VOLUME 9 Issue 1
JULY 2024

E-ISSN: 2622-3384
P-ISSN: 2527-9939

JURNAL MEdu Mangifera Edu

# Analysis of stored carbon reserves in trees in the green open spaces of Panatayuda Park, Bandung City, and surrounding areas

Kurnia Sandi Nugroho Dwi Putra*, Ida Yayu Nurul Hizqiyah, Gurnita.
Departement of Biology Education, Pasundan University, Jl. Tamansari No.6-8 Tamansari, Bandung, Jawa Barat, Indonesia
*Corresponding author: kurniasan937@gmail.com

## ABSTRACT

*Climate change and global warming are partly caused by increasing air pollution. This air pollution results in incomplete carbon combustion, producing toxic gases. Carbon is a key component used by plants in the photosynthesis process. Therefore, trees play an important role in reducing pollution and lowering environmental temperatures that trigger climate change and global warming. The purpose of research on carbon reserves is to provide data for the future management of urban parks, utilizing them for climate change mitigation. The method used in this research is descriptive quantitative. Sampling in this study used the census method with purposive sampling, where all trees with a diameter of ≥ 20 cm were taken as samples. The highest biomass and carbon reserve values stored in trees in Panatayuda Park were found in Ficus elastica, with a biomass value of 51,752.77 kg and a carbon reserve value of 25,876.39 kg. Meanwhile, the lowest values were found in Pterocarpus indicus, with a biomass value of 807.39 kg and a carbon reserve value of 403.69 kg. The total carbon reserve in trees in Panatayuda Park is 79,122.21 kg, with a total biomass of 140,244.41 kg.*

## ARTICLE INFO

**Keywords**
Carbon Reserves, Panatayuda Park, Tree

**Received**
July 2, 2024

**Revised**
July 10, 2024

**Accepted**
July 20, 2024

**Published**
July 31, 2024

**How to cite**
Putra, K. S. N. D., Hizqiyah, I. Y. N., Gurnita. 2024. Analysis of stored carbon reserves in trees in the green open spaces of Panatayuda Park, Bandung City, and surrounding areas. *Jurnal Mangifera Edu*, 9(1), 87-96. https://doi.org/10.31943/mangiferaedu.v7i1.204

## INTRODUCTION

Climate change and global warming are environmental issues that receive great attention both in the academic world and in everyday life. This problem is exacerbated by population growth due to urbanization and the industrialization process which causes increased air pollution and decreased environmental carrying capacity. This air pollution causes a minimum of available oxygen, as a result the combustion of carbon becomes incomplete and produces a toxic gas, namely carbon monoxide. On the other hand, if the oxygen supply is maximal, carbon compounds will react with oxygen, which with the help of sunlight energy will form carbon dioxide gas (Sari, 2014).

Carbon is the main component used by plants in the photosynthesis process. Photosynthesis is a chemical reaction that involves capturing solar energy to convert carbon dioxide ($CO_2$) and water into glucose and oxygen. Thus, trees have an important role in reducing pollution and reducing environmental temperatures, including reducing Green House Gas (GHG) emissions which trigger climate change and global warming. The reason is, trees naturally absorb $CO_2$ gas which is stored in the form of carbon compounds and released in the form of oxygen, while also absorbing heat. This process contributes to nature's carbon cycle, where carbon dioxide taken in by plants during

photosynthesis is then released back into the atmosphere when other organisms exhale the carbon dioxide through respiration. Therefore, trees play an important role in maintaining the carbon balance in the atmosphere and helping reduce CO2 concentrations, which can help reduce the impact of climate change, one of which is caused by the effects of Green House Gases (GHG).

Conservation and development of Green Open Space (RTH) is one of the strategic efforts to reduce atmospheric pollution in urban areas. UU No 26 of 2007 concerning spatial planning states the need to provide green open space in the city area of at least 30% of the city area consisting of 20% public green open space (such as city forests and city parks) and 10% private green open space (such as gardens in yards and gardens). According to DPKP3 of Bandung City, for the city of Bandung itself currently only has around 1700 hectares of RTH from the area of Bandung city which is 16,729.65 hectares. That is still around 12.15% of the area of RTH to the area of Bandung city.

