

CARBON FOOTPRINT STUDY AND THE ABILITY OF PLANTS TO ABSORB CARBON IN ENVIRONMENTALLY BASED SCHOOLS IN DEPOK CITY

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Abstract. This research was conducted to determine the relationship between the carbon footprint resulting from school activities and the ability of trees to absorb carbon. The existence of trees in the school environment is important and needs to be highlighted to find out how much ability these trees have in absorbing carbon in the school environment. Data collection on the amount of carbon that trees can absorb is carried out quantitatively based on the tree's biomass. Carbon footprint data is collected from four sources, namely electricity use, vehicles, food and plastic use. Carbon footprint data was obtained from interviews and electricity bill receipts. The aim of this research is to provide initial data regarding how much potential the world of education, especially schools, has in contributing to reducing world carbon levels in terms of mitigating climate change, at least at the local level. The value of carbon absorption from trees in the Al Muhtadin Vocational School environment is 85,176 Kg CO₂ and the total carbon use is 780,557 Kg CO₂. The largest carbon footprint comes from electricity, food, plastic use and vehicles, respectively. The presence of trees at Al Muhtadin Vocational School can help balance carbon entering and exiting the school environment by 11%. School participation in reducing carbon footprints needs to be increased by reducing electricity use, adding plants to the school environment and sharing vehicles.

Keywords: tree biomass; carbon footprint; climate change mitigation; carbon uptake

I. INTRODUCTION

Carbon is one of the main building blocks of living creatures. Carbon usually combines with other elements such as hydrogen and oxygen. Carbon in the atmosphere is usually in the form of CO₂ which is obtained from the breathing of living things and various human activities, such as burning gasoline, diesel, wood and LPG gas. The carbon produced by human activities is known as the carbon footprint. A carbon footprint is all activities, either directly or indirectly, that produce CO₂ from business activities (1), generated from daily activities (2), from burning fossil fuels (3). Various activities that cause a carbon footprint include: driving a motorized vehicle that runs on petrol, using electrical energy from coal, using paper, industrial activities that produce carbon dioxide, eating beef cattle [1], using electrical energy and water, and consuming food [2]. This carbon footprint will have several negative impacts, including: extreme weather and natural disasters, changes in food chain production, the spread of disease, damage to marine ecosystems, melting of polar ice and reduced clean water [2]. Carbon is in the carbon cycle, where there needs to be a balance between the amount of carbon on the earth's surface and the carbon released into the atmosphere. Carbon found on the earth's surface is found in tree biomass, as well as in peat soil and coal. The carbon released into the atmosphere is mostly in the form of CO₂ gas from burning hydrocarbons. Living creatures emit CO₂ as a waste gas. In the carbon cycle, green plants and green algae which have chlorophyll play a role in maintaining the stability of carbon in the atmosphere. Through the process of photosynthesis, plants

and green algae absorb CO₂ and convert it into glucose. Problems arise when the balance of carbon in the atmosphere is too much compared to the ability of plants to absorb CO₂. This is due to the decreasing number of trees due to land conversion. Excessive levels of CO₂ gas in the earth's atmosphere cause a greenhouse effect which increases global temperatures.

In 2015, Indonesia and 195 other countries in the world agreed to the Paris Agreement which agreed to commit to reducing greenhouse gas emissions and ensuring that global temperatures do not rise by more than 2oC. The agreement is followed by carbon trading schemes that maintain the amount of carbon emissions released into the atmosphere by reforestation. The value of carbon in carbon trading is known as carbon credits. The value of carbon credits can be calculated using globally recognized carbon sequestration potential calculations. Agencies that generate fewer carbon credits than they are entitled to can purchase carbon credits sold on the carbon market. This is done to keep the earth's temperature from rising more than 2oC [3]. Many studies related to carbon footprints calculate the resulting carbon footprint. Related research includes calculating the carbon footprint of electricity and LPG use in Denpasar City, Bali [4]; carbon footprint of land transportation [5]; Analysis of the carbon footprint of liquid waste and electricity in the leather tanning process [6]; Carbon footprint from electricity use at the Yogyakarta Institute of Technology [7]; Reducing greenhouse gas emissions in online home learning activities [8]; Carbon footprint of government employees in the Puspitek area, South Tangerang [9]; Carbon footprint of waste processing at TPS Tlogomas, Malang [10]; Carbon footprint from tofu production activities

