

Carbon Sequestration of Tree Community in Urban Green Spaces of Bekasi City, Indonesia

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ABSTRACT

Bekasi City is experiencing climate problems, one of which is a decrease in rainy days. The existence of the Patriot Bina Bangsa City Forest and Bekasi City Park is expected to reduce the impact of climate change through the role of the tree communities in it as a carbon sink. The problem faced is the absence of data on tree communities, carbon stocks and the potential for carbon dioxide absorption of trees. The purpose of this study was to analyze the relationship between tree communities and stock values as well as to estimate the potential for carbon dioxide uptake and tree demand in the Patriot Bina Bangsa City Forest and Bekasi City Park. Sampling of trees using purposive sampling method with a square plot measuring 20x20 meters. Sampling of motorized vehicles using the survey method. The results of this study indicate a very strong relationship between the importance of trees and carbon sequestration in the Patriot Bina Bangsa Urban Forest and the relationship in the Bekasi City Forest, as well as estimates of the trees needed to absorb carbon dioxide in the Patriot Bina Bangsa City Forest and Bekasi City Park, namely 3093 trees with diameter 0.31 m.

Keywords: Carbon stock, Importance value, Tree community

1. INTRODUCTION

Climate change is a problem experienced by all countries in the world. Climate change is caused by the accumulation of greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), and nitrogen oxides (N₂O) in the atmosphere. Climate change is causing an increase in air temperature, sea level, and ice melting rate in Greenland. Data from [33] shows an increase in temperature and carbon dioxide in the atmosphere from 2000 to 2020. The world average temperature increased by 0.6°C from 2000 to 2020. Carbon dioxide levels increased even more in 2018 to 2019 period (2.6 ppm) compared to 2017 to 2018 (2.3 ppm).

Forests are an important component for absorbing greenhouse gases such as carbon dioxide. Data from FAO [12] shows the weight of carbon absorbed by forests in the world by measure biomass of living trees of 288,821 million tons and dead wood and litter of 71,888 million tons. The carbon weight of living trees covers 44% of the total carbon absorbed by the forest, which is 652,371

million tons. Tree-level plants are woody plants with the largest type of growth, which is >20cm in diameter [4]. Trees have various functions including absorbing carbon dioxide, reducing surface water levels [30, 31, 32], supporting biodiversity and providing natural habitats [35].

Urban areas have a high population density, so that they become the use of centers of human activity. Human activities such as motorized vehicles and industrial activities contribute greatly to the increase in carbon in the atmosphere. Carbon dioxide (CO₂) is one of the greenhouse gases that is increasing in existence. Carbon dioxide is produced mostly by burning fuel oil. Data from [33] shows that Indonesia's carbon dioxide emissions from the use of fuel oil (BBM) in 2015 reached 64%, followed by coal (16%), gas (12%), and LPG (8%).

The accumulation of carbon (C) from carbon dioxide compounds carried out by living trees is called carbon sequestration (C sequestration). Trees in urban areas are needed to absorb large carbon dioxide emissions from various activities, such as motorized vehicles [11,18].

The number of motorized vehicles can be determined using a manual survey by counting motorized vehicles at a certain time. The carbon dioxide emission factor has been determined by the Minister of Environment Regulation No. 12 of 2010 [9, 24].

Bekasi City is experiencing the number of climate problems, one of which is a decrease in rainy days. Data from [3] shows that in 2019 there were three months without existence of the rain, an increase from one month in 2018. The Patriot Bina Bangsa Urban Forest and Bekasi City Park as Ruang Terbuka Hijau (RTH) is expected to reduce the impact of climate change through the role of tree community in them as a carbon sink. Similar research was conducted in the City Forest of DKI Jakarta, namely the Urban Forest of the University of Indonesia, Srengseng, and PT JIEP using an allometric approach, resulting in the largest CO₂ absorption value in the UI Forest, namely 178.82 tons/ha, Srengseng 88.15 tons/ha and PT JIEP 86.76 tons/ha. The largest tree carbon contribution comes from Fabaceae family trees [22].

This research have two objectives. First, the relationship between trees importance value and carbon sequestration. Second, the estimation of trees needs to absorb carbon dioxide from motorized vehicles. The results of this research are expected to be important information in the management of the Patriot Bina Bangsa City Forest and Bekasi City Park. The results of the analysis of the relationship between tree community and their carbon stock can be used as data references for conservation activities and increasing tree carbon uptake. The estimation results of trees potential carbon dioxide uptake can determine the need for additional trees in the Patriot Bina Bangsa City Forest and Bekasi City Park.

