The estimation of CO_2 absorption and O_2 production from trees on main street in The City of Jember

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The estimation of CO_2 absorption and O_2 production from trees on main street in The City of Jember

U H Nursyahbandi[1*], W Subchan[2], and Suratno[3]
[123]Study Program of Biology Education, Faculty of Teacher Training and Education, University of Jember, Jember 68121, Indonesia.

*Corresponding author, e-mail: ubaithakim20@gmail.com

Abstract: One way to decrease the global warming effect is by planting trees on the side and in the middle of the street. Trees thathad already planted must be monitored to know how good those trees are in absorbing CO_2 and producing O_2. Therefore, the purpose of this research was to know the ability of the trees to absorb CO_2 and produce O_2 which had already planted in City Street; and this research can be used as a basis development for the next greenways area. The method that was used to estimate the absorption of CO_2 and the production of O_2 from trees was calculating carbon biomass of the trees firstusing alometric equations. Then, the value of biomass that had been known was multiplied by the conversion factor of CO_2 and O_2;therefore the absorption of CO_2 and the production of O_2 can be estimated. The result of this calculation showed that the trees, which had already planted on Gajah Mada Street,PB Sudirman Street, and Letjen Panjaitan Street, had the capability to absorb all of the CO_2 emission that comes from vehicle activity. The result also showed that Glodokan Tiang (*Polyalthialangifolia*) can absorb CO_2 and produce O_2 more than all tree species which were found in that street.

1. Introduction

Every year,the human population will increase.It is also followed by theincreasing human activity in the city. When human activity increases, the vehicle that supports human activity will be increased too. An increasing number of vehicles will increase the number of a pollutant that will harm our environment[1].One example of an area that encounters this problem is Jember. The number of vehicles in Jember has increased by approximately 6,8% for the past 3 years[2].The vehicles will produce pollutants such as Carbon Monoxide (CO), Hydrocarbon (HC), Oxidized Sulphur (SO_X) and Nitrogen Oxide (NH_X).However, almost all gas that is produced by vehicleis Carbon Monoxide (CO), it is almost 70,5%[3].

In nature, CO will exchange into CO_2[4]. Thus, the increasing number of CO in nature will play a role in increasing the amount of CO_2. CO_2 will be used by plants as an ingredient of photosynthesis to produce O_2. Because of this reason,the planting of trees is done to minimize the amount of CO_2 emission.

After planting trees is done, monitoring will be necessary to observe how good these trees are in absorbing the CO_2. This action had been doneby Tripathi and Joshi (2015) in their research in mapping carbon sequestration in the entire city of Delhi. The same action also had been done by Laksono and Damayanti (2014) in their research in Jl. Ahmad Yani, Surabaya. It showed that the number of vegetation on Jl. Ahmad Yani in Surabaya cannot absorb CO_2 from the vehicle. Because of this reason, the purpose of this research is to know the potency of trees that have been planted on the main street in Jember for their absorption of CO_2 and production of O_2. Furthermore, data that was collected from this research can be used to estimate how good those trees in absorbing CO_2 and producing O_2.Other than that,the calculation of CO_2 production and O_2 production can be used as the basis for the government in planing or developing the green areas in Jember to control air pollution.

2. Methods

This research has been done in the main streetof Jember such as Gajah Mada Street, PB Sudirman Street, and Letjen Panjaitan Street which had held in 17-25 Desember 2018.

