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Analysis of the Availability of Green Open Space in Absorbing CO2 Gas Emissions in Somba Opu District, Gowa Regency

Muhammad Irsyam Bachri[1], Firdaus[2*], Muhammad Nurhidayat[3]
Muhammadiyah University of Makassar
Corresponding Author: Firdaus firdaus.yusuf@unismuh.ac.id

A R T I C L E I N F O

Kata Kunci: Co2 Gas Emissions, Greenhouse Gas, Somba Opu Sub-District, Green Open Space, Vegetation

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A B S T R A C T

Somba Opu sub-district is an urban area with high population activity, this can contribute to global warming due to greenhouse gas (CO2) emissions. This research aims to assess the effectiveness of green open space in absorbing CO2 gas emissions and provide direction for its development. The analysis method used is based on the 2006 IPCC guidelines by calculating emissions and analyzing the absorption capacity of vegetation in green open spaces. The calculation results show that green open space has not been able to absorb all CO2 gas emissions produced. Therefore, it is necessary to develop green open space with a focus on adding vegetation because it is able to absorb CO2 gas emissions in order to support efforts to mitigate climate change and improve environmental quality

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INTRODUCTION

Global warming is a phenomenon that occurs due to the increasing concentration of greenhouse gases in the atmosphere. This phenomenon is influenced by human activities, both directly and indirectly, which cause changes in atmospheric composition and natural climate variability. One of the most contributing gases in global warming is carbon dioxide (CO2) gas that result from the combustion of fossil fuel and the use of electrical energy (Sitadevi, 2017).

As an area develops, physical changes such as increased residential devolepment, industry, and public facilities contribute to increased CO2 emissions (Boedoyo, 2011). Gowa Regency, as buffer zone of Makassar City, is experiencing rapid population growth and increased urban activity. Somba Opu Sub-District, wich is the capital of Gowa Regency, has a high level of population mobility, potentially increasing CO2 emissions, both from the transportation sector (mobile emissions) and the household sector (non-mobile emissions). Based on data from weather spark and accu weather, the average temperature in Somba Opu Sub-District has increased, from 23ºC-31ºC in 2023 to 27ºC-36ºC in 2024, reflecting the ral impact of increased greenhouse gas emissions in this region.

One of the mitigation effort to reduce the impact of greenhouse gases is to provide green open space. Vegetation in green spaces plays a role in absorbing carbon dioxide and reducing greenhouse gas emissions in urban areas (Rawung, 2015). In addition, the selection of approprivate vegetation types and good maintenance of greeb spaces can help reduce temperature increases and increase environmental resilience (Aziz, 2018). Based on the Regulations of the Minister of Agrarian Affairs and Spatial Planning/National Land Agency Number 14 of 2022, ideally an area should have 20%-30% of its total area as green space. RTH contributes to spatial control, ecosystem balance, and improving the quality of the urban environment (Rachmayanti & Mangkoedihardjo, 2021). Therefore, a study is needed to assess the effectiveness of green space reducing the impact of greenhouse gases in Somba Opu Sub-District. This study aims to analyze the extent to which greenspace area able to reduce CO2 emissions in the region.

LITERATURE REVIEW

Urban Area

In Government Regulation of the Republic of Indonesia Number 59 of 2022, urban areas are areas with certain boundaries that are primarily focused on industry, services, and trade. This area does not involve agriculture and consists of residences, government services center, social services, and economic activities. The management of urban areas includes the provision, operation and maintenance of urban sevices, as well as planning to meet the living needs of city residents (Haikal et al., 2023).

Urban areas are areas with dense settlements that are organized, supported by various infrastructure fascilities, and have diverse economic, social and culture acitivities. In the context of rapid urbanization, urban areas are also the focus of sustainable development and urban planning. Therefore, urban areas function as center of activity that influence the development of surrounding district or cities.

Climate Change

Climate change is a long-term change temperature and weather patterns due to an increase in greenhouse gases sucht as carbon dioxide and matthane. The main contributing factor are human activities, such as the burning of fossing fuels and deforestation, although natural factors such as volcanic eruptions are also influential (Samidjo & Suharso, 2017)

In urban areas, emissions from transportation, industry and reduced green space exacertable global warming (Sitadevi, 2017). Indonesia is particularly vulnerable to its impacts, such as floods, droughts and forest fires. According to the 2007 Climate Change Conference, the main cause in Indonesia is deforestation and the destruction of carbon dioxide-absorbing ecosystems.
Solutions to address climate change include mitigation, such as switching to renewable energy and energy efficiency and adaptation, such as building disaster-resistant infrastructure and safeguarding natural resources.

Global Warming

Global warming is an increase in the Earth's surface temperature of about 5°C per year, causing climate change around the world. One of the impacts is the melting of ice at the north and south poles, which has the potential to raise sea levels and submerge many islands. The main cause of global warming is pollution from greenhouse gases, especially carbon dioxide, which traps heat in the atmosphere (Pratama & Parinduri, n.d.). The United Nations established the IPCC (Intergovernmental Panel on Climate Change) research group, which found that global warming is directly linked to human activities that produce greenhouse gases. Although the impact is increasingly evident, concrete efforts to address global warming are still minimal.

