Environmental service assessment of trees at Yogyakarta International Airport open space using CITYGreen 5.2

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Abstract. Urban development has many negative impacts in the form of an increase in the concentration of CO₂ in the air. One of them is due to the increase in the volume of vehicles. CO₂ causes an increase in global temperature (global warming) through the greenhouse effect. Yogyakarta International Airport has a green open space planted with trees to support the existence of the airport itself. Trees have contributed to efforts to reduce CO₂ in the air through CO₂ absorption. Control of the amount of CO₂ emissions in the air is done by adding carbon stocks on land so that the CO₂ concentration does not continue to increase, therefore this research is necessary. The purpose of this study is to analyze the ability of trees to absorb pollutants and store carbon and estimate the value of environmental services that will be contributed by the tree green system at Yogyakarta International Airport based on existing planting plans. The research method used is modeling using CITYGreen 5.2 software to determine the value of tree services in the ability to absorb air pollution, carbon storage capacity, and cost savings that can be done by tree canopies. The method used in this study consisted of preparation, data inventory, and data analysis. The results of this study show that the value of environmental services provided by 125.72 acres of tree canopy cover in absorbing air pollution in the airport area is $ 9,045.54 / year or equivalent to Rp 133,356,587,10 per year, the total concentration of pollutants that can be absorbed is 3,813.30 lbs/year or equivalent to 1,729.68 kg/year, and the capacity of carbon storage is 1,326.46 tons with a sequestration rate of around 29.9 tons/year.

Keywords: air pollution, carbon storage, CITYgreen, environmental service, green open space, tree

1. Introduction

Various cities in Indonesia continue to experience development as well as infrastructure development, one of which is the airport. This activity also has a negative impact in the form of an increase in CO₂ concentration in the air due to the increase in vehicle volume. Vehicle releases the chemical into the air becoming air pollution [1]. The quality and comfort of the urban environment are influenced by the availability and existence of tree canopies, both in the form of urban forests and urban green open spaces [2]. The existence of green open space has the potential to increase the availability of clean water and air [3]. Green open space in the airport landscape has an important role because it supports the existence of the airport itself [4]. Yogyakarta International Airport has green open spaces planted with trees to support the existence of the airport itself. The contribution of trees to improve the quality of health and environmental services is very large. Vegetation is one...
element of the ecosystem that can be manipulated in a planned and cost-effective way [5].
This research purpose to this study is to analyze the ability of trees to absorb pollutants
and store carbon and estimate the value of environmental services that will be contributed
by the green open space at Yogyakarta International Airport based on existing planting
plans. The scope of the study is limited only to the trees. Sources of pollutants studied in
this study are limited to vehicles, both on land and air. The value of tree environmental
services in the area of Yogyakarta International Airport is known by using CITYGreen 5.2
extension which is only limited to studying aspects of the benefits of tree canopies in
storing carbon and absorbing air pollution. The economic value of trees in this study refers
to a cost indirect from social health and environmental damage. A cost that must be issued
by the government in overcoming the problem of damage environment, in this case, is
cased by O₃, SO₂, NO₂, PM₁₀ and, CO.

2. Methods

2.1 Description of the study area
The location of the study was conducted in Kulon Progo District, Special Region of
Yogyakarta Province. This airport has a land area of 587,30 Ha with an undeveloped area
of 251 Ha (open space). The area is divided into segments (lots). This is due to the large
area of the airport and to facilitate calculations. The areas observed in this study are Lot A,
Lot B, Lot C, and Lot E. Lot A and B are the main entry areas for the airport from the
National Road. Lot C is the western supporting area, while Lot E is the eastern supporting
area. Lot D is not included in the study area because it is a terminal building.

![Figure 1](image)

Figure 1 Study sites at Kulon Progo District
(7°54’27″S 110°03’16″E)
Source: PP KSO

2.2 Inventory
Inventory is carried out to obtain a complete picture of site conditions. At the inventory
stage, satellite image preparation, site digitization, and attribute data collections for the
canopy theme are carried out. These data are in the form of secondary data from the
planting plan and masterplan obtained from PP KSO. PP KSO is a state-owned company
that is a main contractor for the Yogyakarta International Airport project. In this study,
google earth satellite imagery was used. CITYGreen identifies land cover as canopy and non-canopy. Canopy is a theme that displays a tree canopy in the form of a view over the trees. Non-canopy is a theme that displays other than the tree canopy.

