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## Estimation Of Aboveground Biomass And Carbon Storage In Pole And Tree Stands Several The Main Road Of Sumber Village, Surakarta

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### Abstrak

Vegetasi menyerap CO<sub>2</sub> dan menyimpannya sebagai biomassa, sehingga berkontribusi dalam mitigasi perubahan iklim. Penelitian ini bertujuan untuk mengestimasi biomassa tegakan pohon dan tiang di beberapa ruas jalan utama di Desa Sumber, Surakarta dan menghitung cadangan karbonnya. Data penelitian meliputi data primer (tinggi pohon, DBH, dan jenis spesies) dan data sekunder dari literatur ilmiah. Pengukuran dilakukan dengan menggunakan metode non-destructive sampling, dan biomassa dihitung dengan menggunakan rumus allometrik, sedangkan stok karbon dihitung dengan menggunakan rumus 50% dari biomassa pohon. Hasil penelitian menunjukkan terdapat 15 jenis pohon dan 12 jenis tiang. Biomassa dan cadangan karbon tertinggi ditemukan di lokasi ketiga (302,6 Ton/ha dan 151,3 Ton/ha) dan terendah di lokasi pertama (210,94 Ton/ha dan 105,7 Ton/ha). Potensi tegakan tiang dan pohon di sepanjang jalan utama di Desa Sumber menunjukkan pentingnya pengelolaan kawasan hijau yang baik di perkotaan dalam menyeimbangkan ekosistem.

Kata Kunci: *Biomassa, Karbon stok, Kelurahan Sumber, Surakarta, Vegetasi*

## Abstract

Vegetation absorb CO<sub>2</sub> and store it as biomass, thus contributing to climate change's mitigation. This study aims to estimate the biomass of tree and pole stands on several main roads in Sumber Village, Surakarta and calculate their carbon stock. The research data included primary data (tree height, DBH, and species type) and secondary data from scientific literature. Measurements were made using non-destructive sampling method, and biomass was calculated using allometric formula, while carbon stock was 50% of tree biomass. Results showed there were 15 tree species and 12 pole species. The highest biomass and carbon stock were found in the third site (302.6 Ton/ha and 151.3 Ton/ha) and the lowest in the first site (210.94 Ton/ha and 105.7 Ton/ha). The potential of pole and tree stands along the main road in Sumber Village shows the importance of good green area management in urban areas in balancing the ecosystem.

Keyword: *Biomass, Carbon stock, Sumber Village, Surakarta, Vegetation*

## INTRODUCTION

The development of urban areas is significantly correlated with the physical growth of cities, which frequently gives rise to conflicts with natural resources and environmental sustainability (Hesty et al. 2019). Therefore, urban development initiatives must be complemented by the conservation and protection of green areas, which play a vital role in maintaining ecological balance and reducing pressure on environmental sustainability (Khairina et al. 2020). Green areas contribute to improved air quality by filtering pollutants and producing oxygen. Furthermore, green areas play a significant role in carbon sequestration, which helps to reduce greenhouse gas emissions and thus mitigate the overall impact of climate change (Qatrunnada et al. 2021). This carbon sequestration occurs through the photosynthesis process carried out by trees in the green area (Samsu and Maros. 2019).

Urban trees play a crucial role beyond aesthetics. In addition to enhancing the environment, trees along main roads act as carbon absorbers and storage systems, contributing to the reduction of greenhouse gas emissions. According to a study by Aprianto et al. (2010), the carbon storage capacity of street trees in urban areas, such as in Yogyakarta, can be estimated using the allometric method. This method takes into account tree diameter and wood density, highlighting that urban trees play a vital role in absorbing atmospheric carbon, which is essential for climate change mitigation. Additionally, a study from Gadjah Mada University shows that trees in urban public spaces, including parks and parking areas, have significant carbon absorption potential (Azis, 2017). This research underscores the importance of tree density in urban areas to enhance annual carbon storage capacity. This strategy not only helps improve air quality but is also effective in

mitigating the impacts of climate change caused by carbon emissions (Hikmatyar et al., 2015). Further research on urban forests in Jakarta indicates that tree species variation and vegetation distribution also determine carbon storage effectiveness. Using a non-destructive allometric method, urban trees can store carbon without the need for logging, aligning with regulations that govern urban vegetation conservation.

