InJAST
Volume 5, Number 1, April 2024
Pages: 29-34

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v5i1.9653

Carbon Dioxide (CO_2) sequestration by trees and green open space (GOS) at the campus of Pakuan University

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Submitted 14 March 2024; Accepted 24 August 2024

ABSTRACT

Pakuan University (Unpak) as one of the largest private campuses in Bogor City, is committed to reducing greenhouse gases (GHG) emissions, especially CO_2, through green open spaces (GOS) and trees on campus. Currently, the GOS and trees on the Unpak campus have not been arranged by CO_2 sequestration as a consideration, even though the source of CO_2 on the Unpak campus apart from the number of students which is more than 15,000 people is also filled with motorized vehicles. Therefore, to participate in reducing GHG emissions, especially CO_2 in Bogor City, and create a comfortable campus, a campus GOS management strategy is needed which is based on CO_2 sequestration. This research aims to analyze the ability of existing trees and GOS to sequester CO_2. CO_2 sequestration calculations are carried out based on the area of the GOS and the sequestration capacity of the trees in the GOS. The research results show that the 6 zones on Unpak's main campus have different CO_2 sequestration capacities depending on the area of space planted with grass and ornamental bushes and the number of trees and shrubs planted. Overall, the CO_2 sequestration capacity of trees and GOS on Unpak's main campus is 282,784.89 kg per year.

ABSTRAK

Universitas Pakuan (Unpak) sebagai salah satu kampus swasta terbesar di Kota Bogor berkomitmen menurunkan emisi gas-gas rumah kaca (GRK), khususnya CO_2 melalui ruang terbuka hijau (RTH) dan pepohonan di dalam kampus. Saat ini RTH dan pepohonan di kampus Unpak belum ditata dengan mempertimbangkan sekuestrasi CO_2, padahal sumber CO_2 di kampus Unpak selain dari jumlah mahasiswa yang lebih dari 15.000 orang juga dipenuhi oleh kendaraan bermotor. Oleh karena itu, untuk ikut serta dalam penurunan emisi GRK khususnya CO_2 di Kota Bogor dan mewujudkan kampus yang nyaman diperlukan strategi pengelolaan RTH kampus yang berbasis pada penyerapan CO_2. Penelitian ini bertujuan untuk menganalisis kemampuan pepohonan dan RTH yang ada dalam menyerap CO_2. Perhitungan sekuestrasi CO_2 dilakukan berdasarkan luas RTH dan kapasitas sekuestrasi pohon-pohon yang ada di dalam RTH. Hasil penelitian menunjukkan bahwa 6 zona di kampus induk Unpak mempunyai kapasitas penyerapan CO_2 yang berbeda-beda tergantung luas ruang yang ditanami rumput dan semak hias serta jumlah pohon dan perdu yang ditanam. Secara keseluruhan, kapasitas sekuestrasi CO_2 pepohonan dan RTH di kampus induk Unpak adalah 282.784,89 kg per tahun.

Keywords: *CO_2 Sequestration, Greenhouse Gases, Green Open Space*

INTRODUCTION

Global warming and climate change have become global environmental problems that urgently need to be addressed. For Indonesia, climate change poses a formidable challenge for its people, as it is the world's fourth most populous nation and the biggest archipelagic country (Priatna & Monk, 2023). One of the factors causing climate change is an increase in the concentration of greenhouse gases (GHG) such as CO_2 in the atmosphere (Roshintha & Mangkoedihardjo, 2016; Baderan, 2017; Rachmayanti & Mangkoedihardjo, 2021; Haruna, 2020). Nature-based solutions are widely recognized as a key means of carbon removal technology, offering significant effectiveness and cost efficiency in addressing climate change (Li et al., 2023). Using the natural-based solution concept, the way to reduce CO_2 concentrations in the atmosphere is through CO_2 sequestration by plants (Ali, 2012; Zhang & Wang, 2022). Sequestration of CO2 by vegetation can be an effective alternative in reducing CO_2 concentration in the atmosphere because all parts of vegetation starting from stems, leaves, and roots store biomass from photosynthesis (Darlina et al., 2023). Plants can sequester CO_2 through the process of photosynthesis and convert it into carbohydrates for plant growth and development (Othman et al., 2019). The presence and content of chlorophyll are crucial for a plant because chlorophyll has an important role in plant biochemical processes, especially in photosynthesis (Latifa et al., 2019). The most important part of the plant in photosynthesis is the leaf (Pertamawati, 2010). The factor causing differences in chlorophyll content is differences in leaf surface width (Latifa et al., 2019). Therefore, different types of vegetation have different abilities to sequester CO_2 from the atmosphere (Mansur & Arief, 2014; Mandal et al., 2016; Othman et al., 2019) . Plants that have wide leaves can sequester CO_2 more effectively because having a wider leaf area allows for greater capture of sunlight and is efficient for photosynthesis (Latifa et al., 2021).

