



The Role of Diponegoro Park Green Open Space in Semarang City in Providing Oxygen, Carbon Absorption, Reducing Temperature, and Humidity, a Case Study of Economic Valuation

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Abstract

The need for a healthy environment is highly valued today. One of the main components of a healthy environment is the presence of green open spaces. Semarang is one of the most densely populated cities in Central Java, resulting in increased mobility.

This study aims to assess the ecological role and economic value of Green Open Space (GOS) in Diponegoro Park, Semarang City, in supporting climate change mitigation. The method used is descriptive quantitative with measurements of biomass, carbon stock, CO₂ absorption, and oxygen production in various tree species, as well as the conversion of ecosystem results to economic value. The results show that Munggur trees have the most dominant contribution with an average biomass of 6,872.45 kg/tree, annual growth (ΔB) of 137.45 m/year, oxygen production of 183.29 ton/ha/year, carbon stock of 3,436.22 ton/ha, and CO₂ absorption of 12,610.94 ton/year. The economic value of oxygen produced reached IDR1,832,881.93, emphasizing the importance of high-biomass vegetation in maintaining air quality and reducing carbon emissions. This study recommends the maintenance and planting of high-biomass trees to optimize the ecological function of GOS in urban areas.

INTRODUCTION

Global warming has become a major crisis that is agreed upon globally. This crisis issue has received special attention from the United Nations and has even set it as a main target in the Sustainable Development Goals (SDGs) in point 13, namely action to address climate change. Global warming can even be interpreted as "global boiling" or Global Blooming (Sudarmaji, Eka; Achsani, Noer Azam; Arkeman, 2022). The main cause of this phenomenon is the increase in greenhouse gases, especially carbon dioxide (CO₂), from human activities such as the burning of fossil fuels and deforestation. CO₂ emissions now reach around 7 billion tons per year, exceeding the Earth's natural absorption capacity, causing a temperature increase of almost 1.5°C since 1880. Massive deforestation is also one of the causes of the severity of global warming that is occurring. Its impacts include extreme climate change, rising sea levels, agricultural disruption, and loss of biodiversity.

In an urban context, public green open spaces (GOS) are an important element in urban spatial planning to support environmental sustainability (Sinaga, A.S., Sinurat, A., Saragih, H, 2025). Through the process of photosynthesis, GOS helps absorb carbon dioxide (CO₂), produced by human activities, such as transportation, industry, and land use (Pakaya et al., 2024). According to the Regulation of the Minister of Public Works and Public Housing No. 5 of 2008, GOS is an open area covered with natural or artificial vegetation, such as city parks, urban forests, and green recreational spaces. GOS with extensive and dense vegetation has the capacity to absorb carbon dioxide to support urban environmental sustainability. Ecologically, GOS plays a role in improving air quality, reducing the effects of urban heat, and providing habitat for biodiversity. Socially, GOS becomes a multifunctional space for the community to carry out activities (Sasana, 2021).

The economic valuation of green open space (GOS) assesses the financial and non-financial benefits it generates for the environment and urban communities (Santoso & Astuti, 2019). Economically, GOS

enhances tourism and recreation value and reduces healthcare costs by providing clean air and space for physical activity. Environmentally, GOS provides essential services such as carbon sequestration, microclimate regulation, flood control, and biodiversity conservation (Ally et al., 2024).

Semarang City is one of the big cities and is the capital of Central Java which has Green Open Space (Arifiah, 2022). The existence of Green Open Space in Semarang City actually needs to be regulated and managed better because the high level of land use change development can reduce the availability of Green Open Space (Dewi & Lituhayu, 2016). The existence of Green Open Space in Semarang City is an effort to meet the minimum Green Open Space standards in Law No. 26 of 2007 and the mandate of the Regional Spatial Planning Regulation Article 24 that each city is at least able to provide Green Open Space of 30% from outside land consisting of 20% Green Open Space for public and 10% for private Green Open Space. Meanwhile, in Semarang City there is still a shortage of public Green Open Space of 13.27%, this shows that Semarang City has not been able to provide Green Open Space adequately.

METHOD

This research applies a quantitative descriptive method, an approach that aims to describe phenomena systematically and accurately through the collection and analysis of numerical data (Waruwu et al., 2025). This method allows researchers to describe the characteristics of a population or phenomenon without manipulating variables, so the results are objective and can represent actual conditions (Astuti et al., 2022). In the context of environmental research, this method is often used to measure physical parameters such as tree diameter, air temperature, and humidity at the research site, because this data can be processed quantitatively to provide an overview of the ecological conditions being studied (Haris et al.).

