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THE EFFECTIVENESS OF GREEN OPEN SPACES IN ABSORBING CARBON DIOXIDE EMISSIONS IN THE AREA OF PT. PELABUHAN INDONESIA (PERSERO) REGIONAL 3 SUBREGIONAL JAWA

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Abstract

Introduction: *Green spaces serve as various ecological purposes, most notably the removal of pollutants. Although PT. Pelabuhan Indonesia (Persero) Regional 3 Subregional Jawa was estimated to have quite significant carbon dioxide (CO_2) emissions, the company had provided green open space in multiple locations. Calculating the effectiveness of green open spaces in absorbing CO_2 emissions in the area of Pelindo Subregional Jawa was the aim of this study.* ***Methods:*** *The primary data used was observation, and secondary data were gathered through document and literature studies. The dependent variable was the calculation of carbon dioxide emissions, while the independent variable was the effectiveness of green open spaces (land cover types and green open spaces area). The IPCC 2006 equations were used for data analysis.* ***Results and Discussion:*** *The estimated carbon dioxide emissions at Pelindo Subregional Jawa came from the following sources: 1,945.51 tons from electricity consumption; 1,845.97 tons from ships; 1,102.30 tons from operational, employee, and passenger vehicles; and 4.49 tons from genset usage. That amounted to 4,898.27 tons per year overall. Based on the calculation, it was found that the green open space could absorb 4,434.94 tons of CO_2 per hectare annually.* ***Conclusion:*** *The existing green open spaces in the area of Pelindo Subregional Jawa were not enough to absorb CO_2 emissions, as CO_2 emissions still left a residual of 463.33 tons/year.*

INTRODUCTION

The threat posed by greenhouse gas emissions became more widely recognized. At the 21st Conference of the Parties (COP) in Paris in 2015, this served as the background for the creation of the Paris Agreement. Preventing a rise in temperature above 2 °C during that century was the primary objective of the Paris Agreement. In line with this, Indonesia ratified the international agreement through The Law of The Republic of Indonesia Number 16 of 2016 about Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change, aimed at pressuring companies to take action in reducing carbon dioxide (CO_2) emissions (1).

Carbon dioxide (CO_2) emissions from fuel combustion are the main source of Greenhouse Gas (GHGs) emissions overall. Since 1990, Indonesia's emissions have increased dramatically, peaking at 581 Mt CO_2 in 2019 (2). With its largest contribution of 37%, the industrial sector is followed by the transportation (27%) and power plant (27%) sectors (3). Surabaya has completed a greenhouse gas emissions inventory. AFOLU (Agriculture, Forestry, and Other Land Uses) accounted for 0.03%, the transportation and energy sectors for 99.33%, the IPPU (Industrial Process and Product Uses) sector for 0.59%, and the waste sector for 0.08% of Surabaya's greenhouse gas emissions in 2019 (4). In 2022, Surabaya's share of GHGs emissions rose. The energy and transportation sector contributed 94.94%, the IPPU sector 2.19%, the AFOLU sector 0.37%, and the waste sector 2.50% of the total (5). Because it uses fossil fuels, the transportation industry

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is still regarded as one of the major producers of GHGs emissions. Decarbonization, or the reduction of carbon dioxide emissions, is therefore crucial in this industry.

The maritime sector is also involved in achieving the goal of reducing carbon dioxide emissions. In its fourth research report on GHGs emissions, the International Maritime Organization (IMO) stated that GHGs emissions globaly in 2012 at 977 million and rosed by 9.6% in 2018 to 1,076 million tons. Ships emitted 0.196 billion tons of NO_X, 0.0173 billion tons of SO_X, and 874.5 billion tons of CO_2 annually on average between 2012 and 2018 (6). In 2023, the IMO updated its plan to reduce GHGs emissions from 2018. The goal of the strategy was to encourage the maritime sector to cut its GHGs emissions by 20% to 30% by 2030 and to zero emissions by the year 2050 (7). Following the path outlined in the Paris Agreement was necessary to meet the 2 °C target. Because of cargo shipping and fishing operations in Indonesia's territorial waters, ports have a significant impact on the country's CO_2 emissions. According to Indonesia's Nationally Determined Contributions (NDC), ship activity accounted for 19% of the country's CO_2 emissions (8).

