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 (CO_2) emissions. Jakarta is one of the cities in Indonesia with the highest amount of CO_2 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 CO_2 emission. The emission is an urban natural hazard, and it needs to addressed immediately. Green open space is the fundamental solution to this problem. The presence of urban green space will reduce the amount of CO_2 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 CO_2 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 CO_2 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 CO_2 sequestration (with the value of 0.79). This study shows that the number of urban green space is one of the solutions to reduce CO_2 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 CO_2 [1]. In the 1990s about two-thirds of CO_2 emissions came from developed countries, but CO_2 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 km^2 or 22.41% of the total area of Jakarta [7].

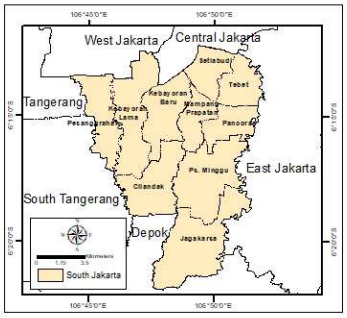

Fig.1. South Jakarta

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:

$$\text{fragmentation index} = \frac{(m-1)}{(n-1)} \quad (1)$$

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]:

$$EVI = G * (NIR_{Band} - Red_{Band}) / (NIR_{Band5} + C1 * Red_{Band} - C2 * Blue_{band} + L) \quad (2)$$

L = 1, C1 = 6, C2 = 7.5, and G (factor gain) = 2.5

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

$$LAI = (3.618 \times EVI - 0.118) \quad (3)$$

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].

Emission (ton / year) = volume of vehicle
VKT x EF x 10^{-6} (4)
VKT: the length of the trip from the vehicle (km)
EF: Emission Factor

Vehicle volume data obtained based on the survey. A survey conducted that is taking ten samples according to the number of sub-districts in South Jakarta. Selection of sample using purposive sampling by determining one street that has traffic using *Waze* application in each sub-district at peak hour that is from 06.30 until 08.00 on weekdays. The road samples presented in figure 2.

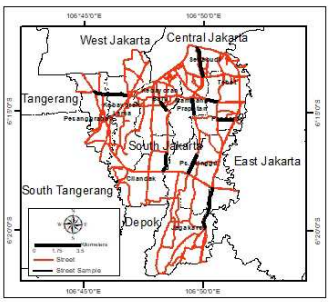

Fig. 2. Road Sample

Table 1. Indonesia Emission Factor (Kementrian Lingkungan Hidup, 2013)

Vehicle Category	CO	HC	NOx	CO_2	SO_2
Motorcycle	14.0	5.9	0.29	3180	0.008
Car	40.0	4.0	0.01	3180	0.026
Truck	2.8	0.2	0.53	3172	0.440

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	2.4km
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

3.1.3.2 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].

Emissions (kg/day) = population x 0.9504 kg/day (5)
Emissions (to /year) = population x 0.347 ton/year (6)

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) = CO_2 absorption by type of vegetation x vegetation cover area (7)

Table 3. CO_2 Absorption

Vegetation type	CO_2 Absorption (kg/ha/hour)	CO_2 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]:

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
Pesanggra-han	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).

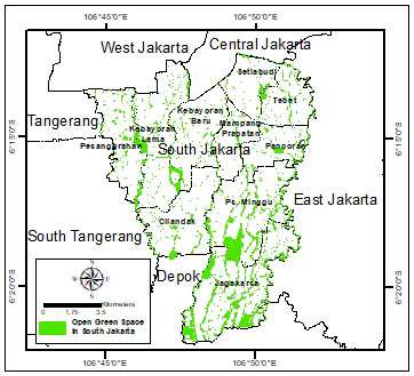

Fig.3. Green Open Space in South Jakarta

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)	Antrho-pogenic 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	49,903.30
Kebayoran Lama	2,929.74	106,371.80	109,301.54
Mampang Prapatan	1,976.21	50,706.76	52,682.97
Pancoran	656,49	56,642.54	57,299.04
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

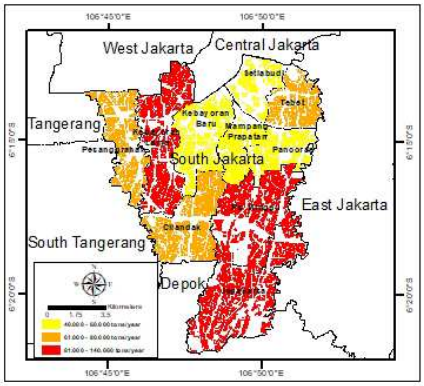

Fig.4. Total Emissions in South Jakarta

Total carbon dioxide emissions divided into three levels. The low level is the total value of carbon dioxide emissions from 40.000 tons/year to 60.000 tons/year. The middle class is the total value of carbon dioxide emissions from 61,000 tons/year to 80,000 tons/year. The high level is the total value of carbon dioxide emissions from 81,000 tons/year to 140,000 tons/year.

4.3. Absorption of Carbon Dioxide Emissions

The absorption capacity of carbon dioxide emissions by green open space in South Jakarta amounted to 337,259.92 tons/year with Setiabudi Sub-district which has the lowest absorption of carbon dioxide emission of 3,960.01 tons/year and green open space in Jagakarsa sub-district which has the highest absorption capacity of carbon dioxide of 121,573.26 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.

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	40,627.03
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.

4.5. 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.

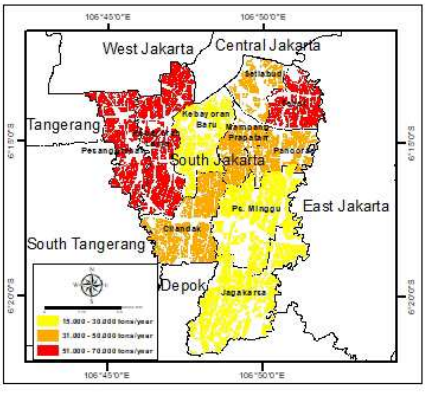

Fig.5. Residual of CO2 Emissions in South Jakarta

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

Correlations

			Dist	Absorp
Spearman's rho	Dist	Correlation Coefficient	1.000	.709*
		Sig. (2-tailed)	.	.022
		N	10	10
	Absorp	Correlation Coefficient	.709*	1.000
		Sig. (2-tailed)	.022	.
		N	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

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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