Study on the Potential of Historical Mahogany Trees in Improving Urban Air Quality

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Abstract

Metro City is one of the cities in Lampung Province, Indonesia, which has experienced various infrastructure development which contributed to the decrease of the air quality. Urbanization also causes constant decrease in term of the number of green open spaces. Yet green open space plays an important role in maintaining urban air quality. Vegetation (i.e., tree) as the main component of green open space has the ability to absorb and store carbon emission. In Metro city, there is a major green open space that includes numerous large-sized Mahogany trees lining along A.H. Nasution Road. The purpose of this study was to estimate the level of air pollution from emissions of the passing-by motorized vehicles, calculate the capacity of carbon sequestration by the Mahogany trees, and determine the potential of the Mahogany trees in improving air quality. Authors collected primary data on the diameter of the tree trunks and the number of passing-by vehicles to estimate the carbon-storing capacity and carbon emission by utilizing allometric equation and emission load analysis. This study concluded that the Mahogany trees could play an important role on storing 74% of expected annual CO2 emission in Metro City. This could be linked to the achievement of the SDGs especially Target 11.6.

Keywords: Mahogany; Sequestration; Metro City; Carbon; Emission; SDGs; Urban

1. Introduction

Metro City is one of the cities in Lampung Province, Indonesia, which has experienced various infrastructure development since its establishment. The increasing rate of population growth and continuous urbanization also increases the use of urban land for various functions (Yuyun, et al., 2017). In addition, the need for transportation and energy is also increasing in line with the increase of the population. Globally in the urban context, the air quality is highly threatened by the ever-rising carbon emission caused by the increasing number of motorized vehicles (Matsumoto, 2005). Therefore, increasing trend of urban activities in the city contribute to the decrease of the air quality. Air pollution is one of the major problems faced by many urban areas in Indonesia. This issue has been firmly addressed on the global commitment of sustainable development, i.e. The 2030 Sustainable Development Goals, especially under Goal 11: Sustainable Cities and Communities.

Urbanization also causes constant decrease in term of the number of green open spaces. Yet one of the efforts that can be implemented to maintain air quality is through the provision of urban green open space. Vegetation (i.e., tree) as the main component of green open space has the ability to absorb carbon emission. In Metro city, there is a major green open space that includes numerous large-sized Mahogany trees lining along A.H. Nasution Road. (Figure 1) This line of trees is a landscape heritage from the colonization era and still exists today. According to a previous study (Nuzir, 2021) this typical streetscape is one of the valuable landscape heritages often found in Indonesian cities, which also has the potential to become the landmark for the city beside its ecological function.

Another follow-up study concluded that there were 158 Mahogany trees on 14 road sections along A.H. Nasution Road by virtual observation comparing Google Street View (GSV) data from 2015, 2018, 2019, and 2021 (Nuzir, 2022). A.H. Nasution Road split Metro City's urban spatial structure in line towards west to east direction. This road segment takes place in the axial position or the axis of the symmetrical spatial structure. The traffic intensity on A.H. Nasution Road is increasing rapidly since the adjacent urban area is getting dominated by economic activities gradually.

The purpose of this study was to estimate the level of air pollution from emissions of the passing-by motorized vehicles, calculate the capacity of carbon sequestration by the Mahogany trees, and determine the potential of the Mahogany trees in improving air quality. In addition, this study also discussed the contribution of the Mahogany trees on the efforts to achieve Goal 11 of the Sustainable Development Goals (SDGs) determined by several targets and indicators. One indicator that is directly related to this study is indicator 11.6.2(b) measuring the Air Quality Index. The result of this study would be very important to add more scientific references for the conservation efforts of the Mahogany trees, or other urban trees, specifically in Metro City and generally in other cities around the world.

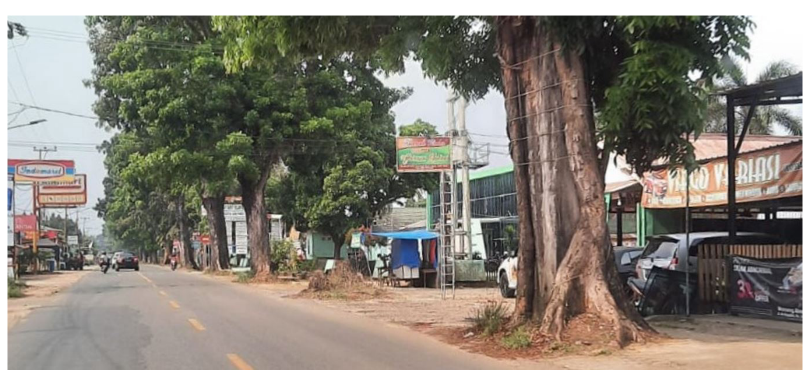

Figure 1. Rows of Mahogany Trees along Jl. AH. Nasution.