2. METHODOLOGY

2.1. Research Location

This research was conducted from January - June 2021. This research was conducted at Patriot Bina Bangsa City Forest and Bekasi City Park Bekasi City, West Java. Geographically, the research location is 6°14'1" -- 6°14'10" South Latitude (SL) and 106°59'28" - - 106°59'34" East Longitude (EL). The research took place during January - May 2021, climatic conditions are hot and in the period January – June 2021. Bekasi City passes through the rainy and dry seasons.

2.2. Determination of Sampling, Form and Number of Plots

Determination of the sampling plot using the purposive sampling method which prioritizes field observations to ensure the plot does not include pedestrian paths. The first plot in the Patriot Bina Bangsa City Forest was placed two meters east of the Unit

Pelaksana Teknis (UPT) office because there was a pedestrian path to the west. Placement of the first plot in Bekasi City Park to the south of the square. The direction of plot placement is then placed according to field conditions.



Figure 1. Research location: 1. Patriot Bina Bangsa Urban Forest; 2. Bekasi City Park; 3. Ir.H.Juanda Street (source: ArcGis Map 10.7)

The number of plots is determined based on the interpretation of 10% of the research site area, which is 600 m² in the Patriot Bina Bangsa City Forest and 280 m² in Bekasi City Park. The number of plots made was 15 plots in the Patriot Bina Bangsa City Forest and 7 plots in Bekasi City Park with a square shape measuring 20x20 meters. The boundaries of the plot are made with the help of a roller meter, stakes, and raffia rope [4, 21].

2.3. Trees Data Inventory

Inventory of trees data is carried out directly in each field plot trees identification using the identification book [8, 22]. The DBH value was used for the calculation of the carbon stock.

2.4. Importance Value and Diversity Index

The importance value (IV) is obtained by adding up the relative dominance, relative frequency and relative density. The value of tree community diversity was determined by the Shannon-Wiener diversity index (H'). The Shannon-Wiener index (H') is calculated using the Equation (1), where H' is the Shannon-Weinner index, ni is the importance value of species-i, and N is the total importance value of all species [15, 23]:

$$H' = -\sum \{(iv-i/IV) \ln (iv-i/IV)\} \quad (1)$$

2.5. Estimation of Tree Carbon Stock

Measurement of tree biomass is carried out if allometric equations for specific tree species are not available. The research of [19] looking for an equation

that is able to calculate the biomass of Indonesian tropical tree species using the average value of Indonesian wood density (0.11), the average value of global tropical forest wood density (0.62), tree diameter at breast height and wood density. Measurement of tree biomass through the equation developed by [19] and carbon stock analysis [4] using the Equation (2), (3), and (4) where B is tree biomass (kg), DBH is diameter breast height (cm), P is wood density (g/cm^3), Cb is carbon stock of tree biomass (kg), l is plot area (m^2), and Cn is carbon stock of tree biomass (tons/ha).

$$B = 0,11 p D^{2,62} \quad (2)$$

$$Cb = 0,47 \times B \quad (3)$$

$$Cn = (Cb \times l) / l \quad (4)$$

2.6. Relationship Between Tree Community and Carbon Stock

The relationship between tree community and carbon stock at Patriot Bina Bangsa Urban Forest and Bekasi City Park was analyzed using linear regression analysis with the help of Microsoft Excel software. The level of confidence used is 95%. Linear regression of tree community and carbon stock used the importance value as the independent variable (x) and the value of the carbon stock as the dependent variable (y) [29].

2.7. Estimation of Carbon Dioxide Emissions Produced by Motorized Vehicles

Motorized vehicles samples were used as emission sources because the locations of the Patriot Bina Bangsa City Forest and Bekasi City Park were connected by Ir. H. Juanda Street which is one of the main road in Bekasi City. Ir. H. Juanda Street has a length of two kilometers. Vehicles sampling was carried out for two weeks, every morning (07:00--08:00) a.m, afternoon (12:00--13:00) p.m, and evening (05:00--06:00) p.m, using the help of a hand counter. These hours are the most effective time for data retrieval, due to very high mobility. Calculation of motorized vehicles emissions uses the Equation (5), where Q_i is the amount of CO_2 emissions of type-i motorized vehicles (tons/year), L is road length (km), K_i is specific energy consumption (liters of fuel/km), N_i is average number of type-i motorized vehicles (type-i vehicles/day), and Fe_i is emission factor for type-i motor vehicles (grams/liter of fuel) [16]:

$$Q_i = N_i \times Fe_i \times K_i \times L \times 365 \times 10^{-6} \quad (5)$$

