako et al. (2019b) linked logging to economic motives and housing needs. Grazing often aimed to reduce tall, dry grass consumed by livestock and prevent fires.

Based on tree-level measurements, *T. grandis* ranked highest in biomass, carbon stock, specific gravity, and carbon sequestration, followed by *M. leucophloea*, *Vachellia leucophloea* (Roxb.) Maslin, Seigler & Ebinger, *S. macrophylla*, and *S. siamea*, with *A. scholaris* ranking lowest. *Tectona grandis* dominated the area due to its origin as a former industrial plantation established by Perum Perhutani, which also included *S. siamea* and *S. macrophylla*. Other species either grew naturally or were introduced by forest managers after Perhutani's departure in 1992. Without active protection efforts, the decline in *T. grandis* populations is possibly to reduce carbon stock and biomass, both in trees and across the forest landscape. In areas affected by landslides, immediate soil conservation is necessary, including reforestation using suitable forest species.

Table 2. Specific gravity and carbon sequestration in the Sisimeni Sanam Forest Area, Timor Island, Indonesia

Species name	Type name	Specific gravity (kg/cm^3)	Carbon sequestration (ton/ha)
Aegle marmelos (L.) Corrêa	*Maja*	771	14.90
Aleurites moluccana (L.) Willd.	*Kemiri*	400	15.08
Alstonia scholaris (L.) R.Br.	*Pulai*	290	7.01
Bauhinia purpurea L.	*Tayuman*	720	39.29
Cassia javanica L.	*Trengguli*	740	15.55
Senna siamea (Lam.) H.S.Irwin & Barneby	*Johar*	680	63.96
Ceiba pentandra (L.) Gaertn.	*Kapuk Hutan*	280	27.94
Cocos nucifera L.	*Kelapa*	900	22.49
Cordia dichotoma G.Forst.	*Nunang*	760	60.97
Eucalyptus alba Reinw. ex Blume	*Kayu Putih*	870	43.55
Hibiscus similis Blume	*Waru Gunung*	474	21.97
Leucaena leucocephala (Lam.) de Wit	*Lamtoro*	450	12.72
Melia azedarach L.	*Mindi*	400	18.27
Mimosa leucophloea (Roxb.) Benth.	*Pilang Putih*	680	89.42
Mimusops elengi L.	*Tanjung*	870	14.29
Paraserianthes falcataria moluccana (Miq.) Barneby & J.W.Grimes	*Sengon*	300	13.99
Pterocarpus indicus Willd.	*Kayu Merah*	800	50.06
Schleichera oleosa (Lour.) Oken	*Kesambi*	810	13.19
Spondias pinnata (L.fil.) Kurz	*Kedondong Hutan*	310	10.27
Swietenia macrophylla G.King	*Mahoni*	510	70.42
Tamarindus indica L.	*Asam*	1,280	52.14
Tectona grandis L.f.	*Jati*	594	430.86
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	*Pilang*	680	73.41
Ziziphus mauritiana Lam.	*Bidara*	583	18.34
Total			1,200.08

Note: Data source from primary data after processing (2024)

