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Species diversity, biomass and carbon stock of Arroceros Forest Park: An urban green space in Manila, Philippines

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ABSTRACT: The Arroceros Forest Park (AFP), an urban green space in Manila, Philippines, is widely considered the "last lung" of Metro Manila. This study assessed the park's tree species diversity, biomass, carbon stock, and the carbon dioxide mitigation value using a non-destructive tree sampling method. A total of 264 individual trees representing 19 species across 14 families were recorded. *Swietenia macrophylla*, a non-native species, was the most dominant, exhibiting the highest importance value index (IVI) and contributing most to the total biomass and carbon storage. *Acacia auriculiformis* and *Pterocarpus indicus* also showed substantial contributions, indicating that large-diameter trees influence the ecosystem-level carbon dynamics. Biodiversity indices revealed moderate species richness with uneven distribution. Simpson's diversity was high, but Shannon's index was lower, suggesting that few species dominate within a stable community. More than 80% of trees had a diameter at breast height exceeding 30 cm, reflecting a mature stand. The estimated total aboveground biomass was 934.95 Mg/ha and belowground biomass was 192.25 Mg/ha, totaling 1,127.20 Mg/ha. The total vegetative carbon stock was 507.24 Mg C/ha, corresponding to a CO_2 equivalent of 1,861.56 Mg/ha with a potential carbon dioxide mitigation value of 4,095.42 Mg. Despite its limited areas, AFP functions as a vital urban carbon storage capacity within an intensely urbanized landscape. These findings highlight the importance of mature tree protection, maintaining existing biomass and carbon stocks while supporting biodiversity stability. The study provides baseline ecological and carbon stock data to inform evidence-based urban forest conservation planning and climate-resilient strategies in rapidly urbanizing cities.

KEY WORDS: allometric equation, Arroceros Forest Park, carbon stock, species diversity, vegetation biomass.

INTRODUCTION

Forests offer a wide range of essential ecosystem services that benefit human society. They regulate the biogeochemical cycle and provide habitat for diverse terrestrial species (Soliño and Raposo, 2022). They comprise a variety of species that shape the ecosystem (Shahid *et al.*, 2016). Tropical forests play a major role in the carbon cycle worldwide, but only 20% are considered intact, and these intact areas store 40% of the aboveground carbon (Dida *et al.*, 2020). Trees in urban areas affect climate change by storing carbon, which is emitted back into the atmosphere upon the death of the tree. They fix carbon dioxide (CO_2) during photosynthesis, prevent carbon dioxide accumulation in the atmosphere, and store carbon as biomass, thus acting as a sink (Nowak *et al.*, 2013; Tutor *et al.*, 2018; Coracero and Malabrigo, 2020).

Trees outside forests like urban green spaces signify the "lungs of the city" and carbon stock reserve (Lahoti *et al.*, 2020), which includes all the trees on the roadside, parks, and green infrastructures (Pati *et al.*, 2023). Parks are urban green spaces which are covered with vegetation, absorb carbon from the atmosphere, resulting in carbon sink enhancement (Zhao *et al.*, 2023). Urban forests and forest parks can remove CO_2 from the atmosphere, improve the quality of surroundings in the cities, and urban dwellers. They also reduce noise, greenhouse gas emissions, and air pollution, mitigate water runoff, and provide aesthetic and recreational benefits (Roeland *et al.*, 2019). They serve as both carbon stocks and active carbon sinks (Febiriyanti *et al.*, 2021). Through the process of carbon sequestration, the atmospheric CO_2 is absorbed via photosynthesis (Zheng *et al.*, 2013). Carbon stock can be quantified by computation. These calculations estimate the carbon storage potential and CO_2 uptake of forest vegetation through biomass (Febiriyanti *et al.*, 2021). The accuracy of measuring how much carbon these forests sequester is crucial for developing effective strategies to lower greenhouse gas emissions and lessen the impacts of climate change (Zheng *et al.*, 2013).

Beyond carbon storage, urban forests support climate action in several ways. They keep cities cooler by moderating urban temperatures. They clean the air by filtering pollutants and prevent floods by absorbing the water through vegetation (Ferrini *et al.*, 2020). These create strong links to Sustainable Development Goals (SDG) like SDG 13 (Climate Action), which highlight urgent measures to combat climate change and its impacts (Filho *et al*., 2023). Forest and trees in urban areas are a systemic and nature-based solution that directly supports SDG targets (United Nations Economic Commission for Europe, 2024).

The National Capital Region (NCR) or Metro Manila is the most densely populated region in the Philippines (Porio *et al*., 2019). Urbanization led to upsurge of population and building density, thus affecting land use and land cover (Bikis *et al*., 2025). With rapid urban growth, Metro Manila faces numerous environmental challenges (Regmi, 2018) including the negative impact of the changes in the land use and land cover (Bikis *et al*., 2025). This undesirable impact has led to the transformation of green areas in urban settings. This process, including urban land transformation, urban extension, and intrusion into green spaces, has significantly reduced the availability of such areas (Lagbas, 2019). The decline in vegetation led to heat excess in the surface temperature resulting in a "heat island effect" (Almadrones-Reyes and Dagamac, 2023). This trend is evident in the City of Manila, where rapid urbanization affects the biodiversity and air quality of the urban area (Lagbas, 2019).

Urban areas are significant contributors to anthropogenic greenhouse gases, particularly CO_2 (Habib and Al-Ghamdi, 2021). They are currently responsible for over 70% of global CO_2 emissions (Dasgupta *et al*., 2022). The amount of greenhouse gas in the atmosphere has increased by heavy industrialization and rapid deforestation. In response to the program of reducing emissions from deforestation and forest degradation (REDD+), forest management focused on the reduction of deforestation and forest degradation (Jaman *et al*., 2016). Using 2010 as the base year, vehicular emissions were identified as the primary source of greenhouse gases, followed by stationary sources such as commercial establishments and industrial facilities. The poor quality of the surrounding air in the locality is due to the population growth in the city and the accelerated progress in the area (Regmi, 2018).

Urban forests provide essential ecosystem services that enhance environmental conditions and societal well-being in densely populated cities like Metro Manila. Arroceros Forest Park (AFP) have been observed to maintain substantially decreased temperatures than surrounding built environments, demonstrating their effectiveness in reducing the urban heat island effect through shading and transpiration (Climate Change Commission, 2024). In Puerto Carreño, Colombia, urban forests can lessen urban heat by up to 9 °C during peak heat hours, underscoring their role in thermal regulation and climate adaptation in tropical cities (Giraldo-Charria *et al*., 2025).

Urban trees contribute to climate regulation through CO_2 absorption and carbon storage in biomass and soil, alongside releasing oxygen, supporting both ecological functions and human health (Climate Change Commission, 2024). They also improve air quality by removing pollutants, thereby reducing exposure to harmful particulates and gases common in megacity environments. Peer-reviewed studies report on the beneficial effect of urban forests such as thermal regulation, air filtration, and increased carbon sequestration, highlighting their synergistic impact on environmental quality (Feng *et al*., 2024; Yin *et al*., 2024).

