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Absorption Capacity of CO_2, NO_2, and Dustfall Emission from Transportation, Industry, and Livestock Sectors in Bogor City by Bogor Botanical Garden

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ABSTRACT

One of the environmental issues was the increasing of air pollution concentration. On the other hand, Bogor Botanical Gardens had high potential as an air quality controller. This study aims to calculate Bogor Botanical Gardens plants ability to reduce CO_2, NO_2, and dustfall emission, analyzing the correlation of leave morphology with the plant ability in absorb dustfall, and determine criteria of plant that can reduce CO_2, NO_2, and dustfall. Total amount of CO_2, NO_2, and dustfall emission and Bogor Botanical Garden sink ability was calculated by secondary data from multiple source unit and its corresponding emission factors. The ability of several plants to absorb dustfall was calculated by gravimetric method using samples from Bogor Botanical Garden. The sample plants were Sansevieria trifasciata, Cinnamomum multiflorum, Callicarpa pedunculata, Carmona retusa, and Antigonon leptopus. The analysis showed that Bogor Botanical Gardens were able to reduce CO_2 emissions by 28.7%, NO_2 by 2.2%, and dustfall by 11.4%. Plant ability to absorb dustfall was 0.02-0.7 mg/cm^2. The most effective species to absorb dustfall was Carmona retusa with maximum capacity of 0.7 mg/cm^2.

Keywords: *absorption, Bogor Botanical Garden, carbon dioxide, dustfall, nitrous dioxide*

1. INTRODUCTION

Air pollution was one of environmental quality degradation indicator that impact on human health. In International Seminar the Utilization of Catalytic Converter and Unleaded Gasoline for Vehicle, it was shown that 70% toxic gases in air comes from land transportation sector. Bogor city had 820,707 citizens, 419,252 males and 401,455 female and average citizens per square kilometre is 6,662 person. Highly population and fast growth rate, food needs, fuel consumption, building, and domestic garbage impacted low environmental quality.

Besides transportation sector, other emission sources come from industrial activities and livestock. Livestock sector produced CO_2 and NO_2, emission from fermentation and animal manure management [1]. Emissions from industry sector are CO_2, NO_2, and dustfall. Dustfall was a particle with size up to 500 µm that formed due to lifted refined fractions from soil surface [2].

Bogor Botanical Garden was ex-situ conservation land in form of urban forest that located in the central of Bogor city. Nowadays, Bogor Botanical Garden acts multifunction as central of tree conservation, air quality control, education function, research object and Bogor city sightseeing icon. The importance of Bogor Botanical Garden must be supported by research results proving its role in reducing the pollution in Bogor city.

2. MATERIAL AND METHODS

2.1 Place and Time Experiment

Sampling was carried out in Bogor Botanical Gardens. Data analysis was carried out in Air Quality and Noise Pollution Laboratory Department of Civil and Environmental Engineering, Faculty of Agricultural Technology, Bogor Agricultural University. Time research was three months (January-March 2014).

2.2 Instruments and Material

Instruments and materials used in this research were:

a. Leaves sample from several tree in Bogor Botanical Garden, as shown in Table 1

Table 1: Examined tree species

Species	Family
Sansevieria trifasciata var. laurentii (De Wild.) N.E.Br.	Agavaceae
Cinnamomum multiflorum (Roxb.) Wight	Lauraceae
Callicarpa pedunculata R. Br.	Verbenaceae
Carmona retusa (Vahl) Masam	Boraginaceae
Antigonon leptopus Hook. Et Arn.	Polygonaceae

b. Aquadest
c. 34 Petri dish [Normax]
d. Tweezers
e. Oven [Memmert]
f. Shaker [Inforst HT Labotron S-000117608]

g. Analytic balance [Ohaus Adventurer Pro AV264]
h. Whatman filter paper 41 diameter 47 mm
i. Filter holder and Erlenmeyer [Pyrex Iwaki TE-32]
j. Water Circulating Vacuum Pump [J.P. Selecta]
k. Beaker glass 250 mL
l. Flip plastic bags
m. Millimetre block
n. Scissors
o. Stationary
p. Microscope [Olympus U-CMAD3 model SSC-G818]
q. Digital camera

2.3 Research Methods

In order to calculate the Garden's ability to reduce CO_2, NO_2, and dustfall, correlation of leave morphology with the plant's ability to absorb CO_2, NO_2, and dustfall emission was analyzed.