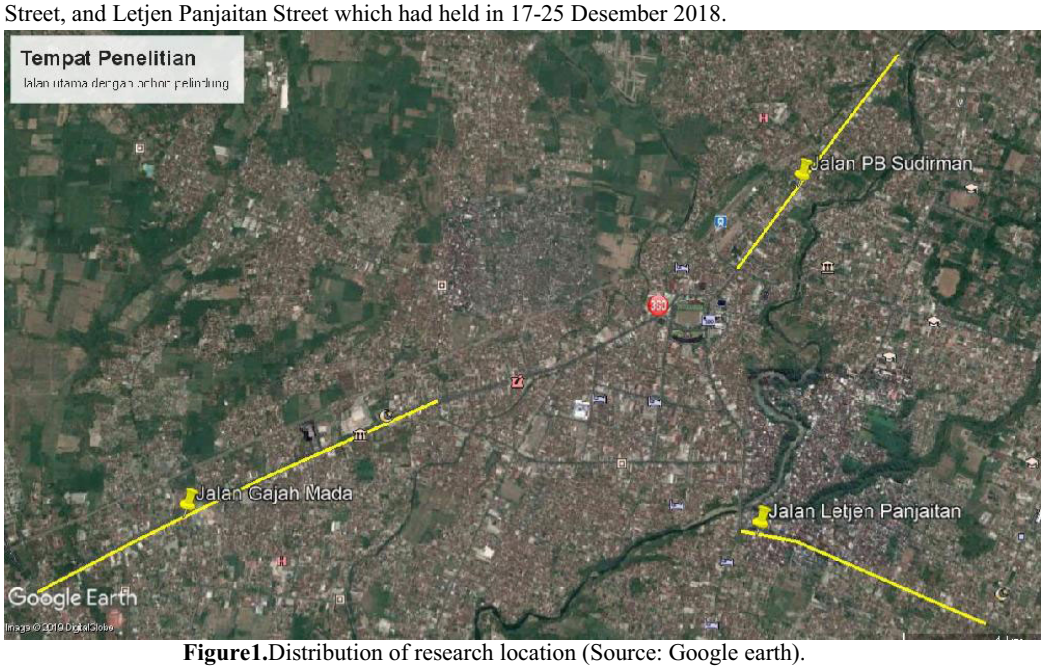

Figure1. Distribution of research location (Source: Google earth).

2.1 Research Procedure

Vehicle data were collected by counting the number of vehicles that pass through the main street of Jember such asGajah Mada Street, PB Sudirman Street, and Letjen Panjaitan Street for 1 hour at active time (07.00 am -08.00 am, 00.00 pm - 01.00 pm, and 03.00 pm - 04.00 pm) in 3 days each street. Data that has been collected is about the number of vehicles and the identification of vehicles that have through that street. After that, vehicles will be ordered by type of fuel. Then, the result of this calculation entered into the formula for the number of emissions developed byLaksono and Damayanti in 2014[5].

The next step was to count the number of trees in Gajah Mada Street, PB Sudirman Street, and Letjen Panjaitan Street and followed by theidentifyingtrees;Then, calculating trees diameter above ground (1.3 meter) and the height of trees. The result of this calculationwas input in thealometric equation to estimate the ability of trees in absorbing CO_2 and producing O_2.

2.2 Data Analysis

Data analysis for this research is comparing the difference between the amount of CO_2 produced by vehicles and estimation of CO_2 absorption and O_2 production from trees. To achieve that, we must know the amount of CO_2 emitted by vehicle first using the equation that had been developed byLaksono&Damayantiin 2014.

$$Q = N \times F \times K \times L \quad (1)$$

Explanation

Q = Amount of emission (kg/hour)
Ni =Amount of vehicle type-i (/hour)
FEi = Emission factor of vehicle type-i($kgCO_2$/unit)
Ki =Fuel consumption of vehicle type-i (liter/100 km)

L = Length of the street (km)

Value of emission factor was obtained from value that was developed by *Department of Energy & Climate Change*in 2012. The value of this emission factor can be seen in Table 1.

Table 1. Vehicle Emission FactorBased On Fuel Type

No	Vehicle Type	**Emission Factor**(kg CO_2/unit)
1	Motorcycle	0,112
2.	Gasoline Car	0,201
3.	Diesel Car	0,186
4.	Truck	0,532
5.	Bus	0,112

Source: *Department of Energy & Climatechange*, 2012.

The amount of fuel from each type of vehicle can be known using value that was developed byKusuma[6]in Table 2. However, in Table 2, the unit of specific fuel consumption is liter for 100 km. Therefore,adjustment must be made to know how much fuel that already used for 1 km. This adjustment can be done by dividing the value in Table 2 with 100, so fuel consumption for 1 km can be obtained.

Table 2. Specific Fuel Consumption of Vehicle.

No	Vehicle Type	**Specific Fuel Consumption**(liter/100km)
1.	Motorcycle	2,66
2.	Gasoline Car	11,79
3.	Diesel Car	11,36
4.	Truck	12,89
5.	Bus	13,92

Source: Kusuma, 2010.