Kelurahan Sumber, located in Surakarta (Solo), Central Java, is an example of a strategic urban area, both geographically and ecologically. Located near the city center, Kelurahan Sumber has good access to facilities and major transportation routes. The existence of major roads connecting the Kelurahan to other areas is one of the important aspects that strengthens its position in the development of the city. However, this condition is also a factor in urban environmental problems (Zaky et al., 2024). Areas with high vehicle volumes generally have higher emission levels, thus requiring more trees or vegetation to absorb excess CO<sub>2</sub> and mitigate its negative impacts (Alfani, 2021).

Vegetation such as trees and stands in cities play an important role in absorbing CO<sub>2</sub> through the process of photosynthesis. Trees in urban environments play a role in stabilizing CO<sub>2</sub> concentrations in the atmosphere by absorbing CO<sub>2</sub> and storing it as biomass during growth (Prastyaningsih et al., 2024). The potential stands of poles and trees along the main road in Kelurahan Sumber show the importance of good green space management in urban areas. Green Open Space can be realized in various forms such as urban parks, urban forests, sports fields, and green lanes (Putri, 2023).

This study aims to estimate the amount of biomass in stands and trees located on several roads in the source village and calculate the carbon storage capacity of tree and pole stands. The urgency of this research is because there is still little research on carbon storage in stands and trees around the source village, so the author is interested in calculating the value of biomass and carbon storage in the area.

## RESEARCH METHODS

### Study Area

This study was conducted on November 8, 2024, along the main roads in Sumber Subdistrict. The research area included Ki Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street. These locations were selected for their characteristics, which are suitable for studying urban carbon storage. Further details on the research locations are provided in Figure 1.2, which presents a map of the study area.

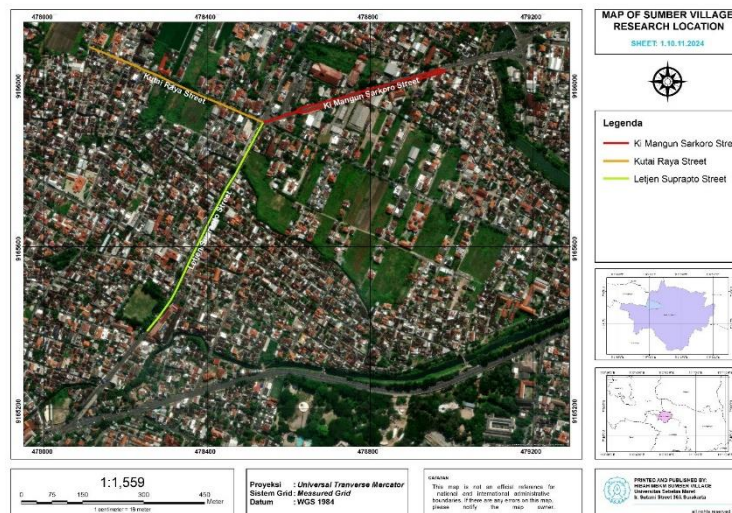


Figure 1.2 study area of Ki Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street

### Data Collection Procedure

The data used in this study consisted of primary and secondary data. Primary data were obtained through direct observation in the field by recording and measuring pole and tree level stands along the roads on Ki Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street. Plant measurements were carried out using a non-destructive sampling method, namely a sampling method without harvesting (Pebriandi et al. 2023), so as not to damage the object under study. Primary data included information on height, diameter at breast height (DBH), and species type used to estimate biomass and carbon storage. Secondary data were obtained through scientific literature to identify plant species and wood density.

### Data Analysis

Biomass measurement was carried out with a Non-Destructive Sampling approach through diameter measurement (Prastyaningsih et al., 2024) and using the allometric equation. Data analysis in this study used specific allometric formulas for each plant species. For unknown plant species, the general allometric formula will be used. The allometric formula is used to estimate the biomass of each pole and tree stand at each location (Syahib et al., 2022). Then for carbon stocks, it is calculated based on 50% carbon content in tree biomass (Basyuni et al., 2023). The formula for calculating total biomass per unit area:

$$\text{Total biomass of poles and trees} = \text{AGB 1} + \text{AGB 2} + \dots + \text{AGB n}$$

