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Full Length Research Article

Estimation of Tree Carbon Stocks in the Green Open Space of the Faculty of Forestry, Tanjungpura University

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ABSTRACT

The presence of green open space containing vegetation in urban areas plays a vital role in absorbing and storing carbon in biomass. Tanjungpura University (Untan) Pontianak has a green open area in the New Building of the Faculty of Forestry. This study aimed to describe carbon reserves stored in biomass above ground level (vegetation) in green open areas around the New Building of Faculty of Forestry Untan Pontianak. Data were collected using an inventory survey by non-destructive sampling, which includes recording with fully enumerated data collection on the type and diameter of trees with a continuous line plot system. The data were then analyzed using allometric equations to obtain biomass values. The results found as many as 56 species of trees with a total of 558 individuals dominated by *Litsea garciae* and *Hevea brasiliensis*. The results showed the amount of carbon stored at the tree level of 59.06 tons/ha (76.18%), pole level of 13.94 tons/ha (17.99%), and sapling level of 4.52 tons/ha (5.83%), with an average carbon stock of 77.52 tons/ha. Thus, the green open area could store 148.53 tons of carbon in tree biomass. Although it is a small area, this peatland ecosystem could accumulate peat in organic soil and its vegetation and should be managed as peatland forests. Therefore, proper management is essential, and hydrology management is needed mainly due to its nature.

1. Introduction

Global warming is a process of increasing the earth's temperature caused by an increase in greenhouse gas concentration in the atmosphere. The surge of greenhouse gasses in the global atmosphere is mainly due to anthropogenic forces (Arto and Dietzenbacher 2014; Delworth et al. 2016). One of the greenhouse gases that contribute greatly to global warming is carbon dioxide (CO_2), whose composition reaches 75% in the atmosphere (Holdaway et al. 2014; Keith et al. 2018). This carbon concentration can be suppressed through the carbon sequestration process (Santori et al. 2018). Trees in forests could absorb CO_2 for photosynthesis and store it in the form of carbohydrates in pools within roots, stems, and leaves before being released into the atmosphere through the carbon cycles. These create a link between forest biomass and carbon content (Bustammante et al. 2016). The activity of measuring the amount of carbon stored in the body of living plants (biomass) on the above and below ground can describe the amount of CO_2 in the atmosphere absorbed by plants.

Vegetation is a natural engine for absorbing and storing carbon and producing oxygen. Therefore its existence is essential, especially in efforts to mitigate the effects of greenhouse gases. Unfortunately, the existence of vegetation is often neglected and sometimes even eliminated by

the development process, as is the case in urban areas (Luo et al. 2015). Carlson et al. (2012) and Houghton et al. (2012) stated that the conversion of forests to other uses triggered the release of large amounts of carbon into the atmosphere. Green open space is one solution for reducing greenhouse gases in urban areas (De Villiers et al. 2014; Tang et al. 2016). Manuri et al. (2014) mentioned that the provision of green open space is part of mitigating global warming; hence it is considered as one of the most implementable efforts to address the increase in greenhouse gas emissions, especially CO_2, compared to other methods. The Indonesian Minister of Public Works and Housing Regulation No. 5 of 2008 stated that the ideal area of green open space in an urban area should be 30% of the city's total area, consisting of 20% public green open space and 10% private space one.

Tanjungpura University (Untan) Pontianak also has some green open spaces, one of which is found in the New Building of the Faculty of Forestry. This area is certainly a part of the green space which is very beneficial for environmental health and the production of fresh air surrounding Untan. An interesting finding on green space in campus study showed that it could effectively improve student health and concentration, especially for students who infrequently go outside (Ibes and Forestell 2020).