PT. Pelabuhan Indonesia (Persero) or Pelindo was a State-Owned Enterprise of Indonesia in the field of port services. In order to support Indonesia's economic development, Pelindo aimed to create a national maritime ecosystem network by increasing connectivity and integrating services. Pelindo embodied the goal of leading an integrated, top-tier marine ecosystem. Pelindo Subregional Jawa was a working area under Regional 3, which consists of several branches/terminals, including the Gapura Surya Nusantara (GSN) Passenger Terminal, Kalimas Terminal, and Ro-Ro Terminal. The operational area of Pelindo Subregional Jawa was located in the Tanjung Perak Port in Surabaya, which was a strategic port in Indonesia because it served as a center for maritime transportation on both local and international scales (9).

Green open space is an area that was open for the growth of plants, whether they were naturally occurring or intentionally planted. Its development had to take into ecological functions, water absorption, socio-cultural aspects, economic factors, and aestheticaly plassing (10). Directorate of Building Arrangement and Environment of Indonesia stated that green open spaces were useful for reducing pollutants, generating oxygen, improving climate quality, controlling solar radiation, enhancing aesthetic value, and could serve as a place for social interaction. The extent of vegetation cover was directly proportional to the absorption capacity of CO_2 (11). One of the districts in Ho Chi Minh City (District Four) has the lowest rate of CO_2 absorption and the least amount of vegetation cover of all the others. Significant reductions in vegetation cover (VC) had the potential to increase carbon emissions, raise surface temperatures, and cause global warming (12).

Based on the high ship activities in the area of Pelindo Subregional Jawa, it was estimated that the carbon dioxide emissions were quite significant. Company in the Environmental Impact Assessment Document for the Operations of Tanjung Perak Port Pelindo Subregional Jawa had provided green open space in several locations (13). The aim of this study was to calculate the effectiveness of green open spaces in absorbing CO_2 emissions in the area of Pelindo Subregional Jawa.

METHODS

Data Collection

Primary data collection was carried out through observation to count the number and types of ships docked, the number of generator sets, and the number of passenger and employee vehicles based on the types of vehicles passing through the road section that is the subject of the research, as well as the number and types of trees found in the green open space of Pelindo Subregional Jawa. Secondary data collection such as electricity consumption, the number of operational vehicles, layout maps of the research location, as well as several other supporting data obtained from literature studies. The dependent variable in this study is the calculation of CO_2 emissions, while the independent variable is the effectiveness of green open spaces (land cover types and green open spaces area). The research location was conducted across the entire area under the responsibility of Pelindo Subregional Jawa, including the Gapura Surya Nusantara (GSN) Passenger Terminal, Kalimas Terminal, and Ro-Ro Terminal.

Estimation of Carbon Dioxide Emissions Calculation

To determine the amount of greenhouse gas emissions, particularly CO_2, it was necessary to calculate the estimated CO_2 emissions. Intergovermental Panel of Climate Change (IPCC) 2006 (14) in its update to the last update of The IPPC Guidelines for National Greenhouse Gas Inventories 2006 (15) formulated the stages and formulas for calculating greenhouse gas emissions, including CO_2 emissions. Emissions could be estimated with varying levels of complexity. The IPCC stated that the level of complexity was referred to as 'Tier', which meant the level of precision in calculations. The differences between each tier related to the sources of data and the calculation methods used. The differences between each tier were explained below. The first tier (Tier 1) of emission estimation calculations was based on activity, while the emission factors used was the default emission factors from IPCC guidelines. The second tier (Tier 2) involved emission estimation calculations based on more accurate activity data, the emission factors used could have been either the default IPCC factors or specific factors from a country/company/research findings. Meanwhile, the third tier (Tier 3) consisted of emission estimation calculations based on direct measurements of each activity, using specific emission factors from a country/company/research findings.