In Indonesia, global warming is causing extreme climate change. Some regions are experiencing droughts and water crises, while others are facing excessive rainfall, floods and landslides (Samidjo & Suharso, 2017). Data from BMKG shows that the average temperature in Indonesia in 2023 will reach 27.2°C, an increase of 0.5°C compared to the average temperature for the 1991-2020 period.

Greenhouse Gas (CO2)

The greenhouse effect causes global warming by trapping solar heat in the atmosphere and the main contributing gases are carbon dioxide (CO2) and methane (CH_4) (Rawung, 2015). UNFCCC menyebut CO2 sebagai penyebab utama perubahan iklim. Secara alami, CO2 diserap tumbuhan dan dilepaskan melalui respirasi serta dekomposisi he UNFCCC names CO2 as the main cause of climate change. Naturally, CO2 is absorbed by plants and released through respiration and decomposition (Aziz, 2018). owever, human activities such as burning fossil fuels and deforestation increase CO2 levels in the atmosphere (Lestari, 2019). The Agency for the Assessment of Climate Policy and Industrial Quality (2012) noted that CO2 accounts for more than 75% of greenhouse gases, causing temperature rise, ice melt, sea level rise, and extreme weather. Solutions to reduce its impact include the use of renewable energy such as wind, solar, and hydroelectric, as well as the development of green spaces to absorb CO2 (Rawung, 2015).

Ruang Terbuka Hijau

Green Open Space (RTH) is an area dominated by vegetation, either in the form of urban parks, urban forests, or green lanes, which serves to improve the quality of the urban environment. According to the Regulation of the Minister of Agrarian Spatial Planning/National Land Agency Number 14 of 2022, RTH includes public and private spaces used to maintain ecological balance and improve the aesthetics of urban areas.

RTH has an important role in reducing the impact of greenhouse gases through the process of photosynthesis, where vegetation absorbs CO2 and produces oxygen. The presence of extensive green spaces can reduce air temperature and increase environmental humidity, thereby reducing the impact of global warming in urban areas (Sitadevi, 2017). In addition, vegetation in green spaces also helps filter air pollutants and improve environmental quality.

METHODOLOGY

This study uses a quantitative method with a comparative approach to compare the ability of green open space to absorb CO2 emissions. The objective was to measure the effectiveness of green open space in reducing CO2 emissions and describe the results.

The research location was in Somba Opu Sub-district, which was divided into three segments based on road function, traffic direction, and building density. Data were collected through field observations by identifying the number and function of buildings, vehicle volume, and the amount of vegetation in green open spaces.

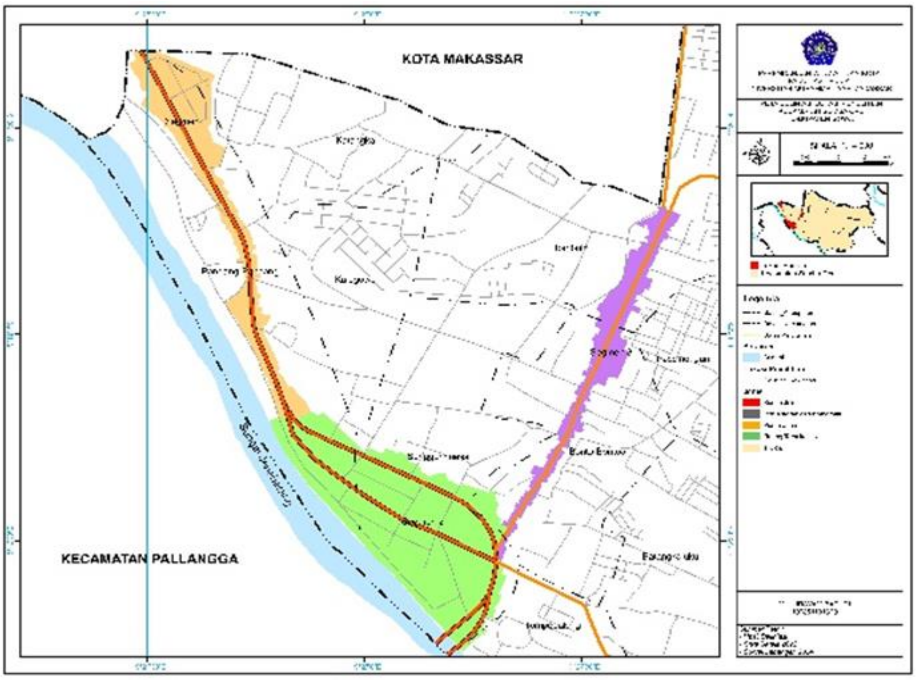


Figure 1. Research Location

This study used a non-probability sampling method with two types of samples: mobile emissions (the number of vehicles passing through the three segments) and stationary emissions (the number of buildings in the area). Vehicle sampling was conducted during peak hours, namely morning (07.00-09.00), afternoon (12.00-14.00), and evening (16.00-18.00). Data analysis is based on the results of field surveys with several approaches used. The following are the analysis methods applied in this study:

CO2 Gas Emission Sources

Sources of CO2 gas emissions at the research site were obtained from literature and field survey results. There are two main generating sources, namely mobile emissions sources that use fossil fuel and can move, while stationary emission sources are activities that are in a fixed location with the use of electrical energy. The classification of emission sources at the research site is shown in table 1.

