

## Estimation of Carbon Dioxide and Carbon Stock of Vegetation along the Sukarno-Hatta Street Sides

Fatma M. Omar Abobsesa<sup>1</sup>, Arief Rachmansyah<sup>2</sup>, Amin Setyo Leksono<sup>3</sup>

<sup>1</sup>Post Graduate School of Environmental and Development, Graduate, Program, Brawijaya University

<sup>2</sup>Department of Civil Engineering Department, Brawijaya University

<sup>3</sup>Biology Department, Faculty of Mathematic and Science, Brawijaya University

### Abstract

Carbon dioxide (CO<sub>2</sub>) is an essential element of the atmosphere that is the basis of photosynthesis process and the vital component of body organism processes. However, if it rises above the normal level, it becomes the most serious cause of global warming. However, the growth of CO<sub>2</sub> in the atmosphere has been slowed by the increase in the ability of plants to absorb the gas. This study is aimed to analyze CO<sub>2</sub> emissions and plant absorption ability to discover carbon stock and carbon balance in the atmosphere. This study used a sample of human activities that contribute to CO<sub>2</sub> emissions along the Soekarno-Hatta Street and the number of trees that soak the emissions. Remote sensing is applied to predict the levels of carbon dioxide emissions and absorption and carbon stocks. The absorption and stock of the carbon are calculated using a specific formula for biomass. The results showed a significant amount of carbon dioxide was emitted by motor vehicles passing through Soekarno-Hatta Street. However, only a small portion was generated by human activities carried out in stores, offices, restaurants, hotels, and hospitals. In line with that, the trees in the Soekarno-Hatta area were able to absorb carbon dioxide about 6 times higher than emitted. It also proved that the Palm tree (*Roystonea regia*) was capable of storing more carbon dioxide in significant amounts than the other two species, the Ashoka tree (*Polyalthia longifolia*), and the Rain tree (*Samanea saman*). Therefore, increasing the number of trees such as Palm tree in the area was recommended.

Keywords: Coaching strategy, Regency *Adiwiyata*, School management, Sintang Regency

### INTRODUCTION

Increased concentrations of atmospheric carbon dioxide are the major threat to ecological balance. The imbalance leads to the increase in the surface temperature in the world by increasing the levels of carbon dioxide, methane and some other gases in the atmosphere. These gases are classified as greenhouse gases that cause the warming of the Earth's atmospheric surface, called global warming [1]. This phenomenon causes the melting of polar ice, the depletion of the ozone layer and the increase of UV radiation on the earth. This has resulted in climate and weather changes that adversely impact on the health and life of human biology [2].

Most of the increase in the atmospheric carbon dioxide concentrations in the atmosphere is due to human activities and transportation [2]. Industrial activities and the combustion of fossil fuels as energy sources rise the atmospheric carbon dioxide concentrations by approximately 35% since the start of the Industrial Revolution.

Because carbon dioxide dissolves in water, it appears naturally in ground water, lakes and rivers, on glaciers and ice caps, and also in seawater. It is liberated from carbonate rocks by dissolution in water and acids. It is also found in petroleum and natural gas deposits.

Global emission rose to its highest point in history to 34 billion metric tons (up 3%). The rise of 2011 CO<sub>2</sub> emissions was beyond the increase in the last decade by 2.7%. However, it was still lower than the 5% increase in 2010. In Asia, Indonesia ranks 4<sup>th</sup> as highest carbon emitter country after China, India and Japan [3]. Carbon emission increased from 373 ppm to 383 ppm during 2004 to 2010 [4].

