Thailand Natural History Museum Journal 18(1):17–40 (2024)

Aboveground biomass estimation and tree vegetation assessment of Bood Promontory and Eco-Park in Butuan City, Philippines after 20 years of establishment

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Article History
Received: 22 February 2023
Accepted: 27 February 2024
Published Online: 15 July 2024
Printed: 31 July 2024

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ABSTRACT

The study was conducted to assess the species diversity, aboveground biomass, and aboveground carbon of forested vegetation in Bood Promontory and Eco-Park, Butuan City, Philippines. Using the quadrat sampling technique, 12 plots (10m X 10m) were established to facilitate the inventory and measurement of trees. The adequacy of the sampling effort was assessed using the Michaelis-Menten equation and depicted by the species accumulation curve. A total of 243 tree individuals from all the sampling plots were identified in the area, with the highest number of individuals being *Artocarpus blancoi* (88), *Swietenia macrophylla* (57), and *Tectona grandis* (47). The abundance of species was recorded in plots 2, 4, 11, and 12, with a 12 plot average abundance of 13.92. At the same time, the Shannon diversity index scored an average of H'=0.8859. The analysis of the importance value index of trees showed that *Tectona grandis* had the highest index with a species importance value of 1.167. Two allometric equations were used to estimate species' aboveground biomass (AGB). The resulting AGB values were utilized to convert into aboveground carbon values. The analysis showed that Brown's equation had the highest value (9.30 t) compared to Chave's equation (2.48 t). The tree species with the highest estimated AGB and AGC are *F. benjamina*, *A. millefora*, *E. deglupta*, *G. alborea*, and *C. nucifera*, respectively. After 20 years of establishment, the Eco-Park showed the potential to significantly contribute to reducing CO_2 gasses in the atmosphere of the urban environment..

Keywords: diversity, urban park, biomass, species importance value.

Citation. Jumawan, J.H., A.J. Sinogbuhan D.D. Atienza and R. Cadavez. 2024. Aboveground biomass estimation and tree vegetation assessment of Bood Promontory and Eco-Park in Butuan City, Philippines after 20 years of establishment. *Thailand Natural History Museum Journal* 18(1): 17-40.

INTRODUCTION

Eco-parks are essential to the city environment and urban residents (Membrebe *et al*., 2017). Exposure to nature could alleviate psychological stress, increase happiness, enhance well-being, and improve a person's health conditions (Bratman *et al*., 2012; Barton *et al*., 2016). Forest urban areas are effective for creating bonds and the well-being of an individual. Urban green landscapes can be significant sources of ecosystem services (ES) that substantially contribute to the sustainability of urban areas and cities in different countries (Paudel and States, 2023). They provide numerous ecosystem services that contribute positively to human health and overall well-being (Zhao *et al*., 2023). Parks and green spaces offer various health benefits by promoting physical activity, connection to nature, and opportunities for social interaction (Larson and Hipp, 2022). This is typified by the establishment of Arroceros Forest Park in Manila City, Philippines, which portrays significant sources of regulating and cultural ES amidst a highly urbanized area (Lagbas, 2019). These urban eco-parks can also facilitate carbon sequestration, attracting considerable interest as a means of ecosystem regulation to counterbalance CO_2 emissions.

Technological advances and rapid urbanization increased atmospheric greenhouse gasses, leading to many ecological problems like global warming (Seto and Shepherd, 2009; Mahmood and Mahdi, 2021). Urbanization has played a vital role in advancing societal progress and development along with increased carbon emissions. As urban areas become more populated, there is a need for carbon sequestration of trees as the exchange of CO_2 over cities is primarily governed by anthropogenic emissions (Kordowski and Kuttler, 2010). In this aspect, enhancing carbon sequestration and decreasing urban carbon emissions have emerged as a critical concern (Wang *et al*., 2023). The function of urban forest vegetation in reducing atmospheric CO_2 content by increasing biomass and carbon storage is appreciated (Fang, 2001). With developing nations undergoing accelerated urbanization, the green spaces occupied by urban trees hold substantial potential to act as crucial sinks through terrestrial carbon sequestration (Vasagadekar *et al*., 2023). In effect, urban trees have the potential to impact the state of the local climate, influence the carbon cycle, reduce greenhouse gas emissions, and contribute to the mitigation of heat island conditions (Woodward *et al*., 2023). Therefore, the role of ecological parks in city landscapes has become more relevant in addressing greenhouse gases and climate change issues.

One essential indicator for quantifying urban Eco-parks' carbon sequestration capacity is aboveground biomass (AGB) estimation (Xiao *et al*., 2022; Agbelade and Onyekwelu, 2020). The AGB of trees is typically favored as underground biomass is usually challenging to obtain (Lin *et al*., 2022). These ground-based AGB estimations of trees are primarily based on sampling plots, inventory, and application of allometric equations derived from tree measurements such as diameter at breast height (DBH), wood density, height, and crown area (Chave *et al*., 2005). It is commonly employed and considered as direct measurement to achieve high levels of accuracy that can be applied in urban eco-parks (Lin *et al*., 2022; Clerici *et al.*, 2016). It was estimated that about 97.3% of trees in Leicester, England, contribute to the total AGB production in the urban landscape compared to other vegetation (Davies *et al*., 2011). On the other hand, studies on urban AGB estimations in the Philippines are considerably few. Some studies on AGB estimation in Philippine urban eco-parks can be found in the published works of Macaraig *et al*. (2021) (Arroceros Forest Park, Manila); Dida and Tiburan (2020) (Forest Reserve of University of the Philippines Los Banos campus); Alimbon and Manseguiao (2021) (Panabo Mangrove Park); Salvaña *et al*. (2019) (Mount Apo Natural Park, Davao City); and Raga-as *et al*. (2022) (Bakhawan Eco-Park, Aklan). These studies employed ground-based estimations and used GIS and remote sensing techniques. Thereby, research on estimating AGB in urban forests and parks of Butuan City, Philippines, is relevant to climate mitigation issues.