The green open space in the New Building of the Faculty of Forestry Untan Pontianak is unique. Apart from being a green open area, it is also a type of degraded tropical peat swamp forest with a peat depth of 50-200 cm, which is rare to find in green open spaces on campus. Importantly, similar to a larger forested area, this green space has been sequestering and stocking carbon within the vegetation biomass. However, the amount of carbon stored is still a knowledge gap to exhibit its role and function for the environment. Therefore, this study aims to estimate the carbon stock stored in aboveground biomass (vegetation) in the green open space around the New Building of the Faculty of Forestry Untan Pontianak. This study is expected to describe the capability of the space to store and sequester carbon and is expected as a basis for consideration in the management and preservation of the green open space of the Untan area.

2. Materials and Methods

2.1. Study Site

The study was conducted in small patches of the green area of the New Building Faculty of Forestry, Tanjungpura University in Pontianak. The soil type is shallow organosol or peatland (0.5–1 m), which grows a peat forest ecosystem. The area has been encroached by the local community, where they plant rubber trees before the new building is established. The Faculty of Forestry recently managed the land space.

The study site was limited to the forest between the Forestry Faculty and the Teaching and Education Faculty to the forest behind the Forestry Faculty canteen (**Fig. 1**). Geographically, the new building of the Faculty of Forestry, Tanjungpura University, is located at the coordinate point 00° 03' 38.32" S, 109° 20' 31.05" E, with area boundaries are as follow:
- North: Boundary of Teacher Training and Education Faculty,
- South: Jalan Reformasi Pontianak,
- East: Boundary of Faculty of Economics and Business,
- West: Jalan Perdana Pontianak.

2.2. Materials

The equipment used in this study was a map of the research location, global positioning system (GPS) tracker, diameter tape (phi band), 1.3 m measuring stick, compass, meter, rope, identification book, tally sheet, tree label, and camera for documentation. The object of research was standing trees with a diameter of > 5 cm.

Fig. 1. The study site is inside the green dot line.

2.3. Sampling Methods

This study used an inventory survey method with non-destructive sampling for trees, including recording species and measuring tree diameter at breast height in a compartmental path. The measurement of tree-level diameter (D) was carried out as a whole (census), while the growth rate measurement of poles and saplings was carried out by sampling using nested plots. The size of the plots at tree level (D ≥ 20 cm) was 20 m x 20 m, pole level (D = 10–19.9 cm) was 10 m x 10 m, and sapling level (D = 5–9.9 cm) was 5 m x 5 m. The plots were placed every 30 m on the line axis. The shape of the plot and the length of the research path were adjusted to the location area (**Fig. 2**).
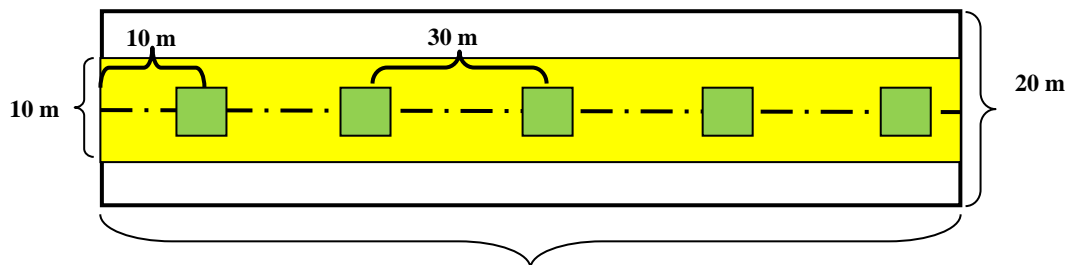
The transect length varies depending on the area perimeter within the green space of the Faculty of Forestry, Tanjungpura University

Notes:

     Plot size 5 m x 5 m for sapling stage assessment

     Continues plot assessment for tree and pole stage

Fig. 2. Plot arrangement within the study site.

The number of individual trees found in the observation plots for each growth rate was also calculated. Species identification found in the observation plots was identified based on a tree identification book and assisted by a tree identifier.