The classification of tier in the CO_2 emissions inventory was heavily impacted by the data availability and the extent to which a country or factory had advanced in researching and developing methodologies or emission factors tailored to their specific context. The Tier 1 and 2 techniques were the simplest methodologies for calculating CO_2 emissions. The emission estimates for Tier 1 and 2 method used the following equations.

$$CO_2 Emission = Activity\ Data \times Emission\ Factor$$

The data activity referred to data concerning the amount of human activities related to the volume of CO_2 emissions. Examples of activity data in the energy sector included the volume of fuel consumed, the weight of coal used, and the amount of oil produced in oil fields (related to fugitive emission) (16). Emission factor was a coefficient that indicates the amount of emissions per unit of activity (the unit of activity could be in terms of volume produced or volume consumed) (17). The default emission factor from the IPCC guidelines was used as the emission factor in tier 1 calculations. In the Tier 2 method, the activity data used in the calculations were more detailed compared to the Tier 1 method. For example, the activity data of Tier 1 for diesel usage in the transportation sector was an aggregate of diesel consumption based on sales data at gas stations, without distinguishing between the types of vehicles using it. In Tier 2 data, the consumption activity of diesel in the transportation sector was broken down by the type of vehicle used. The emission factors used in Tier-2 could be either the default IPCC emission factors or specific to the average case in Indonesia or applicable to a particular facility/company in Indonesia.

Green Open Space Efectiveness in Absorbing Carbon Dioxide Emissions Calculation

The IPCC stated that the carbon dioxide absorption capacity of vegetation could be categorized based on land cover type and tree species (18). In this study, the vegetation absorption capacity was classified according to land cover types, which include trees, shrubs, grasslands, and rice fields (19). Each type had a different capacity to absorb carbon dioxide. The type of land cover for green open spaces in the area of Pelindo Subregional Jawa was tree type, with a vegetation absorption capacity of 569.07 tons/ha/year (20).

An inventory of the current vegetation was the first step in calculating the amount of green open space required. Absorption capacity of green open space is definited as green open spaces ability to absorb CO_2 and Green open space area which is an existing green open space total area (m^2), also absorption capacity of vegetation which is vegetation/plants in green open spaces ability to absorb CO_2.

The calculation of the effectiveness of green open spaces in absorbing CO_2 emissions was done by subtracting the calculated carbon dioxide emissions in an area from green open spaces ability to absorb CO_2, and then multiplying by 100%.

RESULTS

Estimation of Carbon Dioxide Emissions from Ships

The calculation of estimated CO_2 emissions from ships at the terminal area of Pelindo Subregional Jawa used Tier 1 of the IPCC 2006 guidelines. Identifying the fuel consumption based on the ship's Gross Tonnage (GT) was the first step to calculating the carbon dioxide emissions of a ship (22-23). The equation for calculating the fuel consumption of a ship was derived from the guidelines provided by the European Environment Agency (24-25). This equation could be found in Table 1.

Table 1. Equation of Ship Fuel Consumption (kg/day) Using Gross Tonage (GT)

Type of Ship	Ship Fuel Consumption (kg/day)
Solid Bulk	$C_{jk} = 20.1860 + 0.00049 \times GT$
Liquid Bulk/Tanker	$C_{jk} = 14.6850 + 0.00079 \times GT$
General Cargo	$C_{jk} = 9.8197 + 0.00143 \times GT$
Container	$C_{jk} = 8.0552 + 0.00235 \times GT$
Ro-Ro Cargo	$C_{jk} = 12.8340 + 0.00156 \times GT$
Passenger	$C_{jk} = 16.9040 + 0.00198 \times GT$
High Speed Ferry	$C_{jk} = 39.4830 + 0.00972 \times GT$
Inland Cargo	$C_{jk} = 9.8197 + 0.00143 \times GT$
Sail Ship	$C_{jk} = 0.4268 + 0.00100 \times GT$
Tugs	$C_{jk} = 5.6511 + 0.01048 \times GT$
Fishing	$C_{jk} = 20.1860 + 0.00049 \times GT$
Other Ships	$C_{jk} = 20.1860 + 0.00049 \times GT$

