Open Acess
Jurnal Biota Vol. 10 No. 1 (2024) https://doi.org/10.19109/Biota.v10i1.19929

Research Article

Identification of Tree Species and Their Potential as Carbon Stock in Three Urban Forests of Malang City, Indonesia

Dwi Suheriyanto *, Gita Niken Madapuri, Didik Wahyudi
Biology Department, Faculty of Science and Technology, Maulana Malik Ibrahim State Islamic University of Malang, Malang, Indonesia.
*Email: dsuheriyanto@bio.uin-malang.ac.id

Received: 30/10/2023	Revised: 11/12/2023	Accepted: 11/12/2023

ABSTRACT
This study aims to identify tree species and their potential as carbon stock in three urban forests of Malang City. This research was conducted in three urban forests including the Urban Forest of Malabar, Velodrome, and Hamid Rusdi. Data were analyzed with an important value index (IVI) and Carbon stock estimation. There were 41 species of trees in three Malang City Forests. There are differences in tree dominance in the three Malang city forests, namely: the Malabar city forest is Albizia chinensis, the Velodrome city forest is Gmelina arborea, and the Hamid Rusdi city forest is Polyalthia longifolia. The highest value of carbon stock in the Malabar urban forest is A. Chinensis, 6,214.38 kg; in the Velodrome urban forest is Enterolobium cyclocarpum, 7,225.88 kg; and in the Hamid Rusdi Urban Forest is Samanea saman with a carbon stock of 4,757.01 kg.

Keywords: *Carbon Stock; Diversity; Malang; Trees; Urban Forest.*

Introduction

The urban green space is part of green infrastructure or open-space areas reserved for parks and other green spaces, including plant life and water features. Urban green space is regulated and protected to enhance ecological services, including water purification, noise reduction, and recreational benefits [1]. Improving this green area is crucial to increasing the quality of life of city residents [2].

Urbanization is the cause of some environmental problems in the city [3]. Fragmentation of urban green spaces and increasing CO_2 emissions led to greenhouse gases are some of the environmental problems caused by urbanization [4]. Furthermore, the destruction of animal habitat and decreasing biodiversity was also the other cause of urbanization [5]. The same issues have also occurred in Malang Indonesia, the second biggest city in East Java Indonesia. Malang City's population has increased yearly, 843,810 in 2020 and 846,126 in 2022. The increase in population has also impacted the number of vehicles, both two-wheeled and four-wheeled [6]. The increasing number of cars and human population has resulted in the fastest-growing greenhouse gas (GHG) emission especially in Malang [7].

Reducing gas emissions (atmospheric C level) in rural areas can be achieved by optimization of the role of urban green space. There are three ways why urban green space is essential for reducing atmospheric C levels [8]. First, urban trees and shrubs are required to absorb atmospheric C in the environment for their growth and photosynthesis. Second, the vegetation in urban green spaces decreases cooling and heating energy demand by shading and evapotranspiration, thereby increasing the vegetation diversity in rural green areas significantly associated with fossil fuel use. Third, urban green space soils serve as an organic C from litterfall. However, the ecosystem benefit of urban green space is rarely understood even by policymakers, so most vegetation planting in urban green areas only considers the aesthetic value.

The relationship between plant biodiversity, especially in urban green spaces, and carbon stock has become an essential consideration in the carbon cycle and in reducing gas emissions [9]. The assessment for knowing the relationship between carbon stocks and plant biodiversity in an urban area is crucial to optimize environmental services of carbon storage and biodiversity conservation in the urban green space. Therefore, this study aims to determine tree dominance and its potential as carbon stock in three urban forests in Malang City, Indonesia. In addition, such studies help to highlight the global environmental benefits of urban green space [1] and provide basic information for policymakers to consider vegetation diversity in urban green spaces.

Materials and Methods

This study was carried out in the three urban forests in Malang city, i.e., Malabar (112°37'35.46"E, 7°58'6.82"S), Velodrome (112°40'11.35"E 7°58'26.27"S), and Hamid Rusdi (112°39'21.41"E, 8°1'50.08"S). The elevation is around 500 m a.s.l., and the annual rainfall is 1.833 mm/year. The mean annual temperature ranges of Malang City (min. and max.) are from 15.5 to19.7 ºC and 28.5 to 20.2 ºC with humidity of 72%.