A campus provides sufficient land for planting vegetation, which is one solution to mitigating climate change (Sharma et al., 2021). Pakuan University (Unpak) is one of the large and influential private universities in the city of Bogor. which has a main campus area of 3,500 m^2, is certainly committed to assisting the government's efforts to reduce GHG emissions and increase the supply of oxygen (O_2) through the arrangement of GOS. Green Open Space (GOS) on campus has various functions, apart from adding to the beauty of the campus, it is also very beneficial for the civitas academics, including facilitating health and well-being by eliminating stress and allowing relaxation (Sharma et al., 2021). The GOS on campus ideally has a function that supports the activities of the civitas academics (Gandasari et al., 2021). The arrangement of GOS can add comfort because it can regulate air temperature and humidity, reduce CO_2 pollution, and increase O2. A campus that is comfortable and beautiful, because it is equipped with an organized GOS, will make civitas academics more productive. Currently, there is no data and information available regarding the distribution and condition of GOS and trees on the Unpak campus related to the sequestration of CO_2. Therefore, research is needed to analyze the sequestration of CO_2 by trees and GOS on the Unpak campus.

METHODS

Location of Research

The research was conducted at the main campus of Pakuan University, Jalan Pakuan No. 1, Tegallega, sub-district of Central Bogor on 6^0 35’ 59” S and 106^0 48’ 41” E. The area of Pakuan University's main campus is 35,000 m^2. For analysis, the Unpak’s main campus is divided into 6 observation zones, namely: Zone 1 (SPs – Management - Mandiri - Accounting); Zone 2 (UKM – BNI - Accounting); Zone 3 (Vocational – GPS- Back of Rector office); Zone 4 (FISIB - FKIP); Zone 5 (FMIPA); and Zone 6 (Front of Rector Office -FH). Figure 1.

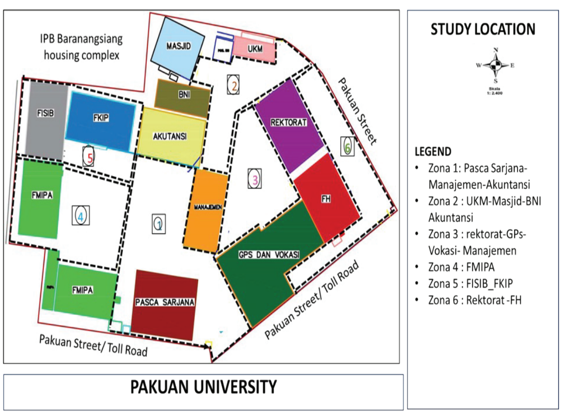

Figure 1. Location of the study.

Data

This study used primary and secondary data. Primary data was obtained by observing and measuring the area of GOS and collecting data on trees/shrubs and ornamental bushes, while secondary data was obtained from documents and websites. The data required and how to search and source the data are shown in Table 1.

Table 1. Data required and source.

No	Data	Data Search Technique
1	Number and type of trees/shrubs	Field observations, interviews, and literature
2	Bushes and grass area	Measurement
3	Name of tree/shrub	Literature
4	Sketch of the main campus of Pakuan University	Document, Unpak website
5	Unpak main campus area	Unpak website

Analysis

Each type of plant has a different rate of CO_2 sequestration due to differences in plant physiology (Mansur & Bayu Arief, 2014). Calculation of CO_2 sequestered uses the formula: Total amount of CO_2 sequestered, equal to CO_2 sequestration rate per tree/shrub multiplied by the number of trees/shrubs (Suryaningsih et al., 2015). Next, to calculate the amount of CO_2 sequestration by trees/shrubs, use Table 2.

Table 2. CO_2 Sequestration Rate by Trees and Shurbs.

