The concentration of CO₂ on two canopy densities in Taman Kota 1 Bumi Serpong Damai, South Tangerang

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Abstract. Global warming occurs because many greenhouse gases (GHG) retain heat from the earth, which causes the earth's surface temperature to increase. The GHG contributing most to global warming is carbon dioxide (CO₂) due to its highest atmosphere concentration and long life span. The increasing CO₂ concentrations in urban areas are caused by transportation and industrial activities. City parks with high tree densities are the potential to reduce CO₂ concentration. However, studies related to tree canopy density in reducing CO₂ concentrations have not been widely carried out. This study aims to determine the CO₂ concentration on two different canopy densities. This research was conducted in March - April 2021 in Taman Kota 1 BSD. Primary data collection was carried out by three replicates based on time as follows: 06.00 am, 01.00 pm, and 05.00 pm at low canopy density and high canopy density locations, respectively, by using the AZ 7725 Carbon dioxide meter tool. The low canopy density had a leaf area index (LAI) of 1.039, whereas the high canopy density had an LAI of 1.409. The highest CO₂ concentration is 582.43 ppm in the high canopy density in the morning, while the lowest is 463.16 ppm occurred at the low canopy density in the afternoon. In the morning, CO₂ from respiration is still concentrated under the dense canopy because there is less wind to disperse. In the afternoon, the wind speed is higher so that CO₂ is more easily distributed.

1. Introduction

The increasing global temperature caused by greenhouse gases (GHG) in the atmosphere makes global warming an environmental issue of greatest concern to the whole world. A large number of greenhouse gases causes the heat reflected by the earth's surface to be restrained [1] so that these heatwaves return to earth and cause global warming [2]. One type of greenhouse gas that contributes the most to hold back the heat reflected from the earth is carbon dioxide because this gas has the highest concentration compared to other greenhouse gases. In addition, this gas has a relatively long lifetime [3].

The main source of increasing CO₂ concentration in the air comes from human activities such as the use of wood fuels, fossil fuels, and forest burning. Problems related to increasing CO₂ concentrations often occur in big cities due to the large number of residents, followed by increased motorized vehicles. At the right level, this gas maintains the earth's surface air temperature to be warm enough for living things to live in. However, if the rate of CO₂ concentration continues to increase, it can cause health problems for living things. The CO₂ threshold that healthy adults can accept is only 5,000 ppm (0.5%) within 8 hours per day.
[4]. A CO₂ concentration of 3% can cause shortness of breath and headaches or start to drowsy [5]. Meanwhile, concentrations above 5% can endanger the survival of living things.

One of the efforts to maintain environmental conditions, especially in urban areas, is to develop urban parks. South Tangerang City built Taman Kota 1 BSD with 60 species of plants with the number of trees reaching 2500 trees [6] intending to control environmental problems such as reducing the rate of excessive CO₂ concentration and lowering air temperature in the area around the city park. Vegetation in city parks plays a role in reducing CO₂ gas through the process of photosynthesis. Trees can reduce CO₂ gas up to 567.07 tons/ha/year, while the grass can only reduce CO₂ gas by 12 tons/ha/year [7]. At night, CO₂ in the park is a source from the respiration of plants [8], so that vegetation with a high canopy density will produce a relatively high concentration of CO₂. Based on the research results [9], at a canopy density of 65%, the CO₂ concentration was measured at 413.56 ppm. Until now, research on CO₂ concentrations in areas with lots of trees, especially in urban parks, is rarely done. Based on this background, this study was conducted with the aim to determine the effect of differences in day conditions, canopy density, time, and distance from emission sources on CO₂ concentrations.

2. Method

2.1. Time and location of the research
The research was carried out from March to April 2021 at Taman Kota 1 BSD, South Tangerang City. The map of the research location is presented in figure 1.

![Figure 1. Research site map.](image)

2.2. Materials and equipment
The materials and equipment used in this study were as follows: (1) for CO₂ measurement: Carbon dioxide measuring device AZ 7725; (2) for determination of Leaf Area Index (LAI): DSLR camera, fisheye lens, Hemiview 2.1 software; (3) for vegetation analysis: clinometer, measuring tape, compass, stationery, thermometer, and tally sheet for data collection. (4) for statistical analysis: SPSS 25.