Table 1. Classification of Emissions Sources of the Stude Site

Mobile Emissions Sourcec	Stationary Emissions Sources
Motorcycle	Office (Commercial)
Sedan Car	Resedential

CO2 Gas Emission Quantity Analysis

CO2 emissions come from fuel combustion and fall into two main categories: mobile and stationary emissions sources. This calculation refers to the 2006 IPCC guidelines with multilevel approach. The CO2 emissions factor in this study is calculated based on table 2 according to the 2006 IPCC guidelines.

Table 2. Greenhous Gas Emissions Factor CO2

Fuel Type	FE Default IPCC Tahun 2006 (Stationary Source)	FE Default IPCC Tahun 2006 (Mobile Sources)
Natural Gas/BBG	56.100	56.100
Premium	-	69.300
Solar	74.100	74.100
LPG	63.100	-
Kerosene	-	-

Emissions from mobile sources were calculated using equation (2). Before that, fuel consumption was calculated based on mileage. Fuel consumption data for each vehicle refers to BPPT (tabel 3) and related formulas. The annual amount of fuel was then converted to Terra Joule (TJ) to determine the total CO2 emissions.

Table 3. Specitic Energy Consumption

Vehicle Type	Fuel Oil Type	Specific Energy Consumption (liter/100km)
Motorcycle	Premium	2,66
Sedan Car	Premium	10,88

$$\text{Daily Fuel Consumption} = \left(\frac{\text{Mileage (km)x SpecificEnergy Consumption}}{100\ (\text{km})}\right) =$$

After knowing the specific energy consumption per mileage, calculate the total annual fuel consumption based on the average daily vehicle volume with the following formula.

$$\text{Annual fuel Consumption} = (\text{Specific Energy Consumption x Averafe Vehicle}) \text{ x Finger Count(year)} =$$

IPCC emissions factors are expressed in kg/TJ/year. Before calculating equation (2), energy consumption must be converted to TJ using equating (3) and table 4 below.

$$\text{Energy Consumption (TJ)} = \text{Energi Consumption i(physical unit)x Calorific Value} \left(\frac{\text{TJ}}{\text{physical unit}}\right) = \cdots \quad (3)$$

Description
Energy Consumption (sat.physical) : Total vehicle fuel consumption
Calorific Value : Factor value (based on Book II Vol. I Greenhouse Gas Emission Rate Calculation Method, Ministry of Environment 2012).

Table 4. Calorific Value of Fuel in Indonesia

Fuel	Calorific Value
Premium	$33 \text{x} 10^{-6}$ TJ/Liter
Solar (HSD, ADO)	$36 \text{x} 10^{-6}$ TJ/Liter
Diesel Oil (IDO)	$38 \text{x} 10^{-6}$ TJ/Liter
MFO	$40 \text{x} 10^{-6}$ TJ/Liter
Natural Gas	$1.055 \text{x} 10^{-6}$ TJ/Liter
LPG	$47{,}3.5 \text{x} 10^{-6}$ TJ/kg
Coal	$18.9 \text{x} 10^{-3}$ TJ/ton

$$\text{GRK Emissions} \left(\frac{\text{kg}}{\text{year}}\right) = \text{Energy Consumption} \left(\frac{\text{tj}}{\text{year}}\right) \text{x Emission Factor} \left(\frac{\text{kg}}{\text{year}}\right) = \quad (2)$$

Description
GRK emissions : Type-specific GRK emissions by fuel type
Energy Consumption : Amount of fuel burned by type
Emission Factor : Emission factor of a specific type of GHG by fuel type

Stationary emission sources come from electricity consumption of offices (17 kWh/day or 6205 kWh/year) and settlements (7 kWh/day or 2555 kWh/year). The total annual electricity consumption for the three segments is calculated by the following formula.

$$\text{Electricity Consumption (kWh)} = \text{Total Building Units x Electricity Consumption Units}\left(\frac{\text{kWh}}{\text{year}}\right) =$$

Furthermore, for the calculation of emissions from electrical energy consumption in stationary source emissions, equation (4) is used.

$$\text{Emissions} = \sum \text{Electricity Consumption X Emissions Factor} = \quad (4)$$

Descripton
Emissions : CO^2 Emissions
Electricity Usage : Electric energy consumption (kWh)
Emission Factor : Baseline CO^2 emission factor of South Sulawesi electricity is 0, 82 kg CO^2/kWh.