2.3 Analysis
The data that has been obtained will then be inputted. The research analysis method used is modeling using Arcview software version 3.3 with extension CITYGreen 5.2 to determine the value of tree services in the ability to absorb air pollution, carbon storage capacity, and cost savings that can be made by tree canopy. CITYGreen can estimate air quality which consists of pollutant concentrations O3, SO2, NO2, PM10 and, CO. The application of CITYGreen in the study of air quality and carbon storage has been widely used in research. [6] [7] [8] The analysis stage was limited to the vegetation aspect, namely trees, while shrubs and ground cover were not included in the analysis.

| Table 1 | Data Required for Analysis |
|---------|----------------------------|
| **Required** | **Values Acquired From Data** | **Within CITYGreen and User Definable** |
| Air Quality | Tree canopy | Closest air quality city |
| Carbon Storage/Sequestration | Tree canopy, trunk diameter | (for individual trees) |

Source: User Manual CITYGreen 5.0

3. Result and Discussion

31. Identify the type of vegetation
Yogyakarta International Airport is a new airport, therefore many new trees are planted and all of them are in young age class. From table 2, it shows that the total number of trees based on the planting plan map in the airport area is 4,488 individual trees. It can be seen that the highest number of trees in the four areas is the Lot B area, which is 2,130 trees with a percentage of up to 48%. Meanwhile, Lot A has the least number of trees with a total of 586 trees with a percentage of 13%. There are 43 species of trees in the airport area. Those species are spreading in four lots. Even though Lot A only has the lowest percentage number of trees, the tree diversity in area A is the highest when compared to the other which is 26 tree species, following by Lot B which is 22 tree species, Lot E which is 13 trees, and Lot C which is 13 tree species. More complete tree species data is presented in Table 3.

| Table 2 | Recapitulation of The Number of Trees Found in All Areas |
|---------|--------------------------------------------------------|
| Area    | Total | Percentage |
| Lot A   | 586   | 13%        |
| Lot B   | 2,130 | 48%        |
| Lot C   | 1,142 | 25%        |
| Lot E   | 630   | 14%        |
| **Total** | **4,488** | **100%** |

Based on the data obtained from the planting plan map, the dominant tree species from the four research areas is Sapodilla trees (Manilkara kauki (L.) Dubard.) totaling 882 trees with a percentage of 18.32% and in second place is Spanish Cherry trees (Mimusops elengi L.) totaling 397 trees with a percentage if 8.85%. More complete data and the existence of each tree species in each area can be seen in table 3.
| Plant species | Lot A | Lot B | Lot C | Lot E | Total | Percentage |
|---------------|-------|-------|-------|-------|-------|------------|
| Aegle marmelos Linn. | 48    | -     | 140   | 25    | 165   | 3.68%      |
| Agathis dammara (Lamb.) Rich | -     | 74    | -     | 99    | 221   | 4.92%      |
| Alstonia scholaris L. | 58    | -     | -     | -     | 58    | 1.29%      |
| Ardisia elliptica Thunb. | 12    | -     | -     | -     | 12    | 0.27%      |
| Arenga pinnata Merr. | -     | 68    | -     | -     | 68    | 1.52%      |
| Barringtonia asiatica (L.) Kutz | 14    | 58    | -     | -     | 72    | 1.60%      |
| Bauhinia purpurea L. | -     | -     | 180   | 28    | 208   | 4.63%      |
| Borassus flabellifer Linn. | 23    | -     | -     | -     | 23    | 0.51%      |
| Cananga odorata (Lam.) Hook f & Thomson | -     | 36    | -     | -     | 36    | 0.80%      |
| Cassia fistula L. | 29    | 177   | -     | -     | 206   | 4.59%      |
| Casuarina sumatrana (de Vriese) L. | -     | -     | 98    | 129   | 227   | 5.06%      |
| Chrysalidocarpus lutescens (H.Wendl.) Beentje & J.Dransf. | -     | 63    | -     | -     | 63    | 1.40%      |
| Cocos nucifera L. | 30    | -     | -     | -     | 30    | 0.67%      |
| Cocos nucifera var. Eburnea | 24    | 38    | -     | -     | 62    | 1.38%      |
| Cyrtostachys lakka Becc. | 6     | -     | -     | -     | 6     | 0.13%      |
| Delonix regia (Hook.) Raf. | 13    | -     | 15    | 3     | 31    | 0.69%      |
| Elaeocarpus ganitrus Roxb. | 8     | -     | -     | -     | 8     | 0.18%      |
| Eucalyptus deglupta Blume. | 19    | 38    | 189   | 19    | 265   | 5.90%      |
| Eugenia uniflora L. | -     | 27    | -     | -     | 27    | 0.60%      |
| Ficus benjamina L. | 10    | 9     | -     | -     | 19    | 0.42%      |
| Ficus elastica var. variegata | -     | 2     | -     | -     | 2     | 0.04%      |
| Ficus religiosa (L.) Gasp. | 10    | 10    | -     | -     | 20    | 0.45%      |
| Fragraea fragrans Roxb. | 28    | -     | -     | -     | 28    | 0.62%      |
| Garcinia mangostana L. | -     | 25    | -     | -     | 25    | 0.56%      |
| Hibiscus tiliaeceus L. | 10    | -     | -     | -     | 10    | 0.22%      |
| Inocarpus fagiferus (Park.) Fosb. | 21    | -     | -     | -     | 21    | 0.47%      |
| Jacaranda acutifolia Bonpl. | -     | -     | -     | 92    | 92    | 2.05%      |
| Khaya senegalensis (Desr.) A. Juss. | -     | -     | 80    | 43    | 123   | 2.74%      |
3.2 Air pollution reduction benefits