However, the growth in the amount of CO<sub>2</sub> in the Earth's atmosphere has been slowed by the increased ability of plants to absorb gas. A recent research report that green vegetation has helped offset most of the human-related carbon emissions between 2002 and 2014. Plants and trees become more absorbing due to the presence of extra CO<sub>2</sub> in the atmosphere. The slowdown, however, cannot keep up with the overall emission scale. Over the past 50 years, the amount of CO<sub>2</sub> absorbed by the oceans, plants and vegetation of the earth has doubled and these carbon sinks now account for about 45% of

Correspondence address:

**Amin Setyo Leksono**

Email : amin28@ub.ac.id

Address : Biology Department, Faculty of Mathematic and Science, Brawijaya University

the gas emitted each year due to human activities. Researchers have recently reported that since the beginning of the 21st century, there has been a significant change in the amount of carbon dioxide taken by plants and trees. Recent studies show that between 2002 and 2014, terrestrial carbon sinks are increasing. There has been a recent pause in atmospheric CO<sub>2</sub> growth rates and a decrease in anthropogenic emission fractions that remain in the atmosphere. The decrease was associated with increased CO<sub>2</sub> in the atmosphere in vegetation [5].

The study area is the Soekarno Hatta Street. The street is about 1.7 kilometers from the Brawijaya University to Permata Jingga residence. It is a main and multi-residential service area and city street and has many restaurants, hotels, shops and beauty shops, auto repair and showroom. There are many services on the street sides because of which it is called Student Roads and local service. The street is always on the move from all means of transportation using fuel causing air pollution consisting of many gases, including carbon dioxide.

#### RESEARCH METHOD

Calculate the Total of Carbon Dioxide Emission

The formula for each calculation is as follows:

Average carbon dioxide emission produced in the restaurants: Number of restaurant x number of people x carbon daily

$$E_r = n \times a \times 0.48m^3 \dots 1$$

Average carbon dioxide emission produced in the shop: Number of shop x number of people x carbon daily.

$$E_s = n \times a \times 0.48m^3 \dots 2$$

Average carbon dioxide emission produced in the office: (number of office x number of worker x carbon daily) + (number of office x number of customers x carbon daily).

$$E_o = (n \times a_1 \times 1.04m^3) + (n \times a_2 \times 0.64m^3) \dots 3$$

Average Carbon dioxide emission produced in the hotel: (number of hotel x number of workers x carbon daily) + (number of hotel x number of guests x carbon daily).

$$E_h = (n \times a_1 \times 3.12m^3) + (n \times a_2 \times 0.312m^3) \dots 4$$

Average carbon dioxide emission produced in the hospital: (number of hospital x number of workers x carbon daily) + (number of hospital x number of patients x carbon daily).

$$E_{hosp} = (n \times a_1 \times 3.12m^3) + (n \times a_2 \times 0.312m^3) \dots 5$$

Average Carbon dioxide emission produced in the traffic: (number of cars and motor cycles x carbon daily) + (number of trucks, buses, and mini buses x carbon daily)

$$E_t = (n_1 \times 11.934kg) + (n_2 \times a_2 \times 12.078kg) \dots 6$$

#### Data Analysis

Using remote sensing to estimate carbon stocks

The study of the use of remote sensing to measure the stock of carbon in terrestrial systems has been done before [6,7]. Remote sensing usually gives spatial information of the size and landscape of the areas. On the other hand, the inventory information is commonly focused on small areas of plots. Using remote sensing, carbon sinks can be calculated by applying the values of carbon density from landscape data or national forest inventories over the land covering vegetation maps.

#### Sampling Design:

The samples were taken from the Soekarno-Hatta street location. The street is as long as 1.760 meters. From this location, the population was allocated into 2 different spaces, green belt and green open space. Field surveys were conducted in February 2017, 8 plots of 100 m x 3 m were randomly allocated to the intact, transformed and degraded thicket strata of the green belt and 8 plots of 100 m x 100 m are allocated for the green open space along the street. One subplot of 10 m x 2 m was also randomly selected from each of the 100 m x 3 m plots and one subplot of 10 m x 5 m.