2.4. Data Collection

Tree diameter was measured on breast height (DBH), which is 1.3 m, and for trees that are not normal, it was measured with reference to **Fig. 3**.
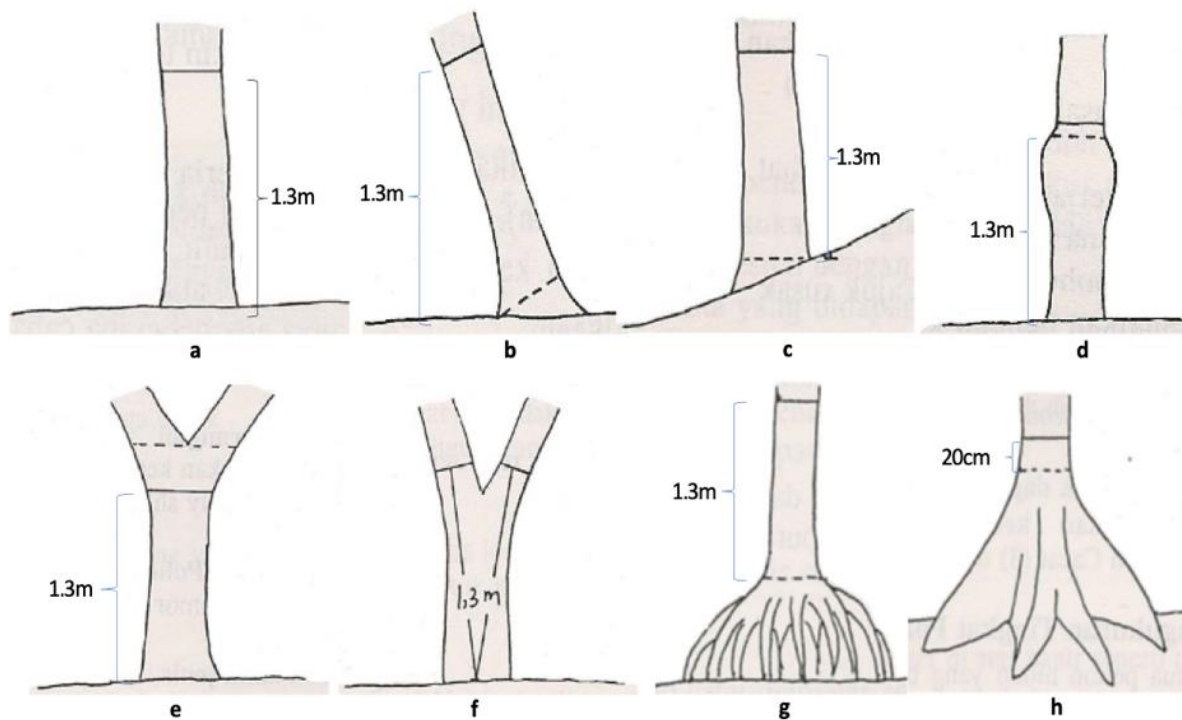

Fig. 3. The rule for determining the tree's DBH measurement (Manuri et al. 2011).

Notes:
a. For normal trees, DBH is measured 1.3 m from the surface of the ground
b. For sloping trees, DBH is measured 1.3 m from the nearest ground level or in the direction of the tree's slope
c. Normal trees on sloping DBH soil are measured 1.3 m from the highest ground level
d. Defective tree, if 1.3 m is right on the defective stem (swollen), DBH is measured at the limit of the part that starts to normal, above or below depending on the nearest
e. For a tree branch, if 1.3 m is right at the beginning of the branch, DBH is measured at the bottom of the branch, which is still normal
f. For a tree branch, if 1.3 meters above the branch, measure the DBH on both branches and assume two stems
g. For supporting root trees, DBH is measured 1.3 m from the upper limit of the supporting roots
h. Tree with buttresses and mangroves, DBH is measured at 20 cm from the edge of the buttress.