The study's main objective is to estimate aboveground biomass and aboveground carbon in urban forests and parks of Butuan City in the Philippines. The 10-hectare agroforestry land of Bood Promontory and Eco-Park in Barangay Pinamanculan, Butuan City, Philippines, is thriving as an ecological park and historical landmark. The eco-park is situated at a bend in the Masao River, where various plant species provide a good and refreshing ambiance to the park (Estrella, 2016). Previous tree planting and flora rehabilitation resulted in vegetation dominated by critically endangered trees such as the Philippine Teak Tree (*Tectona grandis*). More studies are needed on the area's diversity of trees and aboveground biomass and carbon assessment. This study will estimate the above-ground biomass and aboveground carbon of trees planted in the Eco-Park. Specifically, it aims to conduct an inventory of tree species diversity, along with the tree characteristics, above-ground biomass, and aboveground carbon of each tree species in Bood Promontory and Eco-Park after twenty years of its establishment. This study can provide information to help the Local Government Unit and the local folks implement strategies for maximizing the urban vegetation and its ecological functions.

MATERIALS AND METHODS

The Study Area

The Bood Promontory Eco Park is a commemorative site of the Spanish arrival on Mindanao island, turned into an eco-tourism area. Currently, it is a non-protected 10-hectare agroforestry land located at Brgy. Pinamanculan, Butuan City and geographically projected using the Global Positioning System (Lat 8.952725˚N and Long 125.493034˚E). The eco-park is situated at a bend in the Masao River (Fig. 1).

The area was previously open field grassland, a remnant of once forested lands. The open areas of the eco-park were planted and rehabilitated with endemic tree species in the Philippines. After 20 years, it resulted in secondary forest succession with the mosaic growth of planted and naturally grown vegetation. This makes the sampling area suitable for estimating an eco-park's tree biomass and carbon storage.

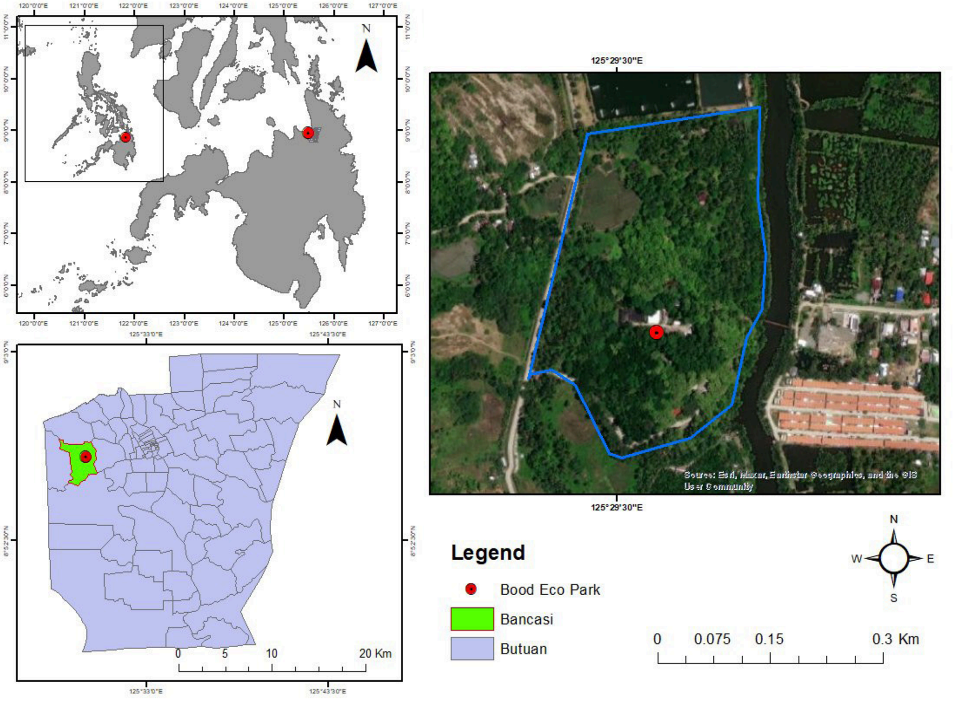

Figure 1. Bood promontory and eco-park in Pinamanculan, Butuan City, Philippines.

Field Sampling, Data Inventory, and Identification of Species

Purposive sampling was conducted in the sampling area with 12 quadrats measuring 10m x 10m plots (Natividad *et al*., 2015). Sampling plots were established in areas with ideal mosaic growth of planted and natural-growth trees. Trees inside each plot were tagged and identified in situ with the assistance of the Department of Environment and Natural Resources (DENR), resident caretaker of the eco-park. Online sources for species identification, like Co's Digital Flora of the Philippines (CDFP), were utilized. The conservation status of species was noted using the IUCN Red List and the Philippine Red List (DAO 2017-11).

Species accumulation curve and biodiversity indices

The species accumulation curve (SAC) was applied to evaluate the adequacy of the sampling effort. The accumulation curve is generated using the number of samples and the species count. Species count estimator using the Michaelis Menten (MM) equation is plotted together with observed species (Sobs), and an asymptotic curve indicates adequacy of sampling intensity (Clarke and Gorley 2006; Jumawan *et al*., 2015).

Similarly, the values for diversity indices were extracted from the species counts in the accumulated plots. The study includes six diversity metrics: Shannon diversity, Simpson diversity, evenness, dominance, and species richness. Using the Fernando *et al*. (1998) diversity scale, the Shannon diversity was interpreted as follows: Very High 3.5 and above, High 3.0 – 3.49, Moderate 2.5 – 2.99, Low 2.0 – 2.49, Very Low 1.9 and below. The PAST software version 4.10 was used to compute diversity indices (Hammer *et al*., 2001) and Microsoft Excel to generate the SAC.