The quadrates in 10 m x 10 m were employed to assess tree species composition in the three urban forests in Malang City. Each urban forest has different total plots, with a sampling of 10% of the total area (Table 1). Every tree in the quadrate was tagged, counted, recorded, and separated into different taxons. All of the tree was identified according to [10]. Tree heights were measured using a clinometer, whereas diameter at breast height was determined with a tapeline.

Table 1. Total plots used in this study according to area

Urban forest	Total area (m^2)	Total plots
Malabar	17.909.27	18
Velodrome	19.186.80	20
Hamid Rusdi	16.362.29	16

The important value index (IVI) was calculated to describe the species dominant in the plots [11]. The IVI formula for trees is as follows:

Density (D):

$$D = \frac{\text{Number of Individuals}}{\text{total area sampled}} \quad (1)$$

Relative Density (RD):

$$RD = \frac{\text{Density of a species}}{\text{Total density for all species}} \text{ X } 100\% \quad (2)$$

Frequency (F):

$$F = \frac{\text{Number of plots in which species recorded}}{\text{Total number of plots sampled}} \quad (3)$$

Relative Frequency (RF):

$$RF = \frac{\text{Frequency of a species}}{\text{Total frequency for all species}} \text{ X } 100\% \quad (4)$$

Dominance (Dom):

$$Dom = \frac{\text{Total basal area of a species}}{\text{Total area sampled}} \quad (5)$$

Relative Dominance (RDom):

$$RDom = \frac{\text{Dominance of a species}}{\text{Total dominance for all species}} \text{ X } 100\% \quad (6)$$

Important Value Index (IVI) formula:

$$IVI = RD + RF + RDom \quad (7)$$

Biomass was determined according to [12]: Biomass (kg) = $0{,}05 \times \rho \times DBH^2 \times H$ Where: ρ: wood density (gr/cm^3) according to global wood density, DBH: Diameter (cm) at Breast Height (1.3m), H: plant height (cm) Carbon stock estimation was calculated by using the formula proposed by [13]: Carbon stock = Biomass×0,5.

