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The Effectiveness of Urban Forest in Absorbing CO_2 Emission at Rajekwesi Type A Terminal

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ABSTRACT

The terminal in Bojonegoro District is Rajekwesi Type A Terminal. It is located close to the CBD that has resulted in a decrease in environmental quality, due to gas emissions released by motor vehicles. The decrease in environmental quality can be overcome with an ecological approach, for example by creating or expanding green open spaces (urban forest). This study aimed to provide information about the capability of urban forest of the terminal to absorb CO_2 emissions. This study began with a survey counting the number of motor vehicles at the gateway of the terminal on Sunday, Monday, Wednesday, Friday and Saturday for 24 hours. Then, the measurement of tree biomass was carried out using the nondestructive method. After the data was collected, the amount of CO_2 emissions from motor vehicles was calculated by adding up CO_2 emissionsin a stationary (idle) position when it was moving. The total CO_2 emissions of motor vehicles at Rajekwesi Type A Terminal was 292.058,087 kgCO_2/year. The amount of carbon sink (Wtc) of a tree was calculated by multiplying the total biomass (Wt) by the carbon concentration. The amount of Wtc at the urban forest of Rajekwesi Type A Terminal was 4.366,059 kg/year. After the amount of Wtc was found out, the amount of CO_2 absorbed by the tree could be found out by multiplying Wtc by the conversion constant of the carbon (C) element to CO_2 (3,67). The amount of CO_2 absorbed by the trees at the urban forest of Rajekwesi Type A Terminal was 16.023,44 kgCO_2/year. If they were compared, the absorption of CO_2 was still much smaller than the emission rate. Thus, the function of the urban forest of terminal as an absorber of CO_2 emissions was still not optimal.

Keywords: Urban forest, CO_2 emissions, Terminals, Motor vehicles, Trees

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1. Introduction

When viewed from the regional transportation network, Bojonegoro District is a crossing area for transportation from various areas, such as Tuban District, Lamongan District, Nganjuk District, Madiun District, Ngawi District and Blora District. This position is also supported by the region's potential as an agricultural, tourism and mining area. Therefore, what needs attention is the transportation network, especially land transportation facilities and terminals, so that it can support all the activities of its districts.

The terminal in Bojonegoro District is Rajekwesi Type A Terminal. As the node of the transportation network, the terminal is a major source of air pollution. The location of the terminal, which is close to office, trade, services, education and health sites, has caused environmental degradation in the surrounding area, due to gas emissions released by motor vehicles. Based on Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah (IKPLHD) Provinsi Jawa Timur in 2016, fuel use from the transportation sector in 2016 was dominated by gasoline, amounting to 14,46 million kiloliters, and diesel, amounting to 6.723,01 kiloliters. By using the IPCC GL 2006 method, from the 2016 fuel use, the greenhouse gas emission was 33.891,51 Gg CO_2e.

The environmental quality degradation can be overcome with an ecological approach. The ecological approach emphasizes the relationship between humans and their environmental activities, so that humans and their various activities continue to be the focus in relation to their abiotic, biotic, social, economic and cultural environments. An example of the effort to overcome environmental degradation, with an ecological approach, is the creation or expansion of urban forests. Urban forest is a form of green open space, which is useful for controlling the microclimate. It serves to absorb solar radiation, lower air temperature, increase air humidity, reduce wind speed and absorb pollutants from transportation activities (Fandeli et al., 2004; Hamdaningsih et al., 2010).

Based on the identification of the problem, this study aims to provide information on the capacity of urban forest to absorb CO_2 emissions at the terminal. The scope of the area in this study is Rajekwesi Type A Terminal, which is located on Veteran Street, Sukorejo Village, Bojonegoro District. For the scope of the material, the measurement of CO_2 levels was limited to the calculation of CO_2 emissions from motor vehicles. This measurement was a measurement of node I (observations made on emission sources), which may produce more accurate pollutant data, because it is directly related to the intensity of the emitter's activities (Soedomo, 2001; Kosegeran et al., 2013). Meanwhile, biomass measurements were only carried out on trees. Measurements of understory biomass were not carried out because of their very low absorption of CO_2. According to Birdsey (1992) and Boyce (1995), the percentage of carbon content in each tree stand was around 30,6 %, while in understory it was around 1,5 % (Fandeli et al., 2004; Hairiah and Rahayu, 2007; Ludang et al., 2017).