Analysis of the Absorbency of the Directive and the Need for Green Open Space (Vegetation)

The absorption capacity of green spaces to CO^2 emissions is calculated based on the amount of vegetation present. The calculation is done by referring to the land cover type and vegetation type using equation (5). The results are used to reduce total CO^2 emissions at the study site.

$$\text{Absorption Capactiy of Exsiting Green Spaces} = \text{CO2 Absorption Capacity X Total Vegetation} = \quad (5)$$

Description
Absorbency of Existing Green Space : The ability of existing green spaces to absorb emissions
CO^2 Absorbency : The ability of vegetation types to absorb emissions
Total Vegetation : Green space based on vegetation cover

The first step in calculating the need for green spaces is to determine the remaining CO^2 emissions that have not been absorbed by existing green spaces. The remaining emissions are obtained by reducing the total CO^2 emissions by the absorption capacity of the existing green space. The following equation (6) is used.

$$\text{Remaining Emissions} = \text{Total Emission CO2} - \text{Absorption Capacity of Exisiting RTH} = \quad (6)$$

Description
Residual Emissions : CO2 emissions that have not been sequestered
Total Emissions : The result of CO2 production calculation
Absorption Capacity of Exsisting RTH : The ability of existing green spaces to absorb emissions

Absorption Capacity of Exsisting RTH : The ability of existing green spaces to absorb emissions

If based on the results of the calculation of residual emissions, that the existing green open space has not been able to reduce the total existing CO^2 gas emissions, then after the calculation in equation (6) will be continued by calculating the need for additional green open space using equation (7) in the following calculation.

$$\text{Green Space Need} = \left(\frac{\text{Residual Emissions}}{\text{Vegetatiton Absorption Capacity}}\right) \quad (7)$$

Description
Green Space Needs : Greenspace addition in reducing CO^2 emission
Residual Emissions : CO2 emissions that have not been absorbed
Vegetation Absorption Capacity : The ability of vegetation to absorb CO^2 emissions

RESULTS AND DISCUSSION

The research location is in Somba Opu Sub-district which is the capital city of Gowa Regency with coordinates 5°12'5'' N-S and 119°27'15'' E and the area reaches 2,869.16 ha. The research location is divided into 3 segments.

1. Segment 1 is located in Kelurahan Pandang-pandang and parts of Kelurahan Katangka (Figure 2) with an area of 21.78 ha. This area is dominated by offices (11.86 ha), followed by housing (4.21 ha), roads (2.69 ha), sidewalks (2.05 ha), shrubs (0.88 ha), and parks (0.09 ha).

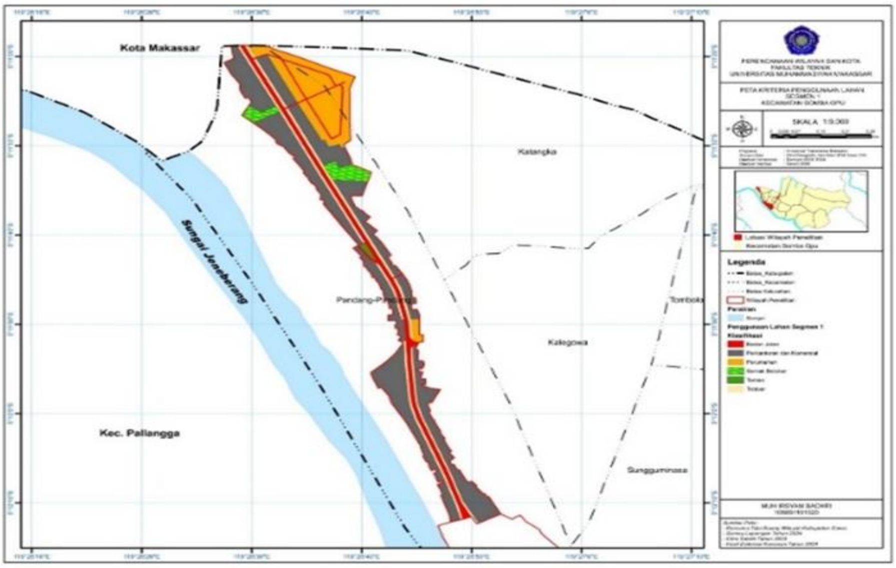


Figure 2. Segment 1 Land Use Characteristics Map

2. Segment 2 is located in Kelurahan Sungguminasa, parts of Kelurahan Pandang-pandang, and Kelurahan Bonto-bontoa (Figure 3) with an area of 48.76 ha. This area is dominated by offices (18.74 ha), followed by housing (14.12 ha), shrubs (5.01 ha), roads (4.96 ha), parks (4.16 ha), and sidewalks (1.77 ha).