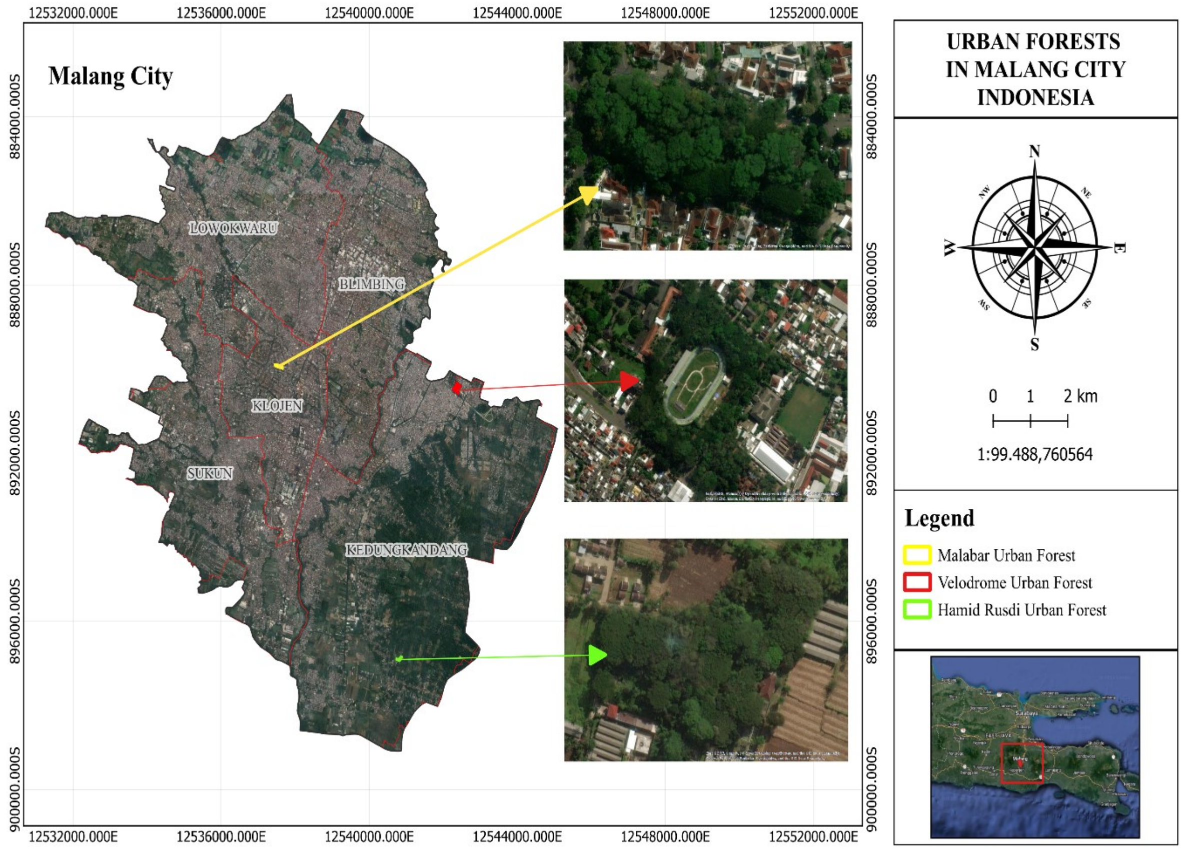

Figure 1. The study area in Malang urban forests

Results and Discussion

Research has identified 41 tree species from three Malang city forests, namely Malabar, Hamid Rusdi, and Velodrome urban forest, with the number of individuals respectively: 148, 188, and 126 (Table 2). *Albizia chinensis* is a species dominated the Malabar urban forest with an IVI value of 53.5% (Eq. 7). The *Albizia* genus has an important role in increasing soil fertility. The nitrogen fixation process is a factor influencing the increase in soil N concentration. This tree can increase the concentration of N in the water, reduce the concentration of organic nitrogen and organic carbon, and increase the engagement of chlorophyll-a in the river flow under its stand as an effect of litter decomposition [14]. The *Albizia* trees have the primary function of filtering and infiltrating water into the soil around springs [15].

A. chinensis, commonly known as *Chinese albizia* or silk tree, may dominate urban forest areas for several reasons. First, it is highly adaptable to various soil types and environmental conditions, making it resilient in urban environments [16]. Second, it overgrows and can provide quick shade and aesthetics, desirable qualities for urban planners and residents [17]. Additionally, its attractive fern-like leaves and fragrant flowers make it a popular ornamental tree choice. However, the dominance of *A. chinensis* can be problematic as it can outcompete native species [18], potentially leading to reduced biodiversity and ecosystem imbalances in urban forests. Managing its spread and promoting native species diversity is essential for maintaining a healthy urban forest ecosystem.

Unlike the Malabar urban forest, the Velodrome urban Forest is dominated by *Gmelina arborea* with an IVI value of 57.11% (Table 2) (Eq.5). *G. arborea* dominates the Jompie Botanical Gardens, City of Pare-Pare, South Sulawesi, due to a reforestation program by the city's Forestry and Plantations Service [19]. *G. arborea* is the second-dominated tree in Kuningan Botanical Garden, with IVI: 30.24% [20].