Research conducted by Ina Darliana (2023) regarding the estimation of carbon reserves and carbon uptake in one of the city parks in the city of Bandung, specifically Maluku Park, said that Maluku Park, Bandung City with an area of 23,633 has carbon reserves of around 179,941 tonnes from trees. The importance of research results regarding carbon reserves can provide data for future management of city parks in the use of city parks to mitigate climate change, one of which is caused by the effects of Green House Gases (GHG).

However, not all parks in the city of Bandung have been researched on carbon stock estimates. One example is the green open space in Panatayuda Park, Bandung City. Located near a school and housing complex that is often passed by vehicles and other living creature activities that produce a lot of CO2 for the surrounding environment, the green open space of the park is the main foundation for storing carbon reserves. Until now, there have been no sufficient research results to provide information about the Panatayuda Park green open space landscape. So that data on carbon reserves stored in the place is still limited. This affects the management and development of the park green open space in the future. Management of green open spaces in the form of public parks and green lanes requires data on the species of trees planted to be used as an inventory of the types of plant vegetation composition in it and to analyze the ability of vegetation that has the potential to be effective as a reserve of stored carbon.

Therefore, a study was conducted with the title "Analysis of Carbon Reserves Stored in Trees in the Green Open Space of Panatayuda Park, Bandung City and its Surroundings", where the results of this study are expected to be a data inventory regarding carbon reserves stored in the Panatayuda Park RTH for further research materials or recommendations for the local government, especially the Bandung City Parks Service in utilizing city parks as climate change mitigation, one of which is caused by the effects of Greenhouse Gases (GHG).

## METHOD

The method used in this research is quantitative descriptive. Sugiyono (2017) said that the quantitative descriptive method is a research approach used to describe the characteristics of a population or sample using statistical analysis techniques. This method requires researchers to conduct studies in the field to find existing data directly to collect and identify. The data sought using this method is the carbon reserves stored in trees in the Taman Panatayuda Green Open Space,

Bandung City and its surroundings. Sampling in this study used the census method with a purposive sampling model where all trees with a diameter of ≥ 20 cm were taken as samples. Sample data was then collected and analyzed using biomass measurements method from Chave (2005), and carbon storage measurements method from the IPCC (2006).

**Table 1.** The formula for data analysis

| Parameter | Formula | Source |
|---|---|---|
| Biomass (kg) | 0,05 x ρ x $d^2$ x T | Chave *et al.*, 2005 |
| Carbon Reserves (kg) | Biomass x 0,5 | IPCC, 2006 |

d = Tree Diameter (cm)
ρ = Wood Density
T = Tree Height (m)

## RESULTS AND DISCUSSION

### Trees in Panatayuda Park

The total number of trees that have been identified is 72 trees which are divided into 11 types of trees, namely *Pterocarpus indicus*, *Casuarina equisetifolia*, *Delonix regia*, *Antidesma bunius Gmelina arborea*, *Ficus elastica*, *Terminalia catappa*, *Filicium decipiens, Swietenia mahagoni*, *Pinus merkusii*, and *Syzygium polyanthum*. The tree with the scientific name Filicium decipiens or better known as the umbrella sunshade tree has the largest number, namely 18 trees. This number is the same as *Pinus merkusii* trees or what we usually call pine trees. Meanwhile, the trees with the smallest number are *Pterocarpus indicus* or Angsana trees, *Delonix regia* or Flamboyan trees, *Antidesma bunius* or Buni trees, and *Ficus elastica* or Rubber Kebo trees with only 1 tree each.