2.5. Biomass and carbon Calculation

Biomass is calculated based on tree diameter and wood density data using the allometric equation following Chave et al. (2005).

$$AGB_{est} = \rho * exp\ (-1.499 + 2.148 * ln(D) + 0.207 * (ln(D)^2 - 0.0281 * (ln(D)^3)) \qquad (1)$$

where AGB_{est} is above ground biomass (kg/tree), D is tree diameter (cm), ρ is wood specific density (g/cm³).

The total biomass of each growth level (saplings, poles, and trees) was calculated using Equation 2:

$$Total\ biomass = AGB_1 + AGB_2 + ... + AGB_n \tag{2}$$

The biomass per unit area (ton/ha) of each growth level was calculated using Equation 3:

$$Biomass = \frac{Total\ Biomass}{total\ area} \tag{3}$$

The amount of carbon is calculated based on the biomass data that has been obtained. The carbon estimate is calculated based on the carbon calculation formula following SNI 7724 (BSN 2011).

$$Total\ Carbon = B\ x\ \%\ carbon \tag{4}$$

where B is total biomass (kg), and *% carbon* is the percentage value of carbon content (47%). Furthermore, the calculation of carbon dioxide is converted by the time of the CO_2 with 3.667.

3. Results and Discussion

3.1. Estimation of Total Biomass and Carbon

The sampling area for tree, poles, and sapling growth levels were 1.92, 0.96, and 0.07 ha, respectively. The biomass and carbon content at each growth stage can be seen in **Table 1**. The largest amount of biomass content per unit area was found at the tree stage, and the lowest amount of biomass was indeed at the sapling stage.

Table 1. The amount of biomass and carbon stocks at trees, poles, and sapling growth stage in the green open areas of the New Building of the Faculty of Forestry, Tanjungpura University

Growth Stage	Biomassa (kg)	Mean Biomass per ha (ton/ha)	Total Biomass in the study area (ton)*	SNI	Mean Carbon (Ton/Ha)	Total C (Ton)*	CO_{2-e} (tCO₂)**
Tree	240,740.70	125.65	240.74	0.47	59.06	113.15	415.26
Pole	28,420.92	29.67	56.84	0.47	13.94	26.72	98.06
Sapling	673.19	9.62	18.43	0.47	4.52	8.66	31.78
Total	269,834.81	164.93	316.01		77.52	148.53	545.11

Notes: * = x 1.916 Ha (total study area), ** = x 3.67 (CO_2 equivalent).

The amount of carbon stored in the green space is relatively reasonable and sufficient to create a different microclimate than outside. Astiani et al. (2017) found that natural peat swamp forest in Kuala Dua Kubu Raya Village stored 55 to 120 tons C per ha, from heavily degraded to low degraded forest conditions. Heriyanto et al. (2020) reported that old secondary peat forest in South Sumatera stored less carbon (55 to 120 tons and 90.75 C/ha consecutively) than the results of this study, while Erly et al. (2021) measured higher carbon (277.64 ton C/ha) in the low land forest of Bukit Barisan. However, the Intergovernmental Panel on Climate Changes recommended that a minimum limit of carbon stock in primary, secondary, and agroforestry forest lands are 138 tons C/ha (IPCC 2014). The carbon stock in the green open space is still low or below the minimum limit recommended by the IPCC but higher than the heavily degraded natural peat swamp forest. This study also demonstrated that the largest amount of carbon stock in tons is at the tree stage (76.18%), and the rest were saved at the pole stage (17.99%) and sapling stage (5.83%) of the total

carbon stocks. Asner and Mascaro (2014) mentioned trees with a larger basal area can store more carbon because the main contribution of biomass is in the trunk.

