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ENVIRONMENTAL SERVICES CARBON STOCK OF TREE ON GREEN BELT ON JENDERAL SUDIRMAN STREET, SUKOHARJO DISTRICT

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Abstract
Trees have capabilities in environmental services related to carbon stocks. Green belts along urban roads have the function of absorbing CO_2 in the air needed for the photosynthesis process, with the result in the form of carbohydrates for growth, and the rest is buried in the form of carbon. This study was conducted to determine the carbon stocks of tree on the green belt on the side of Jenderal Sudirman Street. This study was conducted in May 2023 on Jenderal Sudirman Street in front of the Menara Wijaya Building and Sukoharjo District Head Office. Data was collected using the diameter census method on each tree. Data was analyzed using allometric equations to calculate biomass values and carbon stock equations to determine carbon stock values. The results showed that on the green belt, as many as eight species of trees were found, with 67 individual trees. The most widely planted species on the green belt is Pterocarpus indicus Willd. (Angsana) with a total of 33 individuals. The highest biomass value owned by the species Pterocarpus indicus Willd. (Angsana) at 0.79874 tons. The highest carbon stock value owned by the species Pterocarpus indicus Willd. (Angsana) at 0.39937 tons.
Keywords: *Biomass; Carbon Stock; Green Belt; Sukoharjo District; Tree*

INTRODUCTION

Greenhouse Gas (GHG) has long been a global problem that is still being fought. Based on data from the Indonesia First Biennial Update Report (1stBUR), it is reported that total GHGs have increased annually by 3.6% from all sectors. According to Wahyudi (2019), the type of gas in the atmosphere that has the ability to absorb and emit infrared radiation to the earth's surface produced by sunlight is known as Greenhouse Gas (GHG). Some gases included in GHGs include carbon dioxide (CO_2), nitrogen oxides (N_2O), methane (CH_4), fluorinated gases (HFCs, PFCs, and SF_6), ozone (O_3), aldehyde groups, and water vapor. The gas can occur naturally, but is mostly produced by anthropogenic activity. Anthropogenic activities can be in the form of fossil burning, factory/industrial chimneys, land use change, or other activities. Increased GHG emissions can increase the air temperature on the earth's surface. Increasing air temperature due to GHG emissions is known as global warming (Yuliana, 2017). Global warming can trigger climate change, so weather and climate are increasingly difficult to predict because they exceed the tolerance limit. According to Ishak et al. (2019), GHGs that cause global warming can harm the earth through droughts, extreme hot weather, and floods. Carbon dioxide (CO_2) is one of the gases that contributes the most to the greenhouse effect.

Carbon dioxide gas (CO_2) is produced by fossil fuel vehicles with characteristics that are odorless, colorless, and concentrations that should not exceed 12% (Gunawan et al., 2020). This gas can have a good effect on plants because it is needed to carry out the process of photosynthesis. This gas can be sourced from fossil fuel vehicles, factory/industrial chimneys, waste incineration, etc. Carbon dioxide gas (CO_2) can absorb and reflect infrared waves emitted by the sun to the earth, so the radiation is trapped and causes an increase in the average air temperature on the earth's surface (Aldus, 2017). This phenomenon can impact the occurrence of the greenhouse effect and global warming. Sukoharjo District has priority issues that are considered by the *Dinas Lingkungan Hidup Kabupaten Sukoharjo* (Sukoharjo District Environmental Office), one of which is the decline in air quality (Dinas Lingkungan Hidup Kabupaten Sukoharjo, 2021).