In addition to climate and air quality benefits, urban forests support biodiversity and make healthier and habitable cities for both humans, flora and fauna. Research on plant community dynamics within Metro Manila's urban forests emphasizes the importance of plant functional diversity for ecosystem resilience and stability, which further enhances the ability of these green spaces to deliver critical services under environmental changes (Olfato-Parojinog *et al*., 2025).

Human activities and some aspects of urbanization contribute to biodiversity loss (Shahid *et al*., 2016), arable land loss, and habitat destruction (Clarin *et al*., 2021). Species diversity is vital to understanding the structure and function of the community (Zhao *et al*., 2022). The Estimation of species diversity is common to the community and is frequently used for conservation planning and community monitoring (Zhao *et al*., 2022).

Forest parks serve as vital ecosystems that stabilize the well-being of the people, offering relief from urban issues such as poor air quality, urban crowding, and climate change (Membrebe *et al*, 2017). One of the forest parks located in the heart of Manila, Philippines is a unique Urban Green Space called AFP (Santos Jr., 2019). The place is widely regarded as the "last lung" of the City of Manila (Ancheta *et al*., 2016). It is a 2.2-hectare green space and is one of the remaining urban forest parks in Metro Manila (Ancheta *et al*., 2016a; Membrebe *et al*., 2017; Santos Jr., 2019). The AFP serves as a refuge to some migratory bird species and habitat for other urban animals, and becomes an important ecological, recreational, and educational site (Membrebe *et al*., 2017).

Biomass dynamics act as a mirror for the potential role of terrestrial vegetation to sequester carbon dioxide because it takes part in photosynthesis, litterfall nutrient fluxes, and autotrophic respiration (Thurner *et al*., 2013). The aboveground biomass (AGB) and belowground biomass (BGB) comprises the total forest biomass. The calculation of AGB includes leaves, trunks, and branches (Li *et al*., 2022). In this study, the trunk was measured to get the AGB. Vegetation biomass, such as AGB, describes the function of a forest ecosystem (Behera *et al*., 2016) that includes all the living plant biomass above the soil (Kleinn *et al*., 2020). It is a basis for quantifying potential carbon mitigation value (Chen *et al*., 2023). Belowground biomass represents the major share of total forest biomass and can be used in estimating the transported carbon into the soil and reclaimed nutrients by the site (Magalhães, 2015). Forest lands store carbon in the biomass by photosynthetic process, and undisturbed forest ecosystems store additional biomass and accumulate carbon per unit area equated to agricultural lands (Devagiri *et al.*, 2013). One of the best options to estimate tree biomass and carbon stock is through an allometric equation which is a non-destructive approach where variables such as diameter (Cao *et al.*, 2025), height, and wood-specific gravity are measured (Pati *et al.*, 2022).

Carbon density refers to the amount of carbon stored in each area (Cao *et al.*, 2025), typically expressed in megagrams of carbon per hectare (Mg C/ha) (Aye *et al.*, 2022). Its assessment is essential for climate change mitigation and sustainable urban planning. Estimating carbon density supports evidence-based management and design of green spaces by identifying high-performing plant species (Cao *et al.*, 2025). This enables strategic vegetation selection to maximize carbon storage and contribute to carbon neutrality (Zhao *et al.*, 2023). It is a vital indicator for calculating the amount of carbon stocks and evaluating the carbon mitigation capacity of forests. It also serves as the foundation for studying forest ecosystems in terms of response mechanisms to global climate change (Hao *et al.*, 2019).

The total forest carbon stocks are typically distributed among live biomass, dead biomass, soil carbon, and wood products (Sugiarto *et al.*, 2024; Brinkord *et al.*, 2025). In this study, the potential CO_2 mitigation value is limited to carbon stored in tree biomass, which is converted to CO_2 equivalent.

While numerous studies have explored forest biomass and carbon stock in large natural forests and protected areas, data are scarce on these ecological parameters in urban forests in the Philippines. There seems to be a dearth of studies conducted relative to urban forest vegetation structure and dynamics. Environmental studies concerning vegetation and its part in reducing climate impacts in the last lung of the city of Metro Manila are lacking in scientific literature. Moreover, there is a need for an integrated assessment that connects biodiversity indicators, such as species richness and dominance, with carbon storage metrics.

Hence, this study was conducted to assess the ecological value of Arroceros Forest Park by focusing on three core components such as species diversity, vegetation biomass, and carbon stock. Specifically, the objectives are to: (1) identify and quantify the tree species present in the park and determine their diversity indices; (2) estimate the aboveground and belowground biomass of the tree vegetation using standard allometric methods; (3) compute the total carbon stock and corresponding CO_2 mitigation value; and (4) analyze the relationship between species contribution and carbon storage, providing insights into species-specific roles in urban carbon dynamics. By addressing these objectives, the study contributes valuable baseline information for environmental planning, forest conservation, and urban sustainability strategies in Manila and other comparable urban settings.

MATERIALS AND METHODS

Research design

A descriptive and quantitative field-based type of research was used to determine the species diversity, vegetation biomass, and carbon stock of AFP by measuring the diameter at breast height (DBH) of the trees. The data in DBH were analyzed using allometric equations. The allometric method was employed for forest biomass estimation because this is a non-destructive method and more time-saving than other methods (Chave *et al.*, 2014). The species diversity was described by its richness, abundance, evenness, and dominance. The Reducing Emissions from Deforestation and Forest Degradation-plus (REDD+) framework (Mondal *et al.*, 2020) was utilized in this study to account for the carbon stock of urban forests. This is an approach to climate change mitigation in the Philippines (Avtar *et al.*, 2020).

Study Area

The study was carried out in November of 2024 at AFP, a man-made urban forest (Lagbas, 2018) located on Antonio Villegas Street Barangay 659-A, in the fifth district of Manila. The study site is located at a latitude of 14°35′39.48″N and a longitude of 120°58′55.2″E (Figure 1). Metro Manila is the capital of the Philippines. Covering approximately 2.2 hectares, the forest park sits right in the busy downtown area of Manila. It is surrounded by the Manila Metropolitan Theater, LRT Line 1 Central terminal station, Pasig River, and Quezon Bridge (Ancheta *et al.*, 2016). This place serves as one of the few remaining green spaces in the city.

The topography of AFP is a low-lying or relatively flat terrain with an average elevation of 8 meters (en-ph.topographic-map.com, n.d.). The AFP is irregular in shape with four corners (Macaraig *et al.*, 2021). The park was redeveloped in September 2021 and reopened in 2022. It has various key elements such as green spaces covered by vegetation, elevated path walks, a jogging lane, a trail bridge, and including a fountain and a koi pond (Hestiada Jr., 2022). The climate is characterized as sub-humid with 610 mm annual mean precipitation and a 7.5 °C mean annual air temperature (Berame *et al.*, 2021).

