

## Potential of carbon storage and sequestration in the Heroes Park City Forest, Purworejo Regency, Central Java

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**Abstract.** Heroes Park City Forest has a high vegetation density in Purworejo Regency, Central Java province, absorbing and storing carbon from the atmosphere. This study analyzes the value of carbon stock, sequestration, and tree composition in the Heroes Park City Forest. Data collection was carried out in February 2021, using three randomly distributed 20 x 100 m plots. Analysis of carbon stock data, important value index, and diversity index was carried out quantitatively descriptively. The results showed that the carbon stock value of trees was 116.84 tons ha<sup>-1</sup>, which according to Reducing Emissions from Deforestation and Forest Degradation or REDD+, was included in the high carbon stock category. The value of carbon sequestration in Heroes Park urban forest is 428.80 tons ha<sup>-1</sup>, which is higher than some city forests in Indonesia. The sampling location is covered with 157 tree species, dominated by *Acacia auriculiformis*, and has a moderate level of tree diversity. Vegetation dominated by *Acacia auriculiformis* from Fabaceae contributed 43 percent of the total carbon stock in Heroes Park. Abiotics such as rainfall, air temperature, and humidity in Purworejo City support the growth of plants from the Fabaceae. Therefore, Heroes Park City Forest in Purworejo Regency has high carbon storage or carbon stock and sequestration values and needs to be monitored annually to maintain this potential.

**Keywords:** *Acacia auriculiformis*, carbon, sequestration, stock, trees, urban

### INTRODUCTION

Dynamic urban areas with physical development in various sectors result in disturbances in green open space (GOS) conditions [1,2,3,4]. On the other hand, GOS such as city forests plays a role in maintaining the quality of the urban environment, as city lungs, dust filters, groundwater storage, noise suppression, ecosystem preservation, and global warming mitigation [5,6]. Motorized vehicles, the discharge of industrial waste into the atmosphere, and other anthropogenic activities in urban areas account for seventy-five percent of global carbon dioxide emissions [7,8,9,10]. Disruption to urban forests will reduce vegetation that can absorb and store greenhouse gases such as carbon [11].

The absorption or sequestration of carbon carried out by plants through photosynthesis describes the amount of carbon dioxide (CO<sub>2</sub>) absorbed from the atmosphere [12,13,14]. In addition, plants also can store a certain amount of carbon or known as carbon stock, in the form of biomass by forty-six percent in

their body [15]. According to the Intergovernmental Panel on Climate Change (IPCC), carbon sequestration will be stored in the form of above-ground biomass, below-ground biomass, necromass, litter, and soil organic [16].

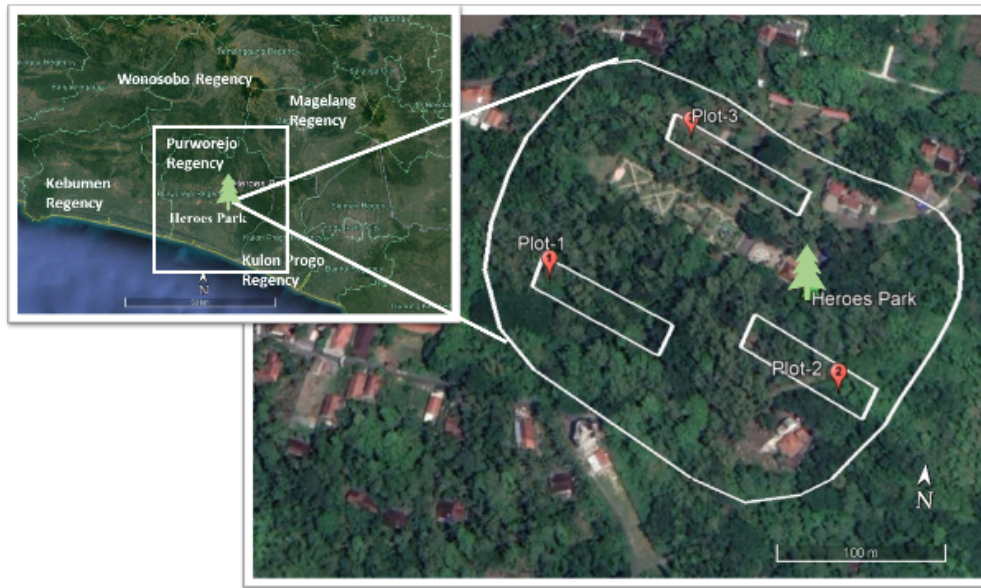
Trees, as woody plants, are the significant sinks in absorbing and storing carbon [17]. After the tree died as a necromass, the carbon stored in the biomass will enter the food chain or into the soil as soil carbon [18]. Tree biomass above ground level is influenced by tree size at maturity, life span and growth rate [19], land type, soil type, land management [20], composition, and diversity of tree vegetation [21].