Transportation activities have more influence on ambient air quality in Sukoharjo District (Dinas Lingkungan Hidup Sukoharjo, 2021). The high mobility of transportation in urban areas can reduce air quality that is affected by the combustion of motor vehicle engines. Transportation is included in the aspect that emphasizes air quality in Sukoharjo. An increase in population can increase the need for motor vehicles. An increase in motor vehicles will cause an increase in exhaust gas concentration due to mobile source emissions derived from fuel use, as well as reduce ambient air quality. Jenderal Sudirman Street is one of the major roads with heavy traffic in Sukoharjo District. A high number of motorized vehicles can trigger a decrease in air quality on highways with traffic congestion. Based on the results of an evaluation conducted by the Sukoharjo District government, the transportation sector with mobile source exhaust emissions has a dominant influence on exposure to ambient air pollutants in the Sukoharjo District area (Pemerintah Kabupaten Sukoharjo, 2021). One of the efforts to reduce exhaust emission pollution is the creation of green belts on road segments planted with tree vegetation. Reducing emissions from mobile sources can be done with tree vegetation on green belt because it is made close to emission-producing on the highway (Hesty et al., 2022).

Trees are woody perennial plants that have an upright main trunk and a crown with several plantations that can generally grow to reach no less than 8 feet. Trees grow with varying degrees of life associated with the size of the height and diameter of the trunk. The growth stage of the tree starts from the seedling to become a large tree. Tree vegetation in an area shows the structure and composition of a tree community (Hidayat et al., 2021). Trees are one of the biotic components that can save the earth from the effects of global warming and climate change. Trees are essential in carbon sequestration and the global carbon cycle (Ramadhani et al., 2022). Plants need sunlight and CO_2 absorbed from the air for their survival. During the photosynthesis process, carbohydrates are produced from CO_2 which has been converted, then carbohydrates are distributed throughout the plant body and stored in plant parts including stems, leaves, twigs, fruits, and flowers (Rinjani et al., 2016). The process of photosynthesis produces oxygen which is released into the air and produces nutrient needed by organism. Stomata are essential plant parts in photosynthesis process because they help absorb CO_2 (Sukmawati et al., 2015). Trees on the green belt have environmental services in carbon storage or storage called carbon sequestration (Sardi et al., 2021).

Environmental services are services obtained from ecosystems, either natural or artificial, with benefits to support the improvement of the quality of life of the community and the environment sustainably (Simarmata and Triastuti, 2021). A sustainable environment will support the magnitude of environmental service benefits (Pambudi et al., 2023). Environmental services are classified into four, namely regulatory services, provision services, support services, and cultural services (Mukaddas and Taufik, 2022). Environmental services are included in something free to be consumed and used by the public, but the scarcity of environmental services results in making them as traded goods (Sulaeman, 2023). An ecosystem with complete components in it will improve the quality and quantity of environmental services (Rachdian et al., 2016). Some examples of environmental services include biological conservation, river flow protection, carbon stocks, and aesthetics. One of the crucial environmental services is regarding carbon stocks related to carbon emissions (Sasongko et al., 2023). Carbon stocks are the large amount of carbon in the pool (where carbon is stored) (Irfan et al., 2021). Carbon stocks in trees can be interpreted as the amount of carbon in trees. The amount of carbon stored at each level of vegetation is interpreted as carbon storage potential, where trees are the level of vegetation that holds the most carbon because it has a larger diameter than other levels (Paradika et al., 2021). The amount of carbon stock value in the ecosystem is influenced by the diversity of species, the density of the existence of trees, the age of trees, the litter produced, and the type of soil in the ecosystem (Rahmayanti et al., 2021).

By knowing the amount of carbon stocks in a tree, it can also be known how much the function of an area is to the environment, especially the function as an effort to mitigate climate change (Azzahra et al., 2020). The green belt on the side of Jenderal Sudirman Street, Sukoharjo District has the potential to bind large amounts of carbon through planted tree vegetation. The potential is based on the physical condition of the green belt which has many large trees in it. More in-depth studies are interesting enough to be carried out so that the value of carbon stocks owned by tree vegetation in the green belt can be known. Known carbon stocks can provide information related to how significant the role of the green belt on the side of Jenderal Sudirman Street in reducing CO_2 concentrations in the surrounding environment. The absence of previous studies that examined carbon stocks on the green belt on the road is the basis of this study. Therefore, this study was conducted to determine the carbon stocks of tree on the green belt on Jenderal Sudirman Street in front of Menara Wijaya Building and Sukoharjo District Head Office.