The AFP traces its roots when the area was once home to *Parián de Arroceros*, a riverside commercial zone linked to the rice trade in the Spanish colonial period, and later the site of a tobacco factory (Fabrica de Cigarillos) in the second half of the 19th century to the early 20th century). After World War II, the buildings were used by the Department of Education (Bautista, 2022). The place

Fig. 1. Study site location of Arroceros Forest Park within Manila, Philippines

Fig. 2. Two 50 × 50 m plots with four 20 × 20 m nested plots each for Tree Sampling

had 150 trees prior to acquisition (Santos Jr., 2019) by the City of Manila in 1992. These century old trees survived World War II (Opol, 2024). According to Roces (2007), the city government introduced 60 Philippine tree species and now has 1,088 mature trees (Gonzales and Magnaye, 2017). In 1993, It was transformed into an urban forest through reforestation efforts led by the city government and the Winner Foundation (Roces, 2007) and planted 3,500 saplings (Santos Jr., 2019). In 2017, the Manila City government declared to vacate the site to make way for gymnasium construction. However, public advocacy helped to preserve the area and in 2020, it was officially declared through an Ordinance No. 8607 designating AFP as a permanent forest park (City Council of Manila, 2020; Galupo, 2020).

The age of 3,500 trees in AFP (Climate Change Commission, 2024) is estimated to be less than 35 years. AFP houses more than 3,000 trees, representing 60 native species including *Pterocarpus indicus* (narra), *Vitex parviflora* (molave) and *Siandora supa* (supa) (Santos Jr., 2019). In essence, AFP is a vital urban forest. The trees are products of modern reforestation efforts, not remnants of an ancient forest (Santos Jr., 2019). The trees themselves are the product of careful, planned urban reforestation and natural restoration efforts from the late 20th century onwards (Santos Jr., 2019; Opol, 2024).

Plot Establishment

A total of two square plots measuring 50 m × 50 m were sampled. In each plot, four 20 m × 20 m nested plots were established with a total of 8 transect plots (Figure 2). Plot shape selection was based on the landscape of the urban forest and the large plot which is (50 m × 50 m), a suitable size for urban park research and inventory

(Shaamala *et al.*, 2024). The Global Positioning System (GPS) data was collected from every corner of the square plot. Inside the nested plot (20 m × 20 m), each tree with a circumference or girth at breast height (GBH) of greater than or equal 10 cm was measured (Pati *et al.*, 2024). The GBH was measured in centimeters at 1.3 m above the ground (Hairiah *et al.*, 2001). The DBH was calculated by dividing the GBH by π (3.1416). The DBH classes of all trees were presented to classify trees based on diameter, which is critical for various purposes such as forest health evaluation, forest management plan, and ecological studies (Erfanifard *et al.*, 2025; Rijal and Sharma, 2024). The classes are typically structured in multiples of 10 (10, 20, 30, 40, etc.) to make them easier to inventory and include relevant charts and maps. These classes help explain how trees are distributed across an area and guide decisions on planting, maintenance, and management (Forest Management Bureau, 2014).

Tree Species Inventory

Each tree within the plots established in the forest park was tagged and identified at the species level. The height and DBH of each tree were measured in the large plot and the nested plot. Height was measured using a laser range finder. On the other hand, the DBH was measured at 1.3 m above the ground (Forest Management Bureau, 2014). Each species was identified with the help of the local workers and gardeners. Plant List Database and Co's Digital Flora of the Philippines (https://philippineplants.org/) were used to verify the tree species (Pelser *et al.*, 2011).

Biomass Estimation

Following the allometric equation of Chave *et al.* (2014), the aboveground biomass of all trees was computed based on DBH, height, and wood density. Wood densities (g cm^{-3}) of each tree species were based on the wood physical properties provided in the International Tropical Timber Organization (ITTO, n.d.) and Food and Agriculture Organization (FAO) list of wood densities for tree species from tropical America, Africa, and Asia (Food and Agriculture Organization of the United Nations, 1997). Model 4 of the said allometric equation was utilized due to the availability of the gathered forest variables. Below is the equation employed in the estimation of biomass.

$$AGB = 0.0673 \times (pD^2H)^{0.976}$$

where D is in cm, H is in m, and ρ is g cm^{-3}.

The BGB of individual trees inside the plots was estimated to get the total biomass. It is difficult and destructive to excavate roots or uproot or dig every individual species, so it is more practical to estimate BGB using an allometric equation. The BGB was determined using the formula below of Cairns *et al.* (1997).

$$BGB = \exp(-1.0587 + 0.8836 \times \ln(AGB))$$

The total biomass was computed by getting the sum of the computed AGB (Mg/ha) and BGB (Mg/ha) of all tree species. For comparison with other tree carbon densities in urban green spaces, Mg/ha was used in expressing the unit of AGB and BGB. Stand-level biomass (Mg/ha) was computed based on Macías *et al.*, (2017).

Calculation of Species Diversity

The computation of species diversity indices was adapted from Magurran (2004) for species richness, Margalef's diversity index (Clifford and Stephenson, 1975), Shannon diversity index (Nolan and Callahan, 2006), Simpson's diversity index (Simpson, 1949), Menhinick's index (Whittaker, 1977), and Evenness (Pielou, 1966).

Species richness is defined as the number of species in a community without considering the evenness (Magurran, 2004).

Species richness = total number of species

Margalef's index assesses species richness in relation to sample size (Clifford & Stephenson, 1975). By accounting for sample size, it helps minimize bias when comparing species richness across different communities or datasets (Kitikidou *et al.*, 2024). The index was computed using the formula below:

$$D_{Mg} = (S-1) / \ln(N)$$

Where in DMg: Margalef's index, S: total number of species, N: total number of individuals in the sample.

Shannon diversity index measures diversity in relation to species richness and evenness (Poudel *et al.*, 2022). It was calculated as follows:

$$H' = \sum_{I=1}^{S} \mathrm{Piln(Pi)}$$

Where H′: Shannon diversity index, S: number of species, p_i: proportion of individuals of each species belonging to the ith species of the total number of individuals.

Simpson's diversity index measures diversity by accounting for the total number of species and the relative abundance of each species. Diversity increases as both species richness and evenness increase. It was computed as follows:

$$D_S = 1 - \Sigma\, n_i\,(n_i - 1) / N\,(N - 1)$$

Where D_S: Simpson's diversity index, n_i: number of individuals of each species, N: total number of individuals of all species

Menhinick's index measures relative species richness but does not account for species evenness (Kitikidou *et al.*, 2024). It was computed as follows:

$$D_{Mn} = S/\sqrt{N}$$

Where D_{Mn}: Menhinick's index, S: total number of species, N: total number of individuals of all species

Species evenness describes how evenly individuals are distributed among the different species in a community or how close the number of each species in a community (Poudel *et al.*, 2022). Pielou (1966) evaluates species evenness by comparing the observed diversity to the maximum possible diversity, thereby indicating the distribution pattern of species within a community. The index is calculated using the following formula:

$$e = H/\ln S$$

Where e: evenness index, H: Shannon diversity index, S: total number of species in the sample. Species evenness ranges from 0 to 1, where 1 signifies complete evenness and 0 signifies no evenness (Kitikidou *et al*., 2024).

The interpretation of species diversity followed the classification provided by (Fernando, 1998, as cited in Baliton *et al*., 2020; Napaldet, 2023).