Determining the species' importance value (SIV)

The Species Importance Values (SIV) depict the status of species in plant communities and were calculated by summation of the relative values of abundance, frequency, and dominance (Mullet *et al*., 2014). The following formulas were utilized, leading to the computation of SIV:

Species Importance Value (SIV): $SIV=RPD+RF+RD$

Population Density: $$Population\ Density = \frac{Number\ of\ Individuals}{Total\ area\ sampled}$$

Relative Population Density: $$Relative\ Population\ Density = \frac{Density\ of\ species}{Total\ density\ for\ all\ species}$$

Frequency: $$Frequency = \frac{Number\ of\ plots\ in\ which\ the\ species\ occurs}{Total\ number\ of\ plots\ sampled}$$

Relative Frequency: $$Relative\ Frequency = \frac{Frequency\ Value\ for\ a\ species}{Total\ of\ frequency\ value\ for\ all\ species}$$

Dominance: $$Dominance = \frac{Total\ of\ basal\ area\ of\ each\ tree\ of\ a\ species\ from\ all\ plots}{Total\ area\ of\ all\ the\ measured\ plots}$$

Relative Dominance: $$Relative\ Dominance = \frac{Dominance\ for\ a\ species}{Total\ dominance\ for\ all\ species} x100\%$$

Where: RPD = Relative Population Density; RF= Relative Frequency; and RD = Relative Dominance.

Measurement of Tree Characteristics

Three tree characteristics were used in the study: diameter at breast height (DBH), tree height, and crown spread. The DBH is the standard method of expressing the diameter of the trunk of a tree. Its measurement is applied to estimate tree volume, biomass, and carbon storage. Inside each plot, a complete inventory of all trees with a diameter at breast height (DBH) of at least four centimeters inside the quadrat was done (Mueller-Dumbois and Ellenburg 1974); the circumference of each tree was measured using a measuring tape, 4.5 feet up the trunk of the tree from the ground. The circumference was then converted to diameter by dividing the circumference by pi (3.14).

$$DBH=Circumference/3.14$$

Tree height was measured in centimeters using improvised tree poles and a height-measuring Smartphone application (Measure Height version 1.4 by Deskis OÜ. 2014). The tree poles and Measure Height Smartphone application were initially compared and calibrated until they reflected similar values. Tree poles were used mainly for the regular height of trees. A few very tall trees required a Measure Height software application, which uses trigonometric equations that estimate the distance between a tree and its height. The Measure Height Smartphone App was suggested at 20m distance from the tree for accuracy (Bijak and Sarzynski, 2015). To find the tree's average crown spread (CS), the left and right points of the crown were measured (in cm). Both values were added together and divided by two to calculate the average crown spread.

Computation of Aboveground Biomass

The AGB of trees is the most obvious of all the carbon pools, and it's a significant indicator of impacts on eco-park rehabilitation about carbon mitigating issues. The AGB of each tree was quantified using an allometric equation recommended by Brown *et al*. (1989) and Chave *et al*. (2005). The allometric equations were determined as follows:

$$ABG = exp(-2.134 + 2.53\ In(D))$$ (Brown *et al.*, 1989)

$$ABG = exp(-2.187 + 0.916 * In(pD\ 2H))$$ (Chave *et al.*, 2005)

Where:

ABG : Aboveground Biomass (kg)

p : Wood Density (cm)

D : Diameter at Breast Height (stem diameter over bark at 1.30 m above ground (cm)

H : Tree Height (m)

Computation of Aboverground Carbon

The aboveground carbon content of trees was estimated to be around 50% of the determined dry biomass weight (Henry *et al*., 2011; Saatchi *et al*., 2011), and the resulting values are expressed in tons per hectare (1 ton = 1000 kg, 1 ha = 10,000 m^2) (Sintayehu *et al*., 2020). In this study, the aboveground carbon is estimated based on the suggested coefficient of 0.47, which converts mean biomass density to mean carbon density for a defined ecosystem (Chabi *et al*., 2019). Further, the aboveground carbon was determined using the formula suggested by Chayaporn *et al*. (2021) and IPCC (2006).

Aboveground Carbon = *AGB**0.47 (Chayaporn *et al*., 2021 and IPCC, 2006)

Where: AGC is the Aboveground Carbon in (kgC tree-1) and the AGB is the Aboveground Biomass

RESULTS AND DISCUSSION

Tree Species Composition in Bood-Promontory and Eco-park

The present species composition in Bood-Promontory and Eco-park provides an updated inventory of mosaics consisting of planted and naturally grown tree species in the area. A total of 243 tree individuals from all the sampling plots were determined across the sampling site. There are 19 tree species identified belonging to 11 families. These are *Cassia fistula* (Linn.), *Samanea saman* (Jacq.) Merr., *Gmelina arborea* (Roxb.) ex Sm., *Swietenia macrophylla* (King), *Ficus septica* (Burm.f.), *Terminalia catappa* (Linn), *Macaranga tanarius* (Linn.), *Artocarpus blancoi* (Elmer) Merr., *Pterocarpus indicus* (Willd), *Dracontomelon dao* (Blanco) Merr. & Rolfe, *Eucalyptus deglupta* (Blume), *Shorea contorta* (S.Vidal) Merr. & Rolfe, *Ficus benjamina* (Linn.), *Intsia bijuga* (Colebr.) Kuntze, *Melia dubia* (Cav), *Antidesma bunius* (L.) Spreng., *Casuarina equisetifolia* (Linn.), *Shorea polysperma* (Blanco) Merr., *Cocos nucifera* (Linn.), *Tectona grandis* (L.f), and four unidentified tree species. Tree individuals were identified as least concerned at 49.64%, vulnerable trees at 23.41%, endangered at 20%, near threatened at 0.41%, and not assessed at 5.82%. Most of the identified species in the study site are listed in the National List of Threatened Philippine Plants and their Categories (see DENR Administrative Nos. 2007-01 and 2017-11). The species composition is summarized in Table 1.

Species Accumulation Curve and Biodiversity Indices in Bood Promontory and Eco-Park

The species accumulation curve (SAC) that is shown (in Fig. 2) takes into account species richness estimators using Michaelis Menten (MM) about the percentage of each species quadrat (Corley and Clarke, 2006). The SAC indicated adequacy of sampling effort as depicted in the curved line approaching the asymptote. The total of 12 quadrats is enough to cover the expected number of species in the sampling area. The species accumulation curve displayed an asymptotic line, suggesting sufficient sampling effort (Jumawan *et al*., 2015).