Estimating the amount of CO_2 absorbed and O_2 produced by trees which already planted in the side and median of the street, it was needed to know biomass of the trees first. Biomass of the trees can be obtained by calculating it using alometric equation which was developed by previous researcher, but alometric equation is different between one tree and the others; because of that, identification process needs to be done to know which species of trees that have been planted. After that,alometric equation based on trees species is searched. Alometric equation that was developed by some researchers have been grouped in Table 3.

Table 3. Treesand Alometric Equation

No	Name of Trees	Alometric Equation	Source
1	*Polyalthialongifolia* (Glodokan Tiang)	$Y = 6{,}4050 * (D^2 * H^{0{,}4137})$	Dung, *et al*., 2012.
2	*Pterocarpusindicus*(Angsana*)*	$Y = 0.1277 * D^{2.3949}$	Hung, *et al*., 2012.
3	*Mimusops elengi*(Tanjung*)*	$Y = \exp[-2{,}289 + 2{,}649 * \ln(D) - 0{,}021 * (\ln(D))^2]$	Moto, *et al*., 2016.
4	*Delonix regia*(Flamboyan*)*	$Y = \exp[-2{,}289 + 2{,}649 * \ln(D) - 0{,}021 * (\ln(D))^2]$	IPCC, 2003.
5	*Peltophorum pterocarpum*(Soga)	$Y = 0{,}1245 * D^{2{,}4163}$	Hung, *et al*., 2012.
6	Branched trees	$Y = 0{,}11 * WD * D^{2{,}62}$	Ketterings, *et al*., 2001.

Explanation:
Y = Tree biomass (kg/ha)
D = Diameter (cm)
H = Height (m)
WD = Wood density (g/cm^3)

After the value of biomass is known, the value of biomass can be converted to estimate carbon stock in those trees, by multiplying biomass and international conversion factor of carbon which can be calculated using this equation [7].

$$C = Y \times 0{,}47 \quad (2)$$

Explanation:
C = Amount of carbon (kg/year)
Y = Tree biomass (kg/year)
0,47 = Conversion factorto estimate carbon

The amount of carbon stock in tree can be used to estimate the amount of CO_2 which was absorbed by tree. To calculate that, this equation can be used[8].

$$nC_2 = C \times 3{,}67 \quad (3)$$

Explanation:
N = CO_2absorption (kg/year)
C = Amount of carbon (kg/year)
3,67 = conversion factor C toCO_2.

Then to estimate the amount of O_2 that was produced, can be estimated using this equation[9].

$$nO_2 = C \times 2{,}67 \quad (4)$$

Explanation:
N = O_2production (kg/year)
C = Amount of carbon (kg/year)
2,67 = conversion factor C to O_2.

The result of analysis will be discussed and then concluded.

3. Results and Discussion

3.1 Estimated Amount of CO2 Emissions on Urban Main Streets

Based on the calculation of the estimated amount of CO_2 emissions from vehicles carried out on the 3 main streets in Jember, namely Gajah Mada Street, PB Sudirman Street, and Letjen PanjaitanStreet, the results of the estimated amount of CO_2 emissions in Gajah Mada Street are stated in Table 4.

Table 4. Estimated Amount of CO_2 emissions in Gajah Mada Street

No	Type of Vehicle	Estimated Amount of Vehicle (/Year)	Estimated Amount of Emissions (Kg/Year)
1.	Motorcycle	28.364.880	386.174,633
2.	Gasoline car	6.929.160	724.439,064
3.	Diesel car	613.200	56.893,159
4.	Truck	788.400	238.280,469
5.	Bus	35.040	1.884,542
Total		36.730.680	1.407.671,868

Based on Table 4, Gajah Mada Street is passed by vehicles as many as 36,730,680 vehicles each year. The vehicle that produces the most CO_2 on this street is the type of car with gasoline fuel which is equal to 724,439,064 kg / year; while the least is the vehicle with the type of bus which is 1,884,542 kg / year.

For PB Sudirman Street, the calculation of the estimated amount of CO_2 emissions is stated in table 5.

