Potential of urban greening for carbon dioxide reduction from transportation sector

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Abstract. Various urban activities which exist in different lands uses in Mojokerto City such as settlement, commercial area, public service, and industrial area form the urban dynamic. Urban dynamic is stimulated by some factors including mobility of people and goods, information, and money. People’s mobility which dominates the urban mobility is accommodated by transportation mode causing transportation sector ranks the top first sector contributing to carbon dioxide (CO₂) emissions in urban area, including Mojokerto City. Therefore, the study aims to propose reasonable solution for CO₂ emissions reduction from transportation sector. The total amount of CO₂ emissions is calculated first, and vegetation capacity to absorb CO₂ is calculated afterwards using the formula for emission generation and bio capacity respectively. Development of urban greening is proposed to improve the bio-capacity of urban greening to absorb the remaining emissions. Based on the emission calculation, the total amount of CO₂ emissions from transportation sector ranges between 6.6 to 262.1 ton/year depending on the traffic volume and the distance covered by motorized vehicles. Meanwhile, calculation of bio capacity shows that the average absorption of vegetation in Mojokerto City is only 863.91 ton/yr. Improving urban greening area by planting more trees with higher absorption capacity is proposed to absorb the remaining emission. Calculation shows that enhanced urban greening can increase the emission absorption from 4% to 7% of the total emission from transportation sector.

1. Introduction
The increase of greenhouse gas emissions (GHG) is the main contributing factor of climate change worldwide which is mainly caused by economic growth and identified as a major threat to the air quality [1,2]. Cities as the center of economic growth have suffered deterioration of air quality which adversely affects public health [3]. Declining urban air quality is also affected by urbanization and industrialization [4,5,6]. Urbanization contributes the most since it accelerates infrastructure development in urban area, switching natural land surfaces to artificial land, altering the capacity of green space to keep energy balance leading to a variety of thermal environment in space and time [7]. This heterogeneity causes thermal divergences between urban and sub-urban areas. Deviations of microclimatic components such as humidity, temperature, and air velocity are influenced mostly due to urbanization [8]. As a result, a phenomenon called urban heat island (UHI) effect, where city is significantly warmer than its surrounding rural areas, occurs and research by [9,10] presented evidence that this effect has been worsening for continuous urbanization over recent decades causing health problems, discomfort on human body and environmental threat. Furthermore, cities worldwide are encountering the deterioration.
of green and open space [11]. Therefore, solutions for GHGs emission reduction are necessarily required to overcome air quality degradation in urban areas.

Urban greening is one of some strategies to reduce temperature and to mitigate UHI effects by absorbing the emitted GHGs for its bio capacity to absorb CO₂ and to supply oxygen (O₂). This capability represents partial city’s bio capacity which is commonly calculated yearly [12]. The concept of bio capacity has been developed to accommodate the demand of carbon absorption [13]. In this context, urban greening represents all type of urban landscaping which consists of various vegetations. According to [14], vegetation functions as regulator for abiotic components i.e., water, soil, humidity, and temperature which are important for better habitat, goods and services provision, while [15] affirmed that carbon absorption by urban greening including parks, urban forest, and residential gardens can partially balance CO₂ emission from vehicles. Increasing urban greening through planting appropriate type and number of vegetations is important to overcome air quality degradation in urban areas, including in Mojokerto City. Previous studies related to urban greening in urban areas were reported, such as design of vegetation composition and structure [16], roof greening system [11,17], estimation of climate [18].

However, calculation of carbon footprint is necessary to determine the properly functional urban greening since it can measure the GHGs emission from any sectors i.e., transportation, buildings, energy consumption, consumption of goods and services, and other direct and indirect activities [19]. It can be individual, group, government, firms, or organization activities [20]. Transportation contributes significantly to global GHG emissions. GHGs emission from transportation is mainly from fossil fuel burning which generates gaseous waste including CO₂, making up 95% of all transportation-related greenhouse gas emissions [21,22]. Vehicles including cars, SUVs, and pickup trucks are the source of emission for mobilization demand in urban areas since these vehicles run on fossil fuels such as gasoline and diesel fuel and they emit carbon dioxide.

In this study, calculation of carbon dioxide emission from transportation are calculated and the total emission will be compared with the total capacity of urban greening in Mojokerto City. Through an alternative solution, i.e. increasing the area and the density of urban greening, increasing the capacity of vegetation in green zone is calculated to reduce the remaining unabsorbed carbon dioxide.