in Pati Regency, Central Java [11]. Not many studies have been linked to efforts to reduce carbon levels significantly. Related research is the ability of green open spaces to absorb carbon in Kuala Lumpur [12]; Green retail model based on carbon footprint in Sleman Regency, Yogyakarta in measuring the amount of vegetation that needs to be planted to absorb CO₂ produced by visitors to retail activities [13]; Study of urban forest needs based on vegetation's ability to absorb carbon in Mataram City [14].

II. RESEARCH METHODS

The research was conducted at several neighborhood-based schools in Depok City, West Java. Target data collection in three schools. The duration of the research is from June to September 2023. Research samples were taken from all trees at the Al Muhtadin Vocational School location. This school was chosen because it was one of the environmentally friendly model schools and received the Adiwiyata School. The tools and materials needed include a meter, stationery, carbon calculator, camera, labels and worksheets. This research measures two things, firstly calculating the carbon footprint produced by a school, and secondly measuring the biomass of trees found at the school location. Measuring tree biomass is needed to calculate the amount of CO₂ that can be absorbed by trees. The two data will be compared to find out whether the number of trees in a school can balance the carbon released into the environment based on school activities. Calculations of carbon footprints in schools are carried out by taking into account four things, namely electricity use, type of transportation and distance from home to school, type of plastic consumption, and type of food. Electricity usage data uses school electricity bill data. Meanwhile, data on types of transportation, types of plastic consumption and types of food were conducted using surveys of students and teachers at schools. Tree biomass calculations are carried out using DBH. Data analysis. Data analysis was carried out to calculate the amount of carbon value produced from various activities carried out at school. The questionnaire results will be calculated using a carbon calculator. Tree biomass can be calculated using the allometric equation which is based on measuring the diameter of the tree trunk multiplied by the number of trees and the coefficient.

III. RESULTS AND DISCUSSION

Plants' ability to absorb carbon

Plants have the ability to absorb carbon which is called carbon sequestration. The amount of carbon stored in plant bodies (biomass) describes the amount of CO₂ absorbed by plants. CO₂ is absorbed by plants through the process of photosynthesis, then carbohydrates are produced which are stored in various parts of plants, such as roots, stems, leaves, flowers and fruit. The process of storing carbon (C) in the plant body is called C-Sequestration. The CO₂ absorption capacity of each plant is influenced by several factors, including plant density, vegetation diversity, soil type and how it is processed.

Long-lived plants have greater carbon storage capacity than annual plants (20). Trees are plants with woody stems with DBH above 10 cm. Tree habitus is a woody plant that has one long trunk and several branches spreading after a certain height to form a canopy. Trees have an important role in reducing CO₂ concentrations in the air. Trees have a higher ability to absorb CO₂ compared to other vegetation (shrubs, shrubs and ground cover). Trees have 50% of wood biomass consisting of CO₂ (21). Tree biomass can be calculated using the allometric equation which is based on measuring the diameter of the tree trunk multiplied by the number of trees and the coefficient. Based on calculations, the total carbon value of plants at Al Muhtadin Vocational School is 138,227 kg. Meanwhile, the carbon storage value and carbon uptake value are 63.58 Kg and 233.35 Kg respectively (Table 1).

Table 1. Total carbon value, carbon storage and carbon uptake at Al Muhtadin Vocational School

	BK (Kg/m ²)	Area (m ²)	Carbon Total (Kg)	Carbon Storage (Kg)	Carbon Sequestration (Kg)
Pohon	0,106714592	1287	137,34	63,18	231,86
Tiang	6,9603E-05	1287	0,089	0,04	0,15
Pancang	1,90443E-05	1287	0,024	0,01	0,04
Semai	0,000599806	1287	0,77	0,36	1,30
Total	0,107403046		138,22	63,58	233,35

Based on the size of the stem diameter, plants are divided into four types, namely trees, poles, saplings and seedlings. Trees are plants with a trunk diameter of more than 20 cm. The pole is a tree sapling with a diameter of 10-20 cm. Saplings are tree saplings with a trunk diameter of less than 10 cm and a height of more than 1.5 m. Seedlings are tree saplings less than 1.5 m tall. Based on the size of the trunk diameter, the most abundant plants are in the tree group, with a carbon uptake value of 231.86 Kg (Figure 1).