Table 2. Total species and their IVI values in Malang urban forest

Species	Total (individual)			IVI (%)		
	A	B	C	A	B	C
Acacia mangium	-	1	-	-	2,41	-
Albizia chinensis	9	-	-	**53.3 ***	-	-
Aleurites moluccanus	-	2	-	-	4.03	-
Araucaria sp	4	-	-	7.9	-	-
Artocarpus heterophyllus	8	2	1	13.7	4.43	2.9
Artocarpus integra	-	1	-	-	1.92	-
Azadirachta indica	-	3	-	-	4.28	-
Barringtonia asiatica	1	-	-	2.0	-	-
Bauhinia purpurea	-	14	3	-	17.78	6.3
Bunchosia argentea	-	1	-	-	1.58	-
Canarium sp.	-	4	-	-	6.03	-
Cerbera manghas	1	-	-	2.3	-	-
Chrysophyllum cainito	-	1	3	-	1.62	5.9
Cinnamomum burmanni	2	7	-	4.2	8.15	-
Delonix regia	9	6	-	20.4	10.21	-
Dimocarpus longan	-	4	-	-	5.38	-
Durio zibethinus	-	-	4	-	-	5.9
Enterolobium cyclocarpum	-	7	-	-	52.59	-
Eugenia uniflora	3	-	-	7.5	-	-
Ficus benjamina	4	-	1	6.1	-	3.4
Filicium decipiens	8	-	-	9.8	-	-
Garcinia dulcis	4	-	-	6.7	-	-
Gmelina arborea	15	37	-	30.7	**57.11 ***	-
Macadamia ternifolia	6	4	-	8.7	4.58	-
Mangifera indica	3	9	2	6.2	10.30	3.3
Manilkara kauki	2	1	-	2.8	1.59	-
Mimusops elengi	13	2	-	23.1	2.17	-
Morinda citrifolia	1	-	-	2.0	-	-
Parkia speciosa	-	1	-	-	1.98	-
Peltophorum pterocarpum	13	-	-	33.9	-	-
Polyalthia longifolia	20	40	42	27.0	36.36	**59.1 ***
Pometia pinnata	1	-	8	2.0	-	26.1
Pterocarpus indicus	-	2	20	-	3.86	46.6
Samanea saman	-	2	11	-	10.39	55.9
Spathodea campanulata	-	10	-	-	12.94	-
Swietenia macrophylla	2	16	14	4.0	21.16	46.7
Syzygium aqueum	3	2	12	3.4	2.18	21.1
Syzygium cumini	-	6	5	-	10.03	16.5
Tamarindus indica	10	-	-	11.1	-	-
Tectona grandis	4	-	-	7.2	-	-
Terminalia catappa	2	3	-	4.1	4.95	-
Total	**148**	**188**	**126**	**300**	**300**	**300**

Notes *: the highest value, A. Malabar urban forest, B. Velodrome urban forest, C. Hamid Rudi urban forest

Table 3. The biomass and potential tree carbon stocks in Malang urban forests

Species	Biomass (kg)			Carbon Stock (kg)		
	A	B	C	A	B	C
A. mangium	-	409,18	-	-	204.59	-
A. chinensis	12,428.76	**-**	**-**	**6,214.38 ***	-	-
A. moluccanus	-	173.70	-	-	86.85	-
A. heterophylla	516.93	-	-	258.47	-	-
A. heterophyllus	587.44	355.38	41.18	293.72	177.69	20.59
A. integra	-	107.03	-	-	53.51	-
A. indica	-	352.67	-	-	176.33	-
B. asiatica	3.93	-	-	1.97	-	-
B. purpurea	-	384.16	138.98	-	192.08	69.49
B. argentea	-	6.67	-	-	3.33	-
Canarium sp.	-	257.10	-	-	128.55	-
C. manghas	25.56	-	-	12.78	-	-
C. cainito	-	8.93	23.70	-	4.47	11.85
C. burmanni	155.58	252.37	-	77.79	126.19	-
D. regia	2,019.54	687.91	-	1,009.77	343.95	-
D. longan	-	34.59	-	-	17.29	-
D. zibethinus	-	-	75.28	-	-	37.64
E. cyclocarpum	-	1,4451.76	-	-	**7,225.88 ***	-
E. uniflora	1,036.45	-	-	518.22	-	-
F. benjamina	389.26	-	205.41	194.63	-	102.71
F. decipiens	107.39	-	-	53.69	-	-
G. dulcis	90.04	-	-	45.02	-	-
G. arborea	2,842.08	6,929.16	-	1,421.04	3,464.58	-
M. ternifolia	264.31	128.48	-	132.15	64.24	-
M. indica	29.03	53.10	7.70	14.52	26.55	3.85
M. kauki	23.85	7.50	-	11.92	3.75	-
M. elengi	321.04	23.02	-	160.52	11.51	-
M. citrifolia	5.08	-	-	2.54	-	-
P. speciosa	-	103.79	-	-	51.89	-
P. pterocarpum	7,034.13	-	-	3,517.07	-	-
P. longifolia	145.69	1035.58	974.92	72.84	517.79	487.46
P. pinnata	4.50	-	2,394.68	2.25	-	1,197.34
P. indicus	-	205.72	3,855.31	-	102.86	1,927.65
S. saman	-	2,886.84	9,514.02	-	1,443.42	**4,757.01 ***
S. campanulata	-	264.22	-	-	132.11	-
S. macrophylla	9.31	1,444.91	3,326.13	4.65	722.45	1,663.07
S. aqueum	17.43	25.97	2,889.56	8.71	12.98	1,444.78
S. cumini	-	236.52	779.42	-	118.26	389.71
T. indica	72.04	-	-	36.02	-	-
T. grandis	86.25	-	-	43.12	-	-
T. catappa	74.36	62.14	-	37.18	31.07	-

Notes *: the highest value, A. Malabar urban forest, B. Velodrome urban forest, C. Hamid Rudi urban forest

G. arborea dominates urban forest areas primarily due to its rapid growth, adaptability, and desirable wood properties. This species is resilient to various environmental conditions, thriving in urban settings with diverse soil types and climates. Its valuable timber properties and versatility for wood-based products further contribute to its widespread cultivation in urban forests [21].