**Cjk : Fuel consumption of the ship (kg/day) when the ship is at maximum speed*

The dock under the responsibility of the Kalimas Terminal and GSN Pelindo Subregional Jawa could only accommodate 9-19 ships per day. The following step was to determine the amount of CO_2 emissions obtained from multiplying the fuel consumption value in kilograms per day (kg/day) by the emission factor in kilograms per ton of fuel per day (kg/ton fuel). Therefore, the next calculation stage was as follows:

Based on variables like the engine, fuel type, and vessel operating mode, emission factors were calculated (26). The type of fuel used in passenger ships and Ro-Ro (Roll on- Roll Off) cargo vessels was marine diesel fuel (27), which had a carbon dioxide emission factor of 3,200 kg/ton (28). The calculation results for carbon dioxide emissions for each ship docked at the Kalimas-GSN Terminal were detailed in the following Table 2.

The total carbon dioxide emissions from ships at the Kalimas-GSN Terminal amounted to 1,845.97 tons per year. The results of the calculations occurred when the number of docked ships reached its maximum in a day, although this condition did not happen every day and the types of ships varied. The largest carbon dioxide emissions were produced by the KM. Dharma Ferry V at 172.86 tons/year with a GT of 26,400. Meanwhile, the smallest carbon dioxide emissions were produced by the KM. Kirana VII at 50.72 tons/year with a GT of 1,933.

Table 2. Calculation of Carbon Dioxide Emissions Estimation from Ships in Pelindo Subregional Jawa Area

Name of Ships	Type of Ships	*Gross Tonage* (GT)	Fuel Consumption (kg/day)	Carbon Dioxide Factor Emission (kg/ton fuel)	Carbon Dioxide Emission (ton/tahun)
KM. Dorolonda	Passenger	14,685	45.98	3,200	147.14
KM. DLN Oasis	Ro-Ro Cargo	9,170	27.14	3,200	86.85
KM. Sinabung	Passenger	14,716	46.04	3,200	147.33
KM. Awu	Passenger	6,022	28.83	3,200	92.25
KM. Dharma Ferry V	Ro-Ro Cargo	26,400	54.02	3,200	172.86
KM. Dharma Rucitra VII	Ro-Ro Cargo	15,854	37.57	3,200	120.21
KM. DLN Nusantara	Ro-Ro Cargo	12,242	31.93	3,200	102.18
KM. DLN Batu Layar	Ro-Ro Cargo	9,187	27.17	3,200	86.93
KM. DLN Nusantara	Ro-Ro Cargo	12,242	31.93	3,200	102.18
KM. Niki Mila Utama	Ro-Ro Cargo	7,626	24.73	3,200	79.14
KM. HAI DA	Ro-Ro Cargo	9,353	27.42	3,200	87.76
KM. Niki Sejahtera	Ro-Ro Cargo	9,982	28.41	3,200	90.90
KM. Mutiara Ferindo II	Ro-Ro Cargo	11,114	30.17	3,200	96.55
KM. Jambo XIV	Ro-Ro Cargo	3,664	18.55	3,200	59.36
KM. Mutiara Ferindo II	Ro-Ro Cargo	11,114	30.17	3,200	96.55
KM. Kirana VII	Ro-Ro Cargo	1,933	15.85	3,200	50.72
KM. Dharma Kencana III	Ro-Ro Cargo	2,510	16.75	3,200	53.60
KM. Dharma Kartika V	Ro-Ro Cargo	9,245	27.26	3,200	87.22
KM. Jambo XI	Ro-Ro Cargo	9,052	26.96	3,200	86.26
1,845.97					