Species	CO_2 Sequestration Rate (Kg/Tree-Y)
Alpukat (*Persea americana Mill*)[1)]	113
Angsana (*Pterocarpus indicus*)[2)]	2,804.93
Asem Jawa (*Tamarindus indica*)[3]	8.48
Belimbing (Averrhoa carambola)[1)]	132
Beringin (*Ficus benjamina*)[4)]	1,917.56
Beringin kimeng (*Ficus Microcarpa*)[5)]	5,728.20
Bintaro (*Cerbera manghas*)[6)]	4,509
Biola cantik (*Ficus lyrata Warb*)[1]	11,919
Bougenville (*Bougainvillea spectabills*)[4)]	2.63
Bunga merak (*Caesalpinia pulcherrima*)[7)]	30.95
Bungur (*Lagerstroemia speciosa*)[7)]	160.14
Cemara laut (*Casuarina equisetifolia*)[8)]	394.20
Dadap Hijau (*Erythrina variegata*)[9)]	1,445.40
Flamboyan (*Delonix regia*)[6)]	42.20
Jamblang (*Syzygium cumini*)[5)]	4,135.99
Jambu Air (*Syzygium aqueum*)[10)]	1,543
Jambu biji (*Psidium guajava Linn*)[1]	602
Jambu Jamaica (*Syzygium malaccense*)[1]	9,419
Kamboja kuning (*Plumeria acuminate*)[6)]	220
Kelapa (*Cocos nucifera*)[4)]	804.17

Kenari (*Canarium asperum*) [11]	38,964
Kepel/Kiburahol (*Stelechocarpus burahol*) [11]	8,606
Ketapang Badak (*Terminalia catappa*) [10]	7,272
Ketapang Kencana (*Terminalia Mantaly*) [10]	689.60
Kiputri (*Podocarpus macrophyllus*) [12]	1.63
Krey Payung (*Fellicium decipiens*) [6]	404.83
Mahoni (*Swietenia mahagoni*) [14]	295.73
Mangga (*Mangifera indica*) [4]	455.52
Matoa (*Pometia pinnata*) [7]	329.76
Nangka (*Arthocarpus heterophyllus*) [11]	1,108
Nyamplung (*Calophyllum inophyllum*) [10]	2,047.56
Pakis Brazil (*Schizolobium parahybum*) [13]	52.51
Palem Bismarck (*Bismarckia nobilis*) [16]	23.91
Palem kipas (*Livistona saribus*) [17]	43.81
Palem Kuning (*Dypsis lutescens*) [9]	3.42
Palem Putri (*Veitchia merrillii*) [9]	285.58
Palem sadeng (*Livistona rotundifolia*) [13]	29.75
Pandan Bali (*Cordyline australis*) [16]	13.30
Pucuk merah (*Oleina syzygium*) [8]	1,362.88
Pulai (*Alstonia scholaris*) [8]	11,557.51
Rambutan (*Nephelium lappaceum*) [7]	2.19
Salam (*Syzygium polyanthum*) [2]	749.78
Song of India (*Dracaena reflexa*) [15]	550.30
Sukun (*Artocarpus communis*) [6]	815.19
Tanjung (*Mimusops elengi Linn*) [11]	4,856

Source: [1] (Santoso et al., 2021); [2] (Misni et al., 2015); [3] (Febriansyah et al., 2022); [4] (W. O. D. M. Lestari et al., 2021); [5] (Sharma et al., 2021); [6] (Suryaningsih et al., 2015); [7] (Dahlan, 2008); [8] (Untajana et al., 2019); [9] (Roshintha & Mangkoedihardjo, 2016); [10] (Darlina et al., 2023); [11] (Lailati, 2013); [12] (Gharge & Menon, 2017); [13] (Milantara & Gustin, 2023); [14] (Othman et al., 2019); [15] (Pasaribu & Tangahu, 2016); [16] (Wesport, 2022); [17] (Dinas Lingkungan Hidup Kota Surabaya, 2017).

The CO_2 sequestration rate for each type of GOS cover is different. The CO_2 sequestration rate in GOS with ornamental bushes cover is 131.99 kg/m^2-year, while GOS with grass cover is 28,803 kg/m^2-year (Dinas Lingkungan Hidup Kota Surabaya, 2017). The amount of CO_2 sequestered on the GOS cover is equal to the rate of CO_2 sequestration multiplied by the area of the GOS cover (Suryaningsih et al., 2015).