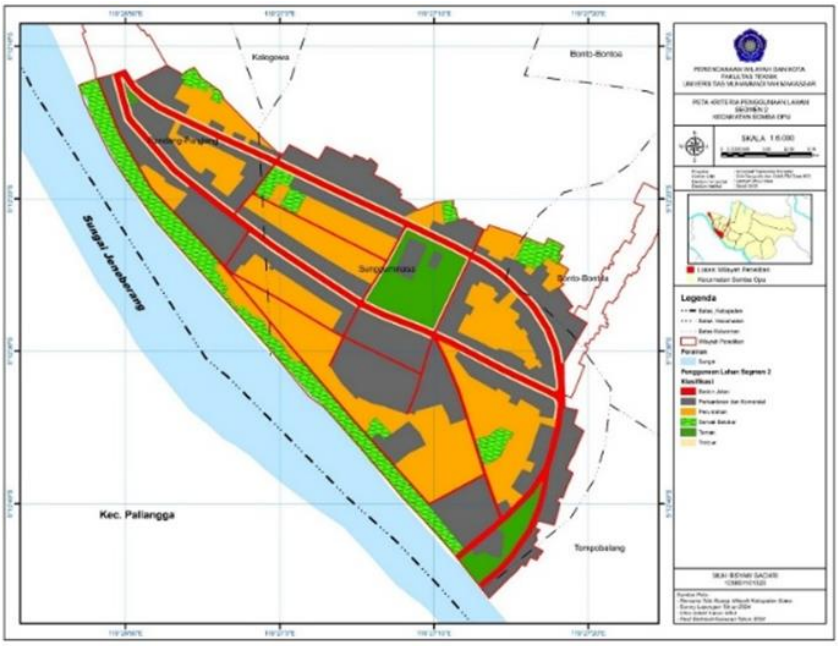


Figure 3. Segment 2 Land Use Characteristics Map

3. Segment 3, covering 14.20 ha in Tombolo, Bonto-bontoa, and Sungguminasa Villages, is mainly used for offices (6.86 ha), followed by shrubs (2.63 ha), housing (2.15 ha), roads (1.44 ha), rice fields (1.05 ha), and grassland (0.08 ha).

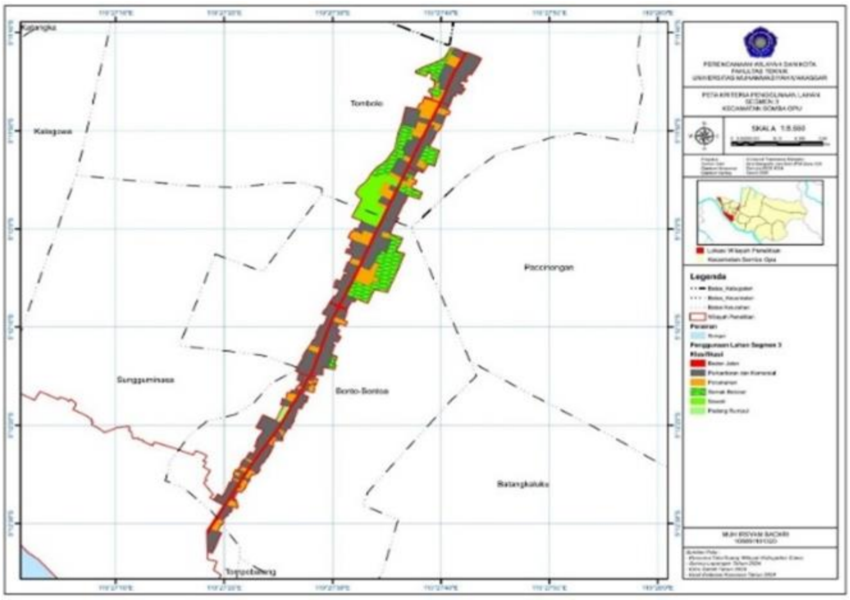


Figure 4. Segment 3 Land Use Characteristics Map

Sourch of Co2 Gas Emissions

In the technical guidelines for the preparation of greenhouse gas inventories, there are two main sources of air pollution that contribute to CO2 emissions.

1. Mobile Emission Sources, after calculating the average volume of vehicles in the three segments, the next step is to determine the fuel consumption per year based on the number of vehicles and distance traveled. As an illustration, one motorcycle requires 2.66 liters of fuel per 100 km (BPPT, Jinca 2009). This means that to cover 1.71 km in Segment 1, one motorcycle requires about 0.04 liters of fuel. The same applies to cars (sedans) based on the specified specific energy consumption. The following are the results of the calculation of total fuel consumption in the three segments.