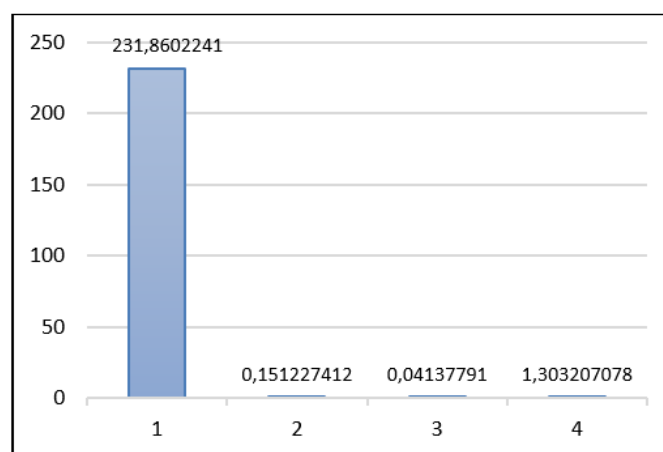


Figure 1. Plant Carbon Uptake Values at Al Muhtadin Vocational School Based on Plant Type (Note: 1= tree; 2= pole; 3= sapling; 4= seedling)

Carbon Footprint

Carbon footprint calculations can be measured from electricity use over a certain period of time. The amount of electricity costs incurred is equivalent to carbon use.

Table 2. The amount of electrical power used by Al Muhtadin Vocational School per month

No.	Electricity Bill (per month)	Power (KWh)
1	Rp498.960	294
2	Rp498.960	294
3	Rp1.071.961	631
4	Rp549.045	323
5	Rp2.752.544	1620
Total	Rp5.371.470	3161

Ket: 1 KWh= Rp1699,53 (July 2023)

The value of Al Muhtadin Vocational School's electrical power in one month is 3,161 KWh. This value is then converted into Kg CO₂ using the carbon calculator Carbon Calculator - Zero Waste Indonesia. The value of electricity used by Al Muhtadin Vocational School for one month is equivalent to 35,254 Kg. This value is equivalent to 423.05 Kg CO₂ in a year (Figure 2).

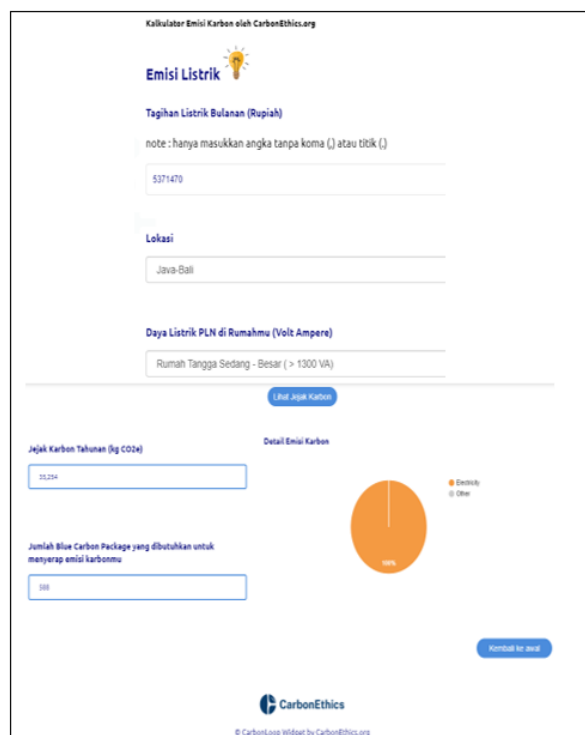


Figure 2. Conversion of Electric Power into Kg CO₂ Emissions. Source: <https://zerowaste.id/carbon-calculator>

The carbon footprint assessment, apart from electricity use, is also calculated from the type of vehicle and distance traveled by students from home to school, the type of plastic consumed and the type of food eaten on the lunch menu. All

student and teacher activities related to teaching and learning activities during school hours are taken into account so that the range of carbon footprints produced by Al Muhtadin Vocational School can be known. The total carbon footprint based on carbon source is presented in Table 3.

