Carbon Sequestration Capability Analysis of Urban Green Space Using Geospatial Data

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Abstract. Indonesia is the world’s sixth largest producer of Carbon Dioxide (CO2) emissions. Jakarta is one of the cities in Indonesia with the highest amount of CO2 emission, due to the growing number of population within the city. Anthropogenic activities in the form of industry, transportation, and housing have become one of the primary sources of CO2 emission. The emission is an urban natural hazard, and it needs to be addressed immediately. Green open space is the fundamental solution to this problem. The presence of urban green space will reduce the amount of CO2 emission. Unfortunately, the extent of reduction remains unclear, especially in South Jakarta. The study aims to analyze the capability of urban green space in sequestering CO2 from anthropological aspects such as some population and vehicle in South Jakarta. The sequestration capability of each green open space is measured using the Leaf Area Index generated from remote sensing imagery. The CO2 emission was calculated from some population and the number of vehicles collected from statistical data and ground measurement, respectively. The result shows that green open space distribution significantly correlated with the CO2 sequestration (with the value of 0.79). This study shows that the number of urban green space is one of the solutions to reduce CO2 emissions.

Keywords: urban green space; CO2 sequestration; CO2 emissions; geospatial data.

1 Introduction

Global warming is a phenomenon of rising earth temperatures due to the production of Greenhouse Gases (GHG) one of the CO2 [1]. In the 1990s about two-thirds of CO2 emissions came from developed countries, but CO2 emissions come from developing countries such as Indonesia, which is the world’s sixth largest emitters [2].

Jakarta is the capital of Indonesia which is one of the urban areas. The city of Jakarta which is the capital makes it a center of government and economic activity [3]. The city of Jakarta is the center of activity to make the city of Jakarta has a large population and amount of vehicles, so they make the amount of carbon dioxide emissions getting risen. Large amounts of carbon dioxide emissions can be absorbed with green open space. Green space is a land that consists mostly of surfaces such as grass, shrubs, and trees [4]. Open space defined as part of an urban area that contributes to its ease, both visually by positively contributing to the urban landscape, or based on public access, so that green open space is a combination of green space and public space [4]. South Jakarta is the largest open green city with the widest area of 398.2197 Ha [5]. Also, South Jakarta has the best green open space regarding its utilization in Jakarta [6].

2 The Study Area

South Jakarta located at 106° 22”42 East Longitude s.d. 106° 58”18 ‘east, and 5° 19”12 South Latitude. The total area by the Decision of the Governor of KDKI No. 1815 of 1989 is 141.37 km² or 22.41% of the total area of Jakarta [7].

Fig.1. South Jakarta

3 Methodology

3.1. Data

3.1.1 Green Open Space Distribution

The distribution of green open space can know through the fragmentation index [8] with the equation below:

\[
\text{fragmentation index} = \frac{(m-1)}{(n-2)}
\]

m: number of green open space polygons in the sub-district analysis unit

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n: the total number of polygons in the sub-district analysis unit

The fragmentation index value is between 0 and 1. 0 – 0.5: the distribution of green open space tend to gather. 0.6 – 1: the distribution of green open space tend to spread.

3.1.2 Vegetation Index

The vegetation index is the greenish vegetation value obtained from the digital signal processing of the brightness value data of several satellite sensor data channels. Vegetation index data obtained from SPOT 6 that have processed Method of vegetation index conducted in this research is using the Leaf Area Index (LAI). LAI defined as the leaf area of each unit of surface area covered by a tree canopy [9]. LAI used through the approach of EVI value. EVI (Enhanced Vegetation Index) is an index developed by MODIS data as an improvement of NDVI. EVI showed by equation [10]:

\[
\text{EVI} = G \times \frac{(\text{NIR}_{\text{band}} - \text{Red}_{\text{band}})}{(\text{NIR}_{\text{band}} + C1 \times \text{Red}_{\text{band}} - C2 \times \text{Blue}_{\text{band}} + L)}
\]

\[ L = 1, C1 = 6, C2 = 7.5, \text{ and } G \text{ (factor gain)} = 2.5 \]