Table 5. Mobile Emission Sources

Vehicle Type	Fuel Type	Segment 1 (1,71 km)			
		Fuel consumption/ Unit/Day	Average Vehicle Vol. / Day	Total fuel consumption/vehicle	
				Ltr/Day	Ltr/year
Motorcycle	Premium	0,04	1.461	58,44	21.330
Sedan Car	Premium	0,18	409	73,62	26.871
		Total		132,06	48.201
Vehicle Type	**Fuel Type**	**Segment 2 (2,68 km)**			
		Fuel consumption/ Unit/Day	**Average Vehicle Vol. / Day**	**Total fuel consumption/vehicle**	
				Ltr/Day	**Ltr/year**
Motorcycle	Premium	0,07	2.151	150,57	54.958
Sedan Car	Premium	0,29	763	221,27	80.763
		Total		371,84	135.721
	Fuel Type				

Vehicle Type		Segment 3 (1,72 km)			
		Fuel consumption/ Unit/Day	Average Vehicle Vol. / Day	Total fuel consumption/vehicle	
				Ltr/Day	Ltr/year
Motorcycle	Premium	0,04	909	36,36	13.271
Sedan Car	Premium	0,18	349	62,82	22.929
		Total		99,18	36.200

2. Stationary emissions in this study come from electricity consumption in offices and residences. Power plants that supply energy produce greenhouse gas emissions and other pollutants. Office electricity consumption averages 17 kWh per day or 6,205 kWh per year, while residential consumes 7 kWh per day or 2,555 kWh per year.

Table 6. Total Electricity Consumption Per Year

Segment	Activity	Emission Sources	Average Electricity Consumption/year (kWh)	Number of Units	Total Consumption Electricity/year (kWh)
Segement 1	Office (Commercial)	electricity	6.205	257	1.594.685
	Residential		2.555	108	275.940
Segement 2	Office (Commercial)	electricity	6.205	357	2.215.185
	Residential		2.555	569	1.453.795
Segement 3	Office (Commercial)	electricity	6.205	185	1.147.925
	Residential		2.555	75	191.625

Amount of CO2 Gas Emissions

After knowing the source of emissions from calculating the total amount of fuel consumption and electricity consumption per year, it will be continued by calculating the amount of CO2 gas emissions generated from both sources of emissions.

1. Mobile Emissions, such as motorcycles and cars (sedans) are significant contributors to CO2 gas emissions. In this case both vehicles play an important role in increasing the concentration of greenhouse gases in the atmosphere. To calculate the emissions produced, therefore before calculating total CO2 emissions, energy consumption data must first be converted into TJ (Terra Jaoule) energy units using the formula equation (3).

Table 7. CO2 Gas Emissions from Mobile Sources

Segment	Total Fuel Consumption (ltr/year)	Calorific Value (10^{-6}tj.ltr)	Convert (tj)	CO² Gas Emissions Factor (kg/tj)	CO² Emsissions (kg/year)	CO² Emissions (ton/year)
Segment 1	48.202		1,59		101.601	102
Segment 2	135.721	33	4,47	69.300	285.633	286
Segment 3	36.200		1,19		76.041	76

2. Non-Moving Emissions, Previously known total kWh energy consumption per year in each building activity per segment. Then proceed to calculate the amount of CO2 gas emissions tons per year using the formula equation (4).

Table 8. Co2 Gas Emissions from Stationary Sources

<table>
<tr><th>Segment</th><th>Activities</th><th>Emissions Sources</th><th>Total Consumption Electricity/year (kWh)</th><th>CO² Emissions Factor (kg/year)</th><th>CO² Emissions (kg/year)</th><th>CO² Emissions (ton/thn)</th></tr>
<tr><td rowspan="2">Segement 1</td><td>Office (Commercial)</td><td rowspan="2">Electricity</td><td>1.594.685</td><td rowspan="2">0,82</td><td>1.307.641</td><td>1.307,64</td></tr>
<tr><td>Residential</td><td>275.940</td><td>226.270</td><td>226,27</td></tr>
<tr><td colspan="6">Total Emissions</td><td>1.533,91</td></tr>
<tr><td rowspan="2">Segement 2</td><td>Office (Commercial)</td><td rowspan="2">Electricity</td><td>2.215.185</td><td rowspan="2">0,82</td><td>1.816.451</td><td>1.816,45</td></tr>
<tr><td>Residential</td><td>1.453.795</td><td>1.192.111</td><td>1.192,11</td></tr>
<tr><td colspan="6">Total Emissions</td><td>3.008,65</td></tr>
<tr><td rowspan="2">Segement 3</td><td>Office (Commercial)</td><td rowspan="2">Electricity</td><td>1.147.925</td><td rowspan="2">0,82</td><td>941.298</td><td>941,29</td></tr>
<tr><td>Residential</td><td>191.625</td><td>157.132</td><td>157,13</td></tr>
<tr><td colspan="6">Total Emissions</td><td>1.098,43</td></tr>
</table>

Absorbency of Green Open Space

1. Absorbency of Exsisting Green Space Vegetation

Field surveys were conducted to record the type and amount of vegetation and measure CO2 absorption based on literature. This data was used to assess the contribution of green spaces in reducing CO2 emissions in each segment. After that, the CO2 absorption capacity of each vegetation was calculated using equation (5) to determine the total absorption capacity of exsisting green spaces in each segment.

