

Vegetation resilience to absorbing carbon dioxide emissions in the Gajahmada Street

Miftachurahma Widanirmala^{1,3*}, *Maryono* Maryono^{2,3}, and *Fuad* Muhammad^{1,3}

¹ Master Program of Environmental Science, School of Postgraduate, Diponegoro University, Indonesia

² Department of Urban and Regional Planning, Faculty Engineering, Diponegoro University, Indonesia

³ Centre for Green Infrastructure Resilience and Development, School of Postgraduate, Diponegoro University, Indonesia

Abstrak. Gajahmada Street is one of the main streets in the city of Semarang. The location is very strategic, which connects the Golden Triangle Region in Semarang City which is the center of the city. As a city center, transportation activities in the area are very high. Transportation activities produce carbon dioxide emissions. The accumulation of carbon dioxide emissions is dangerous for health and the environment. Semarang City Government provides green open space along the road section to reduce carbon dioxide emissions. The purpose of this study was to determine the vegetation resilience to absorbing carbon dioxide at that location. The data collection method uses literature collection and field observations. The results showed the ability of green open space to absorb carbon dioxide emissions is 1.218,7 tons/ha/year. While the emissions produced are 6.832 tons/year, meaning that there is residual carbon dioxide that is not absorbed, that is 5.613,3 tons/year.

Keywords: vegetation resilience, carbon absorption, emissions, Gajahmada Street

1 Introduction

Global warming is an increase in the earth's average temperature due to the concentration of greenhouse gases (GHGs) [1]. Increase in average temperature - based on increasing concentrations of GHGs [2]. GHGs consists of CO₂, N₂O, NO₂, CH₄, CFC, etc. The gas will accumulate in the earth and form a transparent layer in the earth's atmosphere which is likened to the glass layer. As a result, sunlight cannot be reflected and becomes trapped on earth. This causes an increase in the temperature of the earth.

* Corresponding author: widanirmalawini@gmail.com

Carbon dioxide is the gas that can last the longest in the atmosphere. CO₂ can last 50-200 years, N₂O for 114-120 years, CH₄ and CFC substitutes for 12 years [3]. Basically, carbon dioxide is an important gas for photosynthesis. However, excessive levels can be dangerous for the environment, which triggers global warming, acid rain, etc. For health, exposure to low levels of carbon dioxide gas can cause dizziness, hyperventilation, eye and throat irritation, minor lung disorders, central nervous system injuries, etc. While exposure to high levels can cause oxygen supply to be obstructed, which can cause seizures - even death.

Based on IPCC data at 2007, from 1970 to 2004 there has been an increase in carbon dioxide equivalent of 77%, from 21 Gt of CO₂-eq to 31 Gt of CO₂-eq [2]. In Indonesia, based on the 2018 Greenhouse Gas inventory report by the Ministry of Environment and Forestry, during the last 17 (seventeen) years there was an increase in carbon dioxide of 124,879 Gg (124,879,000 Tons). Transportation activities were the second largest contributor to the increase in carbon dioxide, which amounted to 17.20%.

For modern urban society, transportation is a vital means of movement that cannot be separated from daily activities. Especially in Indonesia, almost all of the cities are developed based on the pattern of land transportation networks. This creates a dilemma, on the one hand the land transportation system has become a dependency for the community, but on the other hand land transportation is suspected to threaten urban ecological conditions.

Green open space is one solution to reduce global warming [4]. Green open space is an area that extends or lines and or groups, the use of which is more open, a place to grow plants, both naturally and intentionally planted. The provision of green open space is suspected to reduce carbon dioxide [5]. Green open space has an important role to improve the quality of life in urban areas, one of them as a very effective air purifier [6]. Green vegetation, especially trees, has the ability to absorb large amounts of carbon dioxide. One tree has the ability to absorb carbon dioxide of 569 tons / ha / year.

Trees are vegetation that have an important role in the process of reducing the concentration of CO₂ in the air through the process of photosynthesis. Trees have the highest CO₂ absorption compared to other types of vegetation (shrubs and groundcovers), because they have greater biomass compared to other vegetation. The part of the tree in charge of absorbing CO₂ is the leaves through the stomata. Then the carbon will be stored in the biomass, namely in the stems and leaves. Compared to leaves, stems can deviate far more carbon [5]. Even 50% of the total dry stem consists of carbon. The amount of carbon stored in biomass is called carbon storage. While the ability of plants to absorb carbon is called carbon sequestration [7].