2.3.1 Transportation sector

Energy activities calculated using vehicle number and its fuel. Energy intensity value for each vehicle was shown in Table 2.

Table 2: Energy intensity for each vehicle

Vehicle Type	Intensity (l/km)
Bemo/Bajaj	0.024
Taxi	0.115
Pick-up	0.109
Motorcycle	0.031
Public transportation	0.168
Bus	0.265
Truck	0.198

Source: [3]

Fuel specification and emission factor value shown in Table 3.

Table 3: Emission factor and fuel specification in Indonesia

Fuel	Specific Gravity (kg/l)	Emission Factors		
		CO_2 (kg/ton)	NO_2 (kg/ton)	Dustfall (kg/ton)
Gasoline	0.746	18.9	10.3	2
Diesel fuel	0.837	20.2	11	2.4

Source: [4, 5]

Emission from transportation sector related to fuel consumption of each vehicle. The formulation to calculate total vehicle emission was:

$$C_{BBM} = I \times N_K \times V_{rata\text{-}rata} \quad (1)$$

$$v = C_{BBM} \times EF_K \quad (2)$$

Notes:
C_{BBM} = fuel consumption (l/hour)
I = energy intensity (l/hour)
N_K = vehicle number (unit)
$V_{rata\text{-}rata}$ = average velocity (km/hour)
v = emission rate (g/hour)
EF_K = emission factor (g/l)

2.3.2 Industrial Sector

Bogor city has an area of 118.5 km^2 and mixing height of 1,417 m [6]. The data used for analysis and predict air mass dispersion capacity due to transformation process "emission→ambient". Emission calculation for industrial sector was based on secondary data. Calculated emission was stack emission. The measured parameter were NO_2 and dustfall. Emission calculation using the following equation:

$$v = E_C \times V_u \div 1{,}000 \text{ mg/g} \quad (3)$$

Notes:
v = emission rate (g/hour)
E_c = stack emission (mg/Nm^3/hour)
V_u = dry air volume (Nm^3)

Stack emission measurement data was subsequently used to estimate total emission from Bogor industries. Number industries operated in Bogor city was 2,724 units with 56 units' large/medium industries, 728 units' small-formal industries, and 1,938 units' small-non formal industries [7].

2.3.3 Livestock Sector

CO_2 and NO_2 emission calculated using mole concept based on The Law of Conservation of Mass (Lavoisier), The Law of Definite Proportion (Proust), and The Law of Partial Pressures (Dalton) [8]. Ruminant's animal produced CH_4 emission through fermentation process and manure management, but CH_4 emission from non-ruminants animal such as poultry only produced from manure management. Methane gases from fermentation process comes from carb digestion by microorganisms, whereas methane and nitrous oxide from manure management occurs due to decomposition under anaerobic condition. CO_2 contained in CH_4 content transformed using chemical reaction.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

When CH_4 reacts with O_2 gas in the atmosphere, then it creates CO_2 and water vapour. While NO_2 gas content derived from N_2O when it react with O_2 shown by the following chemical reaction:

$$2N_2O + 3O_2 \rightarrow 4NO_2$$

Methane and nitrous oxide emission factor value shown in Table 4.

CO_2 emission calculated using the following equation:

$$E_{CH_4(EF)} = N_T \times EF_{Tf} \quad (4)$$

$$E_{CH_4(MM)} = N_T \times EF_{Tm} \quad (5)$$

$$TE_{CH_4} = E_{CH_4(EF)} + E_{CH_4(MM)} \quad (6)$$

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$TE_{CO_2}= TE_{CH_4} \times MrCO_2 \div MrCH_4 \div 8{,}640$ hour/year (7)

Notes:
$E_{CH4(EF)}$ = emission from fermentation (kg/year)
N_T = number of animal (head)
EF_{Tf} = CH_4 emission from fermentation (kg/head/year)
$E_{CH4(MM)}$ = manure management emission (kg/year)
EF_{Tm} = CH_4 emission factor from manure management (kg/head/year)
TE_{CH4} = total CH_4 emission (kg/year)
TE_{CO2} = Total CO_2 emission (kg/hour)
$MrCO_2$ = CO_2 relative molecular mass
$MrCH_4$ = CH_4 relative molecular mass