MATERIALS AND METHODS

Study Area

This study was conducted on Jenderal Sudirman Street Number 199, Gabusan, Jombor Village, Bendosari Sub-District, Sukoharjo District, Central Java Province. This study will be conducted in May 2023. The location used as the object of this

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study is two green belts that cross each other on the right and left sides of Jenderal Sudirman Street, precisely in front of the Menara Wijaya Building and the Sukoharjo District Head Office.

Figure 1. Map of Study Location

Procedures

Data collection will take place in May 2023. Data was collected by measuring the BHD (Breast Height Diameter) of the tree on the green belt on the side of Jenderal Sudirman Street. BHD data collection was collected using the diameter census method on each tree. BHD measurement results are used for the calculation of aboveground biomass of a tree. Data was collected on two green belts opposite each other in front of Menara Wijaya Building and Sukoharjo District Head Office. The first green belt has a length of 226.26 m and the second green belt has a length of 211.6 m. The name of the species, the number of individuals, as well as the BHD of the tree are recorded. Tree species identification is done using tree documentation results to analyze species names using Google Image.

Data Analysis

This study used quantitative descriptive method. Descriptive with a quantitative approach focuses on numbers, so that the results of data analysis are described based on numbers obtained from the equations used (Haidiputri and Cahyanti, 2019). Biomass determination along the green belt was determined using no-harvest or non-destructive sampling methods. This method measures biomass in living trees, dead trees, and dead wood (Anggraini and Afriyanti, 2019). Allometric equations are based on the type of tree species are used in the method. The allometric equation is used to determine the relationship between the physical size of the tree and the weight of the tree. In this study, allometric equations were used on each type of tree obtained. Table 1 presents tree species and their allometric equations based on previous study:

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Table 1. Allometric Equations

Type of Trees	Allometric Equations	References
Swietenia mahagoni (L.) Jacq (*Mahoni*)	$Y = 0{,}048 \times D^{2{,}68}$	Hairiah et al., 2011
Branched Tree	$Y = 0{,}11 \times p \times D^{2{,}62}$	Ketterings et al., 2001

Information:
Y : Tree biomass (kg)
D : Breast Height Diameter (BHD) (cm)
p : Specific gravity of wood (gr/cm^3)

The biomass value obtained from the calculation results with the allometric equation above, can then be used to determine the value of carbon stocks stored in tree vegetation. About half of the biomass of a plant consists of carbon derived from the process of photosynthesis, where in the process, there is absorption of CO_2 which then becomes organic carbon and is stored in biomass in all parts of the vegetation (Nedhisa and Tjahjaningrum, 2019). Therefore, based on Ulianata et al. (2021), the results of the calculation of biomass value are used in calculating carbon stocks using the equation:

$$\mathbf{C = 0{,}5 \times Y}$$

Information:

C : Carbon stocks
0,5 : Conversion factors
Y : Tree biomass

RESULTS AND DISCUSSIONS

Green Belt Conditions

The green belt is a concept of road development planted with various types of trees and involves an aspect, one of which is the width of the road (Noseka, 2020). In principle, specific requirements apply to plants grown in green zones, so as not to occur carelessness when planting green zones on the roadside, center line, or bends. The main requirements in choosing plants for road landscapes are that the roots do not damage the road structure, are easy to maintain, not easy to break stems or branches, not easy to shed leaves, and consider the safety and comfort factors of drivers and road users. Roadside plants must be windproof, have a fruit size that is not large, shady, have little litter, not too dark, can absorb pollutants, exhaust fumes, or car dust, and have aesthetic value (Safitri et al., 2016).

