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Carbon dioxide (CO_2) emissions and mitigation efforts based on Bogor City's green open space

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ABSTRACT

One of the risks associated with climate change is carbon dioxide (CO_2) emission, which can negatively affect human health and the ecosystem. The CO_2 emission can lead to a decline in urban area quality that surpasses the environment's carrying capacity. This research aimed to investigate the relationship between CO_2 Emissions from Transportation (X_1), Household (X_2), and Business Sector (X_3) with the CO_2 reduction of green open space (Y). The hypothesis is that there is a negative correlation between CO_2 emissions from transportation, households, and businesses and CO_2 reduction from green open spaces. A quantitative research design was adopted using the Slovin formula and cluster random sampling. The Normality and Homogeneity Tests are used to analyze research data. The study yielded the following results: first, the coefficient of determination (r^2) = 0.003 indicates a relationship between CO_2 emissions from transportation with CO_2 reduction from green open space, with a 0.3% contribution. The second finding is that there is a 0.1% contribution from CO_2 reduction from green open space to the CO_2 emissions of households, as indicated by the coefficient of determination (r^2) = 0.001. Third, a correlation of 0.1% between CO_2 reduction from green open space and CO_2 emissions from the Business Sector is indicated by the coefficient of determination (r^2) = 0.001. Thus, using the regression equation $Y = 2320.432 - 0.16X_1 - 0,25\ X_2 - 0,007\ X_3$, there is an overall significant relationship between CO_2 emissions from transportation, CO_2 emissions from households, and CO_2 emissions from the business sector with the reduction of CO_2 from green open space.

ABSTRAK

Salah satu risiko yang terkait dengan perubahan iklim adalah emisi karbon dioksida (CO_2), yang dapat berdampak negatif terhadap kesehatan manusia dan ekosistem. Hal ini dapat mengakibatkan penurunan kualitas kawasan perkotaan hingga melampaui daya dukung lingkungan. Penelitian ini bertujuan untuk mengetahui hubungan Emisi CO_2 dari Transportasi (X_1), Rumah Tangga (X_2), dan Dunia Usaha (X_3) dengan penurunan CO_2 pada Ruang Terbuka Hijau (Y). Hipotesisnya adalah terdapat korelasi negatif antara emisi CO_2 dari transportasi, rumah tangga, dan dunia usaha dengan penurunan CO_2 dari ruang terbuka hijau. Dengan menggunakan rumus Slovin dan cluster random sampling, desain penelitian yang digunakan adalah kuantitatif. Uji Normalitas dan Homogenitas digunakan untuk menganalisis data penelitian. Penelitian ini menghasilkan hasil sebagai berikut: pertama, koefisien determinasi (r^2) = 0,003 menunjukkan adanya hubungan antara emisi CO_2 dari transportasi dengan penurunan CO_2 dari ruang terbuka hijau, dengan kontribusi sebesar 0,3%. Temuan kedua, terdapat kontribusi penurunan CO_2 dari ruang terbuka hijau terhadap emisi CO_2 rumah tangga sebesar 0,1% yang ditunjukkan dengan koefisien determinasi (r^2) = 0,001. Ketiga, korelasi sebesar 0,1% antara penurunan CO_2 dari RTH dengan emisi CO_2 dari Dunia Usaha ditunjukkan dengan koefisien determinasi (r^2) = 0,001. Dengan demikian, dengan menggunakan persamaan regresi $Y = 2320.432 - 0.16X_1 - 0,25\ X_2 - 0,007\ X_3$, secara keseluruhan terdapat hubungan yang signifikan antara emisi CO_2 dari transportasi, emisi CO_2 dari rumah tangga, dan emisi CO_2 dari dunia usaha dengan penurunan emisi CO_2 dari ruang terbuka hijau.

Keywords: *Bogor city, carbon dioxide emission, green open space*

INTRODUCTION

Climate Change is currently an issue that is quite important as a cause of climate anomalies in a region. For Indonesia, climate change poses a formidable challenge for its people, as it is the world's fourth most populous nation and the biggest archipelagic country (Priatna & Monk, 2023). The problem of global warming occurs throughout the world, including Indonesia. As the temperature increases by 1oC on the earth, it will impact ecosystems and species of flora and fauna, resulting in hydrometeorological disasters.