The value of EVI obtained is then entered into the LAI equation [11].

\[
\text{LAI} = \frac{3.618 \times \text{EVI} - 0.118}{(\text{Red}_{\text{band}} - \text{NIR}_{\text{band}})}
\]

The vegetation index can determine the type of vegetation and the area of each cover of vegetation. Emission of Carbon Dioxide is the total carbon dioxide emissions in this study based on transportation and anthropogenic. Carbon dioxide emissions from transportation are Carbon dioxide emissions from transport use the equation [12].

\[
\text{Emission (ton/year)} = \text{volume of vehicle} \times \text{EF} \times 10^{-6}
\]

Emission (ton/year) = population x 0.9504 kg/day

Emissions (kg/day) = population x 0.347 ton/year

3.1.3 Carbon dioxide emissions from anthropogenic

Calculation of emissions of carbon dioxide from anthropogenic emissions released by human respiration. The amount of carbon dioxide emitted during the respiratory process is assumed to be the same for every human [13].

\[
\text{Emissions (kg/day)} = \text{population} \times 0.9504 \text{ kg/day} \]

\[
\text{Emissions (to/year)} = \text{population} \times 0.347 \text{ ton/year}
\]

3.1.4 Absorption of Carbon Dioxide Emissions

The absorption capacity of carbon dioxide obtained through the equation (Prasetyo, 2002 cited in Rawung, 2015): The absorption of carbon dioxide (ton/year) = CO₂ absorption by type of vegetation x vegetation cover area (7)

\[
\text{Table 3. CO₂ Absorption}
\]

| Vegetation type | CO₂ Absorption (kg/ha/hour) | CO₂ Absorption (ton/ha/year) |
|-----------------|-----------------------------|-----------------------------|
| Tree            | 129.92                      | 569.07                      |
| Grass           | 2.74                        | 12.00                       |

3.1.5 Residual of Carbon Dioxide Emissions

The residual carbon dioxide emissions obtained from the equation [14]:

\[
\text{Table 2. Sample Location}
\]

| Sample | Sub-district | Street Name        | Street Length |
|--------|--------------|--------------------|---------------|
| 1      | Cilandak     | Pangeran Antasari  | 2.34 km       |
| 2      | Jagakarsa    | Raya Lenteng Agung | 2.45 km       |
| 3      | Kebayoran Baru | Iskandar Syah Raya | 0.54 km       |
| 4      | Kebayoran Lama | Ciledug Raya       | 2.4 km        |
| 5      | Mampang Prapatan | Mampang Prapatan | 1.53 km       |
| 6      | Pancoran     | Pahlawan Kalibata  | 1.27 km       |
| 7      | Pasar Minggu | Warung Jati        | 1.72 km       |
| 8      | Pesanggrahan | Ciledug Raya      | 1.93 km       |
| 9      | Setiabudi    | Rasuna Said        | 2.45 km       |
| 10     | Tebet        | Gatot Subroto      | 1.01 km       |
Residual emissions = Total emissions of CO$_2$ – absorption of CO$_2$ emissions \( (8) \)

3.2. Analysis
The analysis used is descriptive analysis and correlation analysis to determine the strength of the relationship between green open space distribution and the absorption of carbon dioxide emissions by vegetation. Correlation analysis used in this research is the Spearman rank.

4 Result

4.1. Green Open Space Distribution

The fragmentation index can know the distribution of green open space in each sub-district of South Jakarta. Fragmentation index in ten sub-districts in South Jakarta has a value less than 0.5 which means green open space tend to gather in each sub-district.