2. Research Methods

2.1. Data Collection Method

Data collection in this study was carried out through a survey of counting the number of motor vehicles and a survey of tree biomass measurements. The survey to count the number of motor vehicles was conducted on Sunday, Monday, Wednesday, Friday and Saturday, for 24 hours, with 15 minute intervals. This survey was conducted at the terminal entrance by counting the number of motor vehicles entering the terminal.

For the survey, the measurement of tree biomass was carried out by means of nondestructive technique (not cutting down trees) (Hairiah and Rahayu, 2007; Ihsan et al., 2015), by recording the names, ages and diameter of the trunk at breast height (1,3 m from the ground) of all trees. Consequently, the specific gravity (SG) of wood from each tree species was calculated by cutting the wood from one of the branches, then by measuring its length and diameter. The wood samples were put in an oven at 100°C for 48 hours and then weighed for their dry weights. The wood SG could be calculated by dividing its dry weight by its volume.

2.2. Data Analysis Method

Data analysis in this study included the analysis of calculating CO_2 emissions and the analysis of calculating the carbon sink in trees. The CO_2 emission of each type of motor vehicle can be obtained by adding up the CO_2 emission of a motor vehicle when it was in a stationary (idle) position and when it moved, based on the following equations.

$$ECO_2 = t_{stationary} x cons_{fuel} x conv_{fuel}$$

where:

$ECO_2(s)$	: CO_2 emission of motor vehicle in stationary position ($kgCO_2$)
tstationary	: duration of the vehicle engine run in stationary position (minutes)
confuel	: total fuel consumption at stationary position per minute (l/minute)
convfuel	: fuel conversion factor to CO_2 ($kgCO_2$/l)

$$ECO_2(g) = l_{travel} x conv_{fuel}$$

where:

$ECO_2(g)$	: motor vehicle CO_2 emissions when moving ($kgCO_2$)
ltravel	: the distance traveled by a motor vehicle while at the terminal (km)
convfuel	: fuel conversion factor to CO_2 ($kgCO_2$/km)

First, the amount of CO_2 emission for each type of motor vehicle was calculated; then it was multiplied by the number of units for each type of motor vehicle in the terminal on Sunday, Monday, Wednesday, Friday and Saturday. Next, it was averaged for each day's character, so that the average daily CO_2 emissions were obtained. Finally, it was multiplied by 365 to find the total annual CO_2 emission.

The analysis of the carbon sink in trees was preceded by the processing of biomass data. The method of processing tree biomass data (Hairiah and Rahayu, 2007; Ihsan et al., 2015) is to use allometric equations that have been developed by previous researchers, whose measurements begin with felling and weighing several trees.

$$Y = 0,11p\ d^{2,62}$$

where:

Y	: tree biomass (kg/tree)
d	: stem diameter at breast height/ dbh (cm)
p	: wood SG (g/cm^3)

Then, the tree biomass was divided by the age of the tree to obtain the tree biomass per year. The total biomass of all trees at the terminal were added up, whether they were small, medium or large, to obtain the total tree biomass (Wt).

The carbon concentration in biomass was about 46 %. Therefore, the estimated amount of carbon sink (Wtc) can be calculated by multiplying the total tree biomass (Wt) by the carbon concentration (Hairiah and Rahayu, 2007; Fitrada et al., 2020). After the amount of carbon sink (Wtc) was known, the amount of CO_2 absorbed by trees could be calculated by multiplying the amount of carbon sink by the constant for the conversion from carbon (C) to CO_2 (3,67) (Fandeli and Muhammad, 2009; Anonymous, 2012).

3. Results and Discussion

3.1. Motor Vehicles and CO_2 Emissions at Rajekwesi Type A Terminal

The routes and mileages of motor vehicles at Rajekwesi Type A Terminal were different. The closer the distance a motor vehicle traveled, the less was its CO_2 emissions. Conversely, the farther the distance it traveled, the more was its CO_2 emissions. The routes and mileages of motor vehicles at Rajekwesi Type A Terminal can be seen in Table 1.