Table 4: Methane and nitrous oxide emission factor value for livestock sector

Animal	Fermentation Emission Factor (kg CH_4/ head/year)	Manure Emission Factor (kg CH_4/ head/year)	Animal Manure Process	Direct N_2O-N Emission Factor (kg N_2O/kg N)
Dairy cow	61	31.0	Dry stack	0.02
Beef cow	47	1.0		
Buffalo	55	2.0		
Horse	18	2.19		
Goat	5	0.22		
Sheep	8	0.20		
Poultry	-	0.02	Poultry with fencing	0.01

Source: [11]

Besides producing CH_4 and CO_2 emission, animal manure management also produced N_2O and NO_2 emission. Total NO_2 emission from animal calculated using the following equation:

$N_2O_{D(mm)} = N_T \times EF_{3S} \times Nex_T \times MS_T \times TAM \times 365$ day/year (8)

$TE_{NO_2} = N_2O_{D(mm)} \times MrNO_2 \div MrN_2O \div 8{,}640$ hour/year (9)

Notes:
$N_2O_{D(mm)}$ = manure management emission (kg/year)
N_T = number of animal (head)
EF_{3S} = N_2O emission factor from animal manure management (kg/kgN)
Nex_T = average N excretion per head species (kgN/kg/day)
TAM = animal weight (kg/head)
TE_{NO2} = total NO_2 emission (kg/hour)
$MrNO_2$ = NO_2 mass molecular relative
MrN_2O = N_2O mass molecular relative

Calculation for emission absorption per hour by plants in Bogor Botanical Garden using the following equation:

$D_{CO_2} = Dn_{CO_2} \times N$ (10)

$D_{NO_2} = Dn_{NO_2} \times W_n \times \sum d \times N \div 10^6$ µg/g (11)

$D_{dustfall} = Dn_{dustfall} \times V_u$ (12)

Notes:
D_{CO2} = total CO_2 absorption (g/hour)
Dn_{CO2} = CO_2 absorption per specimen/family (g/hour/tree)
N = number of specimen (tree)
D_{NO2} = total NO_2 absorption (g/hour)
Dn_{NO2} = NO_2 absorption per specimen/family (µg/g/hour)
W_n = leaf weight (g/strand)

$\sum d$ = number of leaves (strand)
$D_{dustfall}$ = total dustfall absorption (g/hour)
$Dn_{dustfall}$ = total dustfall per specimen/family (g/m^3/hour)
V_u = air dry volume (m^3)

Methods to calculate dustfall capacity that catch by leaves was:

a. Sampling leaves

Tree leaves taken from each type of plant at the same height but different leaf position. Leaf samples were taken from perfect breeding leaves. Sampling was done by cutting the base of the leaf and then stored in a labelled Petri dish

b. Calculation of leaf area

Leaf area was measured using gravimetric method, by drawing a square on millimetre block with an area 1 cm^2 and then weighed (W_i). The square made into a standard for measuring leaf area. Each sample was made leaf pattern on millimetre block and then weighed (W_t)

$A=\frac{Wt}{Wi}\times 1$ cm (13)

Notes:
A = leaf area (cm^2)
Wt = paper weight for each leaf sample (g)
Wi = standard paper leaf (g)

c. Amount of dustfall on leaf surface

Measurement of the amount of dustfall suspended by leaf was measured by dipping the leaf in 250 ml of distilled water. Water and leaf was shaked using HT Inforst shaker with a constant speed of 200 rpm for 15

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minutes. Furthermore, filter paper oven and weighed (W_1), filter holder, and Erlenmeyer vacuum pump was used to filtering water that used for wash leaf. Afterwards, the filter oven for two hours and weighed (W_2). The difference between W_1 and W_2 was the amount of dustfall on leaf. Calculation of dustfall content per leaf area using the following equation:

$$W=(W_1-W_2)/A \qquad (14)$$

Notes:

A = leaf area (cm^2)
W_1 = filter paper weight before filtering (g)
W_2 = filter paper weight after filtering (g)
W = amount of dustfall on leaf surface (g/cm^2)

3. RESULT AND DISCUSSION

3.1 Bogor Botanical Garden Characteristics

Bogor Botanical Garden has an area of 754.8 m^2. The cover land composition of Bogor Botanical Garden was presented in Figure 1. Facilities include toilets, bridges, and roads, while building includes offices, warehouses, laboratories, observatories, places of worship, sport venues, office buildings, guard post, garage, walkway, country houses, mess, and gazebo. From total land area in Bogor Botanical Garden, 86.3% is used as tree planting area.

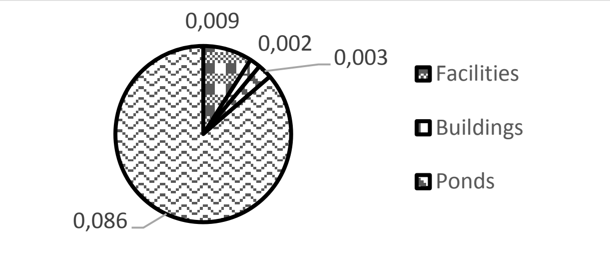

Fig 1: Bogor Botanical Garden cover land composition
Source: [9]

Recorded 213 families, 1,248 genera, 166 indeterminant, 8,000 genus, and 14,057 species has been found in Bogor Botanical Garden [9]. Mostly come from Arecaceae and Araceae family (Table 5). These families commonly used as a roadside tree or in a variety of land owned by institutions, such as government land, offices, schools, and housing because it has a high tolerance to solid ground, air pollution, and droughts.

Table 5: Top 10 families in Bogor Botanical Garden

Family	Number of specimen (Tree)
Arecaceae	1,568
Araceae	742
Zingiberaceae	581
Euphorbiaceae	504
Apocynaceae	477
Rubiaceae	473
Caesalpiniaceae	392
Sapindaceae	366
Meliaceae	361
Myrtaceae	332

Source: [9]

3.2 Bogor City Emissions

3.2.1 Transportation sector

High rate emission of CO_2, NO_2, and dustfall was identified from the correlation between the numbers of vehicles with its fuel consumption. According to data gathered from DLLAJ Bogor city in 2014, vehicle in Bogor city mostly used gasoline and diesel fuel. The result of the calculation of the theoretical emission from transportation sector in Bogor city are presented in Table 6.

Table 6: Theoretical emission from transportation sector

Vehicle Types	Number of Vehicles (unit)[a)]	Fuel Consumption (l/hour)	Emission Factors (g/l)[b)]			Emission Rate (kg/hour)		
			CO_2	NO_2	Dustfall	CO_2	NO_2	Dustfall
Public transportation	5,292	3.6E+04				502.7	273.9	53.2
Private transportation	1,570	7.2E+03	14.1	7.7	1.5	101.8	55.5	10.8
Motorcycle	12,172	1.5E+04				214.9	117.1	22.740
Small pick up	609	2.7E+03				37.4	20.4	4.0
Big pick up	3,400	1.5E+04				250.7	136.5	29.8
Bus	409	4.3E+03	16.9	9.2	2.0	73.2	39.9	8.7
Truck	4,792	3.8E+04				643.2	350.3	76.4
TOTAL	**28,244**	1.2E+05				**1,824.0**	**993.6**	**205.6**

Sources: a) [10], b) [11]

Based on calculation result, type of vehicle that has the highest fuel consumption was truck followed by public transportation. This was happened because although type vehicle with the highest number was public transportation, based on machine test performed by DLLAJ Bogor city, truck was the most fuel consumptive. Besides that, diesel fuel has higher specific gravity than gasoline. Total emission calculated by count emission from all number vehicles and CO_2 resulted was in amount of 1,824.0 kg/hour, NO_2 in amount of 993.6 kg/hour, and dustfall in amount of 205.6 kg/hour.

3.2.2 Industrial sector

Emission calculation from industrial sector was based on testing result of stack emission from four biggest contributing industries performed by BPLH Bogor city in 2013. Calculation result of emission from industrial result shown in Table 7.