Estimation of Carbon Dioxide Emissions from Electricity Usage

Depending on the equation established by Directorate General of Electricity of Indonesia (29) for calculating exhaust gas emissions, the calculation of CO_2 emissions from electricity usage in the zone of Pelindo Subregional Jawa could be outlined in Table 3 as follows. Estimation of CO_2 emissions from electricity usage in the zone of Pelindo Subregional Jawa was 1,945.51 ton/year.

Table 3. Calculation of Carbon Dioxide Emissions Estimation from Electricity Usage in Pelindo Subregional Jawa Area

Time of Electricity Usage	Total Electricity Usage a Year (kWh)	Emission Factor ($kgCO_2$/kWh)	Emission (ton/year)
January-December 2023	2,683,461	0.725	**1,945.51**

Estimation of Carbon Dioxide Emissions from Generator Set (Genset) Usage

The process of calculating carbon dioxide emissions from generator usage used the same equation as electricity usage. The results of CO_2 emission calculations from generator set usage in the zone of Pelindo Subregional Jawa was detailed in the following Table 4. The total CO_2 emissions from generator set usage in the Pelindo Subregional Jawa zone were calculated to be 4.49 tons over a year based on the data in Table 4.

Estimation of Carbon Dioxide Emissions from Operational, Passengers, and Employes Vehicles

The calculation of CO_2 emissions from operational vehicles, passengers, and employees was done by using the perception of vehicle mileage, which required data on vehicle volume, kilometer rates of the vehicle,

Table 4. Calculation of Carbon Dioxide Emissions Estimation from Generator Set Usage in Pelindo Subregional Jawa Area

Location	Type of Fuel	Fuel Consumption (L/year)	Calor Value (TJ/L)	Fuel Consumption (TJ/thn)	CO_2 Emission Factor (kg/TJ)	CO_2 Emission (ton/year)
Office	Solar	841	0.000036	0.030276	74,100	2.24
Kalimas-GSN Terminal	Solar	841	0.000036	0.030276	74,100	2.24
Total Carbon Dioxide Emission from Generator Set Usage						**4.49**

and the type of fuel used by the vehicle (30-32). Vehicle data was categorized based on type (motorcycles and cars) and fuel type. The calculation of CO_2 emissions from operational, passengers, and employes vehicles in the zone of Pelindo Subregional Jawa could be outlined in the following Table 5. Based on the calculations in Table 5, it was known that the total CO_2 emissions from operational, passengers, and also employees vehicles in the zone of Pelindo Subregional Jawa amounted to 1,102.30 tons over a period of one year.

Table 5. Calculation of Carbon Emissions Estimation from Operational, Passengers, and Employes Vehicles in Pelindo Subregional Jawa Area

Type of Vehicle	Type of Fuel	Amount of Vehicle	Average Distance (km)	CO_2 Emission Factor (g/km)	CO_2 Emission (ton/year)
Operational Vehicles					
Car	Solar	33	3.5	3,172	95.26
Motorbike	Gasoline	6	3.5	3,180	63.45
Car	Gasoline	24	3.5	3,180	17.36
Passengers Vehicles					
Motorbike	Gasoline	238	1.5	3,180	307.57
Car	Gasoline	248	1.5	3,180	295.17
Employes Vehicles					
Motorbike	Gasoline	207	1.5	3,180	60.77
Car	Gasoline	49	1.5	3,180	256.72
Total Carbon Emissions from Operational, Passengers, and Employes Vehicles					**1,102.30**

The results of the CO_2 emission calculations conducted on several activities, including ship sailing, electricity consumption, the use of generator sets (gensets) as backup power sources, and emissions from operational, passengers, and employees vehicles in the zone of Pelindo Subregional Jawa could be detailed in the following Table 6. It was determined from Table 6 that the total CO_2 emissions on ships, electricity usage, generator set (genset) usage, and emissions from operational, passengers, and employees vehicles in the zone of Pelindo Subregional Jawa amounted to 4,898.27 tons/year.