Calculation of Importance Value Index

The indication of the structural importance of species diversity is the importance value index (IVI) (Bulenga *et al*., 2023). This was obtained by adding the percentage values of relative frequency (RF), relative dominance (RDom), and relative density (RD), where:

RF = Frequency of a species/Total frequency of all species × 100

RD = Density of a species/Total density of all species × 100

RDom = Dominance of a species/Total dominance of all species × 100

IVI = RF + RDom + RD

Estimation of Carbon Density and Carbon Stock

The carbon density of individual trees based on the biomasses (AGB and BGB) inside the 8 plots was determined using the formula:

CD = Biomass (Mg/ha) × 0.45

where CD: carbon density, 0.45: carbon fraction of dry matter.

Total carbon density was computed using the total computed biomass (Mg/ha), and it was multiplied by 0.45. The computed carbon densities for all species were added to obtain the total carbon stock (Mg/ha).

Estimation of CO_2 Mitigation Value

The potential CO_2 mitigation value of the AFP was computed following IPCC (2007). The conversion factor 3.67 is derived from the ratio of the molecular weight of CO_2 (44) to that of carbon (12).

CO_2 Mitigation Value (Mg) = total carbon stock (Mg/ha) × Area (ha) × 3.67

RESULTS

Tree Species Inventory and Importance Value Index

A total of 264 individual trees representing 13 families were recorded from the 8 sampling plots: Fabaceae, Moraceae, Meliaceae, Ebenaceae, Anacardiaceae, Myrtaceae, Malvaceae, Urticaceae, Rubiaceae, Apocynaceae, Bignoniaceae, Combretaceae, and Lamiaceae (Figure 3). There were 19 species of trees, including *Acacia auriculiformis*, *Artocarpus heterophyllus*, *Azadirachta indica*, *Delonix regia*, *Diospyros blancoi*, *Dracontomelon dao*, *Eucalyptus deglupta*, *Kleinhovia hospita*, *Leucaena leucocephala*, *Leucosyke capitellata*, *Mangifera indica*, *Morinda citrifolia*, *Nerium oleander*, *Pterocarpus indicus*, *Samanea saman*, *Spathodea campanulata*, *Swietenia macrophylla*, *Terminalia catappa*, and *Vitex parviflora* (Table 1).

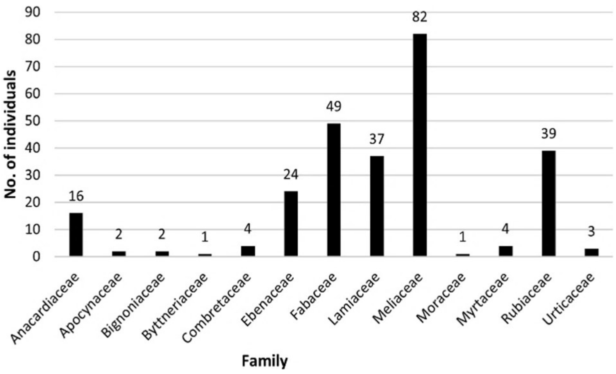

Fig. 3. Number of individual trees per Family

There were observed native and exotic species in the area. *S. macrophylla,* an exotic and invasive species under the family Meliaceae, recorded the highest number of individuals among all species observed. This was followed by species belonging to the family Fabaceae. In contrast, the lowest number of individuals was recorded for the families of Moraceae and Byttneriaceae. The family Fabaceae was represented by five species (*A. auriculiformis, D. regia, L. leucocephala*, *P. indicus* and *S. saman*).

The IVI was computed for each species to determine their ecological importance. As shown in Table 1, the species with the highest IVI was *S. macrophylla* (62.59), indicating it is the most ecologically significant in the park due to its high relative density, frequency, and dominance. Other common species included are *Vitex parviflora* (28.57), *M. citrifolia* (27.01), and *D. regia* (26.34). Several species showed low IVI values, such as *A. heterophyllus* (3.34), *K. hospita* (3.51), and *S. campanulata* (4.18), suggesting that they are either rare or sparsely distributed within the sampled area.

Species Diversity Indices

Based on the forest survey, there were 264 individual trees. The species richness is 19 with a Margalef index of 3.228 and a Menhinick index of 1.169. The Simpson diversity index (0.865) indicates high species diversity, suggesting that no single species dominates the community. This is consistent with the moderate evenness value (0.559), which reflects a semi-balanced distribution of individuals where several species are relatively abundant, while others occur at lower frequencies. In contrast, the Shannon index (2.362) is comparatively lower due to its sensitivity to both species richness and the abundance of rare species. This suggests that while some species are more dominant in terms of abundance, other species are still present in relatively

Table 1. Tree species inventory and vegetation analysis - Importance value index

Species	No. of Individuals	Origin	Relative Dominance (%)	Relative Density (%)	Relative Frequency (%)	Importance Value Index (IVI)
Acacia auriculiformis	8	exotic	11.15	3.03	5.88	20.06
Artocarpus heterophyllus	1	exotic	0.02	0.38	2.94	3.34
Azadirachta indica	10	exotic	1.73	3.79	5.88	11.40
Delonix regia	20	exotic	12.88	7.58	5.88	26.34
Diospyros blancoi	24	native	5.06	9.09	5.88	20.03
Dracontomelon dao	13	native	3.54	4.92	5.88	14.34
Eucalyptus deglupta	4	native	2.15	1.52	2.94	6.61
Kleinhovia hospita	1	native	0.19	0.38	2.94	3.51
Leucaena leucocephala	4	exotic	0.54	1.52	5.88	7.94
Leucosyke capitellata	3	native	0.56	1.14	5.88	7.58
Mangifera indica	3	exotic	0.55	1.14	5.88	7.57
Morinda citrifolia	39	native	6.36	14.77	5.88	27.01
Nerium oleander	2	exotic	0.13	0.76	5.88	6.77
Pterocarpus indicus	12	native	12.23	4.55	5.88	22.66
Samanea saman	5	exotic	3.16	1.89	5.88	10.93
Spathodea campanulata	2	exotic	0.48	0.76	2.94	4.18
Swietenia macrophylla	72	exotic	29.44	27.27	5.88	62.59
Terminalia catappa	4	native	1.149	1.52	5.88	8.54
Vitex parviflora	37	native	8.67	14.02	5.88	28.57

smaller but noticeable proportions. The community shows neither perfect evenness, in which all species have equal numbers of individuals, nor extreme dominance by a single species. This level of evenness reflects a semi-balanced ecosystem, where biodiversity is present but not optimally distributed. This difference between the Simpson and Shannon indices is typical of urban forest ecosystems, where dominance among common species is relatively balanced, but overall species richness and evenness remain moderate. Together, these diversity indices suggest that the urban tree community in AFP is characterized by moderate species richness, controlled dominance, and ecological stability.

Table 2. Diameter at breast height (dbh) class distribution of sampled trees.