2. Methods
The area of study covers all main streets and urban greening areas in Mojokerto City. Emission generated from transportation is calculated based on the peak days determined beforehand, namely Monday for weekday and Sunday for weekend. The peak hour is determined later and categorized into three sessions which were in the morning, noon, and afternoon.

Urban greening areas in Mojokerto City covers the area of ± 50.1 Ha consisting of public parks, cemeteries, and green path such as riverside, green area along railway, boulevard, and pedestrian. Various trees listed in Table 3 are planted in these urban greening areas. Identification of vegetation types was conducted and the total absorption of each type of urban greening area was conducted based on the assumption that only urban greening areas adjacent to main streets contribute significant carbon absorption.

2.1. Emission Calculation
Carbon dioxide calculation is conducted using the formula proposed by [23] which requires measurement of total distance and total fuel consumption using equation 1 and equation 2. The number of vehicles are calculated during peak hours and divided into 3 different sessions, i.e. 7 until 8 am, 12 – 13 pm, and 5 until 6 pm.

\[ D = L \times N_v \]  

\[ \text{Where:} \]
\[ D = \text{distance [km]} \]
$L_r = \text{road length [km]}$

$N_v = \text{number of vehicles}$

Total fuel consumption is calculated using obtained value of distance ($D$) afterwards.

$$C_{tot} = D \times C_s$$

(2)

Where:

$D = \text{distance [km]}$

$C_{tot} = \text{total fuel consumption [liter]}$

$C_s = \text{Specific energy consumption [liter/km]}$

Each type of vehicle has a unique specific energy consumption presented in Table 1.

| Type of vehicle | Specific energy consumption [liter/km] |
|-----------------|--------------------------------------|
| Personal vehicle| 0.118                                 |
| Bus             | 0.169                                 |
| Minibus         | 0.118                                 |
| Taxi            | 0.109                                 |
| Truck           | 0.158                                 |
| Pick-up         | 0.081                                 |
| Motorbike       | 0.027                                 |

Source:[24]

Once total fuel consumption is gained, total carbon dioxide emission from transportation is calculated using equation 3. The value of emission factor varies with the type of fuels, and default value of emission factor proposed by IPCC is used in this study. Gasoline and diesel fuel are typical fuels used by vehicles in Mojokerto City, and the emission factor is presented in Table 2.

$$\text{Em}_{tot} = C_{tot} \times EF$$

(3)

Where:

$\text{Em}_{tot} = \text{Emission}$

$C_{tot} = \text{total fuel consumption [liter]}$

$EF = \text{Emission factor [kg/liter]}$

| Fuel Type   | Emission Factor Kg/liter |
|-------------|--------------------------|
| Gasoline    | 69.3                     |
| Diesel fuel | 74.1                     |

Source:[24]

2.2 Carbon dioxide absorption capacity of urban greening

Total capacity of urban greening to absorb carbon dioxide is calculated using the following equation (Eq.4)

$$Abs_{tot} = \sum (Bc_i \times N_i)$$

(4)

Where:

$Abs_{tot} = \text{Total absorption [kg CO}_2\text{]}$

$Bc_i = \text{absorption capacity of each type of tree [kg CO}_2\text{/tree]}$

$N_i = \text{total number of each type of tree [tree]}$
If the amount of emission is larger than the total absorption, further calculation is conducted using equation 5 which determines the amount of CO$_2$ emission not absorbed by trees.

$$\Delta Em = Em_{tot} - Abs_{tot}$$  \hspace{1cm} (5)

Where:
- $Em_{tot}$ = Total emission [kg]
- $\Delta Em$ = residue [kg]
- $Abs_{tot}$ = Total absorption [kg CO$_2$]

The value of tree absorption rate (Abs) can be categorized based on the types of trees, and the values refer to the previous study from [3] as it is explained in Table 3.

| No. | Local Name      | Scientific Name          | Absorption of CO$_2$  |
|-----|-----------------|--------------------------|------------------------|
| 1.  | Trembesi        | Samanea saman            | 28,448.39              |
| 2.  | Kenanga         | Canangium odoratum       | 756.59                 |
| 3.  | Pingku          | Dysoxylum excelsum       | 720.49                 |
| 4.  | Beringin        | Ficus benyamina          | 535.9                  |
| 5.  | Krey Payung     | Fellicium decipiens      | 404.83                 |
| 6.  | Mahoni          | Swettiana mahagoni       | 295.73                 |
| 7.  | Akasia (auriculiformis) | Acacia auriculiformis | 48.68                  |
| 8.  | Flamboyan       | Delonix regia            | 42.2                   |
| 9.  | Tanjung         | Minusops elengi          | 34.29                  |
| 10. | Bunga Merak     | Caesalpinia pulcherrima  | 30.95                  |
| 11. | Angsana         | Pterocarpus indicus      | 11.12                  |