Greenhouse effect gases come from energy use such as the use of fossil fuels for industry and motorized vehicles, changes in forest land use to other areas, the livestock sector is produced from the decomposition of livestock manure, the agricultural industry produces CO_2 through the use of fertilizers, decomposing agrarian residues, and burning agricultural areas. Carbon dioxide gas (CO_2) is the largest contributor to emissions, at around 50%,

compared to other greenhouse gases (Nugroho & Fazzry, 2016).

With increasing development and population growth today, in the next 100 years, CO_2 concentration levels in the atmosphere will increase twice compared to the industrial era, around 580 ppm (Akhadi, 2009). Based on these estimates, it will cause problems that impact the environment, and the earth's temperature will continue to increase yearly. CO_2 emissions can come from motorized vehicles, households, and the business sectors.

Household CO_2 emissions come from energy consumption using electronic devices (television, computer, refrigerator), cooking (LPG), and other activities. Total energy consumption in 2018 in the household sector is around 16%, and it is projected that in 2025, there will be an increase in the number of households by 70.6 million. The dominant energy used is electricity in 2018 by 60%, then the industrial, commercial, and other sectors. The dominant energy can be caused by the increasing level of people's income, which encourages the use of electronic goods (DEN, 2019).

Bogor has approximately 144.75 ha of urban forests, namely CIFOR's Dramaga Research Forest and the Bogor Botanical Gardens. In addition, several forms of green open space can absorb CO_2 (Nugraha et al., 2022). The results of the study by Dewi et al. (2024) show that the CO_2 absorption capacity of trees and green open space on one campus in Bogor, with an area of 35,000 m^2, is 282,784.89 kg per year. However, the area of green open space in Bogor City has been decreased from time to time (Dahlan 2008). Therefore, to reduce carbon dioxide emissions from households, transportation, and businesses in urban areas, one alternative is to optimize and maximize green open spaces, so research is needed. As a strategic urban area, Bogor City is expected to become an environmentally friendly, beautiful and comfortable city for residents and visitors from outside the city. Absorption of CO_2 through green open space in urban areas is one climate action that can contributed by the community and local government, which aligns with Sustainable Development Goal 13, "Climate Action", but it should also be synergized with the efforts from other sectors (Priatna & Khan, 2024).

METHODS

Data Collection and Analysis Techniques

In this study, the data analyzed included calculations of CO_2 emissions, divided into four factors: the size of green open space CO_2 reduction and analysis related to the calculation of emissions from transportation, emissions from households, and emissions from the businesses sector. The method used in this research is quantitative.

CO_2 Reduction of green open space

To determine the amount of CO_2 reduction, we measured the CO_2 absorption by plants. Based on the results of previous studies, it is known that the ability of each plant to absorb CO_2 is different. (Dahlan, 2007). The absorption capacity of CO_2 by plants in open space can be seen in Table 1.

Table 1. CO_2 absorption capacity by each species of plants.

No	Species	CO_2 Absorption Capacity (kg/tree/year)
1	*Pometia pinnata*	329.76
2	*Swietenia mahagoni*	295.73
3	*Swietenia macrophylla*	114.03
4	*Artocarpus heterophyllus*	126.51
5	*Tectona grandis*	135.27
6	*Manilkara kauki*	41.78

Source: Dahlan (2007)

CO_2 emission from transportation

The following formula is a formula to calculate the CO_2 emission from the transportation sector (IPCC, 2006).