DBH Classes (cm)	DBH Range (cm)	Frequency	%
10	5-14	5	1.89
20	15-24	18	6.82
30	25-34	24	9.09
40	35-44	43	16.29
50	45-54	38	14.39
60	55-64	27	10.23
70	65-74	31	11.74
80	75-84	21	7.95
90	85-94	21	7.95
100	95-104	7	2.65
110	105-114	9	3.41
120	115 and above	20	7.58

Tree Size Class Distribution

In terms of DBH classes, classes 40 and 50 had the highest recorded DBH based on the classification system of FMB (2014). The DBH class distribution of sampled trees is shown in Table 2. The highest number of trees was recorded in the 35–44 cm DBH class with 43 individuals (16.29%), followed by the 45–54 cm class with 38 individuals (14.39%) and the 65–74 cm class with 31 individuals (11.74%). The lowest frequency was observed in the 5–14 cm class with 5 trees (1.89%). Trees with DBH of 115 cm and above accounted for 20 individuals (7.58%), indicating the presence of large-sized trees in the study area. The DBH distribution indicates AFP stands dominated by intermediate to large-sized trees, which may reflect a relatively mature forest structure with ongoing recruitment of younger individuals.

The overall mean DBH was 59.99 cm, and mean height was 9.07 m, indicating a stand dominated by medium to large-sized trees (Table 2). Several focal species exhibited large mean DBH values, particularly *A. auriculiformis* (129.54 cm), *P. indicus* (94.98 cm), *S. saman* (88.64 cm), and *D. regia* (86.06 cm), reflecting the presence of mature canopy trees. Conversely, species such as *A. heterophyllus* (15 cm) and *N. oleander* (28.1 cm) were represented by smaller individuals, reflecting understory or younger growth stages.

Aboveground, Belowground and Total Biomass of Tree Species

The AGB, BGB, and total biomass estimated per species are summarized in Table 3. The total AGB was 934.95 Mg/ha, while the BGB was 192.25 Mg/ha, resulting in a total biomass of 1,127.20 Mg/ha across all species. The total biomass varied widely among species, ranging from 0.15 to 299.58 Mg/ha. The total biomass per tree was computed for each species to account for differences in population size. This measure indicates the average biomass of an individual tree of a given species

Table 4. Aboveground, belowground and total biomass based on height and DBH.

Species	No. of Individuals	Mean DBH (cm)	Mean Height (m)	AGB (Mg/ha)	BGB (Mg/ha)	Total Biomass (Mg/ha)
Acacia auriculiformis	8	129.54	11.2	127.17	39.11	166.29±142.24
Artocarpus heterophyllus	1	15	6.7	0.10	0.04	0.15
Azadirachta indica	10	45.65	8.6	17.37	1.72	19.09±17.47
Delonix regia	20	86.06	10.0	118.86	19.51	138.37±183.06
Diospyros blancoi	24	52.90	9.04	51.46	0.55	52.01±32.34
Dracontomelon dao	13	58.79	9.24	27.85	9.38	37.22±29.77
Eucalyptus deglupta	4	70.68	9.37	24.84	7.70	32.54±52.35
Kleinhovia hospita	1	52.3	9.11	0.97	0.02	0.99
Leucaena leucocephala	4	53.31	9.05	8.12	0.09	8.22±5.95
Leucosyke capitellata	3	28.77	7.58	1.79	0.89	2.68±3.76
Mangifera indica	3	46.43	8.62	5.20	0.06	5.26±5.86
Morinda citrifolia	39	45.78	8.68	50.20	16.82	67.02±52.13
Nerium oleander	2	28.1	7.63	0.95	0.07	1.02±1.03
Pterocarpus indicus	12	94.98	10.05	130.54	20.98	151.52±252.39
Samanea saman	5	88.64	10.21	24.05	0.61	24.66±19.26
Spathodea campanulata	2	61.5	9.36	2.28	1.91	4.19±4.87
Swietenia macrophylla	72	70.09	9.60	244.49	55.09	299.58±353.85
Terminalia catappa	4	59.08	9.31	8.42	4.07	12.49±8.57
Vitex parviflora	37	52.29	8.89	90.27	13.62	103.89±105.84
Total				**934.95**	**192.25**	**1,127.20**

and allows fair comparison of tree size and growth across species. The highest biomass contributors were *S. macrophylla* (299.58±353.85 Mg/ha), *A. auriculiformis* (166.29±142.24 Mg/ha), *P. indicus* (151.52±252.39 Mg/ha), and *D. regia* (138.37±183.06 Mg/ha). Large standard deviations in these dominant species indicate wide differences in individual tree size, showing that a small number of large trees store a disproportionate share of stand biomass.

Conversely, species such as *A. heterophyllus* (0.15 Mg/ha) and *K. hospita* (0.99 Mg/ha) showed very low or no SD because only one individual was recorded, or individuals were similar in size. Species like *N. oleander* (1.02±1.03 Mg/ha) exhibited low SD values, indicating more uniform tree sizes and carbon stock.

Carbon Stock of Tree Species and CO_2 Mitigation Value of the Forest Park

The total carbon stock indicates the overall contribution of each species to the forest stand, while carbon per tree indicates the carbon stored by an average individual. Tree density ranged from 2 to 144 stems/ha, with *S. macrophylla* recording the highest density and the greatest biomass (299.58 Mg/ha), vegetative carbon (134.81 Mg C/ha), and CO_2 equivalent (494.76 Mg CO_2/ha) (Table 4). Other major biomass contributors were *A. auriculiformis* (166.29 Mg/ha) and *P. indicus* (151.52 Mg/ha), reflecting the influence of large-diameter trees on stand carbon stocks. Moderately abundant species such as *M. citrifolia* and *V. parviflora* also contributed notably to biomass, while low-density species contributed minimally.

The total biomass was 1,127.20 Mg/ha, corresponding to 507.24 Mg C/ha total carbon stock of all species and an overall CO_2 equivalent of 4,095.42 Mg, indicating that carbon storage in the site is concentrated in a few dominant high biomass species and the potential climate mitigation value of the park.

DISCUSSION

The tree community in the AFP is a mixture of native and exotic species, reflecting both historical planting practices and ongoing ecological processes in urban green spaces. The native species recorded include *D. blancoi* (velvet apple), *D. dao* (dao), *E. deglupta* (rainbow eucalyptus), *K. hospita* (guest tree), *L. capitellata* (toothscrubber), *M. citrifolia* (noni), *T. catappa* (tropical almond), *P. indicus* (narra), and *V. parviflora* (molave) (Forest Management Bureau - Department of Environment and Natural Resources, 2022; National Parks Development Committee, 2023). Native trees are vital components of greening efforts to enhance biodiversity and restore forest landscapes (Engay-Gutierrez *et al*., 2023).

In contrast, several exotic invasive species were also identified, including *A. auriculiformis* (earleaf acacia), *A. indica* (neem), *L. leucocephala* (lead tree), *S. campanulata* (African tulip), and *S. macrophylla* (big-leaf mahogany). In terms of invasiveness, the study of Coracero (2023) situated near the periphery of Mt. Banahaw de Nagcarlan in Kanluran Lazaan, emphasizes the invasive potential of *S. macrophylla* due to rapid proliferation. This invasive potential is attributed to its allelopathic potential to prevent the plant growth of other species beneath its canopy (Mukaromah *et al*., 2016; Agoto *et al*., 2024;

Table 5. Carbon stock and potential CO_2 mitigation value.