One way to monitor changes in vegetation structure and composition is through vegetation analysis [22]. Changes in vegetation have an essential effect on stability, productivity, trophic structure, movement of ecosystem components, and abiotic factors such as temperature and humidity [23]. The parameters of density, dominance, frequency, species composition, and level of diversity will be measured [24]. Vegetation analysis also analyzes the relationship between changes in vulnerable communities such as green open spaces to micro and macro climates [25].

Heroes Park City Forest is a green open space area with the highest vegetation density in Purworejo

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Received: July 2021 | Revised: January 2022 |  
Accepted: February 2022



**Figure 1.** Map of sampling locations

Regency, Central Java [26]. Before being managed by *Dinas Lingkungan Hidup* (DLH) Purworejo Regency, this area was the Arga Putra Campground managed by *Dinas Pemuda dan Olahraga*, Purworejo Regency [27]. Vegetation collection and monitoring have never been done at this location. The results of the research on carbon stocks in green open spaces in other regencies in Indonesia are known that city forests in Gresik Regency have carbon storage of  $65.09 \text{ ton ha}^{-1}$ , and carbon sequestration of  $238.91 \text{ ton ha}^{-1}$  [28] or city forests in Jambi obtained the value of carbon stock is  $164.78 \text{ ton ha}^{-1}$ . Carbon sequestration is  $604.20 \text{ ton ha}^{-1}$  [29]. The diversity of carbon stock values in various urban parks is influenced by several parameters, such as plant species diversity, individual density, forest type, vegetation type, climate, rainfall, and topography [30].

Heroes Park City Forest is expected to help optimize the role of urban forests as carbon sinks in the Purworejo Regency. Analysis of vegetation composition, diversity, and monitoring of potential carbon storage needs to be carried out regularly as a database for local governments to monitor environmental conditions. This study analyzes the value of carbon stocks and sequestration and tree composition in the Heroes Park City Forest, Purworejo Regency, Central Java Province. The results of this study can be used as information and input for the *Dinas Lingkungan Hidup* Purworejo Regency in planning conservation or protection efforts for tree communities in urban GOS.

## METHODOLOGY

### Research Design

This research is a descriptive quantitative study comparing data on carbon stock and diversity in Heroes Park with similar studies in other city forests in Indonesia. Primary data collection was carried out in February 2021 in the Heroes Park City Forest, Purworejo Regency, Central Java Province. Forest City Heroes Park is geographically located at  $7^{\circ}43'29.91'' \text{ S } 110^{\circ}00'45.10'' \text{ E}$ .

### Materials and Equipment

The tools used in this research are roll meter, sewing meter, thermohygrometer, laptop, camera, Google Earth Pro application for making sampling maps, Flora of Java identification book, PlantNet application, GPS, label paper, thread, paper, insulation, press, 70% alcohol to preserve specimens.

### Data Collection

Measurement of carbon stock and analysis of tree vegetation in Heroes Park was carried out on a plot measuring  $20 \times 100 \text{ m}$  [20] in three plots randomly distributed over an area of  $60,044 \text{ m}^2$  (Figure 1). The three plots with a total area of  $0.6 \text{ ha}$  or  $6,000 \text{ m}^2$  have been adapted to forest groups with an area of 1,000 hectares with a sampling intensity of ten percent [31].