$$\text{Biomass of poles and trees} = \text{Total biomass} / \text{Area}$$

Table 1. Trees and Allometric Equation

No	Name of Trees	Allometric Equation	Source
1	Jati ( <i>Tectona Grandis</i> )	$Y = 0.290091 \times D^{2.3}$	Nur et al., 2022
2	Sengon ( <i>Paraserianthes falcata</i> (L) Nielsen)	$Y = 0.08062 \times D^{2.36816}$	Dung, et al., 2012.
3	Angsana ( <i>Pterocarpus indicus</i> Willd.)	$Y = 0.1277 \times D^{2.3949}$	Hung, et al., 2012.
4	Kersen ( <i>Muntingia calabura</i> L.)	$Y = 0,0509 \times (\rho \times D^2 \times H)$	Sari et al., 2021
5	Mahoni ( <i>Swietenia macrophylla</i> G.King)	$Y = 0.048 \times D^{2.3}$	Adinugroho et al., 2006
6	Glodokan tiang ( <i>Polyalthia longifolia</i> )	$Y = 6,4050 \times D^2 \times H^{0.4137}$	Dung et al., 2021
7	Waru ( <i>Hibiscus tiliaceus</i> )	$Y = 116.6 [(DBH) \times 2H]^{0.8877}$	Kasawani et al., 2021
8	Mangga ( <i>Mangifera indica</i> L.)	$Y = 0.1043 \times D^{2.6}$	Djafar et al., 2021
9	Trembesi ( <i>Samanea saman</i> (Jacq.) Merr.)	$Y = 2172,6 D - 8821,9$	Mardiatmoko, 2014
10	Palem ( <i>Roystonea regia</i> (Kunth) O.F.Cook)	$Y = \exp(-2.134) \times D^{2.53}$	Samosir, 2015
11	Common species	$Y = 0.059 \cdot \mu \cdot D^2 \times H$	Rahajoe et al., 2023

Explanation:

Y = Tree biomass

D = Diameter

H = Height

## RESULT AND DISCUSSION

### RESULT

#### Species Found

Table 2. Tree-stands species found at 3 locations, Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street, Sumber Village, Banjarsari Regency, Surakarta City

Family	Species	Local Name	Location		
			1	2	3
Anacardiaceae	<i>Mangifera indica</i> L.	Mangga	-	9	15
Annonaceae	<i>Polyalthia longifolia</i> (Sonn.) Thwaites	Glondogan	7	1	5
Apocynaceae	<i>Plumeria Tourn. ex L.</i>	Kamboja	2	-	3
Arecaceae	<i>Roystonea regia</i> (Kunth) O.F.Cook	Palem	4	-	1
Bignoniaceae	<i>Handroanthus chrysotrichus</i> (Mart. ex DC.) Mattos	Tabebuia	2	-	-
Combretaceae	<i>Terminalia catappa</i> L.	Sukun	-	1	-
Fabaceae	<i>Pterocarpus indicus</i> Willd.	Angsana	32	-	-
Fabaceae	<i>Sesbania grandiflora</i> (L.) Poir.	Turi	1	-	-
Fabaceae	<i>Samanea saman</i> (Jacq.) Merr.	Trembesi	1	4	-
Fabaceae	<i>Albizia chinensis</i> (Osbeck) Merr.	Sengon	-	5	5
Lamiaceae	<i>Tectona grandis</i> L.f.	Jati	-	8	-
Malvaceae	<i>Hibiscus tiliaceus</i> L.	Waru	1	-	2
Meliaceae	<i>Swietenia macrophylla</i> G.King	Mahoni	8	10	-
Muntingiaceae	<i>Muntingia calabura</i> L.	Kersen	-	1	-
Myrtaceae	<i>Syzygium cumini</i> (L.) Skeels	Jamblang	-	3	-
TOTAL			58	42	31

Table 3. Pole-stands species found at 3 locations, Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street, Sumber Village, Banjarsari Regency, Surakarta City

Family	Species	Local Name	Location		
			1	2	3
Anacardiaceae	<i>Mangifera indica</i> L.	Mangga	4	2	2
Annonaceae	<i>Polyalthia longifolia</i> (Sonn.) Thwaites	Glondogan	4	3	1
Apocynaceae	<i>Plumeria Tourn. ex L.</i>	Kamboja	2	1	-
Arecaceae	<i>Roystonea regia</i> (Kunth) O.F.Cook	Palem	-	2	-
Bignoniaceae	<i>Handroanthus chrysotrichus</i> (Mart. ex DC.) Mattos	Tabebuia	-	2	-