Table 3. Carbon Footprint Value Based on Carbon Source

Source of Carbon Footprint	Value Kg CO ₂ /year
Vehicle	72.891
Plastic	81.292
Food	203.326
Electricity	423.048
Total	780.557

The largest carbon footprint value comes from electricity use, which is 423,048 Kg CO₂/year (Table 3). The next largest carbon footprint values, respectively, are consumption patterns (food), plastic consumption and motor vehicle use. Electricity usage is quite high due to the large number of classes and especially the use of laboratory equipment which requires quite large electricity consumption.

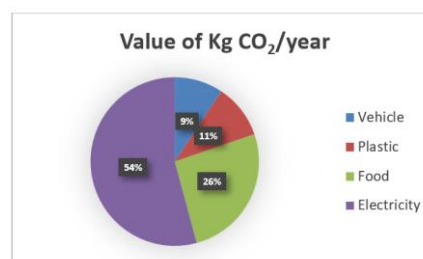


Figure 3. Percentage of Carbon Footprint Based on Source

The carbon footprint from food sources comes from animal protein sources consumed by students on the lunch menu. As many as 51% of students chose rice, chicken and vegetables for lunch (Figure 4). Menus with meat dishes were only 5% of the sample. Even so, the carbon footprint value is half that of the chicken menu which was the choice of half the research samples. The carbon footprint value of the chicken menu (100 g) is 208 Kg CO₂/year, while the carbon footprint value of the meat menu (100 g) is 1123 Kg CO₂/year, with an estimated consumption of 4-5 times a week (22).

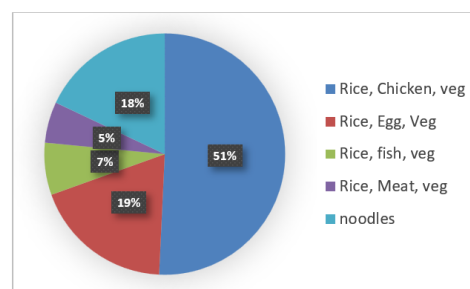


Figure 4. Percentage of Al Muhtadin Vocational School Students' Lunch Menu

It was found that the carbon footprint from plastic is not large because this school requires students to bring food containers and drinking bottles (tumblers) from home that can be used repeatedly. This habit simply reduces the carbon footprint of food wrappers or packaged drinks that are obtained when buying ready-to-eat food or packaged drinks. Purchases of packaged drinks are only made occasionally, and everything else is made from plastic packaging for snacks.

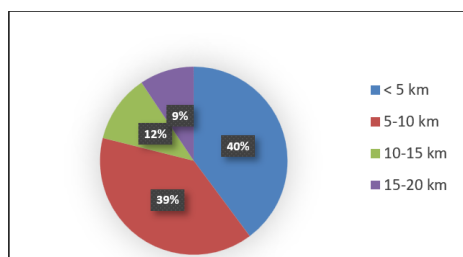


Figure 5. Percentage of distance between school and residence of Al Muhtadin Vocational School students

The carbon footprint of vehicles is the smallest contribution to CO₂ emissions. This is because many students live close to the school. The majority, namely 40% of students live less than 5 km away (Figure 5).

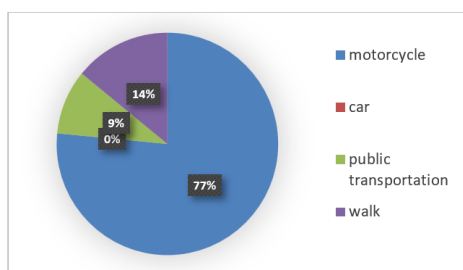


Figure 6. Percentage of Types of Transportation for Students to School

Most students use motorbikes (77%), walk (14%) and use public transportation such as public transportation (9%) (Figure 6). The motorbikes used are less than 125 CC and this is the most popular choice because of practicality and economic background. Motorized vehicles are the best choice for families from lower middle class backgrounds. Walking is the second most popular choice, because many students have their homes close to school.