Table 4. Fragmentation Index

| Sub-district   | GOS (polygon) | NONGOS (polygon) | Fragmentation Index |
|----------------|---------------|------------------|--------------------|
| Cilandak       | 298           | 601              | 0.3307             |
| Jagakarsa      | 549           | 560              | 0.4945             |
| Kebayoran Baru | 362           | 703              | 0.3392             |
| Kebayoran Lama | 494           | 661              | 0.4272             |
| Mampang Prapatan | 151       | 407              | 0.2693             |
| Pancoran       | 242           | 397              | 0.3777             |
| Pasar Minggu   | 478           | 560              | 0.4599             |
| Pesanggrahan   | 421           | 464              | 0.4751             |
| Setiabudi      | 177           | 437              | 0.2871             |
| Tebet          | 221           | 357              | 0.3812             |

GOS: Green Open Space

4.2. Emission of Carbon Dioxide

4.2.1. Transportation and Population Data

Transportation data divided into two data, motorcycle and car (see Table 5). Population data divided into ten according to the number of sub-districts in South Jakarta (see Table 6).

Table 5. Number of Vehicles On Weekdays (260 days) Motorcycle (M) and Car (C) in Each Subdistrict in South Jakarta

| Kecamatan   | M       | C       |
|-------------|---------|---------|
| Cilandak    | 3,293,811| 1,138,529|
| Jagakarsa   | 7,642,149| 1,269,553|
| Kebayoran Baru | 5,268,407| 1,564,091|
| Kebayoran Lama | 4,232,107| 554,471  |
| Mampang Prapatan | 6,178,702| 1,222,268|
| Pancoran    | 3,351,134| 456,996 |
| Pasar Minggu| 2,466,990| 659,871 |
| Pesanggrahan| 1,994,408| 283,707 |
| Setiabudi   | 5,551,322| 2,169,546|
| Tebet       | 7,117,791| 955,466 |

4.2.2. Emissions Data

The highest total carbon dioxide emissions are in Jagakarsa sub-district at 137,381.69 tons/year while the lowest total carbon dioxide emissions in Setiabudi sub-district are 44,738.56 tons/year.

Table 6. Population Data

| Sub-district | Population |
|--------------|------------|
| Cilandak     | 200,358    |
| Jagakarsa    | 378,877    |
| Kebayoran Baru | 143,577  |
| Kebayoran Lama | 306,544  |
| Mampang Prapatan | 146,130  |
| Pancoran     | 153,819    |
| Pasar Minggu | 305,259    |
| Pesanggrahan | 221,584    |
| Setiabudi    | 139,596    |
| Tebet        | 210,978    |
### Table 7. Total Emissions of Carbon Dioxide

| Sub-district    | Transportation Emissions (ton/year) | Anthropogenic Emission (ton/year) | Total Emission of CO2 (ton/year) |
|-----------------|-------------------------------------|---------------------------------|---------------------------------|
| Cilandak        | 3,134.38                            | 71,304.68                       | 74,439.51                      |
| Jagakarsa       | 5,915.54                            | 131,466.15                      | 137,381.69                     |
| Kebayoran Baru  | 248.29                              | 49,655.00                       | 50,903.29                      |
| Kebayoran Lama  | 2,929.74                            | 106,371.80                      | 112,301.80                     |
| Mampang Prapatan| 1,976.21                            | 50,706.76                       | 52,682.97                      |
| Pancoran        | 656.49                              | 56,642.54                       | 57,309.04                      |
| Pasar Minggu    | 1,121.43                            | 105,922.09                      | 107,043.52                     |
| Pesanggrahan    | 913.70                              | 76,887.56                       | 77,801.26                      |
| Setiabudi       | 6,129.96                            | 38,608.60                       | 44,738.56                      |
| Tebet           | 878.48                              | 73,209.36                       | 74,087.85                      |