Table 1. Types, Routes and Mileages of Motor Vehicles at Rajekwesi Type A Terminal

No.	Motor Vehicle Type	Routes Taken within the Terminal	Distance Travelled (km)
1.	Motorcycle (small, medium, big)	Entrance gate – private vehicle parking lot – exit	0,213
2.	Sedan/ jeep	Entrance gate – private vehicle parking lot – exit	0,213
3.	Family car/ MPV	Entrance gate – private vehicle parking lot – exit	0,213
4.	Pick-up	Entrance gate – private vehicle parking lot – exit	0,213
5.	Microbus	Entrance gate – rural transport arrival route – rural transport vehicle waiting area – rural transport departure route – exit	0,297
6.	Bus	Entrance gate – inter province/ within province transport arrival route – inter province/ within province transport vehicle waiting area – inter province/ within province transport departure route – exit	0,442

Source: Primary survey, 2020

In addition to the distance traveled, the amount of CO_2 emissions released by motor vehicles was also influenced by the number of motor vehicles (Saadah, 2002; Tim Penulis Pedoman Penyelenggaraan Inventarisasi GRK Nasional, 2012). The highest number of motor vehicles occurred on Friday (a normal day before the weekend). On Fridays, the number of prospective passengers, especially workers, was higher compared to those of other days, and thus the number of private vehicles used and public vehicles operated were also greater. The number of motor vehicles in Rajekwesi Type A Terminal can be seen in Table 2.

Table 2. Number of Motor Vehicles at Rajekwesi Type A Terminal

Day	Motorcycle			Sedan/ Jeep	Family Car/ MPV	Pick-up	Microbus	Bus	Total
	Small (unit)	Medium (unit)	Big (unit)	(unit)	(unit)	(unit)	(unit)	(unit)	(unit)
Sunday	0	474	20	8	17	5	14	114	652
Monday	2	731	61	10	26	8	12	133	983
Wednesday	1	806	93	8	23	7	14	135	1.087
Friday	4	909	69	5	27	6	14	135	1.169
Saturday	1	717	50	7	11	9	16	136	947

Source: Primary survey, 2020

The amount of CO_2 emissions contained in the Rajekwesi Type A Terminal can be calculated by adding up the CO_2 emissions of each type of motor vehicle in stationary (idle) and moving positions. The CO_2 emissions of each type of motor vehicle in stationary (idle) position can be seen in Table 3, while the CO_2 emissions of each type of motor vehicle in moving position can be seen in Table 4.

Table 3. CO_2 Emission for Each Type of Motor Vehicle in Stationary (Idle) Position

No.	Motor Vehicle Type		Running Machine Duration in Stationary Position (minute)	Fuel Consumption in Stationary/ Idle Position* (l/minute)	Conversion Factor Oil Fuel to CO_2** (kgCO_2/l)	CO_2 Emission of Motor Vehicle in Stationary Position (kgCO_2)
1.	Motor cycle	Small	0,1	0,014	2,10	0,003
		Medium	0,1	0,017	2,10	0,004
		Big	0,1	0,024	2,10	0,005
2.	Sedan/ jeep		0,1	0,127	2,10	0,027
3.	Family car/ MPV		0,1	0,148	2,10	0,031
4.	Pick-up		0,2	0,083	2,58	0,043
5.	Microbus		10,0	0,105	2,58	2,709
6.	Bus		15,0	0,144	2,58	5,573

Source: Primary survey and analysis results, 2020
** Anonymous, 2012*
*** Tim Penulis Pedoman Penyelenggaraan Inventarisasi GRK Nasional, 2012*

Table 4. CO_2 Emission of Each Type of Motor Vehicle When Moving

No.	Motor Vehicle Type		Mileage Average (km)	Conversion Factor Oil Fuel to CO_2** (kgCO_2/km)	CO_2 Emission of Motor Vehicle in Moving Position (kgCO_2)
1.	Motor cycle	Small	0,213	0,08	0,017
		Medium	0,213	0,10	0,021
		Big	0,213	0,14	0,030
2.	Sedan/ jeep		0,213	0,18	0,020
3.	Family car/ MPV		0,213	0,21	0,023
4.	Pick-up		0,213	0,15	0,017
5.	Microbus		0,297	0,19	0,014
6.	Bus		0,442	0,26	0,031