RESULT AND DISCUSSION

Trees and Shrubs Sequestration

On the Unpak main campus, there is GOS in the form of a garden with ornamental bushes and trees/shrubs, a field with grass and trees/shrubs, as well as a box planter with ornamental bushes and shrubs. The area of the Unpak main campus is 35,000 m^2 with a GOS of 1,090.11 m^2 (3.11%). Based on Law No. 26 of 2007 about Spatial Planning, the GOS of the campus of Unpak is a private GOS. Provision on the Green Coefficient (KDH), by Bogor City Regulation No. 6 of 2021 about Amendments to Bogor City Regulation No. 8 of 2011 about Regional Spatial Planning (RTRW) Bogor City 2011-2031, is 10% of campus area. Thus, the area of GOS on the main campus, which is only 3.11% of the campus area, is still very small. This certainly affects the amount of CO_2 sequestration.

On Unpak's main campus are 45 species of trees and shrubs were identified with a total number are 208 trees and shrubs. The CO_2 sequestration rate for each tree is not the same, so a large number of trees/shrubs does not automatically cause a high amount of CO_2 sequestration. The zone with an abundance of trees is Zona 1 with 47 trees/shrubs, but CO_2 sequestration is 32,842.70 kg/y lower than zone 4 which has 45 trees/shrubs with CO_2 sequestration of 70,664.57 kg. This is because in Zone 4, the CO_2 sequestration rate of existing trees/shrubs is higher than in Zone 1. One example is a tree with the highest sequestration rate is Ficus lyrata Warb (11,919 kg/tree-year), Alstonia scholaris (11,557.5 kg/tree-year), and Syzigium cumini (4,136 kg/tree-year). The total CO_2 sequestered by all the trees in a year on Unpak's main campus is 220,960.53 kg or 220,960 tons. The average, CO_2 sequestered by an individual tree/shurb on Unpak's main campus is 1.06 tons per year (Table 3).

Table 3. CO_2 sequestration by trees/shrubs at Unpak's main campus in 2023.

Zone	Number of Trees/Shrubs	CO^2 Sequestration (kg/y)
Zone 1: SPs-Mjn -Mandiri-Acc	47	32,842.70
Zone 2: UKM-BNI-Acc	31	17,174.18
Zone 3 : Vokasi-GPS	35	25,497.47
Zone 4 : MIPA	45	70,664.57
Zone 5 : FISIB-FKIP	36	19,114.71
Zone 6 : Rector's Office-FH	24	55,666.91
Total amount	208	220,960.53

Source: Analysis 2023

Green Open Space with Covered by Ornamental Bushes and Grass

CO_2 sequestration on Unpak's main campus, besides trees, was also identified by the area of GOS covered by ornamental bushes and grass. The total CO_2 sequestration on Unpak's main campus by the GOS that is covered by ornamental bushes (294.85 m^2) and grass (706.50 m^2) is 61,824.34 kg/year. Zone 6 is the zone with the largest area of GOS with ornamental bushes because in this zone there are 11 forms of elongated GOS planted with ornamental bushes. Even though Zones 4 and 5 are the zones with the most extensive GOS planted with grass, the amount of CO_2 sequestration is smaller than in Zone 6 where the GOS is covered by ornamental shrubs. This is because the CO_2 sequestration rate of grass is lower than ornamental shrubs (Table 4).

Overall the amount of CO_2 sequestration by grassy GOS, ornamental bushes GOS, and trees is 282,784.87 kg/year. The zone with the highest CO_2 absorption is

Zone 6 (81,546.05 kg/y) which comes from trees/shrubs and GOS covered with ornamental bushes. In zone 4 (80,547.97 kg/y) CO_2 sequestration comes from trees/shrubs and GOS covered with grasses. The ability to sequester CO_2 by ornamental bushes, grasses, and trees/shrubs for each zone on the Unpak campus is different, depending on the area and cover of GOS by grass, ornamental bushes, or trees and shrubs. According to ATR/BPN Ministerial Regulation no. 14 of 2022 article 4(1), one of the GOS typology classifications is space objects that function as GOS. Therefore, it is necessary to expand GOS, by creating a type of GOS in the form of a space object that functions as GOS in the form of a building surface planted with vegetation. Space objects that function as GOS are in the form of roof gardens (Lestari et al., 2018) vertical gardens (Alfaatihah et al., 2022),(Indriani et al., 2020), or planter box gardens (Widyaputra, 2020).