Table 6. Results of Carbon Dioxide Emission Estimation Calculation on All Activities in Pelindo Subregional Jawa Area

Activities	Estimation CO_2 Emission (tons/year)
Ships	1,845.97
Electricity Usage	1,945.51
Generator Set Usage	4.49
Operational, Passengers, and Employees Vehicles	1,102.30
Total Carbon Dioxide Emission Estimation	**4,898.27**

The Effectiveness of Green Open Spaces in Absorbing Carbon Dioxide Emissions

It was known that there were several green open spaces scattered across 16 locations. The total area of green open space in the zone of Pelindo Subregional Jawa was 7.79 hectares. After conducting an inventory, the calculation of the effectiveness of green open spaces was displayed in Table 7. The calculation results of the existing green open space effectiveness in absorbing CO_2 was 90.5%, leaving a residual carbon dioxide emission amount of 463.33 tons/year.

Table 7. The Effectiveness of Green Open Space in Carbon Dioxide Emission Absorption in Pelindo Subregional Jawa Area

Total Area (ha)	Absorption Capacity of Vegetation (tons/ha/year)	Absorption Capacity of Green Open Space (tons/ha/tahun)	CO_2 Emission (tons/year)	Remaining CO_2 Emission (tons/year)	Green Open Spaces Effectiveness in Absorbing CO_2
7.79	569.07	4,434.94	4,898.27	463.33	**90.5%**

DISCUSSION

Decarbonization is the process of reducing carbon emissions into the atmosphere, particularly carbon dioxide (CO_2). The Paris Agreement of 2015 popularized the term decarbonization as the process of eliminating or reducing human-made carbon emissions to achieve net-zero emissions (33). Net zero emissions referred to the balance between the amount of emissions produced and the amount absorbed, so that no greenhouse gases were released into the atmosphere (34). The effort for decarbonization involved providing green open spaces.

Carbon dioxide absorption was defined as the annual amount of CO_2 stored in biomass (wood) both above and below ground during a single growing season (35). CO_2 in the atmosphere entered the leaves along with water through its surface pores during photosynthesis. During that cycle, CO_2 was chemically bound by sunlight to cellulose, sugars, and other materials. The capability of the vegetation to absorb CO_2 varied according to the type and age of the plant. The IPCC further claimed that different vegetation types and tree species could be used to classify vegetation's ability to absorb CO_2 (36).

The IPCC stated that the CO_2 absorption capacity of vegetation could be categorized based on land cover type and tree species. In this study, the vegetation absorption capacity was classified according to land cover types, which included trees, shrubs, grasslands, and rice fields. Each type had a different capacity to absorb carbon dioxide gas. The type of land closure for green open spaces in the area of Pelindo 3 Subregional Jawa was of the tree type, with a vegetation absorption capacity of 569.07 tons/ha/year (37).

In the Pelindo Subregional Jawa zone, the effectiveness of green open spaces in absorbing CO_2 emissions was calculated, and the findings were 90.5%. As shown in Table 7, it was known that there was still a residual carbon dioxide amount of 463.33 tons/year. This suggested that company did not have enough green space to absorb the CO_2 emissions from the various activities this study examined. The emissions from ship navigation, electricity use, the use of generator sets as backup power sources, and vehicle emissions from passenger, operational, and employee vehicles were among these activities.

The Minister of Industry Regulation Number 40/M-IND/PER/6/2016 about Technical Standards for Industrial Regions had mandated that every industrial area with an area of 20 to 500 hectares had to have at least 10% of green open space (38). There are several ways to create green open space, including parks, green belts, and perimeters. Green open space could be provided in the form of green belts beside roads and green open space atop buildings when arranging green spaces in corridors with previously densely populated land (39). Green belt along roads could be provided by placing plants in between 20 and 30 percent of the road's right-of-way, depending on the classification of the area (40). The functions of the various vegetation types as well as the site requirements had to be taken into account. Selecting native plant species with low rates of evapotranspiration and bird favoritism was a better idea (41).