2. Literature Review

In urban context, one of the major contributors to the air pollution is transportation. The Ministry of Environment of Indonesia stated that air pollution from gasoline-based motorized vehicle (spark ignition engine) contributed 70% of carbon monoxide (CO), 100% of lead (Pb), 60% of hydrocarbons (HC), and 60% of nitrogen oxides (NOx) (Martuti, 2013). A study from Soedomo (2001) concluded that the amount of air which has been polluted with emissions from vehicles has a negative impact on human health such as disrupting the respiratory system, damaging the nervous system and digestive problems, causing cancer and various other diseases (Harunsyah, 2017). The amount of emission could be estimated from the number of vehicles passing by the road. Direct survey on selected site could be conducted by counting the vehicles that passing by a particular road and then calculating the emissions based on the type of the vehicle, standard fuel consumption for each type, and the length of the road (Suryani & Damayanti, 2014).

As one of the strategies to directly address the air pollution caused by transportation, large trees such as Mahogany tree, are often planted along the public roads. Nazaruddin (1996) regarded this strategy as reforestation of which creates the green line (Manado et al., 2017). The green line can be in the middle of the road for highways or two-way roads or on the right and left side of the road. It is also often found that there are also spaces for pedestrian on the right and left side of the road which can still be planted with trees or other kind of vegetation aiming to filter the CO emission.

Meanwhile, CO is one of the major Green-House Gases (GHG) since the increasing presence of CO could highly contribute to the green-house effect. CO gas through natural processes in the atmosphere could be oxidized to carbon dioxide (CO_2). Fortunately, it is possible to reduce CO_2 with the help of vegetation. Vegetation utilize CO_2 for its photosynthesis and produce oxygen (O_2). Within this process, vegetation is also able to store the carbon and transform it into biomass which is referred as carbon sequestration. According to Hairiah and Rahayu (2007) in (Tuah et al., 2017) tree biomass content is the sum of the biomass content of each tree organ which is a picture of the total organic material resulting from photosynthesis. Mahogany tree (Swietenia mahagoni), or in local language called as "Pohon Mahoni", has a massive physical character which can reach a height up to 30 meters with a large trunk diameter indicating the possession of large amount of biomass as well. (Figure 2) It is a tropical plant that has a long age and can grow in places exposed to direct sunlight. It can be used as a shading element, a natural medicine and pesticide, a raw material for furniture and handicraft, as well as a very prominent streetscape element (Sutarni, 1995). Due to the potential large sum of biomass possessed by the Mahogany tree, biomass calculations using allometric equation which could find a relationship between tree dimensions and volume of biomass or carbon content would be focused on this study in order to measure the level of carbon sequestration (Picard et al., 2012). By measuring the carbon stocks, the potential carbon uptake could be estimated as well (Rinjani et al., 2016).

In order to measure the carbon content without harming the tree, a study from Adinugroho and Sidiyasa (2006) utilized the allometric equation and tried to take into accounts the dimension of all parts of the Mahogany tree, such as: stem, branches, stump, leaves, and twigs. It was concluded that the stem part covered the most of biomass content. Therefore, allometric equation based on the stem dimension would be more representative and measurable compare to other parts of the tree due to its physical condition. For example, it is rather more difficult to measure the dimension of the branches or the weight of the leaves and the stump if the tree is still intact and protected.

Based on the conclusion above, the suitable model of allometric equation would be the model that calculate the Above Ground Biomass (AGB) (Adinugroho & Sidiyasa, 2006). Then, the conversion of the biomass into carbon stock would need to be determined. A previous study concluded that the conversion number would be 46% of the total biomass (Salsabili, et al., 2019). Authors could not find the conversion number that is applicable to Mahogany tree, therefore authors would argue to use this conversion number in this study as a minimum estimation. This will be one of the research components that will be improved in the future studies.

3. Methodology

This study was conducted on A.H. Nasution Road, Metro City with the area of observation starting from the western-end of the road adjacent to the Merdeka Park at the city center until the eastern-end of the road which is directly bordering with the Pekalongan District, East Lampung Regency. (Figure 3 - 4) The data collected in this study are primary and secondary data. Primary data included data on the number of the passing-by motorized vehicles in order to estimate the level of carbon emission and data on the diameter of the Mahogany trees on A.H. Nasution to calculate the level of carbon sequestration. Secondary data included data from journals, books, and other sources.