### Table 8. Absorption of Carbon Dioxide Emissions

| Sub-district    | Vegetation (Ha) | Total Absorptions (tons/year) |
|-----------------|-----------------|------------------------------|
|                 | Grass           | Tree                         |                               |
| Cilandak        | 14.10           | 39.56                        | 22,681.79                     |
| Jagakarsa       | 70.53           | 212.14                       | 121,573.26                    |
| Kebayoran Baru  | 11.82           | 43.28                        | 24,773.21                     |
| Kebayoran Lama  | 24.56           | 70.87                        | 50,367.02                     |
| Mampang Prapatan| 5.18            | 9.48                         | 5,462.06                      |
| Pancoran        | 11.47           | 11.55                        | 6,715.62                      |
| Pasar Minggu    | 41.64           | 154.71                       | 88,541.67                     |
| Pesanggrahan    | 18.13           | 28.45                        | 16,411.28                     |
| Setiabudi       | 6.31            | 6.82                         | 3,960.01                      |
| Tebet           | 8.70            | 11.26                        | 6,513.95                      |

The residual of carbon dioxide emissions divided into three levels. The low level is the value of residual of carbon dioxide emissions from 15,000 tons/year to 30,000 tons/year. The middle class is the value of residual of carbon dioxide emissions from 31,000 tons/year to 50,000 tons/year. The high level is the residual value of carbon dioxide emissions from 51,000 tons/year to 70,000 tons/year.

### 4.4. Residual of Carbon Dioxide Emissions

The highest residual carbon dioxide emissions in Kebayoran Lama Sub-district are 68,674.51 tons/year, and the lowest in Jagakarsa Sub-district is 15,808.43 tons/year.

The residual of carbon dioxide emissions divided into three levels. The low level is the value of residual of carbon dioxide emissions from 15,000 tons/year to 30,000 tons/year. The middle class is the value of residual of carbon dioxide emissions from 31,000 tons/year to 50,000 tons/year. The high level is the residual value of carbon dioxide emissions from 51,000 tons/year to 70,000 tons/year.

### 4.5. The Relationship between The Characteristics of Green Open Space Distribution and The Absorption of Carbon Dioxide Emissions

The distribution of green open spaces in South Jakarta tends to gather based on fragmentation index that has a value less than 0.5 in ten sub-districts. The distribution of green open space has a significant effect on the absorption capacity of carbon dioxide emission based on statistical test result with a significance value of 0.22. Based on the data obtained, the green open spaces that gather have a significant influence and have a positive influence. The positive influence means that the green open space is getting together, the higher the absorption capacity of carbon dioxide emissions. Also, the distribution of green open space and carbon dioxide emission absorption have interrelated relationships based on correlation test results with a correlation coefficient of 0.79.
Table 9. Residual of Carbon Dioxide Emissions

| Sub-district    | Residual carbon dioxide emissions (tons/year) |
|-----------------|-----------------------------------------------|
| Cilandak        | 51,757.72                                     |
| Jagakarsa       | 15,808.43                                     |
| Kebayoran Baru  | 25,130.09                                     |
| Kebayoran Lama  | 68,674.51                                     |
| Mampang Prapatan| 47,220.92                                     |
| Pancoran        | 50,583.41                                     |
| Pasar Minggu    | 18,501.85                                     |
| Pesanggrahan    | 61,389.98                                     |
| Setiabudi       | 40,778.55                                     |
| Tebet           | 67,573.9                                      |

Fig.6. Correlation Table

5 Conclusion

Distribution of green open space in ten districts in South Jakarta tends to cluster with fragmentation index value less than 0.5. The absorption capacity of carbon dioxide emissions by the smallest green open space found in Setiabudi Sub-district and the most massive absorption capacity of carbon dioxide emission green open space is Jagakarsa Sub-district. The lowest total carbon dioxide emissions are Setiabudi Sub-district, and the most significant total carbon dioxide emissions are Jagakarsa Sub-district. The lowest residual carbon dioxide emissions are Jagakarsa Sub-district, then the most massive residual carbon dioxide emissions are Kebayoran Lama Sub-district. The distribution of green open space has a significant effect on the absorption of carbon dioxide emissions. The distribution of green open space and carbon dioxide emission absorption have interrelated relationships based on correlation test results with a correlation coefficient of 0.79.

Acknowledgement

This study is supported and funded by University of Indonesia under the Publikasi Terindeks International untuk Tugas Akhir Mahasiswa (Hibah PITTA) research grant 2018.

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