Procedures of Tree Measurement

$$d = \text{Girth} / \pi \dots 7$$

where: d = diameter

girth = tape measurement

$$\pi = 3.14$$

#### Converting Tree Measurement to Aboveground Biomass

The absorption ability of the trees is calculated according to size of the trees. The carbon dioxide absorption of the trees is calculated by the number of the trees x unit per hectare x constant of adsorption x 24h. the formulas of carbon dioxide absorption by big, medium, and small trees are as follows.

$$A_b = n_b \times u_b \times 129.92 \times 24 \dots 8$$

$$A_m = n_m \times u_m \times 12.56 \times 24 \dots 9$$

$$A_s = n_s \times u_s \times 2.74 \times 24 \dots 10$$

Carbon stock of Ashoka and Rain trees = number of trees x constant x (diameter) 2.62, and 2). Carbon stock of palm tree = number of trees x constant x diameter x height. They are formulated as follows:

$$S_{ar} = n \times 0.0238 \times D \times 2.62 \dots\dots\dots 11$$

$$S_p = n \times 1.712 \times D \times h \dots\dots\dots 12$$

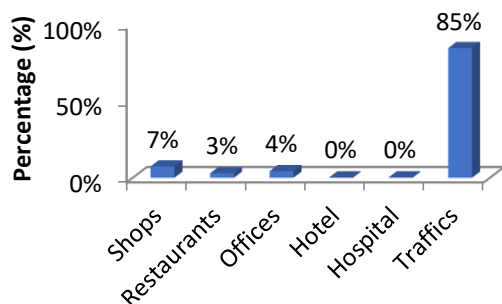
**Root Cause Analysis**

Simple root cause analysis is used to identify not only what and how an event occurs, but also why it happens. If the reason for an event or failure is determined, any possible remedial action that prevents future events of the observed type can be determined. There is a four-step process involved in root cause analysis, including data collection, charting causes, identification root causes, and generation of recommendations and implementation.

**RESULTS AND DISCUSSION**

**Carbon Dioxide Emission**

The total amount of carbon dioxide emission from human activities in the shops, offices, restaurants, a hotel and a hospital and the combustion of fossil fuels from motorized vehicles reaches 123,481.916 kg/day (Table 1).



**Figure 1.** Carbon Dioxide Emission Percentage

The average rate of carbon emissions generated by human activities in the Soekarno-Hatta road area is 11513.67 kg / ha per day. This has significantly less impact on environmental conditions. However, since this study focuses only on the number of people and their activities that are perceived as activities contributing lightly to carbon emissions, findings of human activity such as rest or low activity, normal work, and sleep activity show low levels of carbon emissions from human activity in the Soekarno-Hatta area. The carbon emissions from human activities in the

Soekarno-Hatta region show low CO<sub>2</sub> levels. This is because there are only shops, restaurants, offices, hotels, and hospitals that contribute lower carbon emissions than factories that are hard work. In addition, the number of people performing activities affects the level of carbon emissions. The linkages between human activity and environmental degradation vary widely. This supported previous studies [9,10]. According to the two studies, the current level of human consumption, combined with growing populations, has a significant negative impact on the natural environment and contributes to climate change. Similarly elasticity of CO<sub>2</sub> emissions and energy use to populations approached unity. This means that the size of the population alone does not significantly affect the level of CO<sub>2</sub> in the air [9].

In addition, the results of the analysis of the amount of carbon emissions from motor vehicles on the Soekarno-Hatta road show a significant amount of CO<sub>2</sub> of 71.301.89 kg / ha per day. This indicates that the rest of the process of burning fossil fuels for motor vehicles contributes significantly to CO<sub>2</sub> emissions. Estimates of one ton / day carbon emissions on the Soekarno-Hatta road can be caused by the number of cars, motorcycles, trucks, and mini buses passing this road which has 4802 motor cycles per hour, 3887 hours per hour, 10 trucks per hour, 2 buses per Hour and 71 mini buses per hour. Apparently, these results support previous research conducted by Salam and Toshikuni who studied the relationship between human activity and CO<sub>2</sub> emissions [11]. According to their research, in developing countries, significant human activities that cause increased CO<sub>2</sub> emissions include: (i) burning of fossil fuels, (ii) the strength of terrestrial ecosystems and (iii) land-use change. Among these factors, the burning of fossil fuels is the most influential human activity for CO<sub>2</sub> emissions in both developed and developing countries. The burning of fossil fuels has a significant positive effect on CO<sub>2</sub> emissions in both developed and developing countries [11].