Table 5. Estimated Amount of CO_2 Emissions in PB Sudirman Street

No	Type of Vehicle	Estimated Amount of Vehicle (/Year)	Estimated Amount of Emissions (Kg/Year)
1.	Motorcycle	14.442.320	104.351,489
2.	Gasoline car	2.803.200	155.561,734
3.	Diesel car	306.600	15.099,214
4.	Truck	443.840	71.202,809
5.	Bus	8.760	316,751
Total		18.004.720	346.531,998

PB Sudirman Street is estimated to be passed by 18,004,720 vehicles each year. The highest amount of CO_2 produced in PB Sudirman Street based on Table 5 is vehicles with gasoline-fueled types of cars with estimated total emissions of 155,561,734 kg / year; and the least are types of bus vehicles with total emissions of 316.751 kg / year.

The calculation results of the estimated amount of CO_2 emissions emitted by vehicles passing through Letjen Panjaitan Street are stated in Table 6.

Table 6. Estimated Amount of CO_2 Emissions in Letjen Panjaitan Street

No	Type of Vehicles	**Estimated Amount of Vehicles** (/Year)	**Estimated Amount of Emissions** (Kg/Year)
1.	Motorcycle	6.438.600	30.064,893
2.	Gasoline car	1.787.040	64.092,353
3.	Diesel car	213.160	6.784,383
4.	Truck	131.400	13.623,530
5.	Bus	29.200	682,374
Total		8.599.400	115.247,534

Based on Table 6, Letjen Panjaitan Street is estimated to be passed by 8,599,400 vehicles each year and becomes the street with the least CO_2emission among the 3 main streets that become the place of this research. CO_2 on Letjen Panjaitan Street is produced mostly by gasoline car with CO_2emission of 64,092,353 kg / year; and the least is the type of bus vehicle with CO_2 emissions of 682,374 kg / year.

Tables 4, 5, and 6 showedthat the amount of CO_2 emitted by gasoline cars is more than the other types of vehicles. This is because most of 4 wheeled vehicle is gasoline cars. Besides, the CO_2 emission factor owned by gasoline cars is also quite large which makes it emits more CO_2 than others. Compared to diesel car, gasoline cars produce more CO_2. This is because in producing energy, diesel engines require a lot of air and use less fuel than petrol engines. The less fuel used, the less carbon dioxide will be produced [10]. However, diesel engines have other disadvantage that is producing NO_2 gas which is harmful to humans.

3.2 Estimated Amount of CO_2 Absorption and O_2 Production on Urban Main Streets

Based on the results of tree calculations that had been done on Gajah Mada Street, there are507 trees in this street consisting of 8 different tree species. The ability of CO_2 absorption and O_2 production contained in this street can be seen in Table 7.

Table 7. Estimation of CO_2 Absorption Capability and O_2 Tree Production on Gajah Mada Street.

No	Types of Tree	Number	**Estimated CO_2 Absorption**(Kg/Year)	**Estimated O_2 Production**(Kg/Year)
1.	*Pterocarpusindicus*(Angsana)	49	157.924,327	114.893,175
2.	*Peltophorumpterocarpum*(Soga)	7	16.054,914	11.680.278
3.	*Polyalthialangifolia* (Glodokan Tiang)	159	1.124.365,138	817.998,615
4.	*Muntingia calabura*(Kersen)	5	1.541,131	1.121,204
5.	*Terminalia catappa*(Ketapang)	3	891,120	648,308
6.	*Filiciumdecipiens* (Kiara Payung)	5	7.716,256	5.613,734
7.	*Mimusops elengi*(Tanjung)	276	334.844,445	243.606,177
8.	*Tiliparititiliaceum*(Waru)	3	4.281,613	3.114,961
Total		507	1.647.618,944	1.203.051,089

Table 7 shows that Tanjung (*Mimusops elengi*) is the most growing tree which are 276 trees; and the least trees are Waru (*Tiliparititiliaceum*) and Ketapang (*Terminalia catappa*) which are only 3 trees. Glodokan Tiang tree is the tree that absorbs the most CO_2 and produces O_2. The CO_2 absorbed is estimated at 1,124,365,138 kg annually and O_2 produced is 817,998,615 kg annually.