According to research by Carpenter et al. [9], the plant can reduce air pollutants through the process of releasing oxygen into the atmosphere called oxygenation and the mixing of polluted air with clean air called dilution. Trees act as air filters [10]. The closer the distance between trees in the green open space, the better the ability of the green open space to absorb pollution. The use of CITYgreen to calculate the ecological benefits has been used in several studies abroad. Among them are an assessment of the carbon fixation function [11] and the benefits of increasing tree canopy through the planting and preservation of appropriate tree species [12]. The ecological benefits calculation for local trees in this site study was approached with the species name in the tree species database available at CITYgreen.

The results of the CITYGreeen analysis estimate the potential ability to absorb air pollutants as listed in Table 4. The total number of pollutants that can be absorbed by the existence of the trees in the four areas in the Yogyakarta International Airport area is 3,813,30 Lbs (1,729,68 kg) per year. The total amount of O3 that can be absorbed is 1,318,65 Lbs/year or equivalent to 598,13 kg (1lbs = 0,453592 kg), SO2 of 442,44 Lbs/year or equivalent to 200,69 kg, NO2 of 682,97 Lbs/year or equivalent to 309,79 kg, PM10 of 1,223,27 Lbs/year or equivalent to 554,87 kg, and CO at 145,97 Lbs/year or equivalent to 66,21 kg, where the heaviest pollutant that can be absorbed is O3 and the lowest pollutant concentration that can be absorbed is CO. Therefore, to further increase the absorbable pollutant mass, it is necessary to add vegetation following the criteria for absorbing pollutant particles.
Table 4 Air Pollution Reduction Benefits

| Area  | Ozone (O3) | Sulfur dioxide (SO2) | Nitrogen dioxide (NO2) | Particulate (PM10) | Carbon monoxide (CO) |
|-------|------------|----------------------|------------------------|--------------------|----------------------|
| Lot A | 197,42     | 66,24                | 102,25                 | 183,14             | 21,85                |
| Lot B | 648,87     | 217,71               | 336,07                 | 601,93             | 71,83                |
| Lot C | 303,5      | 101,83               | 157,19                 | 281,55             | 33,6                 |
| Lot E | 168,86     | 56,66                | 87,46                  | 156,65             | 18,69                |
| Total | 1,318,65   | 442,44               | 682,97                 | 1,223,27           | 145,97               |

3.3 Carbon storage capacity
The carbon storage capacity is estimated from the closure of the study area using CITYGreen 5.2 modeling. Based on the CITYGreen 5.2 recapitulation analysis, it can be seen that the total carbon storage capacity obtained by the Yogyakarta International Airport area is 1,326,46 tons with an annual increase of around 29.9 tons/year. This carbon storage capacity will be achieved by the existing planting plans. The planting program has not yet been fully completed and is expected to be like the planting plan in five to six years. The largest carbon storage capacity is in Lot B of 652.71 tons, while the lowest is Lot E of 169.86 tons/year. Lot B has the largest amount of carbon storage capacity due to a large amount of tree canopy cover in its area, so that the value of its carbon stock is large, while Lot E is the area with the lowest percentage of tree canopy cover, therefore the value of its carbon stock is the lowest. The main carbon stock stores are in tree biomass, floor vegetation, litter, and soil organic matter [13]. Stored carbon in the form of tree biomass constitutes the largest carbon pool.