The dominant tree in Hamid Rusdi urban Forest is *Polyalthia longifoliai,* with an IVI value of 59.1% (Table 2). *P. Longifolia*, commonly known as the Indian Mast Tree. Various compounds from this plant extract are efficacious in treating human diseases, such as fever, ulcers, skin diseases, worms, and heart problems [22]. This tree species aids in stormwater attenuation, reducing the risk of flooding in urban areas [23]. It also acts as an essential habitat for birds and other wildlife, promoting biodiversity in urban settings.

The main element for estimating carbon stocks is the estimation of aboveground stem biomass. Aboveground stem biomass of various trees was determined using tree diameter and wood density. The high amount of carbon storage is influenced by the value of the plant biomass [24]. There is a correlation between an increase in the value of biomass followed by an increase in carbon storage because these two components have a positive correlation value [25]. The structure and composition of vegetation affect aboveground carbon stores. Some researchers show that differences in carbon stocks are affected by tree species [26].

The highest carbon stock value in the Malabar urban forest is *A. Chinensis,* of 6.214.38 kg (Table 3). Albizia plants have a wide cover and a wide tree diameter. The results show that the greater the base area, the greater the carbon stock. The carbon storage will make the tree bigger [27]. *A. chinensis* is recognized for its exceptional carbon storage capabilities due to several key factors. Firstly, its aboveground biomass, including its extensive branches and dense foliage, provides ample space for carbon sequestration through photosynthesis [28]. Secondly, *A. chinensis* is known for its rapid growth, allowing it to accumulate carbon quickly during its life cycle. Additionally, its wood and woody tissues have a high carbon content, contributing significantly to carbon storage. Furthermore, favorable environmental conditions, such as suitable soil and climate, enhance its growth and carbon sequestration potential [29].

The highest carbon stock value in the Velodrome urban forest is *Enterolobium cyclocarpum*, of 7.225.88 kg. *E. Cyclocarpum* is the second dominant tree in the Velodrome urban forest, with an IVI value of 52.59 % (Table 2). *E. cyclocarpum* is a plant species that has the potential for land reclamation because it can overgrow in nutrient-poor soil and its ability to fertilize the soil through nitrogen fixation [30].

The highest carbon stock in the Hamid Rusdi urban forest is *Samanea saman*, of 4.757.01 kg (Table 3). *S. saman* is the second dominant three in Hamid Rusdi urban forest, with an IVI value of 55.9 % (Table 2). The carbon stock potential per hectare of *S. saman* is relatively higher than the cumulative carbon stock potential of urban trees in the USA, namely California (300 kg ha-1 year-1), Texas (300 kg ha-1 year-1), Arizona (300 kg ha-1 year-1), Rhode Island (300 kg ha-1 year-1), North Dakota (200 kg ha-1 year-1), and Wyoming (100 kg ha-1 year-1) [31].

Conclusions

There are differences in tree dominance in the three Malang city forests, namely: the Malabar city forest is *Albizia chinensis*, the Velodrome city forest is *Gmelina arborea*, and the Hamid Rusdi city forest is *Polyalthia longifolia.* The highest value of carbon stock in the Malabar urban forest is *A. Chinensis*, 6.214.38 kg; in the Velodrome urban forest is *Enterolobium cyclocarpum*, 7.225.88 kg; and in the Hamid Rusdi Urban Forest is *Samanea saman* with a carbon stock of 4.757.01 kg.

References

[1] L. Lindén, A. Riikonen, H. Setälä, and V. Yli-Pelkonen, “Quantifying carbon stocks in urban parks under cold

climate conditions," *Urban For. Urban Green.*, vol. 49, p. 126633, Mar. 2020, doi: 10.1016/j.ufug.2020.126633.