Tree carbon stock was obtained from forty-six percent of total tree biomass [15,20]. The tree biomass value was acquired by a non-destructive method by measuring the diameter at breast high (DBH), which was entered into the allometric equation (1) [32]. In contrast, the carbon sequestration was obtained by calculating carbon storage multiplied by 3.67 [33].

$$W = 0.118 \times \text{DBH}^{2.53} \dots\dots\dots(1)$$

Notes:

W = tree biomass ( $\text{ton ha}^{-1}$ )  
DBH = diameter at breast high

The trees in the three plots were then identified and validated using an identification book, and a herbarium was made. After that, all trees were analyzed for Importance Value Index or IVI (2) and Shannon Wiener Diversity Index or  $H'$  (3) [24].

$$\text{Important Value Index} = \text{RDe} + \text{RF} + \text{RDo} \dots\dots (2)$$

Notes:

$$\begin{aligned}\text{Relative Density (RDe)} &= \frac{\text{Density Species-x}}{\text{Total Density}} \times 100\% \\ \text{Relative Frequency (RF)} &= \frac{\text{Frequency species-x}}{\text{Total Frequency}} \times 100\% \\ \text{Relative Dominance (RDo)} &= \frac{\text{Dominance species-x}}{\text{Total Dominance}} \times 100\%\end{aligned}$$

$$H' = -\sum p_i \log p_i \dots\dots\dots (3)$$

Notes:

$$\begin{aligned}H' &= \text{Shannon Wiener Diversity Index} \\ p_i &= \frac{n}{N} \\ n &= \text{Important Value Index species-x} \\ N &= \text{Total Important Value Index}\end{aligned}$$

The criteria for the Shannon Wiener Diversity Index (H') according to Haryadi (2017) are  $H' < 1$  is categorized as low diversity,  $1 \leq H' < 3$  is categorized as moderate, and  $H' \geq 3$  is ranked as high [34].

Abiotic parameters such as air temperature, humidity, and rainfall (obtained from measurement data from the Dinas Pekerjaan Umum dan Penataan Ruang Purworejo Regency) were measured by repeating three times in each plot (except for rainfall data). The abiotic data were then analyzed with tree vegetation biotic data.

### Data Analysis

Data on carbon stock, carbon sequestration, composition, and diversity of tree vegetation were analyzed descriptively. This data is compared with the results of similar research in the last five years in the period 2017 to 2021 at city forest locations in other Regencies in Indonesia. Specifically for carbon stock data, it will be validated with the categories issued by Reducing Emissions from Deforestation and Forest Degradation or REDD+ such as low carbon stock ( $< 35 \text{ ton ha}^{-1}$ ), medium carbon stock ( $35 - 100 \text{ ton ha}^{-1}$ ), and high carbon stock ( $> 100 \text{ ton ha}^{-1}$ ) [35].

## RESULTS AND DISCUSSION

### Carbon Storage and Sequestration

Based on the data measurement, the carbon stock value of tree stands was  $116.84 \text{ ton ha}^{-1}$  and the carbon sequestration value was  $428.80 \text{ ton ha}^{-1}$  in Heroes Park City Forest, Purworejo Regency. The value of carbon stock at this location is included in the recommendations of Rahayu & Harja (2013) and Erly et al. (2019) for carbon stocks in secondary tropical forests in Indonesia (ranging from  $100-300 \text{ ton ha}^{-1}$ ) [36,37]. According to Reducing Emissions from Deforestation and Forest Degradation or REDD+, the value of carbon stock in Heroes Park is included in the high category because it is valued at over  $100 \text{ ton ha}^{-1}$  [35]. The value of carbon stock and carbon sequestration in Heroes Park compared to several urban forest areas in other areas in Indonesia, such as GOS Surabaya and Yogyakarta city, M. Sabki City Forest in Jambi, and Taman Margasatwa Ragunan City Forest, are high category (Table 1). The carbon stock value in Heroes Park is also higher than the University of Indonesia City Forest in Depok and the City Forest in Gresik Regency.