Species richness measures the abundance of species composition in a given area. Bood

Table 1. Tree Species found in Bood Promontory and Eco-Park, Butuan City

Family	Species	Conservation Status	Total # Individual Species
Arecaceae	*Cocos nucifera*	Not assessed	12
Casuarinaceae	*Casuarina equisetifolia*	Least Concern	1
Combretaceae	*Terminalia catappa.*	Least Concern	2
Dipterocarpaceae	*Shorea contorta*	Least Concern	12
Dipterocarpaceae	*Shorea polysperma*	Least Concern	2
Euphorbiaceae	*Macaranga tanarius*	Least Concern	1
Fabaceae	*Cassia fistula*	Least Concern	3
Fabaceae	*Samanea saman*	Not assessed	1
Fabaceae	*Pterocarpus indicus*	Endangered	2
Fabaceae	*Intsia bijuga*	Near Threatened	1
Lamiaceae	*Gmelina arborea*	Least Concern	5
Lamiaceae	*Tectona grandis*	Endangered	47
Meliaceae	*Swietenia macrophylla*	Vulnerable	57
Meliaceae	*Melia dubia*	Not assessed	1
Moraceae	*Ficus septica*	Least Concern	5
Moraceae	*Artocarpus blancoi*	Least Concern	88
Moraceae	*Ficus benjamina*	Least Concern	1
Myrtaceae	*Eucalyptus deglupta*	Vulnerable	1
Phyllanthaceae	*Antidesma bunius*	Least Concern	1

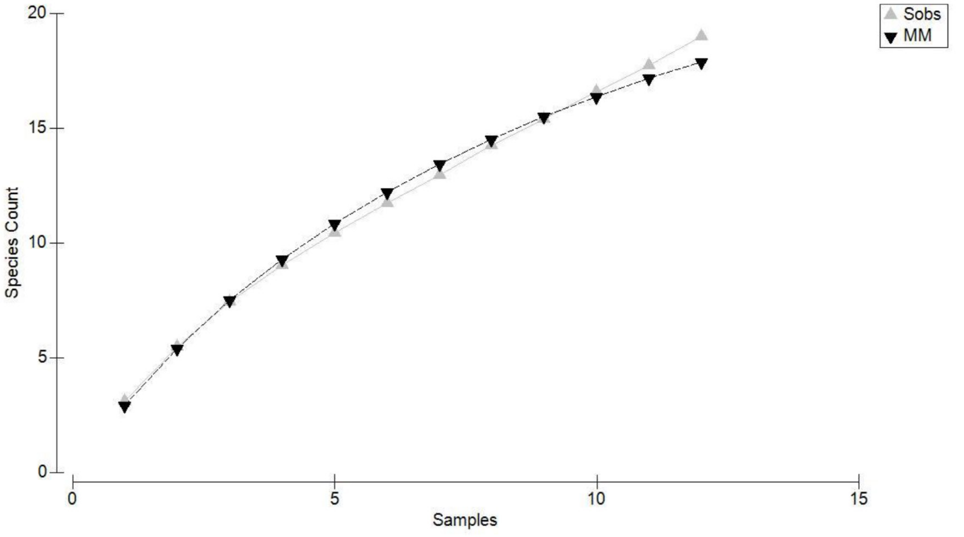

Figure 2. The asymptotic curve of the species accumulation plot with Michaelis Menten (MM) species richness estimator indicated the adequacy of the sampling effort.

Promontory and Eco Park projected a value of 3.17 per plot, which is moderate in species richness. This may be attributed to the hand-in-hand conservation measures done by the Department of Environment and Natural Resources (DENR) and the Department of Tourism (DOT) in the area. Senbeta's (2006) study mentioned that patterns of plant species diversity are used to be noted for ranking conservation activities because they show the underlying ecological processes important for management and conservation. Sampling plots 2, 4, 11, and 12 had at least 21 individuals per quadrat, indicating a highly dense abundance. Shannon's diversity index scored an average of H' = 1.0091, indicating a shallow diversity index based on the scale of Fernando *et al*. (1998). The anthropogenic activities in the area may bring potential factors affecting the low diversity index in eco-parks, for it also plays as a recreational area for the community. According to the study of Ghosh *et al*. (2021), eco-parks are typically established around the world to serve both recreational and conservation reasons for local biodiversity with minimum maintenance. In terms of species evenness, the entire area surveyed accounted for an average evenness value of 1, depicting even distribution in the area with an even number of individuals per plot. At the same time, some eco-park studies found that the amount of biomass produced by communities indicates that specific adaptive/survival strategies contribute disproportionately to ecological processes, as species evenness (relative abundance) is reflected in biomass output (Cerabolini *et al*., 2010).

Species Importance Value

Species importance value (SIV) measures an area's influential species. Species with a higher species importance index indicate higher relative population density, frequency, and dominance values than other species (Zafriakma, 2020). The species with the three highest relative population densities (RPD) are *T. grandis* (RPD = 0.2934), *A. blancoi*

Table 2. Biodiversity indices of tree plant species in Bood Promontory and Eco- Park, Butuan City.

Biodiversity indices	**Value**
Species richness	3.166667
Abundance	13.91667
Dominance	0.52525
Simpson diversity	0.47475
Shannon diversity	0.885867
Evenness	0.90375

(RPD = 0.2754), and *S. macrophylla* (RP D= 0.1677). The species with the highest relative frequencies (RF) are *T. grandis* and *A. blancoi* with RF = 0.1579, respectively, followed by *C. nucifera* (RF =0.1316). The species with the highest relative dominance (RD) are *T. grandis* (RD = 0.7156), *C. nucifera* (RD = 0.1163), and *A. blancoi* (RD = 0.0788). Collectively, the species with the highest SIV are *T. grandis* (SIV = 1.1669), *A. blancoi* (SIV = 0.5122) and *C. nucifera* (SIV = 0.3198). According to the study by Dash *et al*. (2009), he stated that the highest importance value in the study area exerts influence and represents absolute dominance in the tree layering structure. Moreover, species with low importance may be attributed to factors such as poor distribution in the study area or the competition between those species and other species from different families. The species with the lowest SIV are *C. equisetifolia* (SIV = 0.0324) and *I. bijuga* (SIV = 0.0325), respectively. The SIV computation presents a standard tool biologists use to inventory a forest. Table 3 summarizes the computed SIV values of tree species in Bood Promontory and Eco-Park, Pinamanculan, Butuan City.