Combretaceae	<i>Terminalia catappa</i> L.	Ketapang	-	7	-
Fabaceae	<i>Albizia chinensis</i> (Osbeck) Merr.	Sengon	-	-	2
Meliaceae	<i>Swietenia macrophylla</i> G.King	Mahoni	-	-	2
Muntingiaceae	<i>Muntingia calabura</i> L.	Kersen	8	2	-
Gnetaceae	<i>Gnetum gnemon</i> L.	Melinjo	-	7	-
Annonaceae	<i>Annona muricata</i> L.	Sirsak	-	7	-
Arecaceae	<i>Cocos nucifera</i> L.	Kelapa	-	1	-
TOTAL			18	32	7

Based on the research that has been conducted, a total of 15 tree species belonging to 12 families were found in all research locations (Table 2). At the pole level, 12 species were found from 10 families (Table 3). The first location had the largest number of tree species, which was 58 species. The second location had 42 species, while the third location had the smallest number of species, which was 31 species (Table 2). The largest species found at the tree level was angšana or *Pterocarpus indicus* Willd which was found at the first location, which was 32. At the pole level, the second location had the largest number of species, which was 32 species, followed by the first location with 18 species, and the third location with the smallest number of species, which was 7 species (Table 3). At the pole level, the species found the most were kersen or *Muntingia calabura* L. which was found at the first location, totaling 8. Differences in the types and number of species found can be influenced by various factors, such as environmental factors (Laely et al. 2020) and planting designation factors (Siska and Adial, 2021).

#### Above-ground Biomass and Carbon Stock

The three research locations have different areas. The third location is the most extensive location among the others, which is 0.8 ha, followed by the first location of 0.63 ha, and the second location of 0.15 ha (Table 4). At the tree level, the third site had the highest biomass, 301.62 tons/ha and the highest carbon stock, 150.81 tons/ha. This was followed by the first site, which had a biomass of 207.12 tons/ha and a carbon stock of 103.56 tons/ha. The second location had the lowest biomass and carbon stock, at 180.15 Ton/ha and 90.075 Ton/ha, in total (Table 4). On the other hand, at the pole level, the second site had the highest biomass and carbon stock of 34.5 Ton/ha and 17.25 Ton/ha, in total. The first site had a biomass of 3.82 tons/ha and a carbon stock of 1.91 tons/ha. Meanwhile, the third location had the lowest biomass and carbon stock, which were 0.98 Ton/ha and 0.49 Ton/ha, respectively (Table 4). Stand biomass greatly influences the amount of carbon stock. An increase or decrease in biomass will affect the amount of

carbon stock (Sari et al. 2022).

Table 4. Aboveground biomass and carbon stock at 3 locations, Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street, Sumber Village, Banjarsari Regency, Surakarta

Location	Area (ha)	Biomass (Ton/ha)		Carbon Stock (Ton/ha)	
		Tree	Pole	Tree	Pole
		Mangun Sarkoro Street	0.63	207.12	3.82
Kutai Raya Street	0.15	180.15	34.5	90.075	17.25
Letjen Suprpto Street	0.8	301.62	0.98	150.81	0.49
TOTAL		688.89	39.3	344.445	19.65

Overall, biomass and carbon stock in the third location had the highest value, with a biomass of 302.6 tons/ha and carbon stock of 151.3 tons/ha. The second site had a biomass of 214.65 tons/ha and a carbon stock of 107.325 tons/ha, and the first site had the lowest biomass and carbon stock, 210.94 tons/ha and 105.47 tons/ha, in total (Table 5). Carbon stock contained in the stand is influenced by the species present. Stands with high density generally have large biomass, so the carbon stock will also be large (Nuranisa et al. 2020).

Table 5. Biomass and carbon stock total at 3 location, Mangun Sarkoro Street, Kutai Raya Street, and Letjen Suprpto Street, Sumber Village, Banjarsari Regency, Surakarta City.