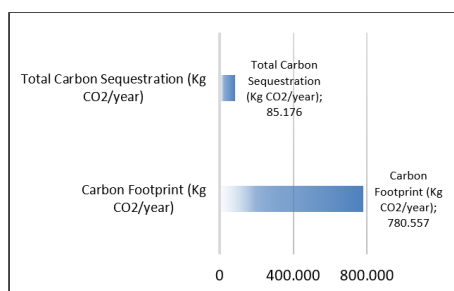


Figure 7. Comparison of Carbon Footprint Data at Al Muhtadin Vocational School with the Total Carbon Uptake

Based on the comparative value of carbon footprint data produced by Al Muhtadin Vocational School, namely 780,577 Kg CO₂/year, compared to the ability of trees to absorb carbon, namely 85,176 Kg CO₂/year, then this value is only around 11% in absorbing the carbon footprint released by various activities at the school.

It is necessary to carry out a scenario to reduce the carbon footprint at Al Muhtadin Vocational School so that the amount of carbon produced does not exceed the amount of carbon that can be absorbed by plants planted in the school area. Suggested scenarios include: 1. Reduce electricity use, including turning off electrical equipment if it is not used for 60 minutes, for example in a computer laboratory. You can also turn off the lights if the sunlight is enough to brighten the room when it is noon. 2. Increase the number of plants in the school area, both plants planted in the ground, in pots, vertical gardens, hydroponics, hanging plants, and so on. It is also possible for each student to have one plant brought to school, named and cared for every day while attending school for individual carbon compensation that the student contributes to reducing their individual carbon footprint. 3. Selection of plant types with high carbon absorption capacity. For example, orchid plants have a better ability to absorb carbon dioxide, compared to Sri Gading and Caisim (23). Sansiviera can also be a plant choice that reduces carbon levels (24). Several other plants that have high carbon uptake include frangipani, croton, fan pandan, fan palm and glodokan pole (25). 4. Reduce plastic consumption, especially from plastic snacks, by providing education about conservation to increase participation in efforts to reduce carbon footprints in schools. A good understanding of conservation can increase the application of conservation values in students' daily lives (26). 5. The carbon footprint of vehicles can be reduced by minimizing the use of motorized vehicles. Another solution is to use vehicle sharing for students whose houses are close to each other to reduce the number of motorbikes used to go to school.

The value of carbon absorption by Al Muhtadin Vocational School, as one of the Adiwiyata Schools, can be used as a model for school participation in climate change mitigation. Although the carbon absorption figure contributed is still small (11%), this needs to be appreciated and used as an example for Adiwiyata Schools in particular, and non-Adiwiyata schools in general. This can also encourage the participation of other schools in efforts to mitigate climate change through carbon sequestration. So that this can be a real step that has an impact, it needs to be encouraged to become part of the obligation, especially for Adiwiyata Schools to take into account the value of carbon absorption in their school agenda and the government's agenda to encourage other schools to participate in contributing to joint efforts to mitigate climate change.

III. CONCLUSION

The carbon footprint in the Al Muhtadin Vocational School environment obtained from calculations is 780,557 Kg CO₂, while the amount of carbon uptake from plants is 85,176 Kg CO₂. The biggest sources of carbon footprints are from

electricity use, food, plastic use and vehicles, respectively. Al Muhtadin Vocational School contributes to reducing the carbon footprint by 11% from the number of trees planted in the school environment. This research was supported by the Ministry of Education and Culture for funding this research. Thank you to Al Muhtadin Vocational School, Depok, West Java for being willing to assist with this research as a location for collecting research data. Hopefully the results of this research can be used as a basis for schools in reducing their carbon footprint in mitigating climate change.

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