Goodyear Indonesia using vapour cattle with coal as its fuel, Boehringer Ingelheim using oil as its fuel, and Unitex and Nutrifood Indonesia using gas as its fuel. Based on calculation result, Goodyear Indonesia is the most emission producer by NO_2 in amount of 3.5 kg/hour and dustfall in amount of 0.2 kg/hour. CO_2 emission does not perform a testing. Testing result shown that total emissions produced by the four industries are NO_2 in amount of 6.9 kg/hour and dustfall in amount of 0.5 kg/hour. Data from Table 7 used for estimated industries emission from Bogor city as shown in Table 8.

Table 7: Emission from four industries in Bogor city

Name of Industries	Testing Result (mg/Nm³)		Emission (kg/hour)	
	NO_2	Dustfall	NO_2	Dustfall
Goodyear Indonesia	498.8	48.2	3.5	0.3
Unitex	192.7	T.A	1.3	T.A
Boehringer Ingelheim	203.2	21.7	1.4	0.2
Nutrifood Indonesia	87.1	T.A	0.6	T.A
TOTAL			**6.9**	**0.5**

Source: [12]

From the data below, it's known that only four of 14 industries that give more than half of the estimated emissions of NO_2 and dustfall in 2013. Such results indicated the relative importance of minerals, textiles, metals, and foods-beverages sector compared to other sectors [13]. A deeper analysis gives more understanding that the amount of emission generated does not always correlate with the number of industries units, but more to the fuel used and intensified equipment maintenance operation. For example, food sector consist of 6 units large/medium industry, 154 units small-formal industry, and 929 small-non formal industry, making this sector as the largest number industry, but the given contribution emission only by 8% [13].

Table 8: Estimated industries emission Bogor city

Industries Group	Contribution Emission (%)[a)]	Estimated Emission (kg/hour)	
		NO_2	Dustfall
Food	8	72.5	7.7
Beverage	8	72.5	7.7
Processing wood	4.7	42.6	4.6
Pulp and paper	7.7	69.8	7.5
Chemical industry	5.7	51.6	5.5
Minerals/non-metallic	18	163.1	17.4
Chemical	7	63.4	6.8
Machinery	6.3	57.1	6.1
Metal	13	117.8	12.6
Transport equipment	4.3	39.0	4.2
Textile industry	13	117.8	12.6
Leather industry	2.3	20.8	2.2
Educations, sports, and other equipments industry	0.7	6.3	0.7
Electronic industry	1.3	11.8	1.3
TOTAL	100	905.6	96.8

Source: [a)] [13]

3.3 Livestock sector

Based on the data obtained from Department of Agriculture and Livestock Bogor city, poultry was the largest number of type of animal kept by Bogor city citizen, in amount of 386.131 head, and the lowest animal population was horses in amount of 76 head. Emission calculation result from livestock sector shown in Table 9.

Table 9: Total emission from livestock sector

Animal Species	Population (head)[a)]	Animal Weight (kg)	Methane Total Emission (kg/ year)	Carbon dioxide Total Emission (kg/hour)	N_2O Total Emission (kg/ year)	NO_2 Total Emission (kg/ hour)
Dairy cow	8.6E+02	750	7.8E+04	25.1	3.2E+04	7.7
Beef cow	2.2E+02	319	1.0E+04	3.4	3.5E+03	0.9
Buffalo	1.9E+02	400	1.0E+04	3.4	3.7E+03	0.9
Horse	7.6E+01	207	1.5E+03	0.5	7.8E+02	0.2
Goat	1.2E+03	40	6.0E+03	1.9	2.3E+03	0.6
Sheep	8.9E+03	23	7.3E+04	23.4	9.9E+03	2.4

Animal Species	Population (head)[a]	Animal Weight (kg)	Methane Total Emission (kg/ year)	Carbon dioxide Total Emission (kg/hour)	N_2O Total Emission (kg/ year)	NO_2 Total Emission (kg/ hour)
Poultry	3.9E+05	2	7.7E+03	2.5	1.8E+04	4.4
TOTAL	**4.0E+05**		**1.8E+05**	**60.1**	**7.0E+04**	**17.1**

Source: [a] [14]

Based on calculation result, dairy cow was animal species that produced largest emission by CO_2 25.1 kg/hour and NO_2 by7.7 kg/hour. Total livestock emission was CO_2 by 60.1 kg/hour and NO_2 by 17.1 kg/hour. The total emission from three sectors was shown in Table 10.