To collect primary data on the number of the passing-by motorized vehicles, a method of vehicle count was selected. The vehicle count activities were conducted within three days: 9, 10, and 24 December 2021. To obtain the number of vehicles for a full day in a traffic flow, the time for conducting the survey was distributed into three time periods: morning (08.00-09.00), afternoon (12.00-13.00), and evening (18.00-1900) using the counter application on the mobile phone. These could be considered as the peak hours since a lot of public activities use the road. In this count, the authors observed five types of vehicles, namely: motorcycles, gasoline-based cars, diesel-based cars, medium trucks, and large trucks. The vehicle count was carried out in front of Bank Mandiri since there was an appropriate space to observe and to register the counts. (Figure 5)

Meanwhile tree diameter measurement activities were carried out for four days: 26 November, 7, 11, and 14 December 2021. Measurement activities were started at Nuwo Intan Culinary Center, in front of the Hati Kudus Catholic Church, and ended at the city border with East Lampung Regency. (Figure 6) Secondary data, including vehicle emission load information, carbon sequestration capacities, etc., were also gathered through the internet amongst other references and literatures. The methodology of this study can be shown as

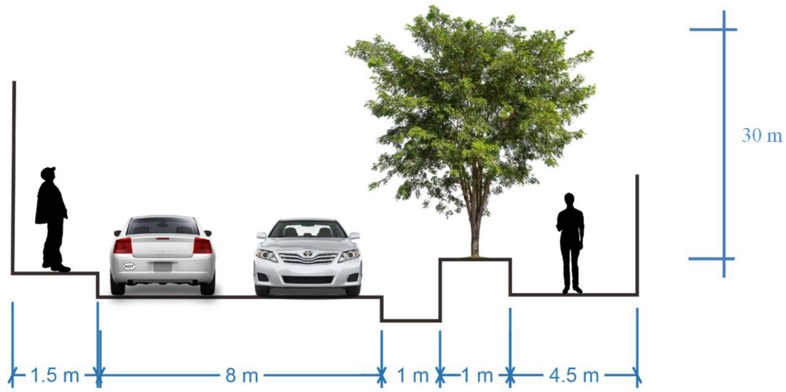

Figure 2. Cross-section Showing the Characteristic of Street with the Mahogany Tree.

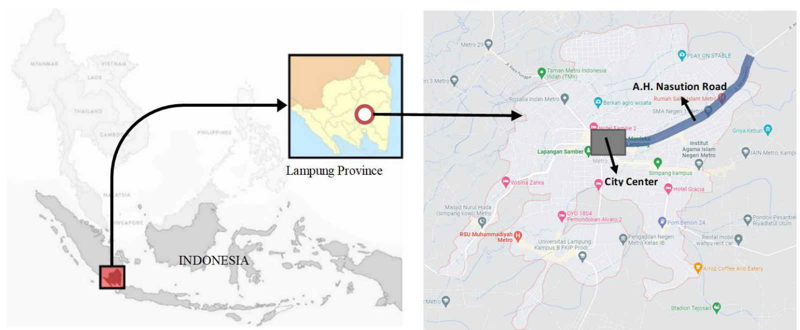

Figure 3. Position of A.H. Nasution Road within Metro City

Figure 4. Satellite Image from Google Maps Showing Partially a Section of A.H. Nasution Road.

diagram in Figure 7 below.

3.1 Procedure and Data Analysis

Data analysis included analysis of CO_2 emission load from fuel combustion, analysis of carbon sequestration of the trees, and descriptive analysis of the potential of the trees to improve the air quality of Metro City. The procedure of the analysis was applied as follows:

- ***Emission Load Analysis***

The first step of the analysis was conducted by acquiring primary data from the vehicle count. From the vehicle count, the number of passing-by vehicles was obtained. Then the number of vehicles was multiplied by the emission factor of each type of the vehicle to obtain CO concentration data. The vehicle count was conducted during peak hours and expected to record the highest total volume of vehicles on that particular observation day. Therefore, the resulting emission estimation was the maximum estimation of emission load.