Source: [3]

### 3. Results and Discussion

#### 3.1. Greenhouse Gas Emission from Transportation

Calculation of CO$_2$ emission depends on the number of vehicles, fuel type, street length, and the value of emission factor which is default value as presented in Table 2. The result of measurement is presented in Figure 1 and Figure 2 for weekday and weekend respectively.
Vehicles with small capacity of 100 until 125 cc, typically motorbike, is the most popular private transportation in Mojokerto City where 125cc motorbike ranks first during weekday and weekend in the morning and noon. Fuel consumption is calculated based on the assumption that motorbike consumes gasoline, car consumes either gasoline or diesel fuel and truck as well as bus consumes diesel fuel. Total fuel consumption is calculated by multiplying it with the distance covered by each vehicle during peak hour. The result of calculation shows that total fuel consumption of motorbike and car which consume gasoline emits the highest emission, while diesel car and truck contribute to less emission though it has higher capacity of 1000cc and above, which is because the number of these vehicles passing through the street are relatively small compared to motorbike. It indicates that people in Mojokerto City prefer to commute using motorbike for low fuel consumption and due to inadequate public transportation. Figure 3 presents the share of fuel consumption of vehicles in Mojokerto City. Consequently, the emission from transportation is mainly contributed by motorbike and gasoline car (Figure 4).

**Figure 2.** The average number and percentage of vehicles in Mojokerto City during weekend

**Figure 3.** Share of fuel consumption of vehicles in Mojokerto City

**Figure 4.** Emission from transportation sector in Mojokerto City
The calculation comes to a result that emission from transportation varies by traffic volume in each street ranging from 6 tons CO$_2$/year to 270 tons CO$_2$/year as described in Figure 5.

3.2. Emission Reduction Calculation through Absorption

Referring to Eq.5, total absorption of emission was calculated according to the bio-capacity of each tree. The result shows that urban greening in Mojokerto cannot absorb all emission and there are about 189.21 ton/year CO2 emission remaining in the atmosphere. Through improvement of urban greening, the absorption capacity can be increased. Improvement is conducted by planting more typical vegetation within the green zones and different trees having higher bio-capacity. Figure 6 shows the decrease of emission remaining in the atmosphere after more vegetation is planted in urban greening areas in Mojokerto City.

Figure 5. Emission from transportation sector in Mojokerto City

Figure 6. Remaining emission after improvement of urban greening
Extension of urban greening areas in Mojokerto City to absorb the remaining emission is not possible since there are no more public areas that can be developed into new green zones. Therefore, appropriate solutions that can be implemented are by traffic management and fossil-to-biofuel shift to reduce emission. Encouraging people to plant more vegetation with high absorption capacity in their private garden is another option to improve carbon emission absorption in Mojokerto City.

4. Conclusion
Mojokerto City needs improvement on its urban greening areas to reduce emission from transportation sector. CO2 emitted by vehicles varies in every street depending on traffic volume and the fuel type consumed by vehicles passing through the street. The emission ranges between 6.6 to 262.1 ton/year. With the total absorption capacity of 863.91 ton/yr of the urban greening areas in Mojokerto City, there is remaining carbon emission which is 189.21 ton every year. By planting more vegetation, this remaining emission can be decreased. Currently, absorption capacity of urban greening areas in Mojokerto City is about 4%. Adding the number of trees can increase the absorption of CO2 emission, although still low, to around 7%. Implementing efficient traffic management and promoting biofuel can decrease emission more effectively.