Based on the Spatial Planning Law, the green space requirements that must be met by the City are 30% of the total area, with the provisions that 20% are public and 10% are private. Semarang City is one of the cities in Indonesia that has fulfilled the provision of public green open space [8]. Based on information from the City of Semarang Department of Commerce, the number of green open space in the city of Semarang is 35%, which means it has exceeded the recommended minimum. Viewed in quantity, the presence of green open space in the city of Semarang has met the provisions. However, judging from its function, is the presence of green space effective enough to reduce the CO₂ emissions produced? For this reason, this study aims to determine the ability of CO₂ absorption by vegetation. Case study was carried out on the Jl. Gajah Mada. The location was chosen because transportation activities on the road section are quite high, resulting in considerable CO₂ emissions. Gajahmada Street is one of the main streets in the city of Semarang. Its location is very strategic, which connects the Golden Triangle Region in Semarang City which is the center of the city. In addition, the use of land on these roads is also very complex, giving rise to high generation and pull

2 Method

2.1 Data collection methods

Data collection methods used in this study are literature studies, observations and interviews. Literature study is carried out by gathering literature related to the topic to be studied. Observations were made by observing daily traffic and inventorying the types of vegetation on Gajah Mada Street. Interviews were conducted with relevant agencies responsible for managing green open spaces on Gajah Mada Street.

2.2 Data analysis method

To find out the adequacy of green open space in absorbing CO₂ emissions in Gajahmada Street, it is done by: 1) calculating the CO₂ absorption by vegetation, 2) calculating CO₂ emissions resulting from transportation activities on Jl. Gajahmada, 3) analysis of the adequacy of green space to absorb emissions.

Analysis of vegetation resilience (carbon stocks by trees)

Plants need CO₂ to carry out photosynthesis. The results of the absorption of CO₂, will be converted into carbohydrates which will then be spread and piled up in the body of the plant. The process is called C-sequestration. Therefore, measuring carbon still stored in the body of living plants (biomass) can describe the amount of CO₂ that can be absorbed by plants. According to the [9], half the biomass of trees is CO₂. Calculation of CO₂ deposits in plant biomass is carried out using a formula developed by [9]:

$$= 0,5 \quad (1)$$

Note :

C : carbon stock (C/Ha)

W : biomass (kg)

0,5 : Coefficient of carbon in plants

Tree biomass is calculated using the allometric formula [5]:

$$= 0,11 \rho^{2,62} \quad (2)$$

Note :

BK : biomass (kg)

D : diameter (cm)

ρ : BJ wood (g cm⁻³)

Furthermore, to find out the potential uptake of CO₂ will be done by adding up carbon stocks in each tree:

$$(carbon\ stocks\ by\ A\ tree\ x\ number\ of\ A\ tree) + (carbon\ stocks\ by\ A\ tree\ x\ number\ of\ A\ tree) + \dots \quad (3)$$

Quantity analysis of CO₂ emissions

Calculate CO₂ emissions generated using the Tier 2 Method [10], with the formula:

$$Q = Ni \times Fei \times L \times Kl \quad (4)$$

Note :

- Q : emission amount (g/hour)
- Ni : number of vehicles (vehicles/hour)
- Fei : emission factor of vehicles (g/liter)
- Kl : fuel usage (liter/100 km)
- L : long road (km)

Table 1. Emission factor

Type of vehicles	Emission factor			
	CH ₄	CO	N ₂ O	CO ₂
Fuel				
Passenger vehicles	0,71	462,63	0,04	2597,86
Small commercial vehicle	0,71	295,37	0,05	2597,87
Big commercial vehicle	0,73	281,14	0,06	2597,88
Mototcycle	3,56	427,05	0,07	2597,89
Diesel				
Passenger vehicles	0,08	11,86	0,16	2924,90
Small commercial vehicle	0,04	15,81	0,16	2924,90
Big commercial vehicle	0,24	35,57	0,12	2924,90
Locomotive	0,24	24,11	0,08	2924,43

Sumber: [10]

Table 2. Fuel consumption of vehicles

No	Type of vehicles	Fuel consumption of vehicles (liter/100 km)
1	Passenger car	
	Fuel	11,79
	Diesel	11,36
2	Big bus	
	Fuel	23,15
	Diesel	16,89
3	Medium bus	13,04
4	Small bus	
	Fuel	11,35
	Diesel	11,83
5	Bemo or bajaj	10,99
6	Taxi	
	Fuel	10,88
	Diesel	6,25
7	Tronton truck	15,82
8	Medium truck	15,15
9	Small truck	
	Fuel	8,11
	Diesel	10,64
10	Mototcycle	2,66

Sumber: [10]

Analysis of the adequacy of green open space to absorb CO₂ emissions

An analysis of the adequacy of green space to absorb CO₂ emissions is done by comparing the carbon stock of green space on Gajahmada Street with CO₂ emissions resulting from transportation activities.