[2] E. Gómez-Baggethun and D. N. Barton, "Classifying and valuing ecosystem services for urban planning," *Ecol. Econ.*, vol. 86, pp. 235–245, 2013, doi: 10.1016/j.ecolecon.2012.08.019.

[3] F. Li *et al.*, "Urban Green Space Fragmentation and Urbanization: A Spatiotemporal Perspective," *Forests*, vol. 10, no. 4, p. 333, Apr. 2019, doi: 10.3390/f10040333.

[4] B. F. Nero, D. Callo-Concha, A. Anning, and M. Denich, "Urban Green Spaces Enhance Climate Change Mitigation in Cities of the Global South: The Case of Kumasi, Ghana," *Procedia Eng.*, vol. 198, pp. 69–83, 2017, doi: 10.1016/j.proeng.2017.07.074.

[5] K.-H. Kim and S. Pauleit, "Landscape character, biodiversity and land use planning: The case of Kwangju City Region, South Korea," *Land Use Policy*, vol. 24, no. 1, pp. 264–274, Jan. 2007, doi: 10.1016/j.landusepol.2005.12.001.

[6] BPS-Statistics of Malang Municipality, *Malang Municipality in Figures 2023*. Malang: BPS-Statistics of Malang Municipality, 2023.

[7] R. Kawamoto *et al.*, "Estimation of CO2 Emissions of Internal Combustion Engine Vehicle and Battery Electric Vehicle Using LCA," *Sustainability*, vol. 11, no. 9, p. 2690, May 2019, doi: 10.3390/su11092690.

[8] H. Jo, "Impacts of urban greenspace on offsetting carbon emissions for middle Korea," *J. Environ. Manage.*, vol. 64, no. 2, pp. 115–126, Feb. 2002, doi: 10.1006/jema.2001.0491.

[9] G. F. Midgley, W. J. Bond, V. Kapos, C. Ravilious, J. P. Scharlemann, and F. I. Woodward, "Terrestrial carbon stocks and biodiversity: key knowledge gaps and some policy implications," *Curr. Opin. Environ. Sustain.*, vol. 2, no. 4, pp. 264–270, Oct. 2010, doi: 10.1016/j.cosust.2010.06.001.

[10] C. G. G. J. van Steenis, *Flora*. Jakarta: Pradnya Paramita, 2006.

[11] M. F. Fachrul, *Metode Sampling Bioekologi*. Jakarta: Bumi Aksara, 2007.

[12] J. Chave *et al.*, "Tree allometry and improved estimation of carbon stocks and balance in tropical forests," *Oecologia*, vol. 145, no. 1, pp. 87–99, Aug. 2005, doi: 10.1007/s00442-005-0100-x.

[13] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories – A primer, Prepared by the National Greenhouse Gas Inventories Programme*. Kanagawa: The Institute for Global Environmental Strategies (IGES), 2008.

[14] T. N. Wiegner, F. Hughes, L. M. Shizuma, D. K. Bishaw, and M. E. Manuel, "Impacts of an Invasive N2-Fixing Tree on Hawaiian Stream Water Quality," *Biotropica*, vol. 45, no. 4, pp. 409–418, Jul. 2013, doi: 10.1111/btp.12024.

[15] E. Wiryani, Murningsih, and Jumari, "The abundance and importance value of tree in 'Sendang Kalimah Toyyibah' surrounding and its implication to the spring," *J. Phys. Conf. Ser.*, vol. 1025, p. 012032, May 2018, doi: 10.1088/1742-6596/1025/1/012032.

[16] A. N. Singh, A. S. Raghubanshi, and J. S. Singh, "Comparative performance and restoration potential of two Albizia species planted on mine spoil in a dry tropical region, India," *Ecol. Eng.*, vol. 22, no. 2, pp. 123–140, Apr. 2004, doi: 10.1016/j.ecoleng.2004.04.001.

[17] S. Latifah *et al.*, "Species composition, structure and endemicity of flora Malesiana in the Udayana urban forest, Mataram City," *IOP Conf. Ser. Earth Environ. Sci.*, vol.

637, no. 1, p. 012088, Jan. 2021, doi: 10.1088/1755-1315/637/1/012088.

[18] K. A. Brown, F. N. Scatena, and J. Gurevitch, "Effects of an invasive tree on community structure and diversity in a tropical forest in Puerto Rico," *For. Ecol. Manag.*, vol. 226, no. 1–3, pp. 145–152, May 2006, doi: 10.1016/j.foreco.2006.01.031.