**Table 2.** Results of tree type identification in Panatayuda Park

| No. | Regional Name | Scientific Name | Famili | Amount |
|---|---|---|---|---|
| 1 | Angsana | *Pterocarpus indicus* | Fabaceae | 1 |
| 2 | Cemara Laut | *Casuarina equisetifolia* | Casuarinaceae | 5 |
| 3 | Flamboyan | *Delonix regia* | Caesalpiniaceae | 1 |
| 4 | Buni | *Antidesma bunius* | Euphorbiaceae | 1 |
| 5 | Jati Putih | *Gmelina arborea* | Verbenaceae | 13 |
| 6 | Karet Kebo | *Ficus elastica* | Moraceae | 1 |
| 7 | Katapang | *Terminalia catappa* | Combretaceae | 2 |
| 8 | Kerai payung | *Filicium decipiens* | Sapindaceae | 18 |
| 9 | Mahoni | *Swietenia mahagoni* | Meliaceae | 10 |
| 10 | Pinus/ Tusam | *Pinus merkusii* | Pinaceae | 18 |
| 11 | Salam | *Syzygium polyanthum* | Myrtaceae | 2 |
| | | **Total** | | **72** |

*Pterocarpus indicus*, also known as the angsana tree, plays an important role in the urban park ecosystem due to its ability to provide shade with its wide canopy. This tree also has yellow flowers that add to the aesthetic value of the park. In addition, *Pterocarpus indicus* is known to have the ability to absorb air pollution, thus contributing to improving air quality in urban areas. This tree is effective in absorbing dust particles and other pollutants from the air, making it an ideal choice for

urban greening (Farosandi *et al*., 2024). This tree is also useful for preventing soil erosion and improving soil quality due to the ability of its roots to add nitrogen to the soil (Syahbudin *et al*., 2018).

*Casuarina equisetifolia*, or sea pine, is often planted in city parks due to its tolerance to poor soil conditions and its ability to withstand wind, making it ideal for coastal areas or places prone to erosion. In addition, this tree has the ability to fix nitrogen in the soil through symbiosis with Frankia bacteria, which helps improve soil fertility. Casuarina equisetifolia can improve soil quality and support the growth of other plants around it (Lili et al., 2023).

*Delonix regia*, or the flamboyant tree, is known for its striking, bright red flowers, which add to the visual beauty of city parks. In addition to its aesthetics, this tree also provides ample shade due to its wide-spreading canopy. *Delonix regia* is also able to survive in dry environmental conditions, making it a good choice for reforestation in areas experiencing water shortages. Flamboyant also provides ample shade due to its wide canopy, thus helping to reduce ambient temperatures through the cooling effect of evapotranspiration (Aravindhan *et al*., 2024).

*Antidesma bunius*, or buni, is a tree that produces edible fruit, adding economic and ecological value to city parks. Buni fruit can attract various species of birds and other animals, which contribute to increasing biodiversity in the park. In addition, this tree has potential as a medicinal plant, with various parts of the plant that can be used for traditional medicinal purposes. *Antidesma bunius* has a high antioxidant content, which is useful for human health (Govil *et al*., 2024).

*Gmelina arborea* is often used in greening city parks because of its rapid growth and ability to provide high-quality wood. This tree also functions as shade and can grow well in various types of soil, including less fertile ones. In addition, *Gmelina arborea* has benefits in groundwater conservation because of its extensive root system. According to Pathala (2015) said that this tree is effective in reducing soil erosion and maintaining soil moisture around it.

*Ficus elastica*, or rubber tree, has high aesthetic value with large, glossy leaves that add to the visual beauty of city parks. This tree is also effective in absorbing air pollutants such as formaldehyde, benzene, and trichloroethylene, making it important in efforts to improve urban air quality. According to Sahli (2022), *Ficus elastica* has been proven effective in improving indoor and outdoor air quality. In addition, *Ficus elastica* has good adaptability to various environmental conditions, including shade and less fertile soil. Some trees from the genus *Ficus* are plants with deep root systems with dense canopies, which is why this tree grows a lot in Urban Parks (Fiqa *et al*., 2005).

*Terminalia catappa*, or ketapang, is a tree that is often found in city parks because of its large, shady leaves that provide extensive shade. Ketapang also has the ability to grow in less fertile soil and is able to adapt to harsh environmental conditions, making it suitable for greening in dense urban areas (Yulfiah *et al*., 2021).