Tree Characteristics

The diameter at breast height (DBH), tree height (TH), and crown cover (CC) were measured to determine the biomass of each distinct species. The tree's diameter, neighborhood-related variables, and climatic factors, including mean annual precipitation and elevation, slope, aspect, and tree competition, all impact the diameter at breast height (DBH) and tree height of trees. The diameter at breast height (DBH) was the most significant factor influencing tree height (Nie and Liu, 2023). Cheng *et al*. (2022) identified other potential factors that positively affect tree height, such as annual precipitation, number of neighbors, DBH dominance, and mean diameter of neighbors. Tree height (TH) is one of the most crucial tree characteristics in a forest inventory, along with diameter at breast height (DBH) (Wang *et al*., 2019). Estimating the vegetation's crown or foliar cover helps characterize plant communities or biomass (Winterberger and Larson, 1988). The mean values of tree characteristics are shown in Table 4. The mean DBH value of each species ranges from 3.31 cm to 53.50 cm. These values were comparable to the study of Fazilah *et al*. (2013), wherein most of the trees they assessed have the DBH range from 3.62cm to 59cm and the largest tree up to 2,453 cm.

The species with the highest DBH mean values are *F. benjamina* (53.50 cm), *A. mellifora* (50.00 cm), and *E. deglupta* (44.90 cm). According to Mulyani *et al*. (2021), the *F. benjamina* tree usually ranges from 19.1 cm to 255 cm, which showed the highest dbh in the area. The TH values of tree species range from 11.40 m to 58.00 m. The species with the highest TH mean values are *E. deglupta* (58.00 m), *A. mellifora* (32.40 m) and *C. nucifera* (30.38 m). The mature *E.deglupta* species usually ranges from 60 to 75 m (Orwa *et al*.,

Table 3. Computed Species Importance value indices and the corresponding rank of tree species in Bood Promontory and Eco- Park Butuan City, Philippines

Scientific Name	Relative Population Density	Relative Frequency	Relative Dominance	Species Importance Value	Rank
Tectona grandis	0.293413	0.157895	0.715631	1.166939	1
Artocarpus blancoi	0.275449	0.157895	0.078836	0.512179	2
Cocos nucifera	0.071856	0.131579	0.116339	0.319774	3
Swietenia macrophylla	0.167665	0.105263	0.032953	0.305881	4
Shorea polysperma	0.071856	0.078947	0.023199	0.174003	5
Gmelina arborea	0.02994	0.026316	0.023474	0.079729	6
Shorea contorta	0.011976	0.026316	0.000254	0.038546	7
Casuarina equisetifolia	0.005988	0.026316	0.000106	0.03241	8
Ficus benjamina	0.005988	0.026316	0.003117	0.035421	9
Samanea saman	0.0059	0.026316	0.002723	0.035026	10
Eucalyptus deglupta	0.005988	0.026316	0.002196	0.0345	11
Antidesma bunius	0.005988	0.026316	0.000372	0.032675	12
Melia dubia Cav	0.005988	0.026316	0.000322	0.032626	13
Intsia bijuga	0.005988	0.026316	0.000168	0.032472	14
Cassia fistula	0.005988	0.026316	0.000106	0.03241	15
Melochia umbelatta	0.005988	0.026316	3.58E-05	0.03234	16
Pterocarpus indicus	0.005988	0.026316	1.87E-05	0.032322	17
Ficus septica	0.005988	0.026316	1.19E-05	0.032316	18
Macaranga tanarius	0.005988	0.026316	2.88E-10	0.032304	19

2009), as this species can reach one of the tallest heights in an area. The CC values of tree species range from 21.50 cm to 1170 cm. The species with the highest average CC values are *A. mellifora* (1170 cm), *E. deglupta* (170 cm), and *T. grandis* (156.46 cm). The rounded or flat, spreading nature of the *A. mellifora* crown cover accounts for its larger size (Pasiecznik 2020). According to a different study, individual tree crowns to total aboveground biomass varied from 3% to 88% (Heiskanen *et al*., 2015). The typical crown cover on tropical trees in Asia varies by location and is also observed in the sampling area.

Estimated Aboveground Biomass and Aboveground Carbon

The AGB is simply described as the aboveground standing dry mass of live or dead matter from tree or shrub life forms, expressed as a mass per unit area (Wilkes *et al*., 2018) and typically expressed kg (kilogram), and Mg (megagram or metric tonne) (Duncanson *et al.,* 2021). A tree's AGB is most of the accounted carbon pool (Vashum and Jayakumar, 2012). Table 5 summarizes the computed AGB using two different allometric equations

Table 4. The mean value of tree metrics is indicated by the diameter at breast height (DBH), total height (TH), and Crown Cover (CC).

Scientific Name	Mean DBH (cm)	Mean TH (m)	Mean CC (cm)
Acacia millefora	50.00	32.40	1170.00
Antidesma bunius	18.47	18.20	55.00
Artocarpus blancoi	14.75	25.86	78.29
Cassia fistula	7.48	17.05	62.50
Casuarina equisetifolia	9.87	17.40	21.50
Cocos nucifera	27.24	30.38	84.67
Eucalyptus deglupta	44.90	58.00	170.00
Ficus benjamina Linn	53.50	28.90	140.00
Ficus septica	3.31	13.00	77.50
Gmelina alborea	29.36	25.80	109.50
Intsia bijuga	12.42	19.80	57.50
Macaranga tanarius	15.61	17.00	135.00
Melia dubia Cav	17.20	22.00	137.50
Melochia umbelatta	5.73	20.80	25.50
Pterocarpus indicus	4.14	11.40	90.00
Shorea contorta	14.60	19.05	51.65
Shorea polysperma	7.64	16.70	52.75
Swietenia macrophylla	20.50	28.05	99.69
Tectona grandis	23.16	25.34	156.46

from Brown *et al.* (1989) and Chave *et al.* (2005). Several studies in the Philippines on biomass estimation used Brown, 1989 and Chave *et al*., 2005 equations (Salvaña *et al*., 2019; Dida and Tibura,n 2020; Lasco *et al*., 2004; Pansit, 2019; Faris Nik Effendi *et al*., 2021). The total estimated AGB in Bood Promontory and Eco-Park using Brown's formula was 9.31 tonnes, while the estimated biomass using Chave's formula was 2.48 tonnes. Based on the considered allometric equations, the Brown's equation generated high AGB values compared to Chave *et al*. (2005).