Calculations carried out on PB Sudirman street shows that this street has 243 trees consisting of 8 different tree species. The ability to absorb CO_2 and produce O_2 trees on this street can be seen in Table 8.

Table 8. Estimation of CO_2 Absorption Capability and O_2 Production on PB Sudirman Street.

No	Types of Trees	Number	Estimated CO_2 Absorption(Kg/ Year)	Estimated O_2 Production (Kg/Year)
1	*Pterocarpusindicus*(Angsana)	40	129.020,339	93.864,934
2	*Bauhinia purpurea* (Pohon Daun Kupu-kupu)	1	2.355,402	12.864,859
3	*Delonix regia*(Flamboyan)	2	24.127,753	17.553,433
4	*Polyalthialangifolia*(Glodokan Tiang)	191	2.648.629,002	1.926.931,726
5	*Muntingia calabura*(Kersen)	3	487,280	354,506
6	*Terminalia catappa* (Ketapang)	1	137,059	99,713
7	*Filiciumdecipiens*(Kiara Payung)	4	5.554,355	4.040,907
8	*Tiliparititiliaceum*(Waru)	1	140,493	102,212
Total		243	2.810.451,684	2.055.812,290

Table 8 shows that the most dominant tree on this street is Glodokan Tiang (*Polyalthialangifolia*) with the total amount of 191 trees. Thus, with this amount, Glodokan Tiang is the tree that absorbs the most CO_2 and produces the most O_2. The CO_2 that can be absorbed is estimated at 2,648,629.002 kg every year and O2 produced is 1,926,931,726 kg annually.

Calculations which were carried out on Letjen Panjaitan Street showed that there are 146 trees consisting of 3 different species. The ability to absorb CO_2 and produce O_2 on this street can be seen in Table 9.

Table 9. Estimation of CO_2 Absorption Capability and O_2 Production on Letjen Panjaitan Street.

No	Types of Trees	Number	Estimated CO_2 Absorption(Kg/Ye ar)	Estimated O_2 Production (Kg/Year)
1,	*Pterocarpusindicus*(Angsana)	129	298.939,687	217.484,731
2,	*Muntingia calabura* (Kersen*)*	5	871,469	634,011
3,	*Mimusops elengi*) (Tanjung	12	11.389,360	8.285,992
Total		146	311.200,516	226.404,735

Table 9 shows that the trees that dominate this street are Angsana trees (*Pterocarpusindicus*), which are 129 trees. Thus, with this number, Angsana is a tree that absorbs CO_2 and produces the most O_2. The absorbed CO_2 is estimated as much as 298,939,687 kg / year and O_2 produced as much as 217,484,731 kg / year.

The ability to absorb CO_2 and produce O_2 of tree and the estimation amount of CO_2 emissions produced by vehicles passing through 3 main streets in Jember are summarized in Table 10.

Table 10. Comparison of the Amount of CO_2 Emissions and CO_2 Absorption as well as O_2 Production

No	Street's Name	Estimated Vehicle's CO_2 Emissions (kg/year)	Estimated Tree's CO_2 Absorption (kg/year)	Estimated Tree's O_2 Production (kg/year)
1	Gajah Mada Streett	1.407.671,868	1.647.618,944	1.203.051,089
2	PB Sudirman street	346.531,998	2.810.451,684	2.055.812,290
3	Letjen Panjaitan street	115.247,534	311.200,516	226.404,735

From Table 10, it can be seen that the ability of the protective tree to absorb the most CO_2 is on PB Sudirman Street which is 2,810,451,684 kg / year and produce O_2 of 2,055,812,290 kg / year, while the least is Letjen Panjaitan Street which is only able to absorb 311,200,516 kg / year of CO_2 and produce 226,404,735 kg / year O_2. Based on that result, Gajah Mada Street, PB Sudirman Street and Letjen Panjaitan Street had been planted with protective trees which can absorb more CO_2 than the amount of CO_2 emitted by vehicles passing through the streets. This shows that the protective trees on those streets are still able to handle CO_2 emissions from motor vehicles.