*Filicium decipiens*, known as the fern tree, is often planted in city parks because of its unique and aesthetic shape. This tree is also useful in absorbing air pollution and providing refreshing shade. In addition, this tree has the ability to grow in various types of soil and conditions, making it a good choice for urban greening (Wang *et al*., 2024).

*Swietenia mahagoni*, or mahogany, is a tree that is often used in urban greening because of its valuable wood and ecological benefits. This tree has the ability to absorb large amounts of carbon

dioxide, thus helping to reduce the greenhouse effect. In addition, mahogany also provides extensive shade and helps reduce noise pollution in urban areas (Karimipour *et al*., 2021).

*Pinus merkusii*, often planted in city parks because of its good ability to withstand wind and prevent soil erosion. In addition, pine is also known to have ecological benefits such as absorbing carbon dioxide and improving air quality. This tree is also often used in reforestation projects and critical land rehabilitation because of its ability to grow in various environmental conditions (Rinaldi *et al*., 2020).

*Syzygium polyanthum*, or bay leaf, is a tree that is often used in city parks because of its benefits as a medicinal plant and spice. In addition, this tree also has the ability to absorb air pollution and provide comfortable shade for pedestrians. Bay leaves are often used in traditional cooking, adding to the economic and cultural value of this tree (Mahmoud *et al*., 2020).

**Figure 1**. Syzygium polyanthum

**Figure 2**. *Syzygium polyanthum* leaves

**Figure 3**. *Syzygium polyanthum* stem

**Classification**
Divisio : Magnoliophyta
Class : Magnoliopsida
Ordo : Myrtales
Famili : Myrtaceae
Genus : *Syzygium*
Species : *Syzygium polyanthum*

**Figure 4**. *Syzygium polyanthum* flower

**Figure 5**. *Syzygium polyanthum* fruit

**Biomass and Carbon Storage in Panatayuda Park**

The total carbon storage in trees in Panatayuda Park is 79,122.21 kg with a total biomass of 140,244.41 kg. The highest value of biomass and carbon reserves stored in trees in the Panatayuda Park Green Open Space is the Ficus elastica or Kebo Rubber tree with a biomass value of 51,752.77 kg and a carbon storage value of 25,876.39 kg. Meanwhile, the lowest value was owned by Pterocarpus indicus with a biomass value of 807.39 kg and carbon storage of 403.69 kg.

The highest value of biomass and carbon reserves stored in trees in the Green Open Space of Panatayuda Park is the Ficus elastica or Kebo Rubber tree with a biomass value of 51,752.77 kg and a carbon storage value of 25,876.39 kg. Meanwhile, the lowest value was owned by Pterocarpus indicus with a biomass value of 807.39 kg and carbon storage of 403.69 kg.

The amount of biomass stored by a tree increases as the trunk diameter increases. This is in line with Kusmana's (2018) statement which states that one of the main factors influencing the amount of biomass in a tree is the diameter of the trunk. The higher the diameter of a tree trunk, the greater the

tree's biomass. The trunk diameter of Ficus elastica is indeed the largest in Panatayuda Park compared to other trees, with a trunk diameter of around 310 cm. This diameter is larger than the diameter of other trees which only ranges from 100 – 200 cm.

**Table 3**. Biomass and carbon storage of Panatayuda Park trees

| No | Regional Name | Scientific Name | Biomass (kg) | Carbon (kg) |
|---|---|---|---|---|
| **1** | Angsana | *Pterocarpus indicus* | 807,39 | 403,69 |
| **2** | Cemara Laut | *Casuarina equisetifolia* | 33.350,79 | 16.675,39 |
| **3** | Flamboyan | *Delonix regia* | 1.430,42 | 715,21 |
| **4** | Huni/Buni | *Antidesma bunius* | 1.942,16 | 971,08 |
| **5** | Jati Putih | *Gmelina arborea* | 2.853,14 | 1.426,57 |
| **6** | Karet Kebo | *Ficus elastica* | 51.752,77 | 25.876,39 |
| **7** | Katapang | *Terminalia catappa* | 1.400,45 | 700,22 |
| **8** | Kerai payung | *Filicium decipiens* | 15.678,30 | 7.839,15 |
| **9** | Mahoni | *Swietenia mahagoni* | 19.019,13 | 9.509.56 |
| **10** | Pinus/Tusam | *Pinus merkusii* | 11,026,97 | 5.513,49 |
| **11** | Salam | *Syzygium polyanthum* | 982,89 | 491,45 |
| | **Total** | | **140.244,41** | **70.122,21** |