The emission load was estimated using the following equation (Suryani & Damayanti, 2014):

$$Q = Ni \times FEi \times Ki \times L \qquad \text{(e.q.1)}$$

Descriptions:

Q : amount of emission (gr/hour)
Ni : number of i-type vehicles (vehicle/hour)
Fei : emission factor of type-i vehicle (gr/liter) (Table 1)
Ki : fuel consumption for type-i motorized vehicles (liter/100km) (Table 2)
L : length of the road (km)

Figure 5. Initial Observation and Vehicle Count

Figure 6. Measurement of Tree Diameter

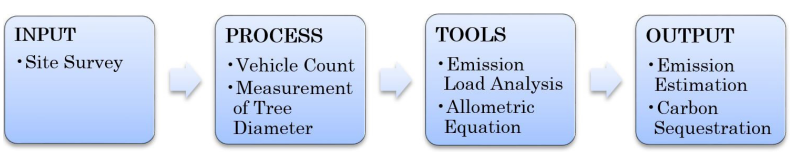

Figure 7. Research Methodology Diagram

The total carbon emission was the sum of the carbon emission values for each type of vehicle that passed by A.H. Nasution Road. By performing mathematical calculations, the residual emission could be estimated by subtracting the total emission with the emission that can be stored by the Mahogany trees as the following equation (Ruliyansyah & Fitrianingsih, 2013):

Residual emission = A (ton/year) – B (ton/year) (e.q. 2)

Descriptions:

A : total estimated CO emissions

B : total CO sequestration by plants

Then, the remaining estimated CO emissions were converted into CO_2. Conversion from CO to CO_2 using the equation (Mulyadin & Gusti, 2013) in (Suryani & Damayanti, 2014) :

$$M\ CO_2 = ((M\ CO)/(MrCO)) \times MrCO2 \qquad (e.q.\ 3)$$

Descriptions:

M : emission load (kg/year)

Mr : relative mass: CO_2 by 44; CO by 28

• *Allometric Equation*

To get the value of carbon storage by plants, the biomass calculation was carried out using the mahogany tree allometric formula as follows (Adinugroho & Sidiyasa, 2006):

$$Y = 0{,}048 \times D^{2{,}68} \qquad (e.q.\ 4)$$

Descriptions:

Y : tree biomass (kg)

D : diameter (cm)

Based on the following equation, the estimation of the biomass stored in the tree above the soil surface were obtained. The biomass was then converted into carbon storage with the following equation (Hairiah, Ekadinata, Sari, & Rahayu, 2011):

Carbon stock (kg)= 0,46 x total AGB (e.q. 5)

Descriptions:

ABG : above ground biomass (kg)

To get the value of carbon sequestration by the tree, the relative atomic mass ratio of carbon was used with the following equation (Bismark et al., 2008).

Carbon sequestration value (kg) = carbon stock x 3,67 (e.q. 6)

4. Result and Discussion

4.1 Calculation of Emission

The vehicle count aims to determine the number and type of vehicles that passed-by. Then the carbon emissions will be estimated according to the type of vehicle. Having counted the vehicles passing-by A.H. Nasution Road for three days, the following results were obtained. (Table 3)

Then the results of the vehicle count were utilized to estimate the emission load using equation Nr. 1. The result was that the total CO emissions generated from three days of survey data collection were 49,62 tons/year. (Table 4) After obtaining the estimation of total CO emissions, conversion from CO to CO_2 was carried out using equation Nr. 3.

The conversion of CO into CO_2 was applied as follows:

CO_2 emission concentration (K) = (49,62/28) x 44
= 77,97 tons/year

4.2 Calculation of Carbon Sequestration

Based on the results of the field survey, various size of tree diameters was obtained. It was then identified into three categories, namely: large tree (101-150 cm) with a total of 70 trees, medium tree (80-100 cm) with a total of 84 trees, and small tree (50-79 cm) with a total of 4 trees as shown in Figure 8.

Based on equation Nr. 4, the tree biomass was 34.019 kg. Biomass was then converted into carbon storage by equation Nr. 5 with the result of 15.648 kg. The carbon sequestration value was then calculated using the equation Nr. 6 with the result of 57,42 ton/year.

4.3 Calculation of Residual Emission

The residual emission could be estimated by subtracting the total emission from motorized vehicles with the emission that can be stored by the Mahogany trees as the following equation:

Residual Emission = total estimated CO emissions (ton/year) – total CO sequestration (ton/year)
= 77,97 ton/year – 57,42 ton/year
= 20,55 ton/year

Table 1. Motor Vehicle Emission Factors Based on Fuel Type. **Source:** Jinca (2009) in (Manado et al., 2017).

Vehicle Type / Fuel	CO Emission Factor (gr/liter)
Gasoline:	
Passenger vehicle	462,63
Small commercial vehicle	295,37
Large commercial vehicle	281,14
Motorcycle	427,05
Diesel:	
Passenger vehicle	11,86
Small commercial vehicle	15,81
Large commercial vehicle	35,57
Locomotive	24,11

Table 2. Motorized Vehicle Specific Energy Consumption. **Source:** Jinca (2009) in (Manado et al., 2017).