Table 4. CO_2 sequestration by GOS with ornamental bushes and grasses cover at Unpak's main campus in 2023.

GOS Location	Area (m^2)		CO_2 Sequestration (kg/y)		Total CO_2 Sequestration (kg)
	Grasses	Ornamental Bushes	Grasses	Ornamental Bushes	
Zone 1	17.17	18.45	494.54	2,435.51	2,930.04
Zone 2	23.52	41.97	677.32	5,539.74	6,217.06
Zone 3	1.49	39.42	42.77	5,202.64	5,245.41
Zone 4	323.36	-	9,883.40	-	9,883.40
Zone 5	409.96	-	11,808.03	-	11,808.03
Zone 6	-	195.01	-	25,740.40	25,740.40
Total	795.27	294.85	22,906.06	38,918.28	61,824.34

Source: Analysis 2023

Table 5. Total CO_2 sequestration at Unpak's main campus in 2023.

Zone	CO_2 Sequestration (kg/y)			Total CO_2 Sequestration (kg)
	Grasses	Ornamental Bushes	Trees/ Shrubs	
1. SPs-Min-Mandiri-Acc	494.54	2,435.51	32,842.70	35,772.74
2. UKM-BNI-Acc	677.32	5,539.74	17,174.18	23,391.24
3. Vokasi-GPS	42.77	5,202.64	25,497.47	30,742.89
4. MIPA	**9,883.40**	0.00	**70,664.57**	80,547.97
5. FISIB-FKIP	**11,808.03**	0.00	19,114.71	30,992.74
6. Rector's Office-FH	0.00	**25,740.40**	**55,666.91**	**81,407.31**
Total	22,906.06	38,918.28	220,960.53	282,784.87

Source: Analysis 2023

GOS of Unpak's main campus in sequestering CO_2 is not optimal because existing conditions show that the quality of the grassy GOS is not well maintained, as well as the quality of trees/shrubs and ornamental bushes. The grassy GOS as well as ornamental bushes is poorly maintained, and some trees require pruning and rejuvenation. Pruning can also improve lighting from sunlight to all parts of the plant so that the photosynthesis process can take place perfectly (Suradinata et al., 2017). A perfect photosynthesis process not only increases CO_2 absorption but also increases the amount of O_2 in the air which has an impact on improving air quality. Several trees with high CO_2 sequestration rates in main campus, for example Ficus lyrata warb, Bauhinia purpurea, Syzygium malaccense, Stelechocarpus burahol, Terminalia cattapa Linn, Syzygium cumini, Ficus Microcarpa, Mimusops elengi Linn, Pterocarpus indicus, and Calophyllum inophyllum, can be an option when rejuvenation of trees. Therefore, to increase the CO_2 sequestration capacity on the GOS of the Unpak campus, it is necessary to maintain the quality of trees, grasses, and ornamental bushes, through pruning, rejuvenation, and fertilization. Besides that, spaces in the form of hallways or corridors or building walls that still allow for planting vegetation in the form of ornamental bushes or shrubs need to be utilized optimally. Based on observations in the field, there are walls/fences that can be used as vertical gardens and corridors/aisles between buildings, as well as parking lots where plant boxes can be placed planted with ornamental bushes.

CONCLUSION

The area of GOS on the Unpak main campus is 3.11% consisting of 795.27 m^2 (grass open space), 294.85 m^2 (ornamental bushes open space), and 208 trees/shrubs with 45 species of trees/shrubs. The GOS area of the Unpak campus does not meet the Green Coefficient (KDH) criteria (10%) for the use of private space. The total CO_2 sequestration from GOS is 282,784.87 kg/year, consisting of: 22,906.06 kg/year (grassy GOS), 38,918.28 kg/year (bushies GOS), and 220,960.53 kg/year (trees). Therefore, a strategy is needed so that the arrangement of GOS in the Unpak campus can be optimal, by adding a vertical garden and planter box garden, as well as regular maintenance of trees and GOS.

ACKNOWLEDGEMENTS

We would like to express our thanks to the Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) at Pakuan University. This paper is part of research funded by an internal research grant from LPPM Pakuan University, in accordance with Chancellor's Decree No 102/KEP/REK/IX/2023.

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