This small forest area needs to be maintained because the benefits are greater for the environment. Its significant function in reducing anthropogenic CO_2 emissions generated from campuses or cities can be offset by conserving or increasing stored carbon (C) (Tang et al. 2016). The degradation of peatland forests could severely impact the environment, particularly the emission of carbon into the atmosphere. Enrichment planting with suitable species and maintaining present vegetation can increase the ability of these areas to both store and sequester carbon. Moreover, the peatland forest itself stores a significant amount of carbon within peat soil biomass below ground (Kurnianto et al. 2014; Leng et al. 2019). Thus, mismanagement of the peatland area will impact more CO_2 emissions from the peat soil (Astiani et al. 2018).

The amount of carbon stocks of the green space, albeit in very small quantities, contributes to mitigating GHG emissions. The value of carbon stocks can be converted to CO_2 by multiplying total carbon (tons) by 3.67. The results showed that the CO_2 absorbed within the vegetation was 545.11 tons of CO_2, and the carbon will be maintained within the vegetation biomass and enhanced as long as they are not died or disturbed. Therefore, this green space plays an important role in reducing greenhouse gases from the atmosphere. Peatland ecosystem, such as this area which accumulated peat, organic soil, and vegetation should be managed as peatland forests, even though its location within the campus environment. Some environmental factors that could influence the peat carbon stocks, i.e., changes in temperature, precipitation or rainfall, atmospheric composition, and fire (Leng et al. 2019). Therefore, proper peatland management is essential, particularly due to its nature, hydrology management is needed (Bispo et al. 2016; Waddington et al. 2015).

3.2. Comparison of Tree Biomass among Allometric Models

Tree biomass was calculated using different allometric models to compare the biomass produced from each allometric model. The allometric model used is adjusted to the type of ecosystem in the green space of the New Building of Faculty of forestry Untan, peatland forest. Based on the West Kalimantan Forest Reference Emission Level (FREL) report compiled by Hardiansyah et al. (2016), several allometric models can be used for peatland forest that has been considered through the allometric selection stage. Information about the biomass among allometric models can be seen in **Table 2**.

The results show that the biomass generated from each allometric model has varying values. According to Krisnawati et al. (2012), this significant diversity of tree biomass estimates, apart from differences in the allometric models used, is also due to differences in diameter size, floristic composition, species, and growth rates in each type of ecosystem that contribute to biomass development. The biomass results from the allometric test comparison can be seen in **Table 3**. It shows that the highest total biomass per hectare is found in the allometric model of Manuri et al. (2013), followed by Chave et al. (2005) and Jaya et al. (2007), and the lowest biomass yield is in the allometric model of Brown et al. (1997).

Table 2. Comparison of tree biomass allometric equation of peatland forests

Source	Allometric Model	DBH (cm)	R	Location	Amount of Sample
Chave et al. (2005)	$AGB_{est} = \rho * exp\,(-1.499+2.148*ln(D) + 0.207*(ln(D))^2 - 0.0281*(ln(D))^3)$	5 – 156	0.97	Indonesia, Kamboja, India, Malaysia, Brazil, Venezuela, Mexico, Costa Rica, Puerto Rico, Australia, and New Guinea.	2,410
Manuri et al. (2013)	$(0.242*D^{2.473}*WD^{0.736})$	2 – 167	0.97	Kapuas Hulu (West Kalimanta)	148
Jaya et al. (2007)	$0.107*D^{2.486}$	2 – 35	0.90	Central Kalimantan	-
Brown et al. (1997)	$AGB_{est} = 13.2579 - 4.8945*D + 0.6713\,(D^2)$	5 – 148	0.97	Pantropical forest, including lowland dipterocarp forest of Asia and Latin America	69

Table 3. Comparison of allometric test results

Growth Stage	Total Area (ha)	Biomass (tons/ha)			
		Chave et al. (2005)	Manuri et al. (2013)	Jaya et al. (2007)	Brown et al. (1997)
Tree	1.916	125.65	128.16	88.37	77.93
Pole	0.958	29.67	33.75	23.61	23.73
Sapling	0.07	9.62	11.92	7,35	6.92
Total		164.93	173.83	119.33	108.58