Sampling was carried out based on the Indonesian National Standard (SNI) which regulates measurement procedures and test sampling so that the data obtained has a high level of accuracy and consistency (Puspitasari et al., 2020).

This standard covers general provisions regarding material conditioning, sample preparation, and reporting of measurement results, ensuring that the research process adheres to applicable scientific principles.

The population of this study is data on humidity, temperature, and trees within the green open space of Diponegoro Park. There are 60 trees in Diponegoro Park and a second location near the Mall project in POJ CITY. Air humidity and temperature samples were taken at three straight points to represent the data at each location. This step utilizes the allometric calculation technique (Allometry, PTM KOROM, A Phua, M MATSUURA, 2016).

The data obtained will then be analyzed regarding the ability of green open space to produce oxygen, absorb carbon dioxide, and reduce temperature and humidity (Rachmayanti, Laras; Mangkoedihardjo, 2020). Each parameter will then be converted into rupiah. Parameters for oxygen production and carbon dioxide absorption will be converted according to the market price of carbon and oxygen, while parameters for temperature and humidity will be converted by calculating the difference in temperature and humidity at the two locations. The economic value will then be calculated using the electricity price per kWh used if the temperature and humidity difference is reduced using an AC or Dehumidifier.

RESULT AND DISCUSSION

As a green open space with a strategic ecological function in the central area of Semarang City, Diponegoro Park is under the authority of the Semarang City Environmental Agency (DLH), which is responsible for all activities.

The following presents eight tree species found in the Diponegoro Park green open space.

Figure 1. Documentation of tree species in



the Diponegoro green open space

The maintenance and management of the environment within it. Diponegoro Park's operations are more focused on maintaining the quality of the vegetation and ensuring its optimal ecological function, as the low visitor activity levels create relatively low social pressure on the park. Operational activities such as waste management, maintaining the cleanliness of green areas, and monitoring facilities are carried out routinely as part of this effort.

Maintaining the role of parks in supporting urban air quality The waste container system in the park is still provided in the form of separate trash bins to support sustainable environmental management practices, while waste transportation is carried out by the Environmental Agency (DLH) to the Jatibarang Landfill. This good management effort is important because the quality of governance is one of the factors that increases the ecological and economic value of a green space, as emphasized by (Mensah et al., 2023) that operational quality influences the perception of environmental value and ecological benefits of green spaces.

In addition to cleanliness, the main operational focus of Diponegoro Park lies in maintaining vegetation as a key component that provides various ecosystem services, particularly in the context of environmental economics and air quality monitoring. Large-diameter vegetation such as Munggur (Salleh et al., 2024), Glodogan, Mahogany, and Ketapang have significant carbon sequestration capabilities, producing oxygen and reducing the temperature and micro-humidity around the park (Khoiruman, 2025). Therefore, the Environmental Agency (DLH) carries out regular pruning, watering, pest control, and tree condition inspections to maintain the effectiveness of these ecological functions.

This vegetation maintenance also strengthens the park's contribution to improving urban air quality through photosynthesis and carbon storage, which have environmental economic value because they can be converted into emissions reduction benefits (Pakaya et al., 2024). This aligns with findings (Mensah et al., 2023) that well-managed vegetation enhances ecological value and provides economically valuable environmental benefits, particularly in terms of its contribution to mitigating air pollution and climate change. Therefore, the operational aspects of Diponegoro Park emphasize maintaining vegetation quality as the primary foundation for providing ecosystem services relevant to environmental economics and urban air quality studies (Saladin et al., 2025). Data on average tree trunk circumference by species are presented in Table 1 in centimeters (cm).

Table 1. Average tree diameter

Average Diameter	
<i>Terminalia catappa</i>	346,38
<i>Spondias dulcis</i>	597,76
<i>Swietenia mahagoni</i>	328,33
<i>Polyalthia longifolia</i>	1046,50
<i>Samanea saman (Jacq.) Merr</i>	6872,45
<i>Arecaceae</i>	397,85
<i>Plumeria</i>	52,70
<i>Pinus.ssp</i>	269,06

Based on the biomass measurements and calculations presented in the table, significant variation is evident among tree species in Diponegoro Park.

The following graph shows the biomass of each tree species in the Diponegoro Green Open Space (GOS).