Figure 3 shows the estimated AGB of species found in Bood Promontory and Eco-Park. The species with the highest estimated AGB are *F. benjamina*, *A. millefora*, *E. deglupta*, *G. alborea*, and *C. nucifera*, respectively. As stated by Lasco *et al*. (2006), the bigger the biomass, the bigger the tree biomass density. Compared to species with low biomass, Origenes and Lapitan (2021) reported that trees with small sizes have a relatively low biomass density. According to Guiabao (2010) and Faris Nik Effendi *et al*. (2021), while the diameter of trees increases, the AGB also increases respectively. A similar study was conducted by De Guzman *et al*. (2021), wherein the highest AGB had the highest DBH values. Variations

Table 5. Aboveground biomass mean value of tree species in Bood promontory and Eco-Park Butuan City using allometric equations of Brown *et al.* (1989) and Chave *et al.* (2005).

Scientific Name	Brown *et al.*, 1989	Chave *et al.*, 2003
Acasia millefora	2.161868955	0.264897572
Antidesma bunios	0.174050818	0.039101140
Artocarpus blancoi	0.191257482	1.494307090
Cassia fistula	0.034405956	0.019434738
Casuarina equisetifolia	0.035673714	0.021119227
Cocos nucifera	0.600861422	0.067015206
Eucalyptus deglupta	1.647128946	0.148401410
Ficus benjamina Linn	2.565876370	0.125704541
Ficus septica	0.002250596	0.001326630
Gmelina alborea	0.656165769	0.083629230
Intsia bijuga	0.063767105	0.028829512
Macaranga tanarius	0.000000003	0.000000154
Melia dubia Cav	0.145264488	0.027417320
Melochia umbelatta	0.009016597	0.002397083
Pterocarpus indicus	0.003958038	0.002599462
Shorea contorta	0.131281620	0.026135651
Shorea polysperma	0.018669715	0.008673529
Swietenia macrophylla	0.385386157	0.038049721
Tectona grandis	0.481032155	0.077501936
Total	9.307915907	2.476541152

in the biomass of tree species may occur due to differences in stand density, tree age, site characteristics, and management (Rahman *et al*. 2021). The findings show that the more mature trees are, the greater their capacity to store carbon in the live biomass.

Aboveground Carbon (AGC) is the sum of carbon stored in stem, branch, bark, and foliage biomass (Mildrexler *et al*., 2020). Table 6 presents the summary of the computed AGC derived from using Brown *et al.* (1989) and Chave *et al*. (2005) AGB values. The estimated AGC derived from Brown's AGB equation was 4.37 tonnes/ha, while the estimated carbon using Chave's AGB equation was 1.16 tonnes/ha. Figure 4 shows AGC, depicted by using the Brown AGB equation, as it generates high carbon values. The Brown's allometric equation has also been adopted by several studies conducted in Southeast Asia (Lumbres *et al*. 2023; Dida andTiburan, 2020; Orella *et al*., 2022; Racelis *et al*., 2019; Labata *et al*., 2012).

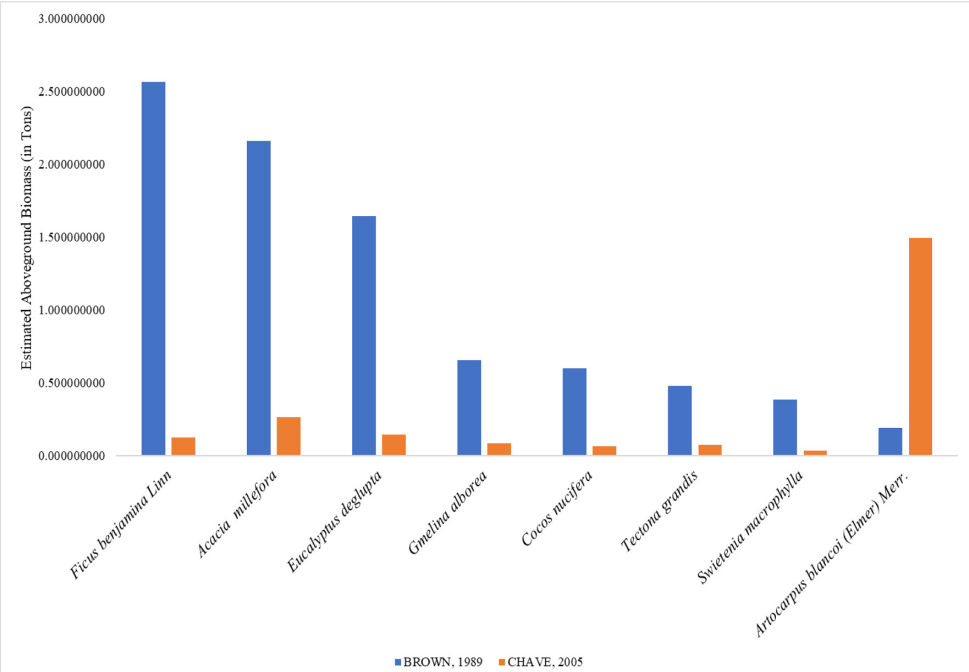

Figure 3. Comparison of Brown *et al.* (1989) and Chave *et al.* (2005) allometric equations in eight species with highest estimated aboveground biomass found in Bood Promontory and Eco-Park.