The form tree planting on the green belt on the side of Jenderal Sudirman Street is planted with a certain distance between the trees. Based on observations, the condition of the trees planted on the green belt is exceptionally well organized and maintained. There are still some trees that grow poorly with few and barren leaves even though trees in the green belt are often watered regularly by the government. In addition, the condition of the leaves on the trees along the green belt looks dirty and dusty, which shows that the trees can catch dust produced by vehicles. This

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phenomenon is in line with study by Rahmadhani et al. (2019), that trees planted along the green belt can absorb dust particles, thereby reducing air pollution. Growing various types of trees on sidewalks or along roads can also be a Green Open Space area that can absorb CO_2 gas and reduce the risk of GHG (Mutia, 2020).

Figure 2. Green Belt 1

Figure 3. Green Belt 2

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Table 2. Tree Species on the Green Belt

Family	Latin Name	Local Name	Number of Species
Anacardiaceae	*Mangifera* sp.	*Mangga*	1
Bignoniaceae	*Annona asiatica* L.	*Srikaya*	5
Bignoniaceae	*Spathodea campanulata* P. Beauv.	*Kiacret*	13
Combretaceae	*Terminalia catappa* L.	*Ketapang*	2
Fabaceae	*Pterocarpus indicus* Willd.	*Angsana*	33
Meliaceae	*Swietenia mahagoni* (L.) Jacq	*Mahoni*	1
Moraceae	*Ficus religiosa* L.	*Bodhi*	1
Sapindaceae	*Filicium decipiens* L.	*Kerai Payung*	11

Based on the results of observations and identification of tree on the green belt on the side of Jenderal Sudirman Street (Table 2), it can be seen that there are eight species of trees planted on the green belt. Among the total species, there are four species with the most significant number, including *Pterocarpus indicus* Willd. (*Angsana*), *Spathodea campanulata* P. Beauv. (*Kiacret*), *Filicium decipiens* L. (*Kerai Payung*), and *Annona asiatica* L. (*Srikaya*). The tree species with the most individual is *Pterocarpus indicus* Willd. (*Angsana*). Species *Pterocarpus indicus* Willd. is a two-legged tree (deciduous) with a height ranging from 30-40 meters and a trunk diameter of more than 2 meters (Firmansyah et al., 2022). Species *Pterocarpus indicus* Willd. is a naturally occurring species native to Southeast Asia (Cambodia, Indonesia, East Timor, Malaysia, Papua New Guinea, Philippines, Thailand, Vietnam) and is native to northern China. The species was most widely planted at the study location. Species *Pterocarpus indicus* Willd. which comes from the family *Fabaceae* (Leguminous), is a protective plant along the way as well as a decoration that has been known for a long time. In general, this species is often used as building materials in building frames, poles, bridges, walls, and railway sleepers with beautiful motifs and large sizes (Jupiter et al., 2022). The leaves are fresh green and oval-shaped is one of the physical characteristics of the species *Pterocarpus indicus* Willd. (Maulida, 2016). However, this species has weaknesses in weak root systems, branchy tree branches that break easily, and leaves often falling off in the dry season (Purwasih et al., 2013). Its ability to absorb dust and store carbon with high capacity is the reason for choosing these species to be planted along the green belt (Marisha, 20202). Based on study by Ayumna (2022), the species *Pterocarpus indicus* Willd. can also reduce noise levels due to the characteristics of its thick and elastic leaves, with a link to the ease of movement of leaves.