3 Results and Discussion

3.1 Type of vegetation in green open spaces pedestrians on Gajahmada Street

Gajahmada street is located in Sekayu Village, Central Semarang District. The location is very strategic, which is located in the city center and connects the golden triangle of the City of Semarang. Based on the Minister of Public Works Regulation No: 05 / PRT / M / 2008, the type of green open space in the study location is pedestrian open space. Green open spaces is provided as one with the pedestrian space along Jalan Gajahmada. The dominance of vegetation in the form of shade vegetation which has the function to provide shade for pedestrians, while reducing CO₂. However, it is very regrettable that the density of trees in this green space is still low.

The type of tree that is on the Gajahmada Street consists of 14 species with a total of 141 trees. The vegetation types are Angsana, Ordinary Glodokan, Mahogany, Pulai, Asa, Java, Glodokan Pole, Tabebuya, Squirrel Tail Palm, Sawo Duren, Cambodia, Acacia, Mango Apple, Mango, and Yellow Coconut. Existing vegetation is dominated by Angsana Tree and Ordinary Glodokan. Vegetation in the study area is included in the category of medium and large trees with varying diameters. Medium category trees have an average diameter of 21 cm, while large category trees are 60 cm.

3.2 Analysis of vegetation resilience (carbon stocks by trees)

Vegetation Resilience of carbon absorption is the ability of trees to absorb CO₂ in their bodies. The following is presented the potential for carbon uptake in the pedestrian green space on Gajahmada Street.

Table 3. CO2 absorption by vegetation

No.	Local name	Latin name	Total of tree	Absorption CO2 on Gajahmada Street (kg/year)
1.	Angsana	<i>Pterocarpus indicus</i>	52	98.950,3
2.	Glodokan Biasa	<i>Polyalthia sp.</i>	14	16.148,4
3.	Mahoni	<i>Swietenia macrophylla</i>	23	5.382
4.	Pulai	<i>Alstonia scholaris</i>	20	9.699,5
5.	Asam Jawa	<i>Tamarindus indica</i>	11	2.950,8
6.	Glodokan Tiang	<i>Polyalthia longifolia</i>	8	1.052,2
7.	Tabebuaya	<i>Handroanthus sp.</i>	2	313
8.	Palem Ekor Tupai	<i>Wodyetia bifurcata</i>	3	119,4
9.	Sawo Duren	<i>Chrysophyllum cainito</i>	1	16,3
10.	Kamboja	<i>Plumeria</i>	1	14,2
11.	Akasia	<i>Acacia sp.</i>	3	4.918
12.	Mangga Apel	<i>Mangifera indica</i>	1	6.403
13.	Mangga	<i>Mangifera sp.</i>	1	138,9
14.	Kelapa Kuning	<i>Cococs nucifera</i>	1	136,8
Total			141 tree	146.243,4 kg/year or 146,3 tons/year
Wide open green space: 1,2 x 1000 m = 1.200			m ² / 0,12 Ha	1.218,7 tons/ha/year

Table 3, potential CO2 uptake on Gajahmada Street is 1,218.7 tons/ha/year. Basically, plants need CO2 gas for photosynthesis. Plants need CO2 to carry out photosynthesis. The results of the absorption of CO2 will be converted into carbohydrates which will then be spread and piled up in the body of the plant. Each type of vegetation has the ability to absorb different CO2. According to Hidayati et al (2013), the ability of carbon dioxide uptake from each tree is influenced by the number of stomata and the ability of stomata to open a plant. The greater the opening of the stomata, the greater the ability of carbon dioxide absorption. In addition, the size of the rod also affects the carbon storage capacity. Because 50% of the carbon stock is stored in the trunk.

3.3 CO2 emissions on Gajahmada Street

CO2 emissions on Gajahmada Street is sourced from transportation activities. Gajahmada Street is the main road that connects the Golden Triangle Region of Semarang City. In addition, the use of surrounding land is quite complex, namely: settlement, trade and services, education, and worship. As a result, the generation and pull of traffic in this area is quite high. The rise and pull of traffic can be seen from the high volume of vehicles passing through this road section. The following is the vehicle volume on Gajahmada Street:

Table 4. CO2 emissions on Gajahmada Street

No.	Type of vehicles	Volume of vehicles*	CO Emission (g/hour)
1.	Kendaraan Ringan (LV)	1142	175.805
2.	Kendaraan Berat (HV)	12	142
3.	Sepeda Motor	2253	320/164
4.	Angkutan Umum	14	166
Total emission of CO			496.277 g/hour or 4.347,4 tons/year
Conversion CO to CO2			6.832 tons/year