The comparisons show the allometric model by Chave et al. (2005) is ~5% below that of Manuri et al. (2013), yet ~38% and 56% above the model produced by Jaya et al. (2007) and Brown et al. (1997), consecutively (**Fig. 4**). Each forest carbon assessment freely to calculate the biomass results using these allometric equations. However, the most appropriate approach will produce better carbon estimation (Roxburgh et al. 2015; Zhao et al. 2012). Chave's equation gave a better matched criteria approach and demonstrated intermediate values, a more reasonable amount of biomass, and carbon estimation.

3.3. Species Density and Richness

The results showed that the density for each type varied. At the tree stage, the highest density per hectare was *Litsea garciae* (30.79 trees/ha). The highest density in the pole stage was found in *Hevea brasiliensis* (62.63 trees/ha), and at the sapling stage, the highest density per hectare was also *Hevea brasiliensis* (171.43 trees/ha). Within the overall study, there are 56 tree species with 558 individuals found in this area. The dominant species found, e.g., *Litsea garciae, Hevea brasiliensis, Nephelium lappaceum, Actinodaphne glabra,* and *Macaranga pruinosa*.
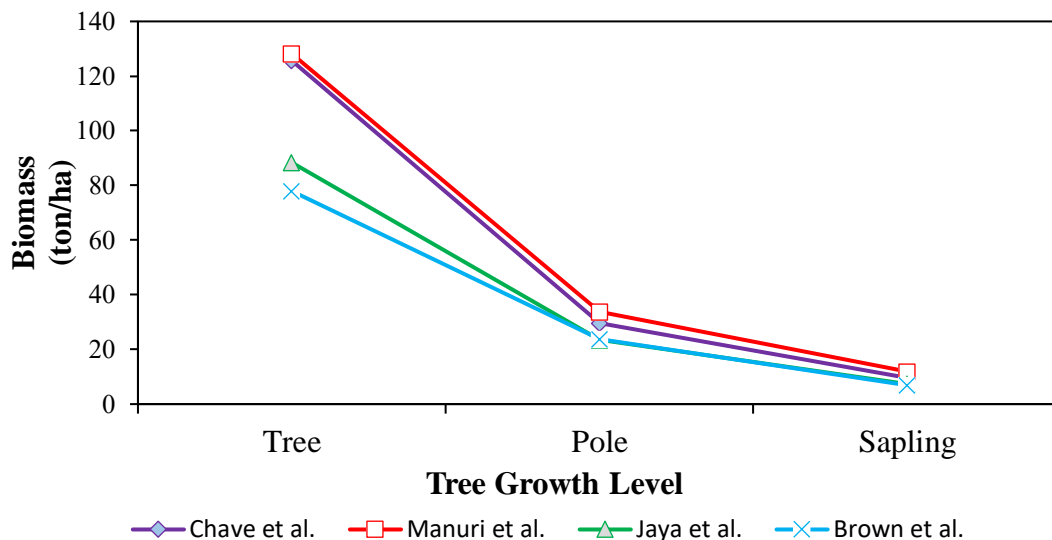
Fig. 4. Biomass comparison among several allometric models.

4. Conclusions

Carbon stock within the tree stage was 59.06 tons/ha (76.18%), while the pole stage was 13.94 tons/ha (17.99%), and the rest was at the sapling stage of 4.52 tons/ha (5.83%). Thus, the overall carbon stored in the green open space of the Faculty of Forestry, Tanjungpura University was 77.52 tons/ha. This amount is relatively low compared to intact peatland forest, yet this carbon stock area should be well managed to enhance its function as a green open area. There were 56 tree species found, with a total of 558 individuals. Dominant tree species, namely *Litsea garciae*, *Hevea brasiliensis*, *Nephelium lappaceum*, *Actinodaphne glabra*, and *Macaranga pruinosa*.

Acknowledgments

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