Location	Biomass (Ton/ha)	Carbon Stock (Ton/ha)
Mangun Sarkoro Street	210.94	105.47
Kutai Raya Street	214.65	107.325
Letjen Suprpto Street	302.6	151.3

## DISCUSSION

Trees are woody plants that produce oxygen and have great benefits as absorbents (Fajar et al., 2023) and have indirect benefits as the largest oxygen contributor (Jatnika &

Zuhair, 2019). A community is said to have high species diversity if the community is composed of many species, otherwise a community is said to have low species diversity if the community is composed of few species and if only a few are dominant (Saputro et al., 2022). In location I, species of waru, palm, kersen, angšana, turi, glodogan, frangipani, trembesi, mahogany, and tabebuia were found. In location II, quite diverse species were found such as sengon, mahogany, mango, teak, frangipani, glodokan, kersen, trembesi, ketapang, mango, breadfruit, tabebuia, melinjo, soursop, jamblang, and trembesi. Then at location III, species of sengon, mango, mahogany, waru, glodokan, frangipani, and palm were found. The average species found in each research location are similar. Trees found in the three locations such as mangga, glodongan, kamboja, mahoni, and palem.

In this study, the most species found at the tree level from the three locations were Angšana (*Pterocarpus indicus*). Angšana is a plant from the papilionaceae family with a height of 25-35 m with deciduous tree type (Rosianty et al., 2021). Angšana has a dense and wide canopy, so it can function as a shade and is able to absorb large amounts of pollution (Danial et al., 2019). Meanwhile, at the pole level, the most common species found was kersen (*Muntingia calabura* L.). Another species found was the mahoni (*Swietenia macrophylla* G.King). Mahoni has a sturdy root system and a trunk that grows upright. In addition, this type of tree is able to adapt well, by shedding its leaves during the dry season to reduce transpiration rates (Agumanis et al., 2021). Roadside trees are generally selected because they have specific benefits related to their protective function and ability to absorb. Angšana and Mahoni are the most commonly found along roads serve as natural filters that improve urban air quality. Kersen (*Muntingia calabura*) and Trembesi (*Samanea saman*) are known as trees that can withstand high pollution environments. Kersen has fast growth and slender proportions and is quick to adapt (Friskandani & Saputri, 2022).

Site I located along Mangun Sarkoro street has a biomass of 210.94 Ton/ha, equivalent to a carbon stock of 105.47 Ton/ha. Site II located along Kutai Raya street has a biomass of 241.665 Ton/ha and is equivalent to a carbon stock of 107.325 Ton/ha. Meanwhile, Site III located along the Letjen Suprpto street has a biomass of 302.6 Ton/ha or equivalent to a carbon stock of 151.3 Ton/ha. Location III has a higher total biomass and carbon stock compared to Location I and Location II. The known biomass value can be used to estimate the carbon stock stored in vegetation because 45-50% of dry matter (biomass) of plants consists of carbon content. This is in accordance with the opinion of Sribianti et al. (2022) that carbon content is directly proportional to biomass, the higher the biomass, the greater the carbon content.

Biomass differences in each location are influenced by various factors such as the number and density of trees, stand age, stand composition and structure (Junaedi et al., 2021), environmental factors including sunlight, moisture content, temperature and soil fertility (Nedhisa & Tjahjaningrum, 2019). In addition to the above factors, tree diameter also affects the comparison of biomass differences (Sribianti et al., 2022). The larger the diameter of a trunk, the greater the value of biomass it contains (Luo et al., 2020). High density will cause reduced light intensity and can inhibit the growth of diameter and biomass in plants. This biomass factor affects the value of carbon content because the greater the biomass value, the higher the carbon content value (Heriyanto et al., 2020). Trees absorb carbon through leaves, then carry out photosynthesis and the results are disseminated to other parts of the tree such as trunks, twigs, and so on (Afandi et al., 2022).

Based on the available data, the carbon stock contribution from trees (344.445 tons/ha) is significantly higher than that of poles (19.65 tons/ha) across the three observed locations, indicating that trees play a more substantial role in carbon storage. Trees generally have larger biomass in their trunks, branches, and leaves, enabling them to absorb and store more carbon compared to smaller vegetation. In addition to their carbon storage function, trees also provide habitat and support biodiversity in urban areas. According to Rahman et al. (2017), urban trees not only absorb carbon but also reduce urban heat and improve air quality, which overall helps mitigate the impacts of climate change in urban areas. Older and larger trees tend to have a higher carbon storage capacity. Therefore, planting and preserving trees in urban areas are crucial strategies to enhance carbon stocks and reduce atmospheric carbon dioxide concentrations. This approach proves more effective than relying on smaller vegetation, such as poles, which have limited carbon storage capacity. The maintenance of trees in urban areas also makes a significant contribution to climate change mitigation and overall environmental quality improvement.