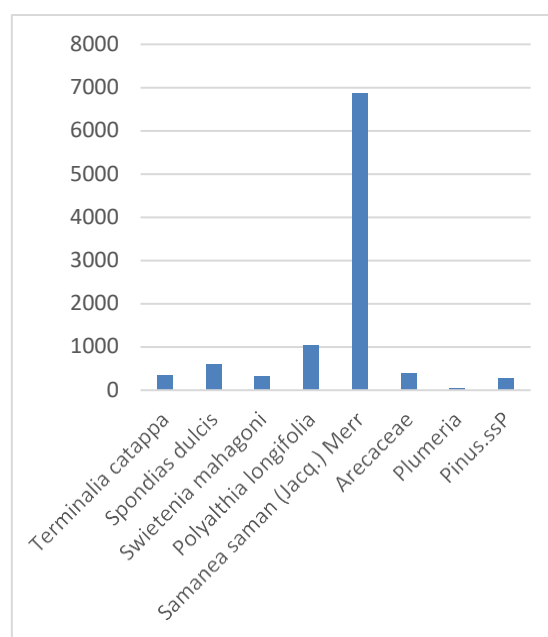


Figure 2. Graph of tree biomass in the Diponegoro Green Open Space (GOS).

The bar graph shows that the Munggur tree has the highest average biomass value, namely 6,872.45, which far exceeds other tree species. This high biomass value reflects the large diameter of the tree trunk and crown, so that the capacity for storing organic matter and the accumulation of photosynthetic material in this tree is very dominant (Haruna, 2020). This condition indicates that the Munggur tree has a very important ecological role in supporting the environmental function of the park, especially as a primary provider of ecosystem services related to carbon sequestration and microclimate regulation (Rosyidah, Aminatur Hidayah, Elok, 2024).

The following table shows the oxygen-producing capacity of each tree species.

Table 2. Oxygen-producing capacity of each tree species.

O ₂	
<i>Terminalia catappa</i>	9,24
<i>Spondias dulcis</i>	15,94
<i>Swietenia mahagoni</i>	8,76
<i>Polyalthia longifolia</i>	27,91
<i>Samanea saman (Jacq.) Merr</i>	183,29
<i>Arecaceae</i>	10,61
<i>Plumeria</i>	1,41
<i>Pinus.ssP</i>	7,18

The average oxygen production of each tree species shown in the O₂ table and bar graph shows a close relationship with the biomass value and previous biomass growth. The bar graph shows that the Munggur Tree has the highest average oxygen production, namely 183.29, which reflects very intensive photosynthetic activity due to the large canopy area and number of leaves. The dominance of the oxygen production value in the Munggur Tree is clearly visible from the striking difference in the height of the graph column compared to other tree species, thus confirming the main role of large biomass vegetation in producing oxygen in the Diponegoro Park area.

The following table shows the Delta B value calculations, which complement the economic valuation data.

Table 3. Annual biomass gain for each tree species.

Delta B	
<i>Terminalia catappa</i>	6,93
<i>Spondias dulcis</i>	11,96
<i>Swietenia mahagoni</i>	6,57
<i>Polyalthia longifolia</i>	20,93
<i>Samanea saman (Jacq.) Merr</i>	137,45
<i>Arecaceae</i>	7,96
<i>Plumeria</i>	1,05
<i>Pinus.ssP</i>	5,38

The annual biomass increase (Delta B) values displayed in the table and bar graph show a pattern consistent with the average biomass distribution of each tree species. The graph shows that the Munggur tree has the highest Delta B value, at 137.45, reflecting a significantly greater biomass growth capacity than other tree species. This high Delta B value is clearly visible in the bar graph, where the Munggur tree column

appears very dominant compared to other vegetation.

This condition indicates that the Munggur tree not only has a large average biomass but is also actively growing, thus increasing its ecological capacity over time. This makes the Munggur one of the most important vegetation components in supporting the ecological function of the green open space in Diponegoro Park.

The following table contains carbon stock data for each tree species in the Diponegoro Green Open Space (GOS) to help us understand CO₂ absorption in the GOS.

Table 4. Carbon stock table for Diponegoro GOS.

Carbon Stock	
<i>Terminalia catappa</i>	173,19
<i>Spondias dulcis</i>	298,88
<i>Swietenia mahagoni</i>	164,17
<i>Polyalthia longifolia</i>	523,25
<i>Samanea saman (Jacq.) Merr</i>	3436,22
<i>Arecaceae</i>	198,92
<i>Plumeria</i>	26,35
<i>Pinus.ssP</i>	134,53

The average carbon stock values presented in the table and bar graph indicate the ability of each tree species to store carbon from CO₂ absorption throughout its growth period. The bar graph shows that the Munggur tree has the highest average carbon stock, at 3,436.22, indicating the dominant role of this vegetation as a carbon store in Diponegoro Park.