In addition to the diameter factor, according to Yuniawati (2014) said that biomass in trees is obtained from photosynthesis. Therefore, factors that affect the rate of photosynthesis directly also affect the biomass value in trees. One of them is temperature, increasing air temperature can reduce air humidity, and air humidity will also affect the rate of photosynthesis. The optimal temperature supports photosynthetic enzymes to work efficiently, so that the process of converting light into chemical energy takes place optimally. High temperatures can increase the rate of photosynthesis to a certain point, but if the temperature continues to increase beyond the optimal limit, photosynthesis will decrease because the Rubisco enzyme denatures and the stomata tend to close to reduce water loss, which reduces the supply of carbon dioxide (Sage, 2020).

The tree with the lowest biomass in Panatayuda Park is *Pterocarpus indicus* with a biomass value of 807.39 kg. Various factors can inhibit the biomass value of a tree, including less than ideal environmental conditions, pest and disease attacks, and disturbances caused by humans. A less than optimal environment, such as lack of water, and insufficient nutrients can reduce the rate of photosynthesis and tree growth, thus inhibiting biomass storage. The biomass stored by a tree can be determined from the amount of soil nutrients absorbed by the tree (Engelstad, 1997). Soils that are nutrient-poor or contaminated can also inhibit root growth and the uptake of essential nutrients. In addition, pests and diseases can damage plant tissues, reducing the ability of trees to produce and store biomass. Disturbances caused by human activities, such as deforestation, air pollution, and land-use change, can also reduce the value of tree biomass by destroying natural habitats and disrupting tree growth cycles. The *Pterocarpus indicus* trees in Panatayuda Park are located in a point that is often passed by vehicles, and lack of maintenance from the park management. This causes all of these factors to interact in a complex manner and can have a significant impact on reducing the tree's ability to reach its optimal biomass potential. Air humidity also affects the rate of photosynthesis, because the stomata on tree leaves need to be open to take in carbon dioxide from the atmosphere. High humidity can help keep the stomata open, allowing more CO2 to enter the leaves for use in

photosynthesis. Conversely, low humidity causes the stomata to close to reduce water loss, which limits CO2 intake and reduces the rate of photosynthesis (Dubey *et al*., 2022).

Light intensity is the main energy source for photosynthesis; with sufficient light intensity, trees can produce more glucose and, therefore, more biomass. However, too high light intensity can cause cell damage and photoinhibition, which actually reduces the efficiency of photosynthesis. These three factors interact in a complex manner in supporting the growth and accumulation of biomass in trees, where photosynthesis is a key process that influences the conversion of light energy into biomass through glucose production. With optimal temperature, humidity, and light conditions, trees can achieve maximum photosynthesis levels, producing larger and healthier biomass so that carbon stores will also be large. This is due to the high relative air pressure compared to the partial pressure of CO2, which makes it easier for water vapor to move through the stomata. As a result, the rate of photosynthesis increases, so that the amount of carbon storage in a stand also becomes higher (Munir, 2017).