Source: Primary survey and analysis results, 2020
*** Tim Penulis Pedoman Penyelenggaraan Inventarisasi GRK Nasional, 2012*

To find out the amount of CO_2 emission for each type of motor vehicle, the CO_2 emissions of motor vehicles in stationary position and moving position were added up. The amount of CO_2 emission for each type of motor vehicle can be seen in Table 5. Based on Table 5, it can be seen that the CO_2 emission of each type of motor vehicle (except motorcyle) was dominated by CO_2 emission in stationary position. This happens because the amount of fuel that a vehicle burns in a stationary position is greater than the fuel it spends when it moves. The more fuel is burned, the more CO_2 emission is released. The stationary position occurs when the vehicle is loading and unloading passengers and goods.

Table 5. CO_2 Emission of Each Type of Motor Vehicle at Rajekwesi Type A Terminal

No.	Motor Vehicle Type		CO_2 Emission of Motor Vehicle in Stationary/ Idle Position ($kgCO_2$)	CO_2 Emission of Motor Vehicle in Moving Position ($kgCO_2$)	CO_2 Emission of Motor Vehicle ($kgCO_2$)
1.	Motor cycle	Small	0,003	0,017	0,020
		Medium	0,004	0,021	0,025
		Big	0,005	0,030	0,035
2.	Sedan/ jeep		0,027	0,020	0,047
3.	Family car/ MPV		0,031	0,023	0,054
4.	Pick-up		0,043	0,017	0,060
5.	Microbus		2,709	0,014	2,723
6.	Bus		5,573	0,031	5,604

Source: Analysis results, 2020

After obtaining the amount of CO_2 emissions for each type of motor vehicle, the CO_2 emissions of motor vehicles in the Rajekwesi Type A Terminal are obtained by multiplying the amount of CO_2 emissions by the number of units for each type of motor vehicle. The CO_2 emissions of motor vehicles at Rajekwesi Type A Terminal can be seen in table 6.

Table 6. Total Motor Vehicle CO_2 Emissions at Rajekwesi Type A Terminal

Day	Motorcycle			Sedan/ Jeep	Family Car/ MPV	Pick-up	Mikrobus	Bus	Total
	Small ($kgCO_2$)	Medium ($kgCO_2$)	Big ($kgCO_2$)	($kgCO_2$)	($kgCO_2$)	($kgCO_2$)	($kgCO_2$)	($kgCO_2$)	($kgCO_2$)
Sunday	0,000	11,850	0,700	0,376	0,918	0,300	38,122	638,856	691,122
Monday	0,040	18,275	2,135	0,470	1,404	0,480	32,676	745,332	800,812
Wednesday	0,020	20,150	3,255	0,376	1,242	0,420	38,122	756,540	820,125
Friday	0,080	22,725	2,415	0,235	1,458	0,360	38,122	756,540	821,935
Saturday	0,020	17,925	1,750	0,329	0,594	0,540	43,568	762,144	826,870
Daily CO_2 emission ($kgCO_2$/day)									800,159
Yearly CO_2 emission(kg CO_2/year)									292.058,087

Source: Analysis results, 2020

3.2. Biomass and Carbon Sink in Rajekwesi Type A Terminal

The urban forest in Rajekwesi Type A Terminal was in the form of an area of 0,5 ha. Based on the growth rate, the trees in the urban forest at Rajekwesi Type A Terminal included:

1. Small trees/ seedling (*dbh* 5 - 20 cm)
   a. Tanjung (*Mimusops elengi*) : 250 trees
   b. Mahogany (*Swietenia mahagoni*) : 71 trees
   c. Trembesi (*Samanea saman*) : 2 trees
   d. Glodokan (*Polyalthia longifolia*) : 102 trees
   e. Sawo kecik (*Manilkara kauki*) : 95 trees
   f. Kiarapayung (*Felicium decipiens*) : 1 tree
   g. Jackfruit (*Artocarpus heterophyllus*) : 2 trees
   h. Mango (*Mangifera indica*) : 1 tree
   i. Bintaro (*Cerbera manghas*) : 1 tree
2. Medium sized trees/ poles (*dbh* 20 - 35 cm)
   a. Tanjung (*Mimusops elengi*) : 3 trees
   b. Mahogany (*Swietenia mahagoni*) : 25 trees
   c. Trembesi (*Samanea saman*) : 2 trees
   d. Sengon (*Albizia chinensis*) : 2 trees
   e. Glodokan (*Polyalthia longifolia*) : 10 trees
   f. Sawo kecik (*Manilkara kauki*) : 2 trees
3. Large trees / trees (*dbh* > 35 cm)
   a. Mahogany (*Swietenia mahagoni*) : 1 tree
   b. Trembesi (*Samanea saman*) : 8 trees
   c. Sengon (*Albizia chinensis*) : 2 trees
   d. Acacia (*Acacia pycnantha*) : 1 tree

Note: dbh (diameter at breast height)

The specific gravity of tree wood/ timber found in the urban forest at Rajekwesi Type A Terminal can be seen in Table 7, while the tree biomass in the urban forest at Rajekwesi Type A Terminal can be seen in Table 8.

The carbon concentration in biomass was around 46 %. Therefore, the estimated amount of carbon sink (Wtc) contained in the urban forest of Rajekwesi Type A Terminal could be calculated by multiplying the total biomass (Wt) in the urban forest at Rajekwesi Type A Terminal by its carbon concentration (Hairiah and Rahayu, 2007; Fitrada et al. al., 2020).

$Wtc = Wt \times 0{,}46$

$Wtc = 9.491{,}430 \times 0{,}46$

$Wtc = 4.366{,}059$ kg/year

where:

Wtc : amount of carbon sink (kg/year)

Wt : total biomass (kg/year)

0,46 : carbon concentration in organic matter

After the amount of carbon sink (Wtc) was known, the amount of CO_2 absorbed by trees in the urban forest at Rajekwesi Type A Terminal could be calculated through the following equation (Fandeli and Muhammad, 2009; Anonymous, 2012):

$WCO_2 = Wtc \times 3{,}67$

WCO_2 = 4.366,059 x 3,67

WCO_2 = 16.023,44 $kgCO_2$/year

where:

WCO_2 : the amount of CO_2 absorbed by trees ($kgCO_2$/year)

Wtc : amount of carbon sink (kg/year)

3,67 : conversion constant of the carbon (C) element to CO_2

Table 7. Timber Specific Gravity (ρ) of the Trees in the Urban Forest at Rajekwesi Type A Terminal

No.	Tree Name		Monocot/	Wood Sample			Timber Specific
	Local Name	Botanical name	Dicot	Diameter (cm)	Length (cm)	Dry Weight (g)	gravity/ρ (g/cm³)
1.	Tanjung	*Mimusops elengi*	Dicot	1,94	20	47,86	0,81
2.	Mahogany	*Swietenia mahagoni*	Dicot	1,52	20	23,21	0,64
3.	Trembesi	*Samanea saman*	Dicot	1,35	20	18,31	0,64
4.	Ketapang	*Terminalia catappa*	Dicot	1,38	20	19,73	0,66
5.	Sengon	*Albizzia chinensis*	Dicot	1,43	20	13,16	0,41
6.	Acacia	*Acacia auriculiformis*	Dicot	1,27	20	18,74	0,74
7.	Glodokan	*Polyalthia longifolia*	Dicot	0,98	20	10,25	0,68
8.	Sawo kecik	*Manilkara kauki*	Dicot	0,79	20	10,39	1,06
9.	Kiarapayung	*Felicium decipiens*	Dicot	1,21	20	22,53	0,98
10.	Jackfruit	*Artocarpus heterophyllus*	Dicot	1,47	20	21,03	0,62
11.	Mango	*Mangifera indica*	Dicot	1,12	20	13,79	0,68
12.	Bintaro	*Cerbera manghas*	Dicot	1,07	20	7,55	0,40