High carbon stock is closely related to the average biomass and large size of the tree, resulting in a much greater accumulation of carbon in the trunk, branches, and crown tissue compared to other tree species. The dominance of the Munggur tree's carbon stock value is clearly evident from the striking difference in the height of the graph's columns.

The following presents the results of data processing, which contain the CO₂ absorption capacity of each tree species in Diponegoro Green Open Space.

Table 5. CO₂ absorption table for Diponegoro GOS

CO ₂ Adsorbtion	
<i>Terminalia catappa</i>	635,61
<i>Spondias dulcis</i>	1096,90
<i>Swietenia mahagoni</i>	602,49
<i>Polyalthia longifolia</i>	192,32
<i>Samanea saman (Jacq.) Merr</i>	12610,94
<i>Arecaceae</i>	730,05
<i>Plumeria</i>	96,71
<i>Pinus.ssP</i>	493,72

The average CO₂ absorption values displayed in the table and bar graph indicate the ability of each tree species to absorb carbon dioxide from the atmosphere through photosynthesis. The bar graph shows that the Munggur tree has the highest CO₂ absorption value, at 12,610.94, indicating its high effectiveness in reducing greenhouse gas concentrations in the Diponegoro Park area. This high CO₂ absorption value is closely related to the average biomass, biomass growth, and large tree canopy area, which optimizes the carbon absorption process. The dominance of the Munggur tree as the primary CO₂ absorber is clearly visible in the graph, with a striking difference in the height of its columns compared to other tree species.

The following presents data on the conversion of economic value into rupiah that would be obtained if the Diponegoro Green Open Space (GOS) were maintained.

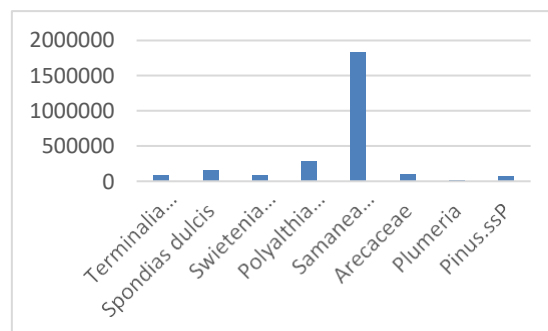
Table 6. Conversion of rupiah values for each tree type.

Conversion to Rupiah	
<i>Terminalia catappa</i>	92379,61
<i>Spondias dulcis</i>	159423,41
<i>Swietenia mahagoni</i>	87566,66
<i>Polyalthia longifolia</i>	279100,83
<i>Samanea saman (Jacq.) Merr</i>	1832881,93
<i>Arecaceae</i>	106105,80
<i>Plumeria</i>	14056,15
<i>Pinus.ssP</i>	71757,30

The results of converting oxygen production into rupiah values, presented in the table and bar graph, demonstrate that the ecosystem services provided by vegetation in Diponegoro Park can be translated into tangible and measurable economic value.

The following bar graph shows the economic value generated by all tree species in the Diponegoro Green Open Space.

Figure 3. Graph of the economic value of various tree species in the Diponegoro Green Open Space



The bar graph shows that the Munggur tree has the highest economic oxygen value, at Rp1,832,881.93, reflecting the significant ecological benefits generated by high-biomass vegetation. This high economic value is in line with the large oxygen production produced, demonstrating a consistent relationship between the tree's ecological capacity and the resulting economic environmental benefits. The dominance of the Munggur tree's economic value is clearly visible in the bar graph, where its column is much higher than that of other tree species.

CONCLUSION

Based on the research findings and discussions, it can be concluded that the management of the Diponegoro Park ecosystem, particularly in terms of vegetation maintenance, has successfully maintained the park's important role as a strategic green open space in Semarang City.

The results show that Munggur trees have the most dominant contribution with an average biomass of 6,872.45 kg/tree, [L6.1][AM6.2]annual growth (ΔB) of 137.45 m/year, oxygen production of 183.29 ton/ha/year, carbon stock of 3,436.22 ton/ha, and CO₂ absorption of 12,610.94 ton/year. The economic value of oxygen produced reached IDR 1,832,881.93. These results support the assertion that the presence of large-diameter vegetation, particularly Munggur trees, plays a crucial role in the park's ecosystem services in mitigating climate change and purifying the air. Therefore, this study recommends

maintaining and planting plants with high biomass to optimally fulfill the ecological role of green open spaces (Kristiyanto, 2023).

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