Table 9. CO2 Absorption by Vegetation Type Segment 1

Vegetation Type	Amount	(kg/year/tree)	(kg/year)	(ton/year)
Mimusops elengi	8	34,29	274,32	0,27
Oleina syzygium	24	155,58	3.733,92	3,73
Roystonea regia	16	52,52	840,32	0,84
Terminalia mantaly	40	211,64	8.465,6	8,47
Mangifera indica	29	455,17	13.199,93	13,20
Delonix regia	140	42,20	5908	5,91
Polyalthia longifolia	70	6.304,92	441.344,4	441,34
Musa	7	113	791	0,79
Arthocarpus Heterohyllus	2	126,51	253,02	0,25
Total	336	Total Absorbency		474,81

Table 10. CO2 Absorption by Vegetation Type Segment 2

Vegetation Type	Amount	(kg/year/tree)	(kg/year)	(ton/year)
Mimusops elengi	45	34,29	1.543,05	1,54
Terminalia mantaly	104	211,64	22,010,56	22,01
Roystonea regia	13	52,52	682,76	0,68
Roystonea regia	51	52,52	2,678,52	2,68
Polyalthia longifolia	73	6.304,92	460.259,16	460,26
Mangifera indica	67	455,17	30.496,39	30,50
Samanea saman	15	28.488,39	427.325,85	427,33
Oleina syzygium	53	155,58	8.245,74	8,25
Arthocarpus	2	126,51	253,02	0,25
Heterohyllus	10	105,87	1.058,7	1,06
Terminalia catappa	8	52,52	420,16	0,42
Cocos nucifera	2	192,72	385,44	0,39
Artocarpus altilis	33	21,28	702,24	0,70
Saraca asoca	4	394,2	1.576,8	1,58
Casuarinaceae	8	113	904	0,90
Musa				
Total	448	Total Absorbency		958,54

Table 11. CO2 Absorption by Vegetation Type Segment 3

Vegetation Type	Amount	(kg/year/tree)	(kg/year)	(ton/year)
Mimusops elengi	35	34,29	1.200,15	1,20
Oleina syzygium	26	155,58	4.045,08	4,05
Samanea saman	20	28.488,39	569.767,8	569,77
Terminalia mantaly	5	211,64	1.058,2	1,06
Mangifera indica	18	455,17	8.193,06	8,19
Psidium guajava	3	390,61	1.171,83	1,17
Polyalthia longifolia	8	6.304,92	50.439,36	44,13
Musa	10	113	1130	1,13
Nephelium lappaceum	1	2,19	2,19	0,002
Total	126	Total Absorbency		830,70

2. Land Cover Absorption Capacity

In addition to calculating the absorption capacity based on the type of plant vegetation, in each segment there are also land cover types that have CO2 gas absorption capacity. To calculate the absorption capacity of land cover types, the same calculation is done using equation (5).

Table 12. CO2 Absorption Capacity Based on Land Cover Type

Segment	Land Cover Type	Area (ha)	CO^2 Gas Absorbency (ton/ha)	CO^2 Gas Absorbency (ton/year)
Segment 1	Shrubs	0,88	55	48,4
Segment 2	Shrubs	5,01	55	275,55
Segment 3	Shrubs	1,05	55	144,65
	Rice Paddy	2,63	12	12,6
	Grassland	0,08	12	0,96

Remaining CO2 Gas Emissions

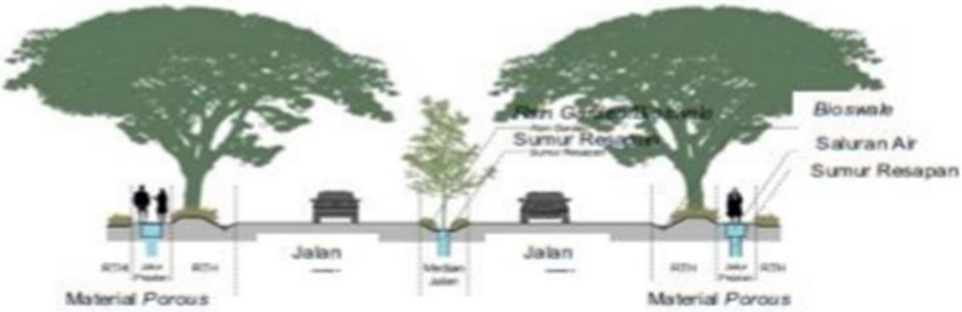
By calculating the CO2 absorption capacity produced by existing green spaces, we can find out how much CO2 emissions remain and need to be managed further. To find out the remaining CO2 gas emissions, equation (6) was calculated. Based on the survey results and data processing in Table 13, the analysis of the remaining CO2 gas emissions shows that the existing green spaces in each segment have not been able to fully absorb the emissions produced.