**Table 1.** Comparison of tree carbon stocks on several city forests

Location	Carbon stock (ton C ha <sup>-1</sup> )	Carbon sequestration (ton C ha <sup>-1</sup> )
Surabaya City GOS [38]	593.93	2,180.21
M. Sabki City Forest Jambi [27]	164.78	604.20
Yogyakarta City GOS [38]	135.35	496.74
Taman Margasatwa Ragunan City Forest [39]	127.07	466.35
<b>Heroes Park City Forest</b>	<b>116.84 ± 8.26</b>	<b>428.80 ± 30.31</b>
University of Indonesia City Forest [40]	87.02	319.36
City Forest of Gresik Regency [28]	65.09	238.91

The absorption of pollutants in urban areas is closely related to carbon sequestration by vegetation in the urban forest. The most significant proportion of carbon storage on land is generally found in the tree component [20]. Therefore, optimizing the carbon sequestration process in urban forest areas is a crucial climate change mitigation measure at this time. Each type of plant can grow, and the number of stomata as a way of carbon absorption is different and can affect the process of carbon sequestration [29]. Increasing carbon sequestration in urban forests can also be done by increasing biomass growth by maintaining trees and increasing wood reserves by planting incredibly fast-growing tree species. However, this carbon sequestration will be insignificant if anthropogenic CO<sub>2</sub> emissions are not controlled.

The tree with the highest carbon stock value in Heroes Park is *Acacia auriculiformis* from the Fabaceae family. *A. auriculiformis* trees have a carbon stock value of  $50.56 \text{ tons ha}^{-1}$  or 43 percent of the total carbon stock in Heroes Park (Table 2). Compared to other plants of the genus *Acacia*, *Acacia mangium* has potential carbon storage of  $52.10 \text{ tons ha}^{-1}$  and carbon sequestration of  $191.20 \text{ tons ha}^{-1}$  [41]. The advantages of trees from the genus *Acacia* are that they grow fast, adapt to acidic pH and minimal water sources, and live in various soil types [41]. In forest areas near Purworejo Regency, such as in the Mount Merapi National Park in Sleman Regency the Pinus Mangunan Forest in Bantul Regency, the genus *Acacia* also dominates in terms of carbon storage compared to other tree species [21,42]. Other tree species with high carbon stock values include *Senna siamea* ( $19.27 \text{ ton ha}^{-1}$ ), *Pterocarpus indicus* ( $14.14 \text{ ton ha}^{-1}$ ), *Tectona grandis* ( $11.74 \text{ ton ha}^{-1}$ ), and *Samanea saman* ( $10.43 \text{ ton ha}^{-1}$ ) (Table 2). The five tree species with the highest carbon stock values have a high total Diameter at the Breast High (DBH), because DBH is the most crucial variable in the allometric equation for biomass measurement [43].

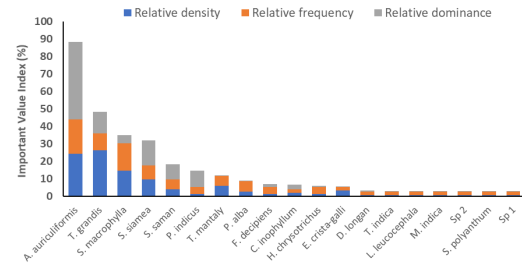
**Table 2.** Carbon stock and carbon sequestration of each species at the sampling location

Species Name	Carbon stock*	Carbon sequestration*
<i>Acacia auriculiformis</i>	50.56	185.56
<i>Senna siamea</i>	19.27	70.72
<i>Pterocarpus indicus</i>	14.14	51.90
<i>Tectona grandis</i>	11.74	43.08
<i>Samanea saman</i>	10.43	38.27
<i>Swietenia mahagoni</i>	4.33	15.90
<i>Colophyllum inophyllum</i>	2.99	10.98
<i>Filicium decipiens</i>	1.64	6.01
<i>Handroanthus chrysotrichus</i>	0.54	1.99
<i>Dimocarpus longan</i>	0.47	1.71
<i>Tamarindus indica</i>	0.32	1.16
<i>Leucaena leucocephala</i>	0.08	0.28
<i>Terminalia mantaly</i>	0.08	0.28
<i>Eritrina crista-galli</i>	0.07	0.25
<i>Plumeria alba</i>	0.07	0.25
<i>Mangifera indica</i>	0.06	0.22
Sp 2	0.06	0.21
<i>Syzygium polyanthum</i>	0.00	0.02
Sp 1	0.00	0.01