Table 10: Recapitulation of emission in Bogor city

Sector	Emission (kg/hour)		
	CO_2	NO_2	Dustfall
Transportation	1,824.0	993.6	205.6
Industry	N.A	905.9	98.8
Livestock	60.1	17.1	N.A
TOTAL EMISSION	**1,884.1**	**1,916.5**	**304.4**

Notes: N.A: data not available

From Table 10 above, it was known that the largest emission produced by transportation sector. The most possible explanation was related due to the high number of vehicles, unmaintained machine [15], and road condition [16]. Besides that, traffic jam caused a longer distance while the vehicle engine still working and consuming energy [17].

3.3 CO_2, NO_2, and Dustfall Absorption by Bogor Botanical Garden

Calculation of the estimation absorption of CO_2, NO_2, and dustfall capacity on leaves surface used the approach of Benson Taxonomic in 1957, which uses value of each family. Each plant family grouped based on its similarity to eight large families, such as Verbenaceae, Sapindaceae, Clusiaceae, Gnetaceae, Annonaceae, Sapotaceae, Burseraceae, and combination plant group. The tree absorbs CO_2 and NO_2 gases through stomata in the leaves and dustfall through interception [18]. CO_2 absorption value were taken from Dahlan research result [19], NO_2 absorption value of Nasrullah et al. research result [20], and dustfall interception value of Wawo research result [5].

Based on the comparison of each family, combination plant group was a family with the highest average of CO_2 absorption, equal to 165 g/hour, while the lowest was Gnetaceae family, equal to 0.39 g/hour. This result has a correlation with an average leaves area, palisade tissue, and stomata density. The order of CO_2 absorption from highest to lowest family are a combination group, Sapotaceae, Burseraceae, Verbenaceae, Annonaceae, Sapindaceae, Clusiaceae, and Gnetaceae.

For NO_2 absorption, family with the highest average absorption was Annonaceae of 93.28 μg/g, while the lowest family was Clusiaceae of 8.46 μg/g. The order of NO_2 absorption from the highest to lowest family are Annonaceae, combination group, Burseraceae, Verbenaceae, Gnetaceae, Sapotaceae, Sapindaceae, and Clusiaceae. The differences between the uptakes of plant were caused by psychological and physiological difference in absorbing gas through the leaves. More weight the leaves, N absorption will be lower and it same less weight of leaves its ability to absorb N will be increasing [21]. Will be need deeper result about stomata characteristic such as stomata open area and stoma conductance [20]. Bogor Botanical Garden plant ability in absorb Bogor city emission shown in Table 11.

Table 11: Bogor Botanical Garden plant ability in absorb Bogor city emission

Parameter	Bogor City Emission (kg/hour)	Absorption by Plant (kg/hour)	Percentage (%)
CO_2	1,884.1	541.6	28.7
NO_2	1,916.5	42.8	2.3
Dustfall	304.4	34.6	11.4

Table 11 above indicated that Bogor Botanical Garden as urban forest has a function as emission absorber in Bogor City. Nevertheless, its contribution percentage still low so it necessary for cropping intensification by selecting plant species for planting programme in the future.

The plants must be has ability to reduced Bogor city emission. The criteria are [22, 2]:

1. Evergreen tree, this kind of tree has high efficiency in absorbing emission due to its long retention time of leaves.
2. Wide leaves tree, because tree dimension affected CO_2 storage concentration as well as surface area needed by air pollutant to deposited and intercepted.
3. Fast-grow tree, because it can maximize early CO_2 absorption and provide sufficient surface area for CO_2 absorption. However, this criterion must be balanced by enough lifetimes to prevent early change of CO_2 absorption.
4. Plant that has trichome, scaly, and rough surface leaves can deposed more dustfall than soft leaves

In addition, plant species selection should also consider the suitability of crops to the environment where the plants will be planted. The suitability affected by several factors as follows [23]:

ARPN Journal of Science and Technology

1. Resistance to disease and pets to prevent the excessive use of pesticide in area with high density
2. Having a high tolerance to various environmental problems such as low aeration, infiltration conductivity, and low supply of nutrients
3. Suitable for local climate. Good moisture for growing crops especially to control dust concentration is above 35% [24].
4. Resistant to drought

3.4 Correlation of Total Dustfall on Leaf to Leaf Morphology

Leaf morphology affects leaf ability to deposed dustfall [25]. Leaf samples were taken from the lower part of canopy. Assuming the dustfall concentration on each canopy was not much different, in accordance with research performed by [26] which states that the difference in canopy height did not significantly affect the concentration of dustfall. This was because the wind circulation will help dustfall distribution on all part of tree canopy so every part of canopy has same opportunity to deposed dustfall in the air [27]. This opinion supported by research result of [28] which stated that the wind speed affect dustfall measurement when falling to the ground by 66.9%. Data of dustfall amount on leaves based on plant species shown in Figure 2.

Figure 2 showed that Carmona retusa (Vahl.) Masam has greater ability to deposed dustfall that other four leaves with maximum capacity of 0.7 mg/cm^2, while the lowest was Antigonon leptopus Hook Et. Arn. Average difference of dustfall retained on leaves between Carmona retusa and Sansevieria trifasciata of 0.27 mg/cm^2 while the average difference dustfall retained on leaves between Carmona retusa and Antigonon leptopus of 0.40 mg/cm^2.

The graph shows that since 9th day, the dustfall concentration began to constant. It was due to variation of dustfall concentration on the stand was affected by vertical movement of air that passes through the canopy. Equal distribution of dustfall on each leaf surface canopy can occur when the most effective points to depose dustfall has reach its maximum capacity causing these dustfall entrained in the most efficient point cannot be attach firmly to the surface leaf and dropped or thrown to other leaves.

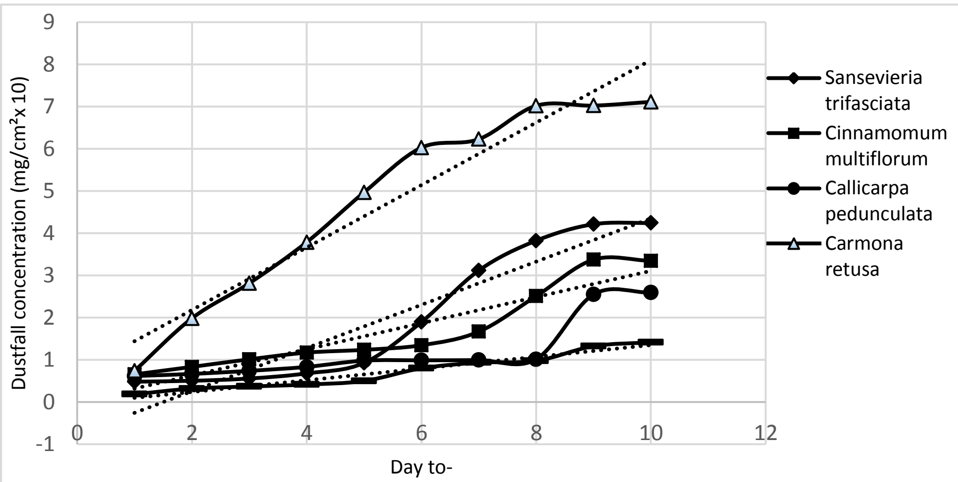

Fig 2: Dustfall amount on leaves based on plant species

The differences of leaves ability to deposed dustfall was influenced by leaf morphology. Effective leaves to depose dustfall was leaves with rough texture and has trichome. Carmona retusa leaves has dense trichome and rough texture so it allow the deposit dustfall that much more. Sansevieria trifasciata leaves coated by lignin, but due to the leaves has curled shape, it lead most of the dustfall stuck inside the leaves, especially in the lower part of leaf. Cinnamomum multiflorum leaves coated by lignin that make the surface leaves slippery so dustfall has a hard time to stick onto the leaves. Callicarpa pedunculata leaves have very tight trichomes but smooth surface that causes dustfall fall easily and soluble in the water when the rains come. While Antigonon leptopus leaves also have trichomes but the distance not too tight and the leaves surface grooved make it easier to bring water and attached dustfall fall to the ground. The number of dustfall per leaves was shown in Figure 3.