Table 13. Remaining CO2 Gas Emissions

Segment	Total CO^2 Gas Emissions (ton/year)	Total Absorbency of Existing Green Space (ton /year)	Remaining CO^2 Gas Emissions (ton/year)
Segment 1	1.635,91	523,21	1.112,70
Segment 2	3.294,56	1.234,09	2.060,47
Segment 3	1.174,43	795,22	379,21

Needs Plan and Development Direction on Green Spaces

The results of the calculation of the absorption capacity of Green Open Space (RTH) to total CO2 gas emissions, show that RTH in the research location has not been able to absorb all emissions generated in each segment. This condition emphasizes the need for additional planning to meet the needs and direction of green space development to reduce the remaining emissions. The direction of RTH development in the research location by improving the quality and quantity of RTH. One of them is in private green spaces such as home and office yards, besides that public green spaces also need to be expanded by focusing on green lanes and roadside parks.



Figuer 5. Example of Green Line Layout (Regulation of the Minister of Agrarian and Spatial Planning/Head of the National Land Agency Number 14 of 2022)

To calculate the amount of plant vegetation development needed in each segment to reduce the remaining CO2 gas emissions, the calculation is done using equation (7). This equation is used to determine the amount of vegetation required based on the CO2 absorption capacity needed to offset the remaining emissions.

Table 14. Total Plant Vegetation Requirements Segment 1

Vegetation Type	Amount	CO^2 Gas Absorbency (kg/year/tree)	Remaining CO^2 Gas Emissions	Total Vegetation Requirement
Mimusops elengi	8	34,29		32
Oleina syzygium	24	155,58		7
Roystonea regia	16	52,52		21
Terminalia mantaly	40	211,64		5
Mangifera indica	29	455,17	1.112,70	2
Delonix regia	140	42,20		26
Polyalthia longifolia	70	6.304,92		1
Musa	7	113		10
Arthocarpus Heterohyllus	2	126,51		9

Table 15. Total Plant Vegetation Requirements Segment 2

Vegetation Type	Amount	CO^2 Gas Absorbency (kg/year/tree)	Remaining CO^2 Gas Emissions	Total Vegetation Requirement
Mimusops elengi	45	34,29		60
Terminalia mantaly	104	211,64		10
Roystonea regia	13	52,52		39
Roystonea regia	51	52,52		39
Polyalthia longifolia	73	6.304,92		1
Mangifera indica	67	455,17		5
Samanea saman	15	28.488,39	2060,47	1
Oleina syzygium	53	155,58		13
Arthocarpus Heterohyllus	2	126,51		16
Terminalia catappa	10	105,87		19
Cocos nucifera	8	52,52		39
Artocarpus altilis	2	192,72		11
Saraca asoca	33	21,28		97
Casuarinaceae	4	394,2		5
Musa	8	113		18

Tabel 16. Total Plant Vegetation Requirements Segment 3

Vegetation Type	Amount	CO^2 Gas Absorbency (kg/year/tree)	Remaining CO^2 Gas Emissions	Total Vegetation Requirement
Mimusops elengi	35	34,29		11
Oleina syzygium	26	155,58		2
Samanea saman	20	28.488,39		1
Terminalia mantaly	5	211,64		2
Mangifera indica	18	455,17	379,21	1
Psidium guajava	3	390,61		1
Polyalthia longifolia	8	6.304,92		1
Musa	10	113		3
Nephelium lappaceum	1	2,19		173

CONCLUSIONS AND RECOMMENDATIONS

The survey and analysis results show that CO2 gas emissions in the study area come from two main sources, namely transportation and electricity consumption in buildings. Of the three segments studied, Segment 2 has the highest total emissions of 3,294.56 tons per year, followed by Segment 1 with 1,635.91 tons per year, and Segment 3 with 1,174.43 tons per year. To reduce the remaining CO2 emissions, the recommended vegetation types vary according to the characteristics of each segment. In Segment 1 and Segment 3, Mimusops elengi trees are the right choice because they can be planted in roadside green spaces or sidewalks. Meanwhile, in Segment 2, which focuses more on private green spaces, Saraca asoca trees are recommended as an effective greening solution.

Figuer 6. Mimusops Elengi and Saraca Asoca

FURTHER STUDY

This study was conducted in several segments that contribute to CO_2 gas emissions in the urban area of Somba Opu District, Gowa Regency. Given the important role of green open space in reducing the impact of greenhouse gases, further research is needed to evaluate its effectiveness in absorbing carbon dioxide emissions.

This study will focus on mapping the existence of existing green spaces and analyzing the types of vegetation that grow in them. Each type of plant will be assessed based on its ability to absorb CO_2, so that it can be seen to what extent the existing green spaces contribute to emission reduction. In addition, this research also includes an analysis of greenhouse gas emissions by identifying and measuring the main sources of emissions in Somba Opu Sub-district.

The results of this research are expected to provide a more comprehensive insight into the effectiveness of green spaces in reducing the impacts of climate change as well as a basis for more sustainable environmental planning in the region.

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