2.8. Estimation of Carbon Dioxide Uptake from the RTH Trees

Data on the carbon content of the biomass of each tree is divided by its age to determine the data on carbon sequestration of each tree per year. The estimation of the carbon dioxide absorption potential of green open space trees is [24]. The tree age data was obtained based on the

information from the UPT City Forest Bina Bangsa and Bekasi City Park officers. The average age of trees in Bina Bangsa City Forest (21 years) is greater than Bekasi City Park (18 years). Carbon dioxide absorption per year in each green open space can be found using the Equation (6), where the Cb/y RTH is the total carbon content of RTH from trees biomass per year (kilograms/year), 3,67 is the ratio of CO_2 to C molecular weight, and $s\text{CO}_2$ RTH is the CO_2 absorption of trees in RTH (tons/year) [16].

$$s\text{CO}_2 \text{ RTH} = Cb/y \text{ RTH} \times 3,67 \times 10^{-3} \quad (6)$$

2.9. Estimation Trees Need

Estimated trees need is determined by dividing the remaining emissions by the average CO_2 uptake per tree. The remaining emissions are the result of the reduction between CO_2 emissions from motorized vehicles (tons/year) and total CO_2 absorption of all RTH (tons/year). The average CO_2 uptake per tree is the result of dividing the CO_2 absorption of Patriot Bina Bangsa Urban Forest and Bekasi City Park (tons/year) by the total number of trees [24].

3. RESULTS AND DISCUSSION

3.1. Tree community

The total number of trees sampled in this study was 193 trees with details of 145 trees in the Patriot Bina Bangsa Urban Forest and 48 trees in Bekasi City Park. The total number of tree species found was nine species. The trees found in both places were *Swietenia macrophylla*, *Ficus lyrata*, and *Mimusops elengi*. The tree species that were found in the Bina Bangsa Urban Forest in this study were *Swietenia macrophylla*, *Terminalia catappa*, *Nauclea orientalis*, *Delonix regia*, *Ficus lyrata* and *Mimusops elengi*. The tree species found in Bekasi City Park in this study were *Swietenia macrophylla*, *Cerbera manghas*, *Casuarina equisetifolia*, *Filicium decipiens*, *Ficus lyrata* and *Mimusops elengi*.

From the observations in six locations of green open space in the form of urban forests, 45 tree species were found that were included in 24 families. Based on their nature, the observed trees were divided into ten species (41.67%) classified as wild trees and 14 species (58.33%) classified as cultivated trees. Meanwhile, in terms of the main benefits, most (46.47%) are fruit or food-producing trees, 24.44% are wood producing trees, and the rest are ornamental trees, shade, shade, spice/medicinal producers, and the benefits are unknown [28]. The important value of each tree species in the Patriot Bina Bangsa Urban Forest and Bekasi City Park can be seen in Table 1.

Table 1. Importance Value of Trees Species at Patriot Bina Bangsa Urban Forest and Bekasi City Park

Location	Tree Species	Relative Dominance (%)	Relative Frequency (%)	Relative Density (%)	Importance Value (%)
Patriot Bina Bangsa Urban Forest	<i>Swietenia macrophylla</i>	37,63	33,33	42,07	113,03
	<i>Terminalia catappa</i>	45,08	30,95	40	116,03
	<i>Nauclea orientalis</i>	7,2	16,67	9,66	33,53
	<i>Delonix regia</i>	6,78	9,52	4,14	20,44
	<i>Ficus lyrata</i>	0,68	2,38	0,69	3,75
	<i>Mimusops elengi</i>	2,63	7,14	3,45	13,22
Bekasi City Park	<i>Swietenia macrophylla</i>	33,01	29,17	37,50	99,68
	<i>Carbera manghas</i>	11,11	16,67	12,50	40,28
	<i>Casuarina equisetifolia</i>	8,82	12,50	12,50	33,82
	<i>Filicium decipiens</i>	27,45	20,83	27,08	75,36
	<i>Ficus lyrata</i>	16,99	12,50	6,25	3,75
	<i>Mimusops elengi</i>	2,61	8,33	4,17	15,11