Species	Tree Density (stems/ha)	Total Biomass (Mg/ha)	Total Vegetative Carbon (Mg C/ha)	CO_2 Mitigation Value (Mg CO_2/ha)
Acacia auriculiformis	16	166.29	74.83	274.63
Artocarpus heterophyllus	2	0.15	0.07	0.24
Azadirachta indica	20	19.09	8.59	31.53
Delonix regia	40	138.37	62.27	228.52
Diospyros blancoi	48	52.01	23.40	85.89
Dracontomelon dao	26	37.22	16.75	61.47
Eucalyptus deglupta	8	32.54	14.64	53.74
Kleinhovia hospita	2	0.99	0.45	1.64
Leucaena leucocephala	8	8.22	3.70	13.58
Leucosyke capitellata	6	2.68	1.21	4.43
Mangifera indica	6	5.26	2.37	8.69
Morinda citrifolia	78	67.02	30.16	110.68
Nerium oleander	4	1.02	0.46	1.68
Pterocarpus indicus	24	151.52	68.18	250.24
Samanea saman	10	24.66	11.10	40.73
Spathodea campanulata	4	4.19	1.89	6.92
Swietenia macrophylla	144	299.58	134.81	494.76
Terminalia catappa	8	12.49	5.62	20.63
Vitex parviflora	74	103.89	46.75	171.57
Total	**528**	**1,127.20**	**507.24**	**1,861.56**
CO_2e (Mg)	**4,095.42**			

Herbito Jr. *et al.*, 2024). Galano and Rodriguez (2021) reported that *S. macrophylla* suppresses the growth rate of native trees. The tree is recognized as an invasive alien species in the Philippines (Coracero *et al.*, 2022). *L. leucocephala* has also an allelopathic property that suppresses the germination and growth of other plants (Herbito Jr. *et al.*, 2024). *A. heterophyllus* (jackfruit) is considered an aggressive invasive species causing native plant biodiversity reduction (Magalhães *et al.*, 2022). Notably, *S. saman* (rain tree) was identified as an exotic, naturalized, potentially invasive species. Exotic but non-invasive species such as *D. regia* (fire tree) and *Nerium oleander* (oleander) were likewise documented (National Parks Development Committee, 2023).

Meanwhile, *M. indica* (mango) was classified as an exotic, naturalized, non-invasive species. It is valued as a garden tree due to its dense spreading canopy that provides shade and shelter for humans and animals (Shah *et al.*, 2010). The dominance of *S. macrophylla,* a member of the Meliaceae family, suggests its successful adaptation or natural proliferation in the study area. This introduced species is commonly used in reforestation (Coracero, 2023). Navarro-Martínez *et al.* (2020) found that high occurrence and higher tree density of the *S. macrophylla* in Mexico both coincide with protected areas promoting sustainable forest management. Their findings support the high individual count of the species in AFP, a protected area of the City of Manila, and are also attributed to management practices and possible widespread planting of the species for responsible forestry practices (Galano and Rodriguez, 2021).

The presence of multiple individuals from the Rubiaceae family indicates their ecological suitability and potential resilience in the local environment (Biag and Alejandro, 2021). In contrast, several species, including *A. heterophyllus* (Moraceae) and *K. hospita* (Byttneriaceae), were represented by only a single individual, reflecting their limited occurrence in urban forest patches such as AFP. This low abundance may result from ecological constraints, competition with invasive species, or management decisions favoring the planting of native or selected non-native trees (Santos Jr., 2019). In other urban parks such as Haikou, non-native plant species were planted to satisfy visual appeal and cultural choices, significantly contributing to tree species diversity in these land-use types (Nizamani *et al.*, 2021). Similarly, AFP management incorporated non-native species such as *S. macrophylla* in their program as reforestation species (Coracero, 2023).

Open spaces provide critical ecosystem services (Department of Human Settlements and Urban Development, 2025) and to maximize the ecological function of the remaining spaces, the management strategy should promote natural regeneration and the planting of native species for the improvement of habitat and biodiversity (Anderson and Minor, 2021). Native trees play a vital role in replanting and revegetation efforts intended at restoring biodiversity and forest landscapes (Engay-Gutierrez *et al.*, 2023). They are naturally robust because they have adapted to local soil and its microorganisms, making them more resilient to damage and less likely to fall over (Tarriela, 2018). The recommended species for planting are *P. indicus* which is considered a promising tree for reforestation activities due to its potential for ecological restoration and resilience against natural disasters (Moncada and Rodrigo, 2019; Engay-Gutierrez *et al*., 2023;). *V. parviflora* is valued for its premium quality, resilient timber, and contributes significantly to ecological balance and is suggested for the phytoremediation of copper-contaminated areas (Goyo *et al*., 2025).

The inclusion of *Intsia bijuga* (ipil) in AFP accentuates the value of incorporating indigenous and endangered tree species into urban green spaces. Its occurrence contributes to improved urban biodiversity and ecosystem services, including air quality improvement and microclimate regulation, while reinforcing in situ conservation of native Philippine flora (National Park Development Committee, 2023; Piñon *et al*., 2024). Planting a vulnerable and native Philippine tree like *Sindora* Merr. (Supa) in urban parks like Arroceros Forest Park is important for conserving its populations, restoring native forest habitats, and enhancing urban biodiversity (Antonio *et al*., 2023).

These findings reflect a combination of native and introduced species influenced by both ecological suitability and planting preferences (Santos Jr., 2019). The observed species composition underscores the importance of integrating ecological and management perspectives in understanding park vegetation dynamics in the area.

Biodiversity indices are vital tools for assessing the structure, complexity, and health of ecosystems. They help determine species richness, evenness, and dominance within ecological communities, offering insight into their resilience and ecological interactions (Magurran, 2004). Species diversity indices are used (Table 2) to determine the diversity in biological samples and communities. This data was collected by quantifying the number of individuals per species in the area. Biodiversity is often characterized by species richness and evenness (Zhao *et al*., 2022).

The biodiversity indices of AFP are comparable with those recorded by Mosyaftiani *et al*. (2022) in Jakarta, Indonesia Urban Forest Parks particularly the Cipayang urban forest with species richness of 19 and Menhinick of 1.9 indicates a moderate level. This suggests that management strategies can be improved to promote more efficient actions that enhance vegetation diversity and contribute to ecosystem stability (Mosyaftiani *et al*., 2022).

The results are also comparable with the findings of Lahoti *et al*. (2020) in urban green spaces in Nagpur City, India with Simpson index of 0.98 indicating high diversity, and evenness of 0.55 showing relatively uneven species distribution. Results of the tree species diversity of AFP using Simpson diversity index are consistent with the findings of Tutor *et al*. (2017) on green spaces in Bacolod City such as Bacolod City Plaza (0.90) and Capitol Lagoon (0.91) but more diverse than Pana-ad Park and Stadium (0.43). In Iloilo City, results are comparable to Jaro Plaza (0.82), Lapaz Plaza (0.83) and Plaza Libertad (0.81). The high Simpson diversity index recorded in AFP indicates that the urban green space supports a relatively even dominance structure among the most abundant tree species despite urbanization pressures. Analogous patterns have been reported in other Asian cities, including Nagpur, India, as well as managed urban plazas in Bacolod and Iloilo Cities, where deliberate planning and protection measures have enabled the persistence of diverse urban tree assemblages (Tutor *et al*., 2018; Lahoti *et al*., 2020).