Source: Analysis results, 2020

Table 8. Tree Biomass in the Urban Forest at Rajekwesi Type A Terminal

No.	Tree Name		Monocot/ Dicot	Tree Biomass (kg/tree)	Tree Age (year)	Tree Biomass per Year (kg/year)
	Local Name	Botanical name				
1.	Tanjung	*Mimusops elengi*	Dicot	10.066,492	6-8	1.646,370
2.	Mahogany	*Swietenia mahagoni*	Dicot	12.403,758	6-14	1.706,114
3.	Trembesi	*Samanea saman*	Dicot	54.436,134	6-17	3.245,903
4.	Ketapang	*Terminalia catappa*	Dicot	156,309	2-8	20,217
5.	Sengon	*Albizzia chinensis*	Dicot	3.537,730	6-17	264,034
6.	Acacia	*Acacia auriculiformis*	Dicot	8.627,777	17	507,516
7.	Glodokan	*Polyalthia longifolia*	Dicot	7.416,387	6-12	1.092,508
8.	Sawo kecik	*Manilkara kauki*	Dicot	5.651,651	6	941,942
9.	Kiarapayung	*Felicium decipiens*	Dicot	550,570	6-15	38,927
10.	Jackfruit	*Artocarpus heterophyllus*	Dicot	51,527	6	8,588
11.	Mango	*Mangifera indica*	Dicot	89,635	6	14,939
12.	Bintaro	*Cerbera manghas*	Dicot	26,243	6	4,374
			Total (kg/year)			9.491,430

Source: Analysis results, 2020

3.3. Comparison between CO_2 Emission with the Trees Capacity to Absorb CO_2

The total CO_2 emission of motor vehicles in Rajekwesi Type A Terminal was 292.058,087 $kgCO_2$/year, while the amount of CO_2 absorbed by trees in the terminal's urban forest was 16.023,44 $kgCO_2$/year. If the amount of CO_2 absorbed by the trees was compared to the amount of CO2 emission from the motor vehicles, the absorption capacity for CO_2 was still much smaller than the emission rate. The percentage of CO_2 balance in Rajekwesi Type A Terminal can be seen in Table 9.

Table 9. CO_2 Balance at Rajekwesi Type A Terminal

No.	CO_2 Balance Component	Motor Vehicle Type		Total ($kgCO_2$ / year)	Percentage (%)
1.	CO_2 Emission	Motor cycle	Small	10,429	0,004
			Medium	6.842,446	2,343
			Big	874,175	0,299
		Sedan/ jeep		132,339	0,045
		Family car/ MPV		422,357	0,145
		Pick-up		153,300	0,052
		Microbus		13.914,530	4,764
		Bus		269.708,511	92,348
		Total		292.058,087	100
2.	CO_2 Sequestration	Trees and seedlings		16.023,440	5,486
3.	CO_2 Emission not absorbed by trees			276.034,650	94,514

Source: Analysis results, 2020

From Table 9, it can be learnt that the trees in the urban forest at Rajekwesi Type A Terminal could only absorb 16.023,44 $kgCO_2$/year (5,486%) of the total motor vehicle CO_2 emissions of 292.058,087 $kgCO_2$/ year. Therefore, the function of the terminal urban forest as an absorber of CO_2 emission is still not optimal.

4. Conclusion

Based on the results of the research and discussion that have been carried out, several conclusions are obtained. First, when compared to other days, the highest CO_2 emission of motor vehicles at Type A Rajekwesi Terminal was on Saturdays (weekends) and it amounted to 826,870 $kgCO_2$, of which 92,17 % was from bus emission (762,144 $kgCO_2$).

Second, the amount of CO_2 absorbed by the trees in the urban forest at Rajekwesi Type A Terminal was 16.023,44 $kgCO_2$/year, where the tree with the highest biomass was Trembesi (Samanea saman), which had 54.436,134 kg/tree.

Third, if the amount of CO_2 absorbed by trees (16.023,440 $kgCO_2$/year) was compared to the total CO_2 emissions of motor vehicles (292.058,087 $kgCO_2$/year), the CO_2 absorption was still smaller than the emission rate. Therefore, the function of the terminal urban forest as an absorber of CO_2 emission was still not optimal.

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