Based on Environmental Impact Assessment Document for the Operations of Tanjung Perak Port Pelindo Subregional Jawa, the types of vegetation planted in the green open space of company are dominated by trees, including *Cerbera Manghas*, *Polyalthia longifolia*, and *Filicium decipiens*. Based on research conducted by Anggara and Rahmawati (37), it was stated that the biomass of trees was proportional to their capacity to absorb CO_2. In the same study, it was found that *Cerbera Manghas* had an average biomass of 4.37 kg/year, *Polyalthia longif* had 1,092.51 kg/year, and *Filicium decipiens* had 38.93 kg/year. Therefore, *Polyalthia longif* was the type of tree with the highest CO_2 absorption capacity compared to other trees planted in the green open space there.

Recommendations for controlling the reduction of carbon dioxide emissions that could be provided to the company included optimizing existing green open spaces by increasing the variety of *Polyalthia longif*, which was one type of tree that had already been planted. Based on the calculation of remaining CO_2 emissions, it was known that there were 463.33 tons/year of CO_2 that could not be absorbed by 7.79 hectares of green open space. If the absorption capacity of the Glodokan Tiang tree for CO_2 was 1,092.51 kg/year, then 421 trees were needed to absorb 463.33 tons/year of remaining CO_2 emissions. The green open space around Jalan Perak Barat and Timur, which served as the entry and exit route for vehicles to and from the terminal, could have been enhanced with *Handroanthus chrysotrichus* . The selection of this type of tree was due to its leaves not easily falling off during the dry season, and its roots tending not to damage buildings or walls. When the flowering season arrived, the flowers were beautiful and lush in lovely colors, such as yellow, pink, and purple, which enhanced the aesthetic value of green open spaces (42). *Handroanthus chrysotrichus*, had a good CO_2 absorption capacity, which was 105.87 kg per year per tree.

In addition, coastal forest areas could be utilized by planting and maintaining mangrove trees. Mitigation efforts to reduce CO_2 emissions could be achieved by applying the Blue Carbon concept, which involved the implementation of seagrass ecosystems, salt marshes, and Mangroves due to their excellent capacity for carbon storage both in their biomass and within their sediments (43-44). Another study indicated that the CO_2 absorption capacity in Mangrove stands was 697.61 tons/ha, while the CO_2 absorption capacity in leaf litter was 0.00606 tons/ha, and in the sediments, it was 1,762.22 tons/ha (45). The company could have collaborated across sectors with institutions or authorities that had a role in rehabilitating The Mangrove forests around there.

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AUTHORS' CONTRIBUTIONS

IF : Concepting, writing, and collecting data. TM : Concepting and reviewing. ART : Reviewing, Checking plagiarism and proofread proof. AZP : Concepting and collecting data

CONCLUSION

The study's findings indicated that various activities in the vicinity Pelindo Subregional Jawa produced CO_2 emissions of 1,945.51 tons annually, 1,845.97 tons annually from ships, 1,102.30 tons annually from operational, passenger, and employee vehicles, and 4.49 tons annually from generator set usage. The estimated total annual CO_2 emissions were 4,898.27 tons. The capacity of the green open space to absorb CO_2 emissions was calculated to be 4,434.94 tons/ha/year. The existing green open spaces in the area of Pelindo Subregional Jawa were not enough to absorb CO_2 emissions, as CO_2 emissions still left a residual of 463.33 tons/year. Thus, increasing the capacity of green open areas through various regulatory techniques became essential, such as planting trees like *Handroanthus chrysotrichus* that have a high absorption capacity and working with government agencies to cultivate Mangroves.

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