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Biomass Calculation Results

Table 3. Value of Tree Biomass on the Green Belt

Family	Latin Name	Local Name	Biomass (ton)
Anacardiaceae	*Mangifera* sp.	*Mangga*	0,00011
Bignoniaceae	*Annona asiatica* L.	*Srikaya*	0,00539
Bignoniaceae	*Spathodea campanulata* P. Beauv.	*Kiacret*	0,01593
Combretaceae	*Terminalia catappa* L.	*Ketapang*	0,00123
Fabaceae	*Pterocarpus indicus* Willd.	*Angsana*	0,79874
Meliaceae	*Swietenia mahagoni* (L.) Jacq	*Mahoni*	0,00070
Moraceae	*Ficus religiosa* L.	*Bodhi*	0,11208
Sapindaceae	*Filicium decipiens* L.	*Kerai Payung*	0,19146

Based on the calculation of the biomass value of trees on the green belt on the side of Jenderal Sudirman Street (Table 3), it can be determined that the average value of biomass is 0.14071 tons. The highest biomass value based on Table 3 belongs to the species *Pterocarpus indicus* Willd. (*Angsana*) at 0.79874 tons. The *Filicium decipiens* L. (*Kerai Payung*) and *Ficus religiosa* L. (*Bodhi*) also have large biomasses at 0.19146 tons and 0.11208 tons. The lowest biomass value owned by the species *Mangifera* sp. (*Mangga*) at 0.00011 tons. The difference in the value of biomass produced is influenced by the size of the tree's diameter and the specific gravity of the wood on each tree. This is in accordance with study by Yusri et al. (2022), where tree species with large trunk diameters will have high biomass values as well. The age of a tree will affect the diameter of the tree. Increased tree's age will be accompanied by a large increase in the size of the trunk diameter (Uthbah et al., 2017). In addition to the diameter and specific gravity of wood, the factor of a significant number of species will affect its biomass value (Latifah et al., 2016). At the study location, the species *Pterocarpus indicus* Willd. planted as many as 33 individuals, or 49% of the total tree species planted. While the species *Mangifera* sp. only one individual. The biomass in trees is the result of photosynthesis process. Plants can absorb CO_2 from the air which is then used as material in the process of photosynthesis. From this process, carbohydrates will be produced, which are then distributed thoroughly throughout the plant body. These results are used for plant growth, both vertically and horizontally. The rest of the use is buried in the form of carbon. Therefore, in measuring the amount of carbon stored (biomass) in a vegetation will show the amount of CO_2 absorbed by the vegetation from the air (Rinjani et al., 2016). An enormous biomass value indicates that the photosynthesis process in vegetation runs smoothly. In accordance with study by Nuranisa et al. (2020), the amount of biomass is primarily determined by the results of the photosynthesis process, so the greater the value of biomass, the greater the results of the photosynthesis process.

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Carbon Stock Calculation Results

Table 4. Value of Carbon Stocks of Trees on the Green Belt

Family	Latin Name	Local Name	Carbon Stock (ton)		
			Min	Max	Total
Anacardiaceae	*Mangifera* sp.	*Mangga*	0,000056	0,000056	0,000056
Bignoniaceae	*Annona asiatica* L.	*Srikaya*	0,000056	0,00198	0,00270
Bignoniaceae	*Spathodea campanulata* P. Beauv.	*Kiacret*	0,00009	0,00169	0,00797
Combretaceae	*Terminalia catappa* L.	*Ketapang*	0,000299	0,000318	0,00062
Fabaceae	*Pterocarpus indicus* Willd.	*Angsana*	0,00076	0,04951	0,39937
Meliaceae	*Swietenia mahagoni* (L.) Jacq	*Mahoni*	0,00035	0,00035	0,00035
Moraceae	*Ficus religiosa* L.	*Bodhi*	0,05604	0,05604	0,05604
Sapindaceae	*Filicium decipiens* L.	*Kerai Payung*	0,00153	0,02545	0,09573