Species with the high AGC values are *F. benjamina* (29%), *A. millefora* (25%), *E. deglupta* (19%), and *G. alborea* (8%), respectively. These species are characterized as the matured tree individuals showing high dbh values. Large-diameter trees are a crucial factor in the carbon cycle dynamics in forests worldwide and store disproportionately large amounts of carbon (Mildrexler *et al*., 2020). According to the study by Racelis *et al*. (2019), large trees (dbh ≥ 60 cm) and biomass greater than 4 tonnes can store large amounts of carbon.

The computed AGB and AGC results indicated comparable values with respect to studies conducted in the Philippines. This study covered an area of 10 hectares generated an AGB value of 9.31 tonnes and AGC value of 4.37 tonnes/ha derived from Brown's equation. A similar study in Arroceros Forest Park with an area of 2.2 hectares sequesters AGC value of 5.04t tonnes/ha using Brown’s equation (Macaraig *et al*., 2021). The estimated 30 hectares nature park inside the University of San Carlos – Talamban Campus showed AGB value of 53.26 tonnes and AGC value of 36.21 tonnes/ha consisting of planted *Vitex parviflora* trees estimated using Chave equation (Parilla *et al*., 2018). The 73-hectare Panabo Mangrove Park has AGB value of 77.45 tonnes and AGC value of 37.18 tonnes/ha estimated using Komiyama equation (Alimbon and Manseguiao, 2021). Within 32 years of mangrove establishment in 250 hectares of Bakhawan Eco-Park showed AGB value of 132 tonnes and

AGC value of 66.02 tonnes/ha estimated using Zanne equation (Raga-as *et al.*, 2022). The variability of AGB and AGC values can be attributed to location, species composition, size of the area, and the equation used in the study.

Most of the trees planted in the Eco-Park were found to have a small DBH range from 0.012 cm-50 cm, attributed to new growth after 20 years from the establishment. Furthermore, the result implied the potential for carbon storage in the Eco-Park due to the many emerging small trees. The city and the local government units (LGU) that manage the area can easily design and implement strategies to maximize a particular forest's desired ecological function to protect and enhance its value (Millward and Sabir, 2011). The results of the present study on AGB and AGC will help conserve these reserved forests under sustainable management

Table 6. Mean values of aboveground carbon of tree species in Bood promontory and Eco-Park Butuan City.

Scientific Name	**Brown *et al.*, 1989**	**Chave *et al.*, 2003**
Acasia millefora	1.016078409	0.124501859
Antidesma bunios	0.081803884	0.018377536
Artocarpus blancoi (Elmer) Merr.	0.089891017	0.702324332
Cassia fistula	0.016170799	0.009134327
Casuarina equisetifolia	0.016766646	0.009926037
Cocos nucifera	0.282404868	0.031497147
Eucalyptus deglupta	0.774150605	0.069748663
Ficus benjamina Linn	1.205961894	0.059081134
Ficus septica	0.001057780	0.000623516
Gmelina alborea	0.308397912	0.039305738
Intsia bijuga	0.029970539	0.013549871
Macaranga tanarius (Linn.)	0.000000002	0.000000072
Melia dubia Cav	0.068274309	0.012886140
Melochia umbelatta Wall	0.004237801	0.001126629
Pterocarpus indicus	0.001860278	0.001221747
Shorea contorta	0.061702361	0.012283756
Shorea polysperma	0.008774766	0.004076559
Swietenia macrophylla	0.181131494	0.017883369
Tectona grandis	0.226085113	0.036425910
Total	4.374720476	1.163974342

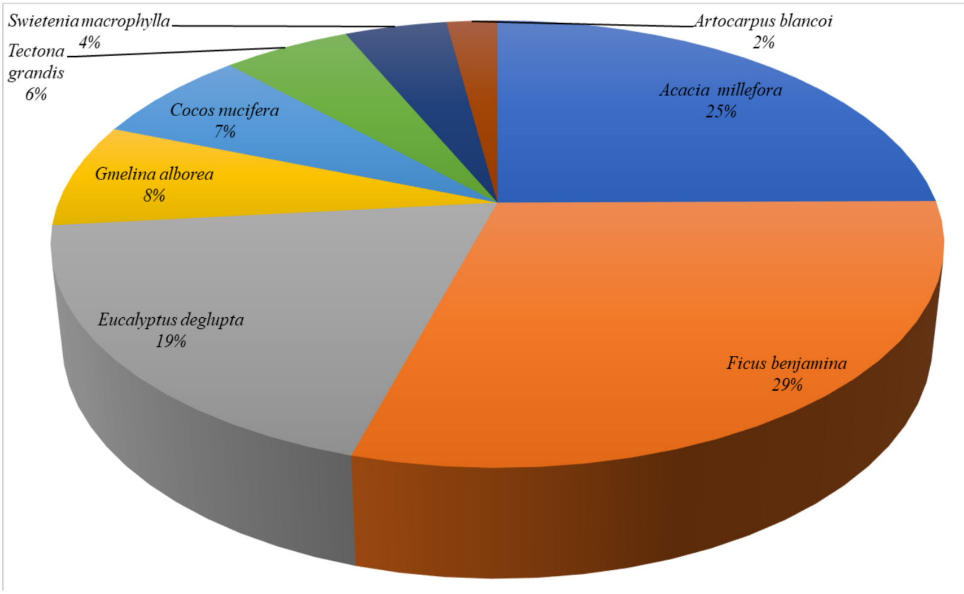

Figure 4. Eight species have the highest aboveground carbon values using Brown's (1989) equation.

CONCLUSION AND RECOMMENDATION

The result demonstrates that there were 243 tree individuals from all the sampling plots in Bood promontory and Eco-Park. Its species richness projected the highest richness value of 3.17. The most abundant species were documented in plots 2, 4, 11, and 12, with a 12-plot average in abundance of 13.92. Out of 19 species identified, there were nine whose conservation status is least concerned. In comparison, three tree species are vulnerable, one species of tree is near threatened, four tree species are critically endangered, and four species of trees were not assessed. Moreover, the Shannon diversity index with an average of H' = 1.0091 indicates a very low diversity, and its evenness portrays an even distribution in the area. On the other hand, the species with the highest importance value was *T. grandis*, and the lowest importance value was *C. equisetifolia*.