Specifically for the aspects of carbon storage and absorption, there is no information available regarding the summary of economic benefits in CITYGreen. The economic benefits for this aspect are derived from the calculation of the amount of stored carbon (tons) multiplied by the carbon price based on international standards (ranging from $ 5.00- $ 15.00 per ton) [14]. In this study, it is assumed that the carbon price (ton) used is $ 5.00. With a carbon sequestration capacity of 1,326.46 tons/year, the economic value that can be received from this service is $ 6.632.30 / year, equivalent to Rp 97,778,672.44 / year (1 $ = IDR 14,742,80) or Rp 8,148,222.70 / month.

Table 5 Carbon storage benefits

| Area  | Carbon storage capacity (tons) | Sequestration rate (tons/year) |
|-------|-------------------------------|-------------------------------|
| Lot A | 198,59                        | 4.48                          |
| Lot B | 652,71                        | 14.71                         |
| Lot C | 305,30                        | 6.88                          |
| Lot E | 169,86                        | 3.83                          |
| Total | 1,326,46                      | 29.9                          |

3.4 The economic value of air pollution reduction benefits
Based on the results of the analysis using CITYGreen 5.2 software, pollutants that can be absorbed by trees in the four areas in the Yogyakarta International Airport area are O3 of 1,318.65 Lbs/year or equivalent to 598.13 kg (1lbs = 0.453592 kg), SO2 442.44 Lbs/year or equivalent to 200.69 kg, NO2 of 682.97 Lbs/year or equivalent to 309.79 kg, PM10 of 1,223.27 Lbs/year or equivalent to 554.87 kg, and CO of 145.97 Lbs/year or equivalent to 66.21 kg, where the heaviest pollutant that can be absorbed is O3 and the lowest pollutant concentration that can be absorbed is CO. Therefore, to further increase the absorbable pollutant mass, it is necessary to add vegetation by the criteria for absorbing pollutant particles.
Table 6 The Economic Value of Air Pollution Reduction Benefits

| Pollutant | Economic benefit value ($) |
|-----------|----------------------------|
| O3        | 4,047.65                   |
| SO2       | 331.82                     |
| NO2       | 2,096.62                   |
| PM10      | 2,506.96                   |
| CO        | 62.49                      |
| Total (USD/year) | 9,045.54 |
| Total (IDR/year)   | 133,356,587.10 |

The value of economic benefits is an external saving, namely, the value that must be spent by the government in overcoming the problem of environmental damage, in this case, is pollution by pollutants in the air. The value of economic benefits that can be saved in the Yogyakarta International Airport area is O3 of $ 4,047.65 or equivalent to Rp 59,673,694.40 (1 $ = IDR 14,742.80), SO2 of $ 331.82 or equivalent to Rp 4,891,955.90, NO2 for $ 2,096.62 or equivalent to Rp 30,910,049.30, PM10 for $ 2,506.96 or equivalent to Rp 36,959,609.90 and CO for $ 62.49 or equivalent to Rp 921,277.57. The greatest economic value that can be saved is O3 and the lowest cost savings is CO. The total economic value that can be saved in the Green Open Space at Yogyakarta International Airport is $ 9,045.54 / year or equivalent to Rp 133,356,587.10 / year or Rp 11,113,048.93 / month.

4. Conclusion
The results of the analysis of the ecological and economic benefits of this study illustrate how much the benefits of trees in a city green open space area. Trees affect the quality of the urban ecosystem in terms of 2 ecological benefits of trees, in terms of the potential for pollutant absorption and the potential for carbon storage. Based on CITYGreen 5.2 analysis, the potential ecological benefits of trees at Yogyakarta International Airport in reducing pollutants in the air are 3,813.3 Lbs or 1.729.68 kg a year. The value is worth the external cost savings that can be incurred community and government due to the pollutants of $ 9,045.54 or Rp 133,356,587.10. The carbon storage capacity obtained is 1,326.46 tons with an increase every year around 29.9 tons/year.

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