Based on Table 1 and 2, *Swietenia macrophylla* as a tree species with the highest importance value in Patriot Bina Bangsa Urban Forest (113.03%) and Bekasi City Park (99.68%). *Ficus lyrata* had the lowest importance value (3.75%) in the Bina Bangsa Urban Forest and Bekasi City Park. The Shannon-Wiener Index (H') in Patriot Bina Bangsa Urban Forest (1.36) and Bekasi City Park (1.63) is in the medium category ($1 \leq H' \leq 3$).

3.2. Carbon stock estimation

The type of land use that has the greatest potential for carbon stocks is plantation forest, which is 64 tons/ha. Meanwhile, the type of land use that has the smallest potential carbon stock is rice fields, at 2 tons/ha and built-up land (other than settlements and commercial industrial areas) at 5 tons/ha [10].

Based on sampling results in the research plot, the estimated tree carbon stock in Bina Bangsa City Forest and Bekasi City Park. The allometric equation for mahogany trees uses the equation developed by [1]. Research by [1] used a sample of 30 mahogany trees in Cianjur with a diameter range of 14.3 to 36.9 cm. Allometric equations were also used to determine the value of biomass, carbon stock, and CO₂ absorption in stems, roots, litter and woody necromass of *Rhizophora stylosa* tree stands in each zone on Camplong beach,

Sampang-Madura [14]. The Table 2 shows that are the allometric equation for mahogany trees [1] and wood density [26] that used in this research:

Table 2. Wood density of trees species at Patriot Bina Bangsa Urban Forest and Bekasi City Park

Tree Species	Wood Density (g/cm ³)
<i>Carbera manghas</i>	0,44
<i>Casuarina equisetifolia</i>	0,91
<i>Filicium decipiens</i>	0,96
<i>Ficus lyrata</i>	0,39
<i>Nauclea orientalis</i>	0,55
<i>Delonix regia</i>	0,32
<i>Mimusops elengi</i>	0,61
<i>Terminalia catappa</i>	0,65

3.3. Relationship between importance value and carbon stock

The value of carbon stock in both places is influenced by the dominating trees. The results of this study are in accordance with study by [29] which showed that some dominating tree species were able to influenced carbon stocks as well. The value of carbon stock in Patriot Bina Bangsa Urban Forest reached 68.85 tons/ha and Bekasi

Table 3. Estimation of carbon dioxide emission by motorized vehicles

Description	Vehicle Type			
	Car	Motorcycle	Truck	Bus
Vehicle Total (14 days survey)	9845	26848	277	176
Daily Average	703	1918	20	13
Working Hour Average	678	1691	21	11
Holiday Average	767	2483	18	16
CO ₂ Emission per Year (tons/year)	142,93	97,44	5,74	3,15

City Park reached 18.89 tons/ha. *Swietenia macrophylla* and *Terminalia catappa* have the largest carbon stock value (57.89 tons/ha / 84.1%) in Bina Bangsa Urban Forest with a total importance value of 229.06 (76.35% of 300). *Swietenia macrophylla* and *Ficus lyrata* have the largest carbon stock value (11.81 tons/ha / 63%) in Bekasi City Park with a total importance value of 175.04 (58.34% of 300). Meanwhile, the dominant species at the tree level in the Gunung Sari forest, Singkawang City, were more dominant than Patriot Bina Bangsa Urban Forest and Bekasi City Park. There were *Alstonia scholaris* with an Importance Value of 64.79%, *Durio zybethinus* of 43.0530%, *Artocarpus elasticus* 31.93% and *Hevea brasiliensis* with an Importance Value of 26.42% [2].

categories and both are positive. This is indicated by the R² value in Patriot Bina Bangsa Urban Forest which is 0.9146 (very strong) and Bekasi City Park of 0.5488 (medium). The relationship between importance value and carbon stock in Patriot Bina Bangsa Urban Forest is stronger than Bekasi City Park and this is influenced by the importance value of dominant tree. The higher importance value is positively correlated with the carbon stock value. The results of this research is similar with [6]. The study conducted by [6] investigated tree community and its carbon stock in the city of Zaria Metropolis, Northern Nigeria. The result showed a relationship between the importance of trees and carbon stocks. Two tree species, namely *Azadirachta indica* and *Manifera indica*, had the highest total importance value (72.9%) and carbon stock (13.75 tons/ha).