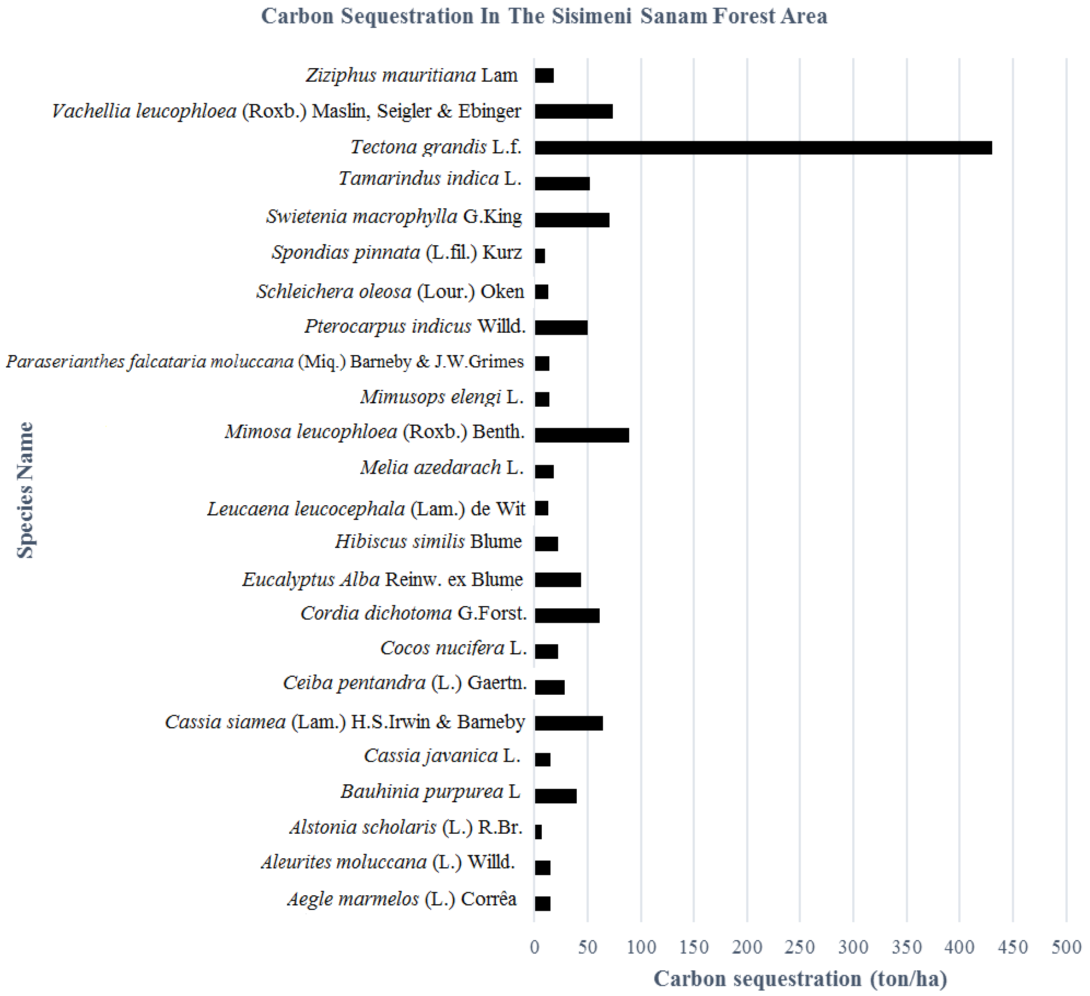

Figure 3. Carbon sequestration in the Sisimeni Sanam Forest Area, Timor Island, Indonesia

According to Dako et al. (2019a), forest landscape management should address not only biophysical aspects but also social, economic, and cultural dimensions to ensure continued ecological functionality. The Sisimeni Sanam forest holds rich biodiversity with the potential to support climate regulation. Its preservation is essential to maintain the role as a carbon sink rather than a carbon source. Forests serve a vital function in mitigating greenhouse gas emissions and minimizing climate change impacts. Expanding rehabilitation and forest development initiatives can enhance carbon absorption through photosynthesis. These efforts offer a strategic approach to reducing global warming while supporting long-term environmental and ecosystem sustainability. In addition, strong efforts are needed to mitigate and repair forest damage to achieve sustainability (Purnomo et al. 2022), as well as restore forest integrity to improve environmental quality, including reducing carbon concentrations in the atmosphere (Locatelli et al. 2015; Vásquez-Grandón et al. 2018).

This study provides the first quantitative assessment of above-ground biomass, carbon stock, and CO_2 sequestration in the Sisimeni Sanam forest of Timor Island. Results show that carbon storage is strongly influenced by species composition and diameter distribution, with *T. grandis* contributing disproportionately to the total biomass. The findings confirm that Sisimeni Sanam functions as an important carbon reservoir within the dry tropical forest ecosystems of eastern Indonesia. Beyond establishing baseline values, this study underscores the critical role of local forests in national and global climate mitigation strategies. Integrating these results into forest management and REDD+ initiatives will be essential to strengthen Indonesia's carbon accounting, while also supporting biodiversity conservation and community livelihoods. Conservation strategies should prioritize high-biomass species, implement enrichment planting in degraded areas, and adopt long-term monitoring to track changes in carbon storage. By filling a major data gap in Timor's dry tropical forests, this research contributes to a broader understanding of carbon dynamics in underrepresented ecosystems. Future studies incorporating belowground biomass, soil carbon, and socio-economic factors will further refine carbon estimates and strengthen the integration of Sisimeni Sanam into regional climate policy and restoration planning.

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