**Carbon Dioxide Adsorption**

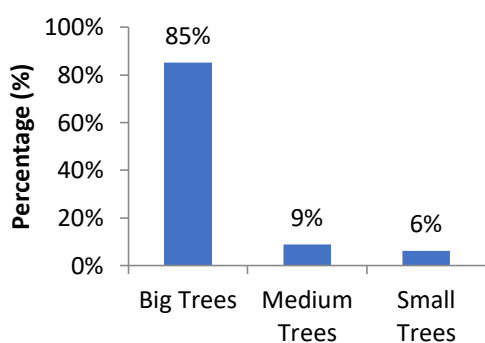
Total Carbon dioxide adsorption by big, medium, and small trees is 802,610.630 kg/ha per day + 82,933.756 kg/ha per day + 57,196.028 kg/ha per day = 942,740.414 kg/ha per day (Table 2).

**Table 1.** Carbon dioxide Emission in Soekarno-Hatta

Emission Source	Shops	Restaurants	Offices	Hotel	Hospital	Traffics	Total
Numbers (unit)	127	52	41	1	1	8772	
Amount in m3/day	4632.96	1847.04	2692.04	151.944	177.744	104697	114198.728
Amount in kg/ha per day	2862.3	1141.12	1663.17	93.87	109.81	32717.81	38588.08

**Table 2.** Carbon Dioxide Absorption in Soekarno-Hatta

Absorption	Big Trees	Medium Trees	Small Trees	Total
Amount in kg/ha per day	802610.63	82933.756	57196.028	942740.414



**Figure 2.** Carbon dioxide Absorption

The absorption of trees along the Soekarno-Hatta street is calculated based on the number of small, medium, and large trees. The results of small tree analysis, 317 medium, and 217 big show the amount of carbon absorbed by these trees. With the area of Soekarno-Hatta road about 3.2 hectares, the carbon absorbed by trees in this area is as much as 942,740,414 kg / ha per day. This is considered a significant amount of absorption. Since the number of large trees on Soekarno-Hatta street is 60% per hectare of large trees, the number of medium trees on Soekarno-Hatta street is 44% per hectare of medium trees and the number of small trees on Soekarno-Hatta street is 55% per hectare of trees Small, carbon absorption ability is also high considering most of the trees in 3.2hectare area of Soekarno-Hatta street. The amount of carbon sequestration of Soekarno-Hatta street trees is considered similar to nearly half a hectare of trees. Thus, it can be repeated that the carbon sequestration of Soekarno-Hatta's street trees is significant when compared to total CO<sub>2</sub> emissions generated by traffic and human activities in this area and therefore trees should be considered an effective mechanism to offset CO<sub>2</sub> emissions.

These results are in line with carbon sequestration standards in cities. A study conducted by Tang, Chen and Zhao found that the urban sequestration of urban trees in Beijing is half the equivalent of non-urban forests in China [12]. In addition, Davies et al. found that large amounts of carbon are deposited in top soil vegetation in Leicester, England, and the tree covers more than 95% of this carbon pool [13]. Furthermore, in some areas, in arid regions, urban forests can store more carbon than adjacent rural and suburban areas, as a result of tree planting and management of urban green space areas [14].