In contrast, Shannon diversity values were comparatively low, reflecting the greater sensitivity of this index to species richness and the contribution of rare species. This discrepancy is further clarified by species richness indices, with Margalef and Menhinick values indicating medium to moderate richness, suggesting a controlled but stable species pool rather than a depauperate community. Evenness values indicated an uneven distribution of individuals among species, wherein several species are relatively abundant while others occur at low frequencies. Such a structure supports high Simpson diversity while limiting Shannon diversity, a pattern characteristic of managed urban green spaces where planting schemes prioritize a subset of resilient or ornamental species depending on the degree of urbanization (Qi *et al*., 2024). Urbanization reduces the richness of plant species relative to land cover change and promotes the invasion of non-native species. It is essential to establish a model plant species that could withstand and be successful in the face of urbanization (Ruas *et al*., 2022). Another reason is that the park is a part of an artificial ecosystem in an urban environment. The inhouse plants are influenced by planners (Ma *et al*., 2022). Similar diversity relationships have been documented in urban forest studies, while unregulated urban expansion threatens biodiversity, effective urban planning, and management (Huang *et al*., 2025).

The observed species diversity and IVI patterns in Arroceros Forest Park reflect historical planting practices and management priorities, where various tree species were planted based on the general belief that any tree can provide shade, oxygen, and flood control (Santos Jr., 2019). Similarly, as in other managed urban forests, species dominance is driven by human intervention. The *Pinus* species dominate Bumi Praja Anduonohu City Forest due to management decisions (Tuwu *et al*., 2025), while *Swietenia macrophylla* is dominant in AFP as a result of past planting practices.

Species such as *V. parviflora*, *M. citrifolia*, and *D. regia* also contribute substantially to the park's canopy structure and urban biodiversity (Al-Hagla and Al-Sulbi, 2025; Goyo *et al*., 2025). In contrast, species with low IVI values are more vulnerable to ecological stress due to limited abundance, restricted distribution, and reduced regeneration capacity (Arafah *et al*., 2021). The low IVI of *A. heterophyllus*, *K. hospita,* and *S. campanulata* are either sparsely distributed or occur in smaller sizes, which may reflect less emphasis in past planting schemes or lower adaptability to current urban conditions.

Even though *S. macrophylla* has the highest IVI, active management is necessary because this invasive alien plant species can disrupt ecosystem functions and reduce habitat suitability for native species (Galano and Rodriguez, 2021; Coracero, 2023). Urban forest management strategies should prioritize diversification by examining the role and planting of native species like *V. parviflora* and *M. citrifolia* as they play an important role in preserving ecosystem balance (Goyo *et al*., 2025). Among the low IVI, it is suggested to increase the representation of *K. hospita*, a native species. A variety of tree species improves the ecosystem's resilience to climatic pressures, loss of habitat, reduces ecological risks, and promotes long-term urban forest stability and efficiency (Jovanović *et al*., 2025).

In terms of the DBH classification, DBH values ranged from 5 cm to ≥115 cm. A total of 42 trees (15.91%) had DBH between 20–30 cm, while 217 trees (82.20%) exceeded 30 cm DBH, indicating dominance of medium to large diameter individuals. The most frequent DBH class was 35–44 cm with 43 trees (16.29%), followed by 45–54 cm with 38 trees (14.39%). The lowest frequency occurred in the 5–14 cm class (5 trees; 1.89%). This shows a stand dominated by mature trees with fewer small diameter individuals. The observed DBH classes distribution in the study area, with prominent medium-sized individuals and fewer small and very large trees, reflects common structural patterns reported in urban forests, where the frequency of trees typically decreases with increasing DBH class across cities (Morgenroth *et al*., 2020).

The total AGB (934.95 Mg/ha), BGB (192.25 Mg/ha), and total biomass (1,127.20 Mg/ha) observed in this study indicate that biomass is unevenly distributed among species, a characteristic pattern in forest ecosystems. The wide range in species-level biomass from 0.15 Mg/ha in *A. heterophyllus* to 299.58 Mg/ha in *S. macrophylla* contributed disproportionately to total biomass. Similar findings have been reported in tropical and subtropical forests, where few dominant taxa account for most biomass production (Sandoya *et al*., 2021; Ruiz-Blandon *et al*., 2025). In the study of Ralhan *et al*. (2024), larger trees contribute to the total biomass based on DBH class distribution results.

The high standard deviations in dominant species such as *S. macrophylla* (299.58±353.85 Mg/ha), *A. auriculiformis* (166.29±142.24 Mg/ha), *P. indicus* (151.52±252.39 Mg/ha) and *D. regia* (138.37±183.06 Mg/ha) reflect large variation in individual tree size, indicating the presence of a few very large trees. This finding supports the results of Hauck *et al*. (2023) citing that large, old trees consistently contribute disproportionately to forest biomass and carbon. A small fraction of large-diameter trees contributes to most of total biomass due to the nonlinear relationship between diameter and biomass (Lutz *et al*., 2018).

In contrast, species with very low biomass and little or no standard deviation such as *A. heterophyllus* (0.15 Mg/ha), *K. hospita* (0.99 Mg/ha) were represented by only one or few similarly sized individuals. Such rare or minimal sized species contribute little to total biomass, a similar result observed in forest studies (He *et al*., 2025).

This study demonstrates that carbon storage in the AFP is determined by species composition and forest structure, with biomass and carbon stocks concentrated in a small number of dominant species. *S. macrophylla* exhibited the highest carbon stock (134.81 Mg C/ha) and CO_2 equivalent (494.76 Mg CO_2/ha). Other large-statured species, notably *A. auriculiformis* and *P. indicus*, also contributed substantially to stand biomass, confirming the disproportionate role of large-diameter trees in regulating forest carbon stocks.