*Source: Field Observation (2017)

Table 4, vehicles passing through Gajahmada Street consist of long vehicles, heavy vehicles, motorbikes, and public transportation. The types of vehicles that pass this road are 2253 units of motorbikes and 1142 private cars. Of the many vehicles that pass through these roads cause exhaust gases that contain emissions, in the form of: Carbon monoxide (CO), Sulfur (SOx), Nitrogen oxide (Nox), Hydro carbon (HC), dust (TSP) and lead (PB). CO gas when oxidized in the earth's atmosphere can turn into CO₂ gas which is a greenhouse gas, triggering global warming.

Based on the calculation results, CO emissions are generated from vehicles passing through Jl. Gajahmada of 4,346.4 tons/year. If converted into CO₂ it becomes 6,832 tons/year. This figure is quite high, and can continue to increase given the trend in the number of vehicles in the city of Semarang is exponential.

3.4 Adequacy of green open space to absorbing CO₂ emissions on Gajahmada Street

Adequacy of green open space : CO₂ absorption – CO₂ emissions

$$: 1.218,7 \text{ ton/ha/year} - 6.832 \text{ tons/year}$$

- 5.613,3 ton/year

From the calculation of CO₂ absorption by vegetation and CO₂ emissions on Gajahmada Street is known to have residual CO₂. That is equal to 5,613.3 tons / year. That is, the amount of green open space provided is insufficient so there is left over. Basically, plants need CO₂ gas for photosynthesis. However, excess CO₂ levels cannot be absorbed and can survive in the atmosphere for up to 200 years. Long-term accumulation of CO₂ gas can cause environmentally and health problems. For the environment it can cause global warming, acid rain, etc. For health, exposure to low levels of CO₂ gas can cause dizziness, hyperventilation, eye and throat irritation, mild lung disorders, central nervous system injuries, etc. While exposure to high levels can cause oxygen supply to be obstructed, which can cause seizures - even death.

4 Conclusions and recommendations

The ability of CO₂ absorption by vegetation on Gajahmada Street of 1,218.7 tons / ha / year. While emissions resulting from transportation activities at these locations are 6,832 tons / year. It can be concluded that there are residual emissions as large as 5,613.3 tons / year, so that the presence of vegetation is not optimal in reducing CO₂.

Suggestions given, it is necessary to add vegetation to the pedestrian green space on Gajahmada Street. It is very possible, seeing the density of trees is still low. In addition, the proposed selection of trees with high carbon absorption: such as trembesi.

Acknowledgement

The research is funded by Directorate Research and Community Services, Deputy of Research Development, Ministry of Research and Technology / National Research and Innovation Board with cooperation between Institute of Research and Community Services Diponegoro University taskforce letter No. 255-141/UN7.6.1/PP/2020

References

1. Rusbiantoro, D, *Global warming for beginner* (2008)
2. IPCC. *Guidelines for National Greenhouse Gas Inventories*. Volume 2: Energy (2008).
3. K. Sejati, *Global Warming, Food, and Water Problems, Solutions, and The Changes of World Geopolitical Constellation* (2011)
4. N. Kusumaningrum, *Jurnal Permukiman, Potensi tanaman dalam menyerap CO₂, dan CO untuk mengurangi dampak pemanasan global*. Vol 3 (2) pp. 97-105 (2008).
5. K. Hairiah et all, *Pengukuran cadangan karbon*, Wolrd Agroforestry Centre (2011).
6. Law of *Permen PU No.5/PRT/M, 2008 Tentang Pedoman Penyediaan dan Pemanfaatan Ruang Terbuka Hijau di Kawasan Perkotaan*.
7. K. Hairiah, S. Rahayu, *Pengukuran karbon tersimpan di berbagai penggunaan lahan*, Wolrd Agroforestry Centre (2007).
8. Law No 26 of 2007 concerning *Spatial planning*
9. IPCC. *Guidelines for National Greenhouse Gas Inventories* (2006).
10. B.A. Laksono, *Jurnal Teknik Lingkungan ITS, Analysis of the sufficiency of vegetation in absorbing carbon monoxide (CO) due to motor vehicles activity on the Ahmad Yani Street Surabaya* (2014)
11. Kementerian Lingkungan Hidup dan Kehutanan Direktorat Jenderal Pengendalian Perubahan Iklim Direktorat Inventarisasi Gas Rumah Kaca dan MPV. *Laporan Inventarisasi Gas Rumah Kaca dan Monitoring, Pelaporan Verifikasi Tahun* (2018)