Vegetation structure, including trunk size, density, and height, plays an important role in carbon storage capacity at each location. In the "TREE" category, trees with larger diameters generally have higher biomass compared to smaller trees. This is evident at Jl. Letjen Suprpto, which has the highest carbon stock (150.81 tons/ha) in the "TREE" category compared to other locations. Conversely, smaller trunks in the "POLE" category have lower carbon storage capacity, but they can contribute significantly if their quantity or density is high. The density of vegetation at a given location also affects carbon storage, with locations that have higher tree density (more trees per hectare) typically showing

higher carbon storage capacity. Although density is not directly shown in the table, the high total carbon at Letjen Suprpto Street (150.81 tons/ha) suggests that this location has denser or larger trees compared to the others. Tree height is also linked to carbon sequestration potential, as taller trees generally have more biomass (trunk, branches, and leaves), and therefore store more carbon. In an urban context, managing vegetation through optimizing its structure can increase carbon storage and support climate change mitigation strategies (Sustainability, 2023).

The data also reveals variations in carbon storage capacity across the locations, particularly between tree and pole levels. At Mangun Sarkoro Street, trees store 103.56 tons/ha of carbon, while poles store only 1.91 tons/ha, confirming that the primary carbon stock at this location comes from trees. At Kutai Raya Street, trees store 90.075 tons/ha, and carbon stock from poles reaches 17.25 tons/ha, which is the highest for poles among the three locations. This indicates that, in addition to trees, the pole-level vegetation at Jl. Kutai Raya significantly contributes to the total carbon stock, likely due to adequate green space management or the presence of more pole vegetation. Meanwhile, at Jl. Letjen Suprpto, tree carbon stock reaches the highest value, 150.81 tons/ha, while poles store only 0.49 tons/ha, the smallest contribution from poles among the three locations. This shows that at this location, the carbon stock is almost entirely dependent on the presence of trees, which likely have larger diameters or biomass. Overall, the tree level at Letjen Suprpto Street serves as the largest carbon sink, followed by Mangun Sarkoro Street, and then Kutai Raya Street.

Urban tree planting in areas such as Kelurahan Sumber holds significant potential for environmental management and carbon conservation. Large tree species such as *Pterocarpus indicus* (Angsana), *Swietenia macrophylla* (Mahogany), and *Samanea saman* (Trembesi) play a crucial role as primary carbon sinks, helping to mitigate the impacts of climate change. These trees not only sequester carbon dioxide but also contribute to reducing urban heat through evapotranspiration, an important process in combating global warming. With the rapid pace of urbanization and increasing greenhouse gas emissions, managing urban vegetation becomes a critical strategy for climate change mitigation. Local policies that encourage greening initiatives and tree planting in urban open spaces can enhance carbon sequestration capacity, reduce air pollution, and create cooler microclimates, all of which contribute to reducing the impacts of climate change. This approach aligns with studies highlighting urban green spaces' essential role in climate mitigation. Research on Jakarta's urban forests, for example, shows that the "Low Carbon City" (LCC) concept can reduce carbon emissions and enhance urban air quality,

supporting the sustainable management of green spaces for both environmental and biodiversity benefits (Aulia., 2023), (Fuady., 2021).

The "Green City" initiative in Indonesia further illustrates these efforts. Fuady et al. discuss this program's aim to ensure urban areas allocate at least 30% of city space for green areas, creating urban resilience to climate-related risks such as heatwaves and pollution, which are particularly impactful in densely populated regions (Fuady., 2021). By integrating green infrastructure in city planning, the initiative directly supports climate adaptation strategies and urban sustainability goals. Therefore, it is essential for local governments to support policies prioritizing tree species adaptable to changing climate conditions. This strategy not only improves environmental quality but also aligns with global efforts to reduce carbon emissions and build more sustainable urban environments, further underscoring urban forests' role in addressing climate change challenges.

## CONCLUSIONS

This study successfully addresses its objective by demonstrating the significant carbon storage potential of trees and poles along Sumber's main roads in Surakarta. Through identification and analysis of 15 tree species from 12 families and 12 pole species from 10 families, it was found that Letjen Suprpto Street holds the highest carbon storage at the tree level (301.62 tons/ha biomass, 150.81 tons/ha carbon), while Kutai Raya Street leads at the pole level (34.5 tons/ha biomass, 17.25 tons/ha carbon). These findings confirm the role of urban green spaces in carbon sequestration, supporting urban sustainability and climate action goals.

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