**Carbon Dioxide Balancing**

Carbon dioxide balancing is the calculation of total carbon dioxide emitted by human activities and motorized vehicles reduced by the total carbon dioxide absorbed by urban street trees on Soekarno-Hatta Street. As daily carbon dioxide emission from human activities and traffics reaches 78935.72 kg/ha per day and the ability of the urban street trees to absorb carbon dioxide accounts for 942,740.414 kg/ha per day, the balance between the emission and the absorption comes to -863804.694 kg/ha per day which means that the trees can effectively absorb carbon dioxide in the air. The negative result indicates that the trees still can absorb about 863804.694 kg/day more carbon dioxide emitted in the air. The result is presented in the figure below.

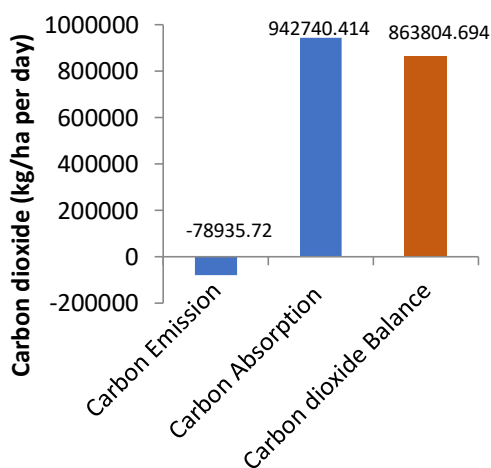
**Carbon Emission Transformation**

The carbon fraction in carbon dioxide is the weight ratio. The weight of carbon atoms is 12 units of atomic mass, while the weight of carbon dioxide is 44, because it contains two oxygen atoms each weighing 16.

**Table 5.** Problem and solution to reduce Carbon dioxide Emission and increase absorption

No	Problems	Roots of Problems	Alternative Solution	Solution
1	Carbon dioxide Emission	Number of People	Limiting the number of population living in an area Restricting urbanization	Limiting the number of population living in an area
		Number of transportation	Reducing number of motorized vehicles Using more efficient fuel Using public transportation	Using more efficient fuel
		The age of transportation The fewer number of urban trees	Doing regular maintenance Planting more trees on the sides of the urban streets	Doing regular maintenance Planting more trees on the sides of the urban streets
2	Absorption	The number of palm trees	Making program on palm tree plantation on the urban streets and in housing areas	Making program on palm tree plantation on the urban streets and in housing areas

Thus, the ratio of molecular weight of carbon dioxide to carbon is 44/12. This means that every 1 kg of carbon equals 3.67 kg of carbon dioxide [8]. Therefore, carbon dioxide emissions by human activities and motor vehicles in the Soekarno-Hatta road area are converted to carbon. The calculation is  $78935.72 \text{ kg} / 3.67 = 21508.37 \text{ kg} / \text{ha}$  per day. Total carbon emissions in the Soekarno-Hatta region are 21508.37 kg / ha per day.



**Figure 3.** Carbon Dioxide Balance

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**Table 3.** Carbon Stock

Sources	Ashoka Trees	Rain Trees	Palm Trees	Total
Amount in kg/ha	0.004	0.168	378.877	379.049

**Carbon Stock**

Total Carbon stock of trees on Sokarno-Hata Street is 1,212.955 m3. It is equal to  $1,212.95511 / 1000 = 1.21295511$  ton or 1,212.95511 kg. It is converted in to hectare as  $1 \text{kg} / 3.2 \text{ ha} = 379.0485 \text{ kg/ha}$ .

The amount of carbon stock in palm trees in Soekarno-Hatta area is higher than Asoka tree (*P. longifolia*) and Rain tree. Other study explored plant species diversity and carbon stock estimates, the findings indicate that among trees, the rubber tree, *Hevea brasiliensis* W., has the highest value index of allometric equations on carbon estimates followed oil palm tree or *Elaeis guineensis* L. and coconut or *Cocos nucifera* L. [15]. Other trees Has a much lower value index. This shows that the palm species have the ability to store more carbon than the Rain tree or Ashoka tree. However, since the number of palm trees is

less than the extensive rainfall trees such as the Rain and Ashoka trees, the amount of carbon stock in the Soekarno-Hatta street area is also low. In addition, found that conversion of land to agriculture and housing causes degradation of carbon sequestration and carbon stocks [16]. The area of Soekarno-Hatta road is heavily densely seen by the number of people performing various activities in the Region, the level of carbon stock is also affected.