Transportation Type	Specific Energy Consumption (liter/100km)
Passenger car:	
Gasoline	11,79
Diesel/Solar	11,36
Large Bus:	
Gasoline	23,15
Diesel/Solar	16,89
Medium Bus	13,04
Small Bus:	
Gasoline	11,35
Diesel/Solar	11,83
Bemo, Bajaj	10,99
Taxi:	
Gasoline	10,88
Diesel/Solar	6,25
Large Truck	15,82
Medium Truck	15,15
Small Truck:	
Gasoline	08,11
Diesel/Solar	10,64
Motorcycle	2,66

Table 3. Average Vehicle Volume

Transportation Type	Number of Vehicle/Hour
Motorcycle	29
Gasoline Passenger Car	18
Diesel Passenger Car	11
Medium Truck	4
Large Truck	6

4.4 Discussion

- ***Potential of the Mahogany Tress on Improving Air Quality***

Based on the calculation of the residual emissions, the Mahogany trees have a major role in storing carbon emissions from the motorized vehicles. The Mahogany trees could contribute to store 74% of carbon emission on A.H. Nasution Road. Benchmarking was carried out to compare the role of the greeneries on emission reduction from other case studies.

A study conducted in the city of Manado (Manado et al., 2017) concluded that the CO_2 absorbed by roadside greeneries was 29.794,25 ton/year and the residual emissions reached 30.360.233,6 ton/year. Another study in Boroko City (Rawung, 2015) concluded that the CO_2 emissions produced in Segment II were 478,58 ton/year and absorption capacity was 271,18 ton/year, which was equivalent to 57%. The results from those other studies indicated that the Mahogany trees on A.H. Nasution Road in Metro City have the potential to reduce carbon emissions better than Manado City and Boroko City.

- ***Contribution of the Mahogany tress on Achieving SDGs***

Previous study by Nuzir tried to understand the relevant factors on achieving SDGs Goal 11 especially Targets 11.3 and 11.4 and concluded that target 11.3 has more interlinkages with other targets under different goals than Target 11.4 (Nuzir, 2021). Meanwhile, this study explored the contribution of the Mahogany trees on the efforts to achieve Goal 11 of the Sustainable Development Goals (SDGs) determined by Target 11.6: "By 2030,

Table 4. Results of the vehicle counts using equation Nr.1

Transportation Type	Equation Nr.1 (Q = Ni x FEi x Ki x L)	Convert gr/hour to ton/year
Motorcycle	1.350,64	11,83
Gasoline Passenger Car	4.025,35	35,28
Diesel Passenger Car	60,76	0,53
Medium Truck	88,37	0,77
Large Truck	138,42	1,21
Total		= 49,62 tons/year

reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management". However, authors did not utilize the original measurement method of this target as defined by Indicator 11.6.2(b): measuring the Air Quality Index.

5. Conclusion

Based on the results of the analysis, it could be concluded that the CO_2 emitted on A.H. Nasution Road in Metro City was estimated to reach 77,97 ton/year which comes from vehicle emissions. Meanwhile the carbon sequestration capacity of the Mahogany trees was able to store carbon emissions of 57,42 ton/year. Therefore, authors would like to conclude that the Mahogany trees have the potential to store the carbon emission on A.H. Nasution Road by 74%, thus the trees play an important role in reducing carbon emissions in Metro City. This study also explored the contribution of Mahogany trees on achieving SGSs especially related to target 11.6.

To follow up this study, authors would like to suggest further studies on measuring the potential of carbon absorption by the trees which could further clarify and mainstream the importance of Mahogany trees in improving air quality in Metro City. Furthermore, future studies that can project the growth rate of CO_2 emissions generated by urban activities in order to develop strategies on improving the role of Mahogany trees and other urban trees within climate mitigation framework would be the next steps in line.

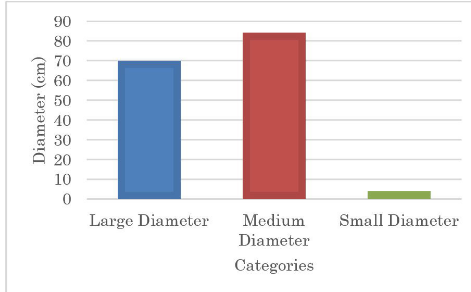

Figure 8. Categories of Tree Diameter Based on its Size

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