In the Philippines, public green spaces such as Pana-ad Park and Stadium, Bacolod City, and Lapaz Plaza, Iloilo City stores carbon with 56.12 Mg/ha and 75.77 Mg/ha respectively (Tutor *et al*., 2018). While Tutor *et al*. (2018) and Lasco and Pulhin (2003) used metric tons per hectare, these are equivalent to megagrams per hectare (Mg C/ha). In comparison, AFP exhibits a higher carbon stock of Mg C/ha, 507.24 Mg C/ha. The findings are higher than the grassland in Leyte with 12.1 MgC/ha (Lasco and Pulhin, 2003) and in Bood Promontory and Eco-Park in Butuan City with a mean aboveground carbon stock of 4. 37 Mg/ha using Brown's equation and 1.16 Mg/ha using Chave equation (Jumawan *et al*., 2024). These differences likely reflect variation in forest age, species composition, management intensity, and methodological approaches among studies. In the case of Elig-Effa West, Yaounde City, Cameroon, the low total carbon stock recorded in the overall surface area covered (68.9 ha) was 16.08 MgC/ha (Tchomcheni *et al*., 2023) which is lower than the result of AFP carbon stock

The data indicate that a small number of dominant, large biomass tree species largely drive carbon stock in AFP. The results specify that a reduced number of trees account for the majority of the carbon stored at the study site. *S. macrophylla* has the largest DBH, contributing nearly 30% of the total vegetative carbon, highlighting its role as a dominant carbon reservoir in the area. Ojeda *et al*. (2024) reported that trees with bigger DBH have higher biomass and carbon stock. Similar findings were reported by Macaraig *et al*. (2021) about *S. macrophylla* having the highest biomass and carbon stock in AFP. The relatively high carbon densities observed in *D. regia* and *P. indicus* also reflect their significant biomass and structural maturity (Macaraig *et al*., 2021). As the age of the tree increases, so does the carbon density contribute to the rise in forest carbon stock in forest ecosystems (Huang *et al*., 2024).

The estimated CO_2 equivalent of 1,861.56 Mg/ha derived from the amount of carbon stored in vegetation biomass underscores the substantial carbon stock of urban forest parks. Carbon stored in trees plays a pivotal role in promoting urban sustainability and offsetting anthropogenic emissions (Kim *et al*., 2024). Furthermore, the total CO_2 mitigation value was 4,095.42 Mg. This highlights the ecological importance of urban green space, such as AFP, in storing carbon, conserving biodiversity, and reducing air pollutants (Athokpam *et al*., 2024). These figures not only reflect the capability of urban forests to act as a nature-based solution but also demonstrate their essential contribution to climate change mitigation, overall environmental resilience (Feng *et al*., 2024), reducing degradation of urban ecosystems, maintaining global mean temperatures at 1.5 °C by 2100 and attain the net-zero emission targets by 2050 (Nero *et al*., 2024).

The AFP stored 4,095.42 Mg CO_2e, representing a climate mitigation potential. Based on U.S. EPA greenhouse gas equivalency factors, this is comparable to the annual emissions of about 50 gasoline-powered vehicles or the CO_2 produced from driving approximately 536,000 miles. It is equivalent to the CO_2 emitted from burning approximately 24,000 gallons of gasoline (U.S. Environmental Protection Agency, 2023). AFP prevents carbon from entering the atmosphere surrounding the congested city.

The findings support the premise that strategic urban greening emphasizes the ecological value of conserving and managing existing urban green spaces. Moreover, the selection of species with high biomass and planting of high-density trees aligns with the study by Tutor *et al.* (2018), which emphasized the value of carbon stock assessment as a scientific basis for planning and managing urban green spaces in Iloilo City and Bacolod City. Their research suggests that properly managed urban forest parks serve as important tools in reducing the urban carbon footprint and contribute meaningfully to local and national climate strategies. Sharma *et al.* (2024) supports the idea that approaches such as planned tree planting and regular maintenance can optimize the quality and functionality of green spaces. On the other hand, the maintenance of carbon stored in forests is an ecosystem service that should be rewarded. The use of land for human and other activities loses ecosystem service, resulting in forest disappearance, thus releasing the carbon stock. This will contribute to climate change (Enríquez-de-Salamanca, 2022).

Hence, forest carbon stock estimation is primarily essential to evaluate the extent of carbon transfer between the forests and the atmosphere (Huang *et al*., 2024). Assessing the amount of carbon sequestration in a forest helps estimate the atmospheric carbon emission resulting from deforestation and forest degradation (Adinugroho *et al*., 2019). On the part of the AFP management, they learned their lessons in planting any type of tree while developing the park before, and they saw the effect over time. The Winner Foundation supports the AFP's development through its initiative by offering a 15-year development plan prioritizing the growing of native, especially the endangered tree species. This was also the realization of the management to focus on planting native species in the Philippines because the invasive tree species such as mahogany contributes to soil acidity and affects the growth of other plants (Santos Jr., 2019).

Invasive alien plant species (IAPS) are a major driver of ecosystem degradation, often reducing biodiversity by outcompeting native flora (Meitha *et al*., 2024). With the presence of invasive species in the park, it can be suggested that the use of invasive biomass into value-added products like biosynthesized nanoparticles supports environmentally sound solutions that transform invasive plants into cost-effective resources while mitigating ecological damage (Palengara *et al*., 2025) and bio-based construction to mitigate climate change (Göswein *et al*., 2021).

However, the advantages of ecological restoration and sustainable biomass utilization can be weakened by political and administrative pressures. The case of AFP in Manila highlights this challenge, where redevelopment plans and unauthorized tree removals, coupled with construction and landscaping with exotic plants, threaten the park's ecological integrity. These actions contravene City Ordinance No. 8607, which prohibits tree cutting, excavation, and waste dumping, emphasizing governance gaps and the need for stronger regulatory enforcement (Hestiada Jr., 2021; Ramos, 2021; Ong, 2024). Effective urban forest conservation requires the implementation of land use planning is practiced in Serbia. This can be adopted to save urban forests as one of the most effective tools for protecting green spaces in cities and (Maruna *et al*., 2019). The active community engagement is also vital to safeguard critical green spaces and threats (Bressane *et al*., 2024).

CONCLUSIONS

This study demonstrates that Arroceros Forest Park (AFP) supports a structurally complex and ecologically significant urban forest shaped by historical planting practices, management decisions, and species ecological adaptability. The coexistence of native, naturalized, and introduced species reflects both biodiversity enhancement efforts and past reliance on fast-growing exotics for urban greening. Biodiversity indices indicate moderate species richness and relatively uneven species distribution, with high Simpson diversity but lower Shannon values, revealing a community dominated by a subset of abundant species while maintaining a stable pool of less common taxa. This pattern is characteristic of managed urban forests where human intervention influences species composition and dominance.

Stand structure analysis shows that AFP is dominated by medium to large diameter trees, with more than 80% of individuals exceeding 30 cm DBH. This mature size structure underpins the park's high biomass accumulation and carbon storage capacity. Biomass and carbon stocks were disproportionately concentrated in a few large-statured species, particularly *S. macrophylla*, along with *A. auriculiformis* and *P. indicus,* confirming that a small fraction of large trees governs ecosystem-level carbon dynamics. The *S. macrophylla* serves as a major carbon reservoir due to its size and dominance, its invasive potential emphasizes the essence of considering potential biodiversity implications in long-term urban forest planning.

The estimated total carbon stock and CO_2 equivalent of stored biomass carbon highlight AFP's substantial contribution to climate mitigation capacity within highly urbanized Metro Manila. Comparisons with other Philippine and international urban forests indicate that AFP functions as a valuable carbon reservoir despite its limited area, reinforcing the role of urban green spaces in densely built environments.

The findings provide baseline ecological and carbon stock information for AFP and demonstrate its importance as a biodiversity refuge and carbon storage site within an intensely urbanized landscape. These results offer scientific support for urban forest management strategies that prioritize protection of mature trees to maintain biomass and carbon stocks, while carefully balancing species composition to enhance long-term ecological stability and resilience.

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