Based on the calculation of carbon stocks owned by trees on the green belt on the side of Jenderal Sudirman Street (Table 4), it is known that carbon stocks in each species have values that vary based on the minimum value and maximum value of carbon stocks. At the minimum value, the species with the highest carbon stock value is *Ficus religiosa* L. (*Bodhi*) at 0.05604 tons. The species with the lowest carbon stock value is *Mangifera* sp. (*Mangga*) at 0.000056 tons. At the maximum value, the species with the highest carbon stock value is *Ficus religiosa* L. (*Bodhi*) at 0.05604 tons. The species with the lowest carbon stock value is *Mangifera* sp. (*Mangga*) at 0.000056 tons. Both species can only be found one individual from all tree species planted at the study location. For other species with more than one individual, the species with the highest carbon stock value at the minimum value is *Filicium decipiens* L. (*Kerai Payung*) at 0.00153 tons, and the lowest is *Annona asiatica* L. (*Srikaya*) at 0.000056 tons. While at maximum value, the species with the highest carbon stock value is *Pterocarpus indicus* Willd. (*Angsana*) at 0.04951 tons, and the species with the lowest carbon stock value was *Terminalia catappa* L. (*Ketapang*) at 0.000318 tons.

Based on the calculation of carbon stocks (Table 4), it is known that the total value of carbon stocks of each species has varying values. The highest total carbon stock is stored by *Pterocarpus indicus* Willd. (*Angsana*) at 0.39937 tons which was then followed by *Filicium decipiens* L. (*Kerai Payung*), *Ficus religiosa* L. (*Bodhi*), *Spathodea campanulata* P. Beauv. (*Kiacret*), *Annona asiatica* L. (*Srikaya*), *Terminalia catappa* L. (*Ketapang*), *Swietenia mahagoni* (L.) Jacq (*Mahoni*), and the lowest is *Mangifera* sp. (*Mangga*) at 0.000056 tons. Species *Pterocarpus indicus* Willd. has a high carbon stock because the number of individuals planted is quite large, which is as many as 33 individuals. In addition, the species *Pterocarpus indicus* Willd. has a larger proportion of trunk where the maximum diameter is 207

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cm, the minimum diameter is 42 cm, and the average is 64.6 cm. The large diameter of the tree vegetation in the green belt is one of the reasons for the high carbon stocks value of the species *Pterocarpus indicus* Willd.. Species *Pterocarpus indicus* Willd. that grow on the green belt are dominated by tree that are still small in diameter because they have not been planted for a long time. In the future, the species *Pterocarpus indicus* Willd. that have grown will have larger trunk, so the carbon stocks owned have the potential to increase significantly. The species *Pterocarpus indicus* Willd. able to absorb carbon as much as 0.011 to 0.74 tons/year/tree with a CO_2 absorption potential greater than species *Swietenia mahagoni* (L.) Jacq (Rachmayanti and Mangkoedihardjo, 2020). Therefore, the species *Pterocarpus indicus* Willd. is one of the various types of protective plants that are most often planted in the green belt along the way. Species *Pterocarpus indicus* Willd. included in the protective tree because it can accumulate contaminants through the leaves. Species *Pterocarpus indicus* Willd. has strong roots, has good resistance from damage due to vehicles vibration, can grow at high temperatures, and is resistant to strong winds (Yusri and Kiswanto, 2022).

CONCLUSIONS

Based on study that has been conducted related to the carbon stocks of tree on the green belt on the side of Jenderal Sudirman Street in front of Menara Wijaya Building and the Sukoharjo District Head Office, it was found that the most planted species on the green belt is *Pterocarpus indicus* Willd. (*Angsana*) with a total of 33 individuals. The biomass value of the entire tree species has an average of 0.14071 tons, with the highest biomass value owned by the species *Pterocarpus indicus* Willd. (*Angsana*) at 0.79874 tons. The carbon stocks value of the entire tree species has an average of 0.07035 tons, where *Pterocarpus indicus* Willd. (*Angsana*) has the highest carbon stock value at 0.39937 tons. Therefore, it can be concluded that the species *Pterocarpus indicus* Willd. (*Angsana*) plays the most significant role in storing carbon stocks on the green belt.

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