Similar to biomass, the main factor that makes carbon storage in large trees is the large diameter of the trunk. This is because the biomass value is directly proportional to the carbon storage value. When the biomass value of a tree is large, then the carbon storage value will also be large, and vice versa. The *Ficus elastica* tree, also known as the rubber tree, has a significant capacity to store carbon reserves. The main factor that supports this ability is the size and rapid growth of the tree. *Ficus elastica* has the ability to grow up to 30 meters in height with a large trunk diameter, which allows for significant biomass storage. A study by Chave *et al* (2014) showed that trees with large biomass play an important role in carbon sequestration and storage. In addition, the extensive and deep root structure of *Ficus elastica* also contributes to carbon sequestration below ground. The wide and numerous leaves of the tree help in efficient photosynthesis, increasing the ability of this tree to absorb carbon dioxide from the atmosphere (Jackson *et al*., 1996). The combination of these factors makes *Ficus elastica* a very effective species in mitigating climate change through large carbon storage (Poorter *et al*., 2012).

*Pterocarpus indicus*, also known as angsana or narra tree, has relatively small carbon stocks that can be caused by several internal and genetic factors. Internally, the photosynthetic efficiency of this tree may be limited by suboptimal leaf structure and nutrient uptake patterns, which affect growth rates and biomass accumulation. In addition, shallow roots and less efficient root system distribution can inhibit the uptake of water and essential nutrients, which ultimately affects the tree's ability to store large amounts of carbon (Zanne *et al*., 2009). From a genetic perspective, variation in gene expression related to carbon metabolism and tree growth may play an important role. Several studies have shown that genetic variation within tree species can affect growth rates and photosynthetic capacity, which in turn affect carbon storage (Poorter *et al*., 2010). In addition, genetic adaptation to local environments, such as climate and soil conditions, may also limit carbon storage capacity (Moles *et al*., 2009).

## CONCLUSION

The total tree biomass in the Green Open Space of Panatayuda Park, Bandung City, is 140,244.41 kg with a total carbon storage value of 70,122.21 kg. The tree with the highest carbon

storage is the Ficus elastica tree with a carbon storage value of 25,876.39 kg. Meanwhile, the tree with the lowest carbon storage is the Pterocarpus indicus tree with a carbon storage value of 403.69 kg. The results of this study can be the basis for formulating better environmental policies in Bandung City. Information on carbon stocks stored in trees in Panatayuda Park can be used to optimize city park management strategies, such as planting new trees and maintaining existing trees to increase carbon absorption capacity. The use of technology such as remote sensing and drones can also help future research in more accurate mapping with accurate imaging of coordination points for each tree stand and monitoring changes in carbon stocks over time. Sustainable and adaptive management needs to be implemented, taking into account the results of this study to improve conservation and restoration strategies for the park.

## ACKNOWLEDGMENT

The researcher would like to express his deepest thanks to all parties who have supported and contributed to this research. Special appreciation goes to the management of Panatayuda Park and DPKP of Bandung City for providing the facilities and time to carry out this research. Researchers hope that the results of this research can provide benefits in future park management.

## REFERENCES

Aravindhan, S., Kumar, G. B., Saravanan, M., & Arumugam, A. (2024). Delonix regia biomass as an eco-friendly biosorbent for effective Alizarin Red S textile dye removal: characterization, kinetics, and isotherm studies. *Bioresource Technology Reports*, *25*, 101721. https://doi.org/10.1016/j.biteb.2023.101721

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., ... & Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, *145*, 87-99. https://link.springer.com/article/10.1007/s00442-005-0100-x

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., & Henry, M. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology*, 20(10), 3177-3190. https://doi.org/10.1111/gcb.12629

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications. https://doi.org/10.5539/elt.v12n5p40

Darlina, I., Wilujeng, S., & Nurmajid, F. (2023). Estimasi cadangan karbon dan serapan karbon di Taman Maluku Kota Bandung. *Paspalum: Jurnal Ilmiah Pertanian*, *11*(1), 163-171. https://doi.org/10.35138/paspalum.v11i1.556

Dubey, R., Dudhagi, S. S., Narayan, S., Kumar, A., Niranjan, A., & Shirke, P. (2022). Stomatal behaviour and endogenous phytohormones promotes intrinsic water use efficiency differently in cotton under drought. *Indian Journal of Experimental Biology (IJEB)*, *60*(02), 112-120. https://doi.org/10.56042/ijeb.v60i02.42969

Engelstad. (1997). *Teknologi dan Penggunaan Pupuk*. UGM Press. Yogyakarta: 293-332.