2.3. Data collection and processing
Primary data collected includes Leaf Area Index (LAI), CO₂ concentration, species, and vegetation density. LAI data is obtained from canopy shooting using a lens with an angle of 180° or known as the hemispherical photograph method [10]. When taking photos, the camera must be placed at the height of ±1 m and
positioned facing north [11]. The time for taking photos is in the afternoon, or when the atmosphere is cloudy. It is intended to reduce the diffraction of sunlight, making the photo become shaded so that the photo is difficult to analyze [12]. There are eight data collection points, namely four points representing low canopy density and four representing high canopy density. Then the results of the shoot header are processed with Hemiview 2.1 software to get the LAI value.

Measurement of CO₂ concentration was carried out on three working days and three holidays—this method to see variations in CO₂ concentration [13]. The sampling was carried out at 06.00 am, 01.00 pm, and 05.00 pm, with three replications. Data collection was carried out when the weather was sunny [8]. The AZ 7727 carbon dioxide device is placed at the height of ±1.5 m from the ground. When measuring, the instrument must be protected from rainwater and direct sunlight.

Vegetation data were obtained from vegetation analysis using a single plot method measuring 20 x 20 m² [14] and only identified tree species. Data analysis used the T-test to determine the effect of the two conditions of canopy density, time of data collection, day conditions, and distance from emission sources on the level of CO₂ concentration in the air. The location of the CO₂ data collection plot is shown in figure 2.

![Figure 2. Point for CO₂ data collection, LAI, and vegetation analysis.](image)

3. Result and discussion

3.1. General condition of the location

Taman Kota 1 BSD is located in Lengkong Gudang Timur Village, Serpong District, South Tangerang City with an area of 2.6 ha. The location of Taman Kota 1 BSD City is very strategic because it is surrounded by many urban activities such as politics, social culture, economy, and technology. The park is bordered by Giri Loka 3 in the north, Giri Loka Park in the east, Islamic School Al Azhar in the west, and Puspita Loka in the north. In addition, access to this park is straightforward because it is located on the main road of South Tangerang City, namely on Jalan Pahlawan Seribu. This park also has direct access to the Jakarta Outer Ring Road (JORR) toll road.

This city park is equipped with public facilities such as a jogging track, staging stage, canteen, toilets, and sports equipment. Then the city park is also overgrown with 60 species of plants with a total of 2500 trees [6]. Several species of vegetation in Taman Kota 1 BSD include Ficus sp., Delonix regia, Cerbera manghas, Ficus elastica, Cynometra ramiflora, and Elaeis guineensis.
3.2. Leaf Area Index (LAI)

One of the characteristics of trees that is thought to affect CO₂ products at night is the level of density indicated by the Leaf Area Index (LAI). LAI is the ratio between the total leaf area to the projected area of the tree canopy on the ground [15]. LAI data is obtained from canopy shooting using a lens with an angle of 180° or known as the hemispherical photograph method [10]. The photos will be analyzed using Hemiview 2.1 software (figure 3).

![Figure 3. Photo of the canopy density at a distance of 25 m (a) low (b) high.](image)

The LAI value from the analysis using Hemiview 2.0 software is shown in table 1. Data collection obtained the average LAI value at a low canopy density of 1.039 and a high canopy density of 1.409. The smaller the LAI value or equal to 0 means that the land condition is getting worse, not vegetated [16]. Even so, the highest LAI value in this city park is still relatively small compared to the LAI value for natural forest types, which is 3.39 [17]. The small LAI value is because not all areas are completely covered by the tree canopy at each data collection point. This is in line with research [18], which states that the low LAI value in green open spaces is due to not all green open spaces being shaded by trees and only a few trees.

| Data collection point | LAI value at low canopy density | LAI value at high canopy density |
|-----------------------|--------------------------------|---------------------------------|
| 0 m                   | 0.988                          | 1.164                           |
| 25 m                  | 0.990                          | 1.147                           |
| 50 m                  | 0.996                          | 1.560                           |
| 75 m                  | 1.180                          | 1.765                           |
| **Average value**     | **1.039**                      | **1.409**                       |