CO_2 emissions = Fuel Consumption (lt) x Fuel EF x NVC Fuel

EF Benzine : 69.300 CO_2 kg/TJ

NVC Benzine : 33 x 10 $^{-6}$ TJ/lt

CO_2 emission from household

The following formula is used to calculate household emissions.

a) CO_2 emissions from household (LPG)

CO_2 emissions = FPG Consumption (kg) x EF LPG x NVC LPG

EF LPG : 63100 CO_2 kg/TJ

NVC LPG : 47.3 MJ/kg

b) CO_2 emissions from household (Electricity)

CO_2 emissions = Electricity Consumption (KWh) x Electricity EF

Electricity EF : 0.719 kg CO_2/KWh

c) CO_2 emissions household (waste)

CO_2 emissions = Consumption of Waste (kg) x EF of Waste

Waste EF : 2.56 kg CO_2/kg waste

CO_2 emission in the business sector

a) CO_2 emission of energy

CO_2 emissions = Mass of fuel (Gg) x Emission Factor (kg/TJ) x NCV (TJ/Gg)

EF LPG : 63100 CO_2 kg/TJ

NVC LPG : 47.3 MJ/kg

b) CO_2 emission of electricity

CO_2 emissions = EF x Electricity Consumption

EF : 0.000817 ton CO2/kWh (DEN, 2019)

RESULTS AND DISCUSSION

Relationship between CO_2 Emissions of Transportation with CO_2 Reduction of Green Open Space

In Figure 1, it can be seen that the direction of both correlations is negative because the line formed decreases. This correlation looks weak because the impact is minimal. The equation formed is Y=-0.1402X+ 5035.9.

Base on the ANOVA result, the F value obtained was 0.255 (Table 2). This F value is used in the F-test to evaluate the hypothesis in predicting the contribution of the independent variable (X_1) to the dependent variable (Y). If the value of Fcount > Ftable, then variable X is affected simultaneously by variable Y. It can be seen that the F count is 0.255 and a significance value of 0.722. Then $\rho_{y1} > 0$, there is a relationship between CO_2 Emissions Transportation and CO_2 reduction in green open space.

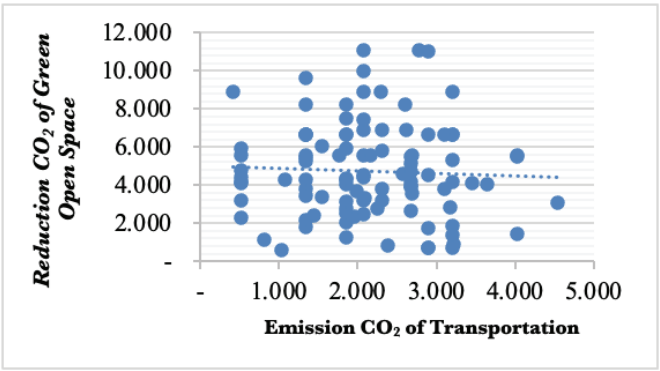

Figure 1. The scatter of the relationship between CO2 emissions of transportation and the CO2 reduction of green open space.

Table 2. ANOVA relationship between CO_2 emissions of transportation and the CO_2 reduction of green open space.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	207448.411	1	208448.411	.255	.615[b]
	Residual	79823822.98	98	814528.806		
	Total	80031271.39	99			

Relationship between CO_2 Emissions of Households and CO_2 Reduction of Green Open Space

Figure 2 illustrates the relationship between Variable X_2 and Variable Y. The scatterplot reveals a negative correlation between the two variables. However, the association is weak, as evidenced by the scattered distribution of data points. The regression equation representing this relationship is Y = -0.0348 X+ 2350.5.

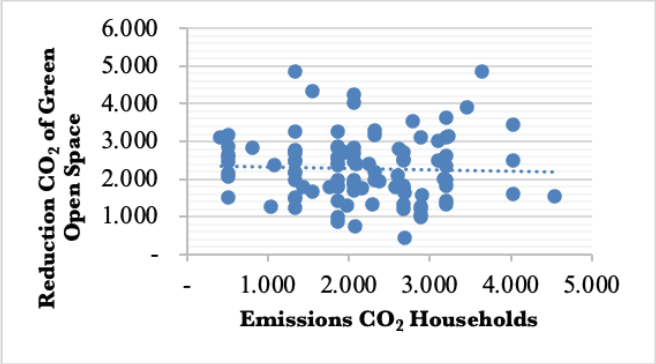

Figure 2. The scatter of the relationship between CO_2 emissions of households and the CO_2 reduction of green open space.

The one-way ANOVA test results revealed that the calculated F-value for the relationship between household CO_2 emissions and the CO_2 reduction provided by green open spaces is 0.128, with a significance value of 0.722 (Table 3). Since $\rho_{y2} > 0$, this indicates a relationship exists between household CO_2 emissions and the CO_2 reduction achieved by green open spaces.