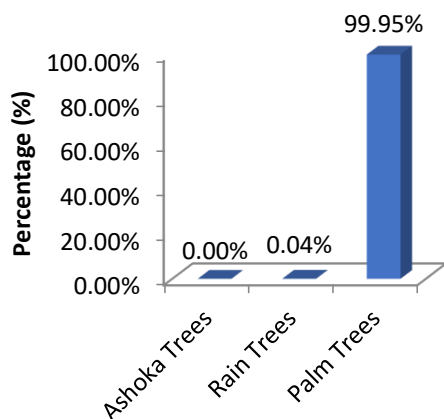


Figure 4. Carbon Stock

Moreover, Vesterdal et al. reported that forest floor C stocks were higher for Coniferous (Pinus) types than agile forests (Betula and Populus) grown in temperate climates [17]. This explains the amount of carbon stock in the coconut trees compared to the Rain trees and Ashoka trees (P. longifolia) because the leaves of the palm trees are more conifers than the broad-leaved trees such as Rain trees and Ashoka trees.

To reduce the high emissions of carbon dioxide, this study recommend 4 solution. First solution was to reduce the number of population living in an area, followed by using more efficient fuel and doing regular maintenance. The second solution was to increase the number of plants and trees in the area, especially tree species such as palm trees and the number of motor vehicles to be controlled and the care and services is necessary to be performed periodically (Table 5).

**Carbon Balance of Emission and Stock**

The carbon balance is the amount of carbon after the calculation between carbon emission and carbon stock. It is obtained from carbon emission reduced by carbon stock. The formula is as follow.

- Carbon Balance = Carbon Emission – Carbon Stock

- Carbon Balance = 10,514.468 kg/ha daily - 379.04847 kg/ha daily

Carbon Balance = 10,135.42 kg/ha daily

Table 4. Carbon Balance

Carbon	Carbon Emission (kg/ha per day)	Carbon Stock (kg/ha)	Balance (kg/ha)
Amount	21508.37	379.049	21129.32

**CONCLUSION**

This study focuses on analyzing the carbon balance between carbon dioxide emissions generated by human activities including respiration and use of LPG and motor vehicles consisting of burning fossil fuels and drivers and passengers breathing and carbon absorption by urban street trees in the area of Soekarno-Hatta. Clearly, large amounts of carbon dioxide are emitted by motor vehicles compared to those generated by human activity. On the contrary, the city street trees which include Ashoka, Rain tree (Samanea saman), and Palm tree (R. regia) in Soekarno-Hatta area have considerable ability to absorb carbon emission, among which Palm tree (Palmam lingo) is able to absorb a large amount of CO. However, the carbon level in the Soekarno-Hatta road area is not balanced because the amount emitted is higher than the stock found in the trees, but the area of Soekarno-Hatta road is not too polluted.

To reduce the high emissions of carbon dioxide, the number of plants and trees in the area has to multiply, especially tree species such as palm trees and the number of motor vehicles to be controlled and the care and services is necessary to be performed periodically.

**SUGGESTION**

It is predicted from the results of this study that CO2 emissions can be decreased by the reduction in the fossil-fuel consumption and alternate to other energy sources, to preserve the current forests, planting trees on abandoned and degraded lands, or by planting more urban street trees by society on urban street lands. Thus, it is recommended that the government and the community control the fossil fuel use as the major factor of the emissions of carbon dioxide and reduce them. In addition, the government should add an effective amount of trees to change emissions of carbon dioxide to become carbon stocks.

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