3.3. Result of vegetation analysis

Woody plants or trees can store CO₂ in the long term compared to non-timber vegetation [8]. Based on the results of vegetation analysis conducted at eight observation points, five species of trees are almost always found: Lagerstroemia speciosa, Adenanthera pavonina, Swietenia mahagoni, Caesalpinia pulcherrima, and Albizia chinensis (figures 4 and 5). Each tree can absorb CO₂ differently depending on the age and species of vegetation [19]. Of the tree species found, the saga tree's highest CO₂ absorption capacity was 221.18 kg/year, followed by the Bungur tree at 160.14 kg/year [20]. The tree with the lowest absorption capacity is the sengon tree which is 1.03 kg/year.
3.4. Results of measurement of CO₂ concentration

CO₂ measurement produces data in ppm units. The average results of CO₂ measurements are shown in table 2. Based on table 2, the concentration of CO₂ at low density ranged from 463.16 ppm - 584.96 ppm while at high density ranged from 469.4 ppm - 582.43 ppm. The highest CO₂ concentration occurred in the morning at high and low densities, namely 584.95 ppm and 582.43 ppm. The high CO₂ concentration in the morning on the plot 75 m from the roadside was due to the dense and intersecting condition of the tree crowns, causing CO₂ gas to become trapped and difficult to get out of the park [8]. In addition, on the morning before sunrise, the mixing layer thins to the lowest thickness, making the atmospheric stability stronger [21]. When atmospheric stability is getting stronger, air conditions tend to settle and cause the concentration of CO₂ to be maximum.

**Figure 4.** Number of trees at low canopy density.

**Figure 5.** Number of trees at high canopy density.
Table 2. Average CO₂ measurement results (ppm).

| Day condition | 0 m | 25 m | 50 m | 75 m | Average based on day condition | Average based on canopy density |
|---------------|-----|------|------|------|--------------------------------|-------------------------------|
| 06.00         | 01.00 | 05.00 | 06.00 | 01.00 | 05.00 | 06.00 | 01.00 | 05.00 |
| A. Low canopy density | | | | | | |
| Weekday | 568.73 | 478.86 | 481.4 | 575.1 | 475.06 | 469.96 | 568.06 | 469.96 | 569.4 | 469.96 | 463.16 | 504.62 |
| Weekend | 575.8 | 488.53 | 491.86 | 584.96 | 484.63 | 494.1 | 577.53 | 478.86 | 494.2 | 582.33 | 478.5 | 491.86 | 518.60 |
| Average of time | 572.27 | 483.70 | 486.63 | 580.03 | 479.85 | 481.97 | 572.80 | 474.41 | 480.08 | 575.87 | 474.23 | 477.51 |
| Average of distance | 514.20 | 513.96 | 509.10 | 510.32 |
| B. High canopy density | | | | | | |
| Weekday | 565.2 | 476.97 | 480.76 | 559.16 | 472.06 | 474.63 | 562.5 | 474.73 | 475.3 | 560.2 | 470.96 | 469.4 | 503.51 |
| Weekend | 568.63 | 497.96 | 510.5 | 570.3 | 484.53 | 502.16 | 570.1 | 482.86 | 496.53 | 582.43 | 485.86 | 493.06 | 520.41 |
| Average of time | 566.92 | 487.47 | 495.63 | 564.73 | 478.30 | 488.40 | 566.3 | 478.80 | 486.03 | 571.32 | 478.41 | 481.23 |
| Average of distance | 516.67 | 510.47 | 510.38 | 510.32 |

Then it can be seen that the average value of CO₂ concentration at the 0 m point in the two conditions of canopy density is always higher than the other 3 points. The reason that high CO₂ is because, at that point, it is directly in contact with the highway and the lack of trees. Then at three points after that, the CO₂ concentration levels were lower. This is because the gas produced from vehicles has accumulated a lot at the 0 m point so that at other points, the type of gas is not too much. Other factors that affect CO₂ were also analyzed using a t-test. This test is carried out to determine whether or not the difference in day conditions, LAI, time, and distance from the roadside are significant to CO₂ concentration (table 3).