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References
[1] Chen P Y, Chen S T, Hsu C S, Chen C C 2016 Modelling the global relationships among economic growth, energy consumption and CO2 emissions Renewable and Sustainable Energy Reviews 65(C) 420 – 431
[2] Kais S, Sami H 2016 An econometric study of the impact of economic growth and energy use on carbon emissions: panel data evidence from fifty-eight countries Renewable and Sustainable Energy Reviews 59(C) 1101 – 1110
[3] Pandey A K 2015 Air Pollution Tolerance Index and Anticipated Performance Index of Some Plant Species for Development of Urban Forest, Urban Forestry and Urban Greening http://dx.doi.org/10.1016/j.ufug.2015.08.001
[4] Liobikien G, Butkus M 2019 Scale, composition, and technique effects through which the economic growth, foreign direct investment, urbanization, and trade affect greenhouse gas emissions Renewable Energy 132(C) 1310 – 1322
[5] Zhang C, Zhou X 2016 Does foreign direct investment lead to lower CO2 emissions? Evidence from a regional analysis in China Renewable and Sustainable Energy Reviews 58(C) 943 – 951
[6] Wang Q, Wu S D, Zeng Y E, Wu B W 2016 Exploring the Relationship Between Urbanization, Energy Consumption, and CO2 Emissions in Different Provinces of China Renewable and Sustainable Energy Reviews 54(C) 1563 – 1579
[7] Wu Z, Ren Y 2018 A Bibliometric Review of Past Trends and Future Prospects in Urban Heat Island Research from 1990 to 2017 Environmental Reviews 27(2) 241–251
[8] Sultana R, Ahmed Z, Hossain M A, Begum B A 2021 Impact of green roof on Human Comfort Level and Carbon Sequestration: A Microclimatic and Comparative Assessment in Dhaka City, Bangladesh Urban Climate 38 (2021) 100878
[9] Huang Q, Lu Y 2018 Long-term Trend of Urban Heat Island Intensity and Climatological Affecting Mechanism in Beijing city Scientia Geographica Sinica 38 (10) 1715–1723
[10] Manoli G, Fatichi S, Bou-Zeid E, Katul G G 2020 Seasonal Hysteresis of Surface Urban Heat Islands Proceedings of the National Academy of Sciences 117(13) 7082–7089
[11] Safayet M, Arefin M F, Hasan M M 2017 Present Practice and Future Prospect of Rooftop
Farming in Dhaka city: a Step Towards Urban Sustainability. *Journal of Urban Management* 6(2) 56–65

[12] Mancini M S, Galli A, Coscieme L, Niccolucci V, Lin D, Pulseli F M, Marchettini N 2018 Exploring ecosystem Services Assessment Through Ecological Footprint Accounting. *Ecosystem Services* 30 228–235

[13] Nowak D J Crane D E 2002 Carbon Storage and Sequestration by Urban Trees in the USA. *Environmental Pollution* 116(3) 381–389

[14] Roeland S, Moretti M, Amorim J H, Branquinho C, Fares S, Morelli F 2019 Towards an Integrative Approach to Evaluate the Environmental Ecosystem Services Provided by Urban Forest. *J. For. Res.* 30 (6) 1981–1996

[15] Li P, Wang Z 2021 Environmental co-benefits of Urban Greening for Mitigating Heat and Carbon Emissions. *Journal of Environmental Management* 293 112963

[16] Hwang Y H, See S C, Patil M A 2021 Short-term vegetation changes in tropical urban parks: Patterns and design-management implications. *Urban Forestry & Urban Greening* 64 1 – 11

[17] Su Y, Wang Y, Fang W D 2020 Increasing Effectiveness of Urban Rooftop Farming Through Reflector-Assisted Double-Layer Hydroponic Production. *Urban Forestry & Urban Greening* 54 126766

[18] Sultana R, Ahmed Z, Hussain M A, Begum B A 2021 Impact of green roof on human comfort level and carbon sequestration: A microclimatic and comparative assessment in Dhaka City, *Bangladesh Urban Climate* 38 (2021) 100878

[19] Awanthi M, Navaratne C 2018 Carbon Footprint of an Organization: a tool for Monitoring Impacts on Global Warming. *Proc. Eng.* 212 729–735

[20] Wiedmann T, Minx J 2008 A Definition of 'Carbon Footprint' In: C. C. Pertsova, *Ecological Economics Research Trends* Chapter 1 pp 1-11 Nova Science Publishers (Hauppauge NY: USA)

[21] García C C, Mota I F D L, Anguiano I S 2021 Proposal for Greenhouse Gas Emissions Reduction in Public Passenger Transportation. *Case Studies on Transport Policy* https://doi.org/10.1016/j.cstp.2021.07.009

[22] Güzel T D, Alp K 2020 Modeling of Greenhouse Gas Emissions From The Transportation Sector in Istanbul by 2050. *Atmospheric Pollution Research* 11 2190 – 2201

[23] IPCC 2006 *Guidelines for National Greenhouse Gas Inventories*

[24] Meidiana C, Setiyono D A, Rohman N R N, Hadid A K 2020 Emission Reduction from Transportation Sector Using Carbon Footprint. *Advances in Engineering Research* 193 36 – 41