Enterprise Jubilee. (2019). *Lancar Menggunakan Fungsi MS Excel 2007-2019*. Jakarta: Elex Media Komputindo.

Farosandi, N. H., Mansur, I., & Istikorini, Y. (2024, March). Carbon stock estimation in post-mining reclamation area of open coal mining in PT Berau Coal, Berau, East Kalimantan. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1315, No. 1, p. 012043). IOP Publishing. https://doi.org/10.1088/1755-1315/1315/1/012043

Fiqa, A. P., Arisoesilaningsih, E., & Soejono. (2005). Konservasi mata air DAS Brantas. Memanfaatkan diversitas flora Indonesia. Seminar Basic Science II. Universitas Brawijaya, Malang.

Forman, R. T. (2014). Forest Carbon Management: A Review of Silvicultural Practices and Management Strategies Across Boreal, Temperate and Tropical Forests. *Springer*. https://link.springer.com/article/10.1007/s40725-021-00151-w

Govil, A., Kanchan, M. R., & Mishra, R. R. (2024). Enhancing and conserving urban biodiversity. In *Managing Urban Rivers* (pp. 109-130). Elsevier. https://doi.org/10.1016/B978-0-323-85703-1.00012-2

Hamka. (1994). *Tafsir Al-Azhar Juz XXI* (p. 94). Jakarta: Pustaka Panjimas.

IPCC. (2006). *Guidelines for National Greenhouse Gas Inventories: References Manual*. Paris, France. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Jackson, R. B., Canadell, J., Ehleringer, J. R., Mooney, H. A., Sala, O. E., & Schulze, E. D. (1996). A global analysis of root distributions for terrestrial biomes. *Oecologia*, 108(3), 389-411. https://doi.org/10.1007/BF00333714

Karimipour, H., Tam, V. W., Le, K. N., & Burnie, H. (2021). A greenhouse-gas emission reduction toolkit at urban scale. *Sustainable Cities and Society*, *73*, 103103. https://doi.org/10.1016/j.scs.2021.103103

Kusmana, C. (2018). *Metode survey dan interpretasi data vegetasi*. Bogor: IPB Press.

Lili, Lin., Zhenbang, Hao., Christopher, J., Post., Elena, A., Mikhailova. (2023). Protection of Coastal Shelter Forests Using UAVs: Individual Tree and Tree-Height Detection in Casuarina Equisetifolia L. Forests. Forests, 14(2):233-233. https://doi.org/10.3390/f14020233

Mahmoud, A. D., Fatihah, H. N. N., Khandaker, M. M., Ali, A. M., & Mat, N. (2020). Ethnobotany of Syzygium polyanthum (Wight) Walp in Terengganu, Peninsular Malaysia. *Journal Of Agrobiotechnology*, *11*(2), 39-47. https://doi.org/10.37231/jab.2020.11.2.212

Malhi, Y., Wood, D., Baker, T.R., Wright, J., Phillips, O.L., Cochrane, T., ... & Vincent, G. (2006). The regional variation of aboveground live biomass in old-growth Amazonian forests. *Global Change Biology*, 12(7), 1107-1138. https://doi.org/10.1111/j.1365-2486.2006.01120.x

Moles, A. T., Wallis, I. R., Foley, W. J., Warton, D. I., Stegen, J. C., Bisigato, A. J., & Whittaker, R. J. (2009). Assessing the evidence for latitudinal gradients in plant defense and herbivory. *Functional Ecology*, 23(4), 789-800. https://doi.org/10.1111/j.1365-2435.2010.01814.x

Munir, M. (2017). Estimasi biomassa, stok karbon, dan sekuestrasi karbon dari berbagai tipe habitat terestrial di Gresik, Jawa Timur secara non-destructive dengan persamaan allometrik. (Skripsi Sarjana, Institut Teknologi Sepuluh Nopember).