[19] M. I. Kadir, A. Umar, and S. Supratman, "Nilai Ekonomi Kayu Kebun Raya Jompie Kota Parepare," *Gorontalo J. For. Res.*, vol. 2, no. 1, p. 19, Apr. 2019, doi: 10.32662/gjfr.v2i1.519.

[20] W. Astari, D. Rosleine, T. Lastini, J. C. Wahyu, and R. Manggala, "Vegetation Analysis And Carbon Stock Estimation In Kuningan Botanical Garden West Java," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 528, no. 1, p. 012002, Jul. 2020, doi: 10.1088/1755-1315/528/1/012002.

[21] D. Baderan, S. Rahim, and E. T. Manyo'e, "Vegetation Structure, Biomass, and Carbon Stock of Urban Forest of Bongohulawa National Wirakarya Campground in Gorontalo Regency - Gorontalo Province," *J. Ilmu Lingkung.*, vol. 21, no. 3, pp. 636–646, Jul. 2023, doi: 10.14710/jil.21.3.636-646.

[22] T. V. Dattatray, S. P. Baburao, and C. S. Shivaji, "A comprehensive review on Polyalthia longifolia," *Tradit. Med. Res.*, 2021, doi: 10.12032/TMR20201218212.

[23] P. Dwivedi, C. S. Rathore, and Y. Dubey, "Ecological benefits of urban forestry: The case of Kerwa Forest Area (KFA), Bhopal, India," *Appl. Geogr.*, vol. 29, no. 2, pp. 194–200, Apr. 2009, doi: 10.1016/j.apgeog.2008.08.008.

[24] A. E. Victor and J. T. Kpadehyea, "Above-ground bole carbon stock estimation using forest inventory of the secondary forest ecosystem in Ibadan, Nigeria," *Res. J. Agric. For. Sci.*, vol. 8, no. 1, pp. 10–21, 2020.

[25] M. Chanan, "Pendugaan Cadangan Karbon (C) Tersimpan di Atas Permukaan Tanah pada Vegetasi Hutan Tanaman Jati (Tectona Grandis Linn. F) di RPH Sengguruh BKPH Sengguruh KPH Malang Perum Perhutani II Jawa Timur," *J. Gamma*, vol. 7, pp. 61–73, 2012.

[26] M. Muhdi, D. S. Hanafiah, and R. D. Butar-Butar, "Diversity, biomass, and carbon stock of understorey plants in the rubber agroforestry and rubber monoculture systems in Central Tapanuli District, North Sumatra, Indonesia," *Biodiversitas J. Biol. Divers.*, vol. 21, no. 8, Jul. 2020, doi: 10.13057/biodiv/d210812.

[27] L. Hutyra, B. Yoon, and M. Alberti, "Terrestrial carbon stocks across a gradient of urbanization: a study of the Seattle, WA region," *Glob. Change Biol.*, vol. 17, pp. 783–797, Feb. 2011, doi: 10.1111/j.1365-2486.2010.02238.x.

[28] S. R. Roshanzada, K. S. Pant, and S. Kar, "Growth and Carbon Storage Potential of Important Agroforestry Trees of North-West Himalaya," *Int. J. Curr. Microbiol. Appl. Sci.*, vol. 7, no. 11, pp. 1804–1818, Nov. 2018, doi: 10.20546/ijcmas.2018.711.205.

[29] M. T. S. Budiastuti, D. Purnomo, and D. Setyaningrum, "Agroforestry System as the Best Vegetation Management to Face Forest Degradation in Indonesia," *Rev. Agric. Sci.*, vol. 10, no. 0, pp. 14–23, 2021, doi: 10.7831/ras.10.0_14.

[30] F. Syarif, "Toleransi Sengon Buto (Enterolobium cyclocarpum Griseb) yang Ditanam pada Media Limbah Tailing Tercemar Sianida dengan Perlakuan Pupuk," *Ber. Biol.*, vol. 9, pp. 105–110, 2008.

[31] M. Udayakumar, "Aboveground Biomass Stockpile and Carbon Sequestration Potential of Albizia saman in Chennai Metropolitan City, India," *Plant*, vol. 6, no. 3, p. 60, 2018, doi: 10.11648/j.plant.20180603.12.