Table 3. T-test to determine the effect of differences in day conditions, canopy density, day conditions, and distance from the roadside to the concentration of CO₂.

| Coefficients | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|--------------|----------------------------|--------------------------|---|------|
| (Constant)   | 579.571                    | 19.752                   | 29.342 | .000 |
| Day          | 15.438                     | 7.213                    | .178 | 2.140 | .038 |
| LAI          | .349                       | 7.213                    | .004 | .048 | .962 |
| Time         | -43.297                    | 4.417                    | -8.17 | -9.803 | .000 |
| Distance     | -1.950                     | 3.226                    | -.050 | -.604 | .549 |

a. Dependent Variable: CO₂

3.4.1. CO₂ concentration based on weekdays and holidays. Based on data from table 3, it is known that the correlation between CO₂ with working days and holidays has a significance (P-value) of 0.038 > 0.05, which means that day conditions affect CO₂ concentrations. The results from table 2 show that the CO₂ value on measured holidays is higher than on weekdays. The amount of CO₂ on holiday conditions is due to more anthropogenic activities around the park, especially from transportation factors, both from visitor vehicles that come alternately around the parking area and other vehicles that only pass on Pahlawan Seribu.
street. This is in line with research [22] which states that the high concentration of CO₂ on holidays is largely determined by motor vehicle activity.

3.4.2. CO₂ concentration based on LAI. The results of statistical calculations between CO₂ with low and high LAI values show a value (P-value) of 0.962 > 0.05. These results stated that the low and high LAI conditions did not affect the CO₂ concentration. Table 2 shows that there are similarities in the final results of CO₂ measurements, namely at a low canopy density of 511.61 ppm and high canopy density of 511.96 ppm. The low value of the density variable is due to in this study, the average value of the LAI for low and high canopy density has a small range of 1,039-1,409. The small range of values indicates that the canopy density conditions in the two locations are similar. It can be seen in figures 3 and 4 that in conditions of low and high canopy density, the number and species composition of vegetation are almost the same. The similarity also affects the CO₂ absorption of the two canopy density conditions, which have similar capabilities, resulting in the same CO₂ accumulation value.

3.4.3. CO₂ concentration based on measurement time. The effect of different times on the CO₂ concentration analyzed produces a (P-value) of 0.000 < 0.05, where the t count is smaller than the t table. This means that the relationship between CO₂ and day conditions has a significant effect. Data retrieval carried out at 06.00, 01.00, and 05.00 resulted in different CO₂ values. The highest CO₂ concentration occurred at 06.00 and decreased at 01.00 and 05.00. The high CO₂ concentration in the morning is caused by the accumulation of CO₂ concentration resulting from respiration. Besides that, there has not been a wind that disperses CO₂ [23]. According to [24], at night, the trees only emit CO₂ and do not absorb the gas. As a result, the concentration of CO₂ reaches its maximum just before sunrise and lasts until 07.00 am.

CO₂ concentrations were lower in the afternoon and evening, with CO₂ levels almost always below 500 ppm. This phenomenon occurs because the gas produced from human activities is absorbed by actively photosynthesizing vegetation. At 01.00 pm, the sun's intensity is at its maximum, followed by the maximum absorption of CO₂ by the vegetation. Another cause of the decrease in CO₂ concentration during the day is that when solar radiation's intensity is at its maximum, the atmospheric conditions become unstable, resulting in CO₂ dilution, mixed or oxidized with other gases and causing the CO₂ concentration to decrease [25]. Due to the difference in conditions at these times, the fluctuations in the gas are visible [25].

3.4.4. CO₂ concentration based on distance from roadside. The distance of 0 m is the point that is in direct contact with the road or emission source, then the distance of 25 m, 50 m, and 75 m is the point away from the emission source or deeper into the park. Based on the t test results, the result is 0.549 > 0.05, meaning that there is no difference between each distance to the CO₂ concentration. Although at the 0 meter point, the CO concentration is always higher, considering the location of the city park, which is surrounded by many sources of emissions from human activities, causing CO concentration at every distance to be potentially penetrated so that the decrease in CO₂ concentration at the next three points is not too significant.

However, this research also has shortcomings, especially in terms of data collection. Further research is recommended by conducting a measurement of the CO₂ concentration from the emission of the vehicles passing around the research site directly and also speed measurement wind to determine the motion of CO₂.

4. Conclusion
This research concludes that the highest average CO₂ concentration under different canopies is 584.96 ppm at low density and 582.43 at high density, respectively. CO₂ concentrations were higher on holidays than those on weekdays. Then there was no difference in CO₂ concentration in two different canopy density conditions. High concentrations of CO₂ often occur in the morning compared to the afternoon and evening. Finally, the difference in distance does not show a significant difference in CO₂ concentration, but at 0 m, the CO₂ concentration is always high because it is in direct contact with the roadside.
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