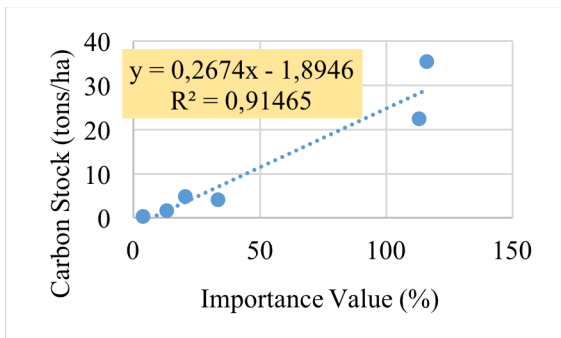


Figure 2. Scatterplot of trees importance value and carbon stock at Patriot Bina Bangsa Urban Forest

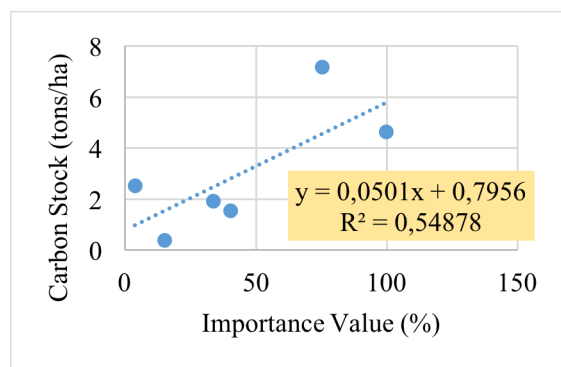


Figure 3. Scatterplot of trees importance value and carbon stock at Bekasi City Park.

Based on Figure 2 and 3, the relationship between importance value and carbon stock in the Patriot Bina Bangsa Urban Forest and Bekasi City Park is in different

3.4. Estimation of carbon dioxide emission by motorized vehicles

The results of observations of motorized vehicles on Ir. H. Juanda Street showed that motorcycles are the dominant vehicles, followed by cars, trucks and buses. The total number of motorized vehicles observed reached 37146. The average number of daily vehicles observed was generally higher on weekend than weekdays. The total estimated CO₂ emissions of motorized vehicles per year reach 249.26 tons. Vehicles are the main source of air pollution in the area urban and pollution 70% NO_x emissions, 52% VOC emissions and 23% particulates [7]. Table 3 and Table 4 are estimation of carbon dioxide emissions of motorized vehicles per year, emission factor [25] and specific energy consumption [33] that used in this research.

Table 4. Emission factor and specific energy consumption

Vehicle	Emission Factor (g/liter gasoline)	Spesific Energy Consumption (liter gasoline/km)
Motorcycle	2320,22	0,03
Car	2320,22	0,12
Bus	2639,10	0,13
Truck	2649,10	0,15

3.5. Estimation of trees need at Patriot Bina Bangsa Urban Forest and Bekasi City Park

Patriot Bina Bangsa Urban Forest and Bekasi City Park based on the data from this research are able to absorb CO₂ of 94.61 tons per year or 37.95% of the total CO₂ emissions of motorized vehicles per year. The tree age data was obtained based on the information from the officers of the Bina Bangsa City Forest and Bekasi City Park. The average age of trees in Bina Bangsa City Forest (21 years) is greater than Bekasi City Park (18 years). The average CO₂ absorption per tree in Patriot Bina Bangsa Urban Forest and Bekasi City Park is 0.05 tons/year. The results of the estimation of tree needs show that the trees needed are 3093 with an average tree diameter of 0.31 m. This high demand for trees is caused by the wide spacing of trees in some areas and the presence of many tree species with a diameter of <20 cm.

The relationship between important value and carbon stock is greater in Patriot Bina Bangsa Urban Forest than Bekasi City Park. This result came from two dominate trees species in Patriot Bina Bangsa Urban Forest are better to save carbon than two species of trees that dominate Bekasi City Park. The results of the estimation of tree needs show that the trees needed are 3093 with an average tree diameter of 0.31 m. The estimated trees needed to absorb carbon dioxide is based on vehicles emission data from two weeks sampling on Ir.H.Juanda Street. This data is on limited scale and need more improvement in the future.

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