Pathala, D., Harini, A., & Hegde, P. L. (2015). A review on gambhari (Gmelina arborea Roxb.). *Journal of Pharmacognosy and Phytochemistry*, *4*(2), 127-132. https://www.phytojournal.com/archives?year=2015&vol=4&issue=2&ArticleId=597

Poorter, L., Wright, S. J., Paz, H., Ackerly, D. D., Condit, R., Ibarra-Manríquez, G., & Wright, I. J. (2010). Are functional traits good predictors of demographic rates? Evidence from five Neotropical forests. *Ecology*, 91(7), 1908-1920. https://doi.org/10.1890/07-0207.1

Rahayu, S., Pambudi, S., Permadi, D., Tata, H. L., Martini, E., Rasnovi, S., & van Noordwijk, M. (2021). Wood density and dispersal modes of trees regenerating in disturbed forests and agroforests in Indonesia. *Research Square*, 6-7/28. https://doi.org/10.21203/rs.3.rs-236533/v1

Rinaldi, Imanuddin., Asep, Hidayat., Henti, Hendalastuti, Rachmat., Maman, Turjaman., Pratiwi., Fitri, Nurfatriani., Yonky, Indrajaya., Arida, Susilowati. (2020). Reforestation and Sustainable Management of Pinus merkusii Forest Plantation in Indonesia: A Review. Forests, 11(12):1235 https://doi.org/10.3390/f11121235

Sage, R. F., & Kubien, D. S. (2020). The temperature response of C3 and C4 photosynthesis. Plant, *Cell & Environment*, 43(1), 169-182. https://doi.org/10.1111/j.1365-3040.2007.01682.x

Sahli, L., & Belhiouani, H. (2022). Ficus retusa L. as possible indicator of air metallic pollution in urban environment. *International Journal of Phytoremediation*, *24*(10), 1050-1059. https://doi.org/10.1080/15226514.2021.1999205

Sari, M. (2014). Analisa kadar CO dan NO2 di udara dan keluhan gangguan saluran pernapasan pada pedagang kaki lima di Pasar Sangkumpal Bonang Kota Padangsidimpuan tahun 2013. *Lingkungan dan Keselamatan Kerja*, 3(1).

Sugiyono. (2017). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta.

Syahbudin, A., Syaufina, R. L., Yudhistira, R., & Sadono, R. (2018, November). Tree architecture models, canopy maintenance, and associated root problems of angsana (Pterocarpus indicus Willd.) in the urban trees of Yogyakarta. In *IOP Conference Series: Earth and Environmental Science* (Vol. 203, No. 1, p. 012010). IOP Publishing. https://doi.org/10.1088/1755-1315/203/1/012010

Taib, & Tazilan. (2017). Urban parks (UP) for all-barrier free (BF) at micro architecture (MA). *Scin International (Lahore)*, 29(2).

Widiastuti, K. (2013). Taman kota dan jalur hijau jalan sebagai ruang terbuka hijau publik di Banjarbaru. Modul, 13(2). https://doi.org/10.14710/mdl.13.2.2013.57-64

Wang, X., Zhou, Z., Xiang, Y., Peng, C., & Peng, C. (2024). Effects of street plants on atmospheric particulate dispersion in urban streets: A review. *Environmental Reviews*, *32*(1), 114-130. https://doi.org/10.1139/er-2023-0103

Yulfiah, Y., Azzahro, F., & Pissera, R. C. (2021). Selecting plant types to control air pollution and developing software to plan green open space in the urban area. *Jurnal Presipitasi: Media Komunikasi Dan Pengembangan Teknik Lingkungan*, *18*(2), 329-337. https://doi.org/10.14710/presipitasi.v18i2.329-337

Yuniawati, & Suhartana, S. (2014). Potensi karbon pada limbah pemanenan kayu acacia crassicarpa. *Jurnal Ilmu Lingkungan*, 12, 21-31. https://doi.org/10.14710/jil.12.1.21-31

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Ilic, J., Jansen, S., Lewis, S. L., & Swenson, N. G. (2009). Global wood density database. *Dryad Data Repository*.