\*) Unit: ton C ha<sup>-1</sup>

### Vegetation Composition and Diversity

The sampling location found 157 individual trees from 19 species (Figure 2) and 11 families. The tree species with the highest importance value was *Acacia auriculiformis* (88.19%), followed by *Tectona grandis* (48.15%), *Swietenia macrophylla* (34.89%), *Senna siamea* (31.75%), *Samanea saman* (18.08%) (Figure 2). *A. auriculiformis* species has the highest carbon stock value and has the highest important value index in Heroes Park City Forest. The basal area and frequency of *A. auriculiformis* are very high, indicating mastery of the sampling area, and its distribution is very high [24]. The type of *T. grandis*, known as Teak, actually has the highest density or number of individuals per area but has not outperformed the frequency and dominance values of *A. auriculiformis*. The IVI value of *A. auriculiformis* and *T. grandis* was classified as high according to Fachrul (2007), with an IVI value above 42.66 [44]. Species with a high IVI category have a dominant number of individuals, the level of distribution and control over the soil surface compared to other species [24,45]. If the IVI value of a species of vegetation type is high, then that type significantly affects the stability of the ecosystem [44]. The species *T. grandis* dominate the city forest in Gresik Regency with the highest IVI value and carbon stock [28]. *S. macrophylla* or mahogany is the third-highest dominant tree in Heroes Park. The same thing was also reported in the Taman Margasatwa Ragunan City Forest, which was dominated by *S. macrophylla* [39]. The Meliaceae family can reduce air pollution by about 47 to 69 percent. *Senna siamea* or Johar and *Samanea saman* or Trembesi come from the Fabaceae family that dominates in Heroes Park City Forest. The Fabaceae family has a wide distribution, especially in the tropics [46].



**Figure 2.** Tree IVI value in Heroes Park City Forest

The abiotic measurements of air temperature and humidity at the time of sampling were 28.85 °C and 64.82%. Rainfall recorded in February 2021 around Heroes Park was 436.5 mm month<sup>-1</sup> because it was entering the peak of the rainy season [47]. During the dry season, such as June to August, the temperature ranges from 25 to 32 °C with rainfall reaching 0 mm month<sup>-1</sup> [48]. Environmental conditions with these abiotic factors affect the dominance of *A. auriculiformis* and *T. grandis* to maximize growth and development. The *Acacia* species can grow in the air temperature range between 12 °C to 34 °C, humidity 53%-85%, and optimum rainfall at 2,000 mm year<sup>-1</sup> [49,50,51]. The optimal type of *T. grandis* grows in environmental conditions with rainfall between 1,200-3,000 mm year<sup>-1</sup>, temperatures ranging from 22-31 °C, and humidity between 60-80% [52,53].

Based on the calculation results, the tree vegetation Diversity Index (*H'*) in the Heroes Park City Forest, Purworejo Regency is 1.08. These results indicate that the Heroes Park City Forest tree has a moderate level of tree diversity. The species diversity index is essential information about a community. The wider the sample area and the more species found, the higher the species diversity index value. Relatively low diversity index values are common in communities that have reached climax [45]. To maintain high diversity, communities require regular and random disturbances [24]. Usually, after the disturbance has passed, there will be an increase in species diversity to a point where the community reaches a climax. Furthermore, after the climax, there is a tendency for the diversity index to decrease again.

### CONCLUSION

The conclusions in this study are as follows:

1. Heroes Park City Forest, Purworejo Regency, Central Java, has a carbon stock and carbon sequestration value of 116.84 ton ha<sup>-1</sup> and 428.80 ton ha<sup>-1</sup>, which are included in the high category to REDD+.
2. At the sampling location in the Heroes Park City Forest, Purworejo Regency, 19 tree species from 11 families were found, with the dominant species being *Acacia auriculiformis*. In addition, Heroes Park City Forest has a moderate level of tree diversity with an *H* value of 1.08.



## ACKNOWLEDGMENT

Thank you to the staff at *Dinas Lingkungan Hidup* and *Dinas Pekerjaan Umum dan Penataan Ruang* Purworejo Regency for their support during data collection.

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