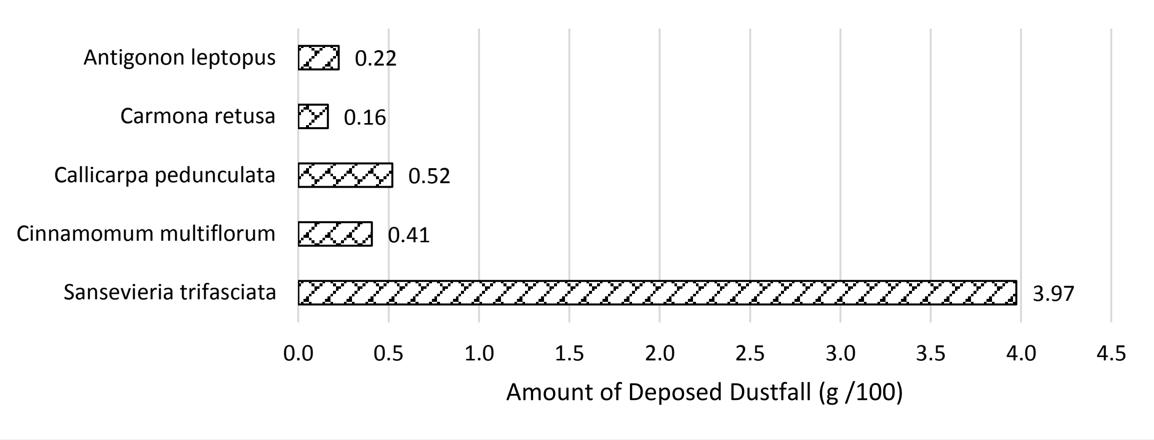

Fig 3: One leaf capacity to deposed dustfall

Differences of dustfall deposit on every type of tree depends on various factors, one of them was leaves surface area [7]. Figure 4 shows that plant that has the highest total dustfall per leaves was Sansevieria trifasciata. This was because it has wider surface area than other four plants by 93.6 cm^2. So, even though the deposed ability per surface area was not the highest one, overall Sansevieria trifasciata was effective to deposed dustfall. Cinnamomum multiforum leaf surface area of 15.3 cm^2, Callicarpa pedunculata of 20.1 cm^2, and Antigonon leptopus of 12.2 cm^2. Instead Carmona retusa has the highest ability to depose dustfall per surface area, but its leaf size much smaller than the other four leaves of 2.4 cm^2 that results in became the lowest rank. The big difference in the size of leaves showed that wider leaf surface area, higher amount of dustfall will deposed on leaves.

Other factor that affects the amount of dustfall deposed on leaf was weight. The average weight of Cinnamomum multiflorum leaf was 0.5 g, Callicarpa pedunculata of 0.1 g, Carmona retusa of 0.2 g, and Antigonon leptopus of 0.3 g. Sansevieria trifasciata weight leaf much different of the other four of 13.1 g. Leaves with a light weight cause it easier shaken when the wind blows, thus reducing dustfall attached on leaves. Instead the stiff and heavy leaf like Sansevieria trifasciata leaves was not easy to shake when the wind blows, so that leaves quite effective to deposed dustfall.

4. CONCLUSIONS

Emission of CO_2 in Bogor city was 1,884.1 kg/hour, NO_2 of 1,916.5 kg/hour, and dustfall of 304.4 kg/hour. Bogor Botanical Gardens absorption ability for each pollutant was CO_2 of 28.7%, NO_2 of 2.2%, and dustfall of 11.4%. Effective leaves to depose dustfall was leaves with rough texture and has trichome. Plant with the highest ability to deposed dustfall per surface area was Carmona retusa and the lowest was Antigonon leptopus. Selected plant to reduced CO_2, NO_2, and dustfall are evergreen plants, fast-growing, long-lived, resistant to pest, disease, and be able to adapt to environmental condition and has trichome, scaly, and rough leaves.

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