The absorption capacity of the streets can also be seen in Table 10. This certainly will not last forever since the number of vehicles will increase. Therefore, it is necessary to develop or add trees on the street. Keeping this in mind, trees play significant role in carbon absorption and thus needs to be effectively monitored, protected, and extended [11,22]. Therefore, tables 7, 8 and 9 can be further developed to determine the ability of CO_2 absorption and O_2 production from each tree species by dividing the estimated ability of CO_2 absorption and O_2 production from each tree species with the total number of each tree species in all streets so that the results are obtained in Table 11.

Table 11.CO_2 Absorption Ability and O_2 Production of Protective Trees

No	Type of trees	Local Names	Estimated CO_2 Absorption (Kg/Year)	Estimated O_2 Production(Kg/Year)
1	*Polyalthialangifolia*	Glodokan Tiang	10.367,59	7.842,66
2	*Delonix regia*	Flamboyan	4.269,11	3.284,88
3	*Pterocarpusindicus*	Angsana	4.050,62	2.983,01
4	*Peltophorumpterocarpum*	Soga	2.293,56	1.668,61
5	*Bauhinia purpurea*	Pohon Daun Kupu-kupu	1.280,68	985,421
6	*Mimusops elengi*	Tanjung	1.199,42	872,599
7	*Filiciumdecipiens*	Kiara Payung	914,053	679,551
8	*Tiliparititiliaceum*	Waru	580,098	422,608
9	*Terminalia catappa*	Ketapang	227,076	166,26
10	*Muntingia calabura*	Kersen	68,706	59,17

Based on Table 11, Glodokan Tiang tree is a tree that can absorb CO_2 and produce the most O_2 among other tree species on all three streets. This tree can absorb 10,367.59 kg / year of CO_2 and produce 7,846.66 kg / year of O_2, so that it makes the trees on PB Sudirman Street has the greatest ability to absorb CO_2 and produce O_2.

Glodokan Tiang tree itself is a tree with a stem that rises upward with a conical type of canopy. This tree has the most amount of biomass when compared to other trees planted on the main street in Jember. Biomass values can be obtained by alometric calculation which uses tree height, diameter at breast height, and wood specific gravity as the determining factor. The increasing diameter of a tree would also increase the amount of biomass and carbon storage capacity in the tree, so that the

tree could absorb more CO_2 in the atmosphere [21]. Therefore, Glodokan Tiang tree can absorb CO_2 and produce more O_2 than other trees found on the main street in Jember.

The addition of trees that will be done to compensate the increasing number of vehicles needs to consider several things, such as:trees must have non-toxic parts, how much waste is produced, the strength of each part of the tree, and roots that emerge to the surface[12]. Based on the criteria of trees that are good to be planted as protective trees and based on the data from Table 11, there are 3 best trees recommended for planting on a street: Glodokan Tiang tree (*Polyalthialangifolia*), Angsana tree (*Pterocarpusindicus*), and Soga tree (*Peltophorumpterocarpum*). Flamboyan tree (*Delonix regia*) has better ability than Angsana and Soga trees, but this tree is not recommended because even though this tree has good ability to absorb CO_2 and produce O_2 and has a strong branching which is equipped with relatively small size of leaves, but this tree has a large root and it emerges to the surface so it can damage the infrastructure above it. If this tree is planted on the street, it can potentially make the street bumpy and can endanger street users.

4. Conclusions

Based on the results of this study, it can be concluded that the ability of trees that have been planted as protective tree can compensate the amount of CO_2 emissions produced by vehicles passing through the main street in Jember. Trees along Gajah Mada Street can absorb 1,647,618,944 kg of CO_2 and produce 1,203,051,089 kg O_2; along PB SudirmanStreet can absorb 2,810,451,684 kg of CO_2 and produce O_2 of 2,055,812,290 kg; while along Letjen PanjaitanStreet can absorb 311,200.516 kg and produce O_2 as much as 226,404,735 kg. The trees recommended to be used as protective trees based on their ability to absorb CO_2 and produce$O_2$and have the characteristics that must be possessed as protective trees are Glodokan Tiang tree (*Polyalthialangifolia*), Angsana tree (*Pterocarpusindicus*), and Soga Tree (*Peltophorumpterocarpum*).

Acknowledgements

The best thanks for the lecturers and researcher colleagues from Biology Education Study Program University of Jember for supporting this research and giving advice to this research activity.

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