Table 3. ANOVA relationship between CO_2 emissions of households and the CO_2 reduction of green open space.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	104167.318	1	104167.318	.128	.722[b]
	Residual	79927104.07	98	815582.695		
	Total	80031271.39	99			

Relationship between CO_2 Emissions of Business Sector and the CO_2 Reduction of Green Open Space

Variabel X_3 and Variable Y are presented in Figure 3. It can be seen that the relationship between both variables is negative. The correlation has a weak or minimal impact, as seen from the slightly scattered points. The equation formed is Y = -0.1185X + 5853.1.

Based on the results of the one-way ANOVA test table, it was found that the significance value between CO_2 emissions of the business sector and the CO_2 reduction green open space is 0.722 (Table 4). This value indicates

that $\rho_{y3} > 0$, then there is a relationship between CO_2 emissions of the business sector and the CO_2 reduction of green open space.

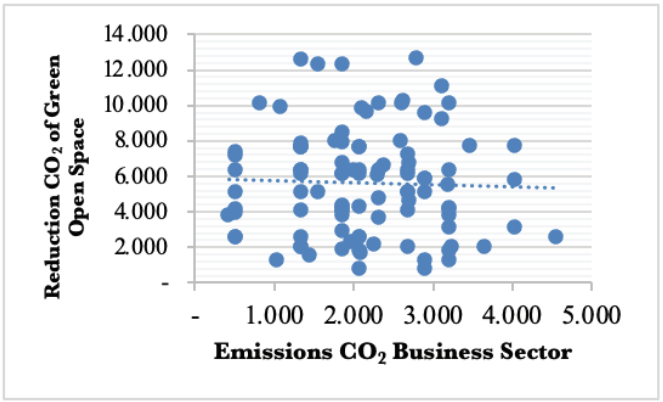

Figure 3. The scatter of the relationship between CO_2 emissions of the business sector and the CO_2 reduction of green open space.

Table 4. ANOVA relationship between CO_2 emissions of business sector and the CO_2 reduction of green open space.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	104062.590	1	104162.590	.128	.722[b]
	Residual	79927208.80	98	815583.763		
	Total	80031271.39	99			

Relationship between Emissions CO_2 Transportation, Emissions CO_2 Households, Emissions CO_2 Business Sector with Reduction CO_2 of Green Open Space

The results of the R Square of 0.004 indicate that a value of 0.4% is the value of the CO_2 Emission effect Transportation to CO_2 Reduction green open space; the remaining 99.6% is influenced by other factors outside the model. It can be seen that the relationship between variables is not good because the value is below 50%. The R-value indicates the relationship between the independent and dependent variables with a value of 0.062, so the level of the relationship is very low.

Table 5. ANOVA relationship between CO_2 emissions of the transportation sector and the CO_2 reduction of green open space.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	310167.798	3	103389.266	.103	.945[b]
	Residual	79721103.59	96	830428.162		
	Total	80031271.39	99			

Based on the results of the one-way ANOVA test table, it was found that the significance value between CO_2 emissions of households and the CO_2 reduction of green open space is 0.945. This value indicates that $\rho_{y123} > 0$, then there is a relationship between the CO_2 emissions of households and the CO_2 reduction of green open space.

CONCLUSION

The relationship between CO_2 emissions of transportation (X_2) and the CO_2 reduction of green open space (Y) has a negative direction of correlation and has the equation Y=-0.1402X+5035.9. There is a negative relationship between the CO_2 emissions of households (X_2) and the CO_2 reduction of green open space (Y). The equation for the relationship between the variables is Y= -0.0348X + 2350.5. The relationship between the CO_2 emissions of the business sector (X_3) and the CO_2 reduction of green open space (Y) has a negative relationship. The relationship between the two variables is as follows: equation Y=-0.1185X+5853.1. There is a relationship between the CO_2 emission of transportation (X_1), CO_2 emissions of households (X_2), and the CO_2 emissions of the business sector (X_3), all together with the CO_2 reduction of green open space (Y).

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