Our data concerning the AGB and AGC capability of the trees in Bood Promontory and Eco-Park can significantly contribute to reducing atmospheric carbon gasses in urban environments. The data supports the importance of an ecological park twenty years after its establishment. It can also be utilized to improve the management of the LGU, implement strategies to maximize the urban vegetation environmental function and inform modification of management practices to more fully realize the benefits of the services that treed urban parks can provide. These findings may also be relevant in international discussions related to the increasing atmospheric CO_2 concentration and its implications within the context of predicted future global change (Idso *et al*., 2001). Thus, planting more trees in urban areas is highly suggested to reduce carbon concentration in the atmosphere.

ACKNOWLEDGEMENTS

The researchers are beyond grateful to the City Tourism Butuan City and the Department of Environment and Natural Resources- Pinamanculan Site for approving the study on the site and its staff for the assistance of tagging and initial identification of species.

REFERENCES

Agbelade, A.D. and J.C. Onyekwelu. 2020. Tree Species Diversity, Volume Yield, Biomass and Carbon Sequestration in Urban Forests in Two Nigerian Cities. *Urban Ecosystem*, (23): 957–970. https://doi.org/10.1007/s11252-020-00994-4.

Alimbon, J.A. and M.R.S. Manseguiao. 2021. Species Composition, Stand Characteristics, Aboveground Biomass, and Carbon Stock of Mangroves in Panabo Mangrove Park, Philippines. *Biodiversitas* 22(6): 3130–3137. https://doi.org/10.13057/biodiv/d220615.

Barton, J. and M. Rogerson. 2017. The Importance of Green Space for Mental Health. *BJ-Psych International* 14(4): 79–81. https://doi:10.1192/s2056474000002051.

Bijak, S. and J. Sarzyński. 2015. Accuracy of smartphone applications in the field measurements of tree height. *Folia Forestalia Polonica* 57(4): 240–244. https://doi.org/10.1515/ffp-2015-0025.

Bohlman, S.A. 2015. Species Diversity of Canopy Versus Understory Trees in a Neotropical Forest: Implications for Forest Structure, *Function and Monitoring. Ecosystems* 18(4): 658–670. https://doi.org/10.1007/s10021-015-9854-0.

Bratman, G.N., H.A. Olvera-Alvarez and J.J. Gross. 2012. The Effective Benefits of Nature Exposure. *Social and Personality Psychology Compass* 15(8). https://doi.org/10.1111/spc3.12630.

Brown, S., A. Gillespie and A.E. Lugo. 1989. Biomass Estimation Methods for Tropical Forests with Applications to Forest Inventory Data. *Forest Science* 35(4): 881–902. https://doi.org/10.1093/forestscience/35.4.881.

Cerabolini, B., S. Pierce, A. Luzzaro and A. Ossola. 2010. Species Evenness Affects Ecosystem Processes in situ via Diversity in the Adaptive Strategies of Dominant Species. *Plant Ecology* 207: 333–345. https://doi.org/10.1007/s11258-009-9677-1.

Chabi A., S. Lautenbach, J.E. Tondoh, V.O.A. Orekan, S. Adu-Bredu, N. Kyei-Baffour, V.J. Mama and J. Fonweban. 2019. The Relevance of Using in Situ Carbon and Nitrogen and Satellite IMages to Assess Aboveground Carbon and Nitrogen Stocks For Supporting National REDD + Programmes in Africa. *Carbon Balance Manage* 14: 12. https://doi.org/10.1186/s13021-019-0127-7.

Chayaporn, P., N. Sasaki, M. Venkatappa and I. Abe. 2021. Assessment of the Overall Carbon Storage in a Teak Plantation in Kanchanaburi Province, Thailand – Implications for Carbon-based Incentives. *Cleaner Environmental Systems* 2. https://doi.org/10.1016/j.cesys.2021.100023.

Chave, J., C. Andalo, S. Brown, M. Cairns, J. Chambers, D. Eamus, H. Fölster, F. Fromard, N. Higuchi, T. Kira, J. Lescure, B. Nelson, H. Ogawa, H. Puig, B. Riera and T. Yamakura. 2005. Tree Allometry and Improved Estimation of Carbon Stocks and Balance in Tropical Forests. *Oecologia* 145: 87– 99. https://doi.org/10.1007/s00442-005-0100-x.

Cheng, X.L., M.M. Nizamani, C.Y. Jim, S. Qureshi, S. Liu, Z.X. Zhu and H.F. Wang. 2022. Response of Urban Tree DBH to Fast Urbanization: Case of coastal Zhanjiang in South China. *Urban Ecosystems* 1–12.

Clarke K.R. and R.N. Gorley. 2006. *PRIMER* v6.1: User Manual/Tutorial. PRIMER-E, Plymouth, United Kingdom.

Clerici, N., K. Rubiano, J.M. Posada Hoestettler and F.J. Escobedo. 2016. Estimating Aboveground Biomass and Carbon Stocks in Periurban Andean Secondary Forests Using Very High Resolution Imagery. *Forests* 7(7): 138. https://doi.org/10.3390/f7070138.

Dabasso, B.H., Z. Taddese and D. Hoag. 2014. Carbon Stocks in Semi-Arid Pastoral Ecosystems of Northern Kenya. *Pastoralism* 4(5). https://doi.org/10.1186/2041-7136-4-5.

Dash, S.K., M.A. Kulkarni, U.C. Mohante and K. Prasad. 2009. Changes in the Characteristics of Rain Events in India. *Journal of Geophysical Research*. https://doi.org/10.1029/2008JD010572.

Davies, Z.G., J.L. Edmondson, A, Heinemeyer, J.R. Leake and K.J. Gaston. 2011. Mapping an Urban Ecosystem Service: Quantifying Above-ground Carbon Storage at a City-wide Scale. *Journal of Applied Ecology* 48(5): 1125–1134. https://doi.org/10.1111/j.1365-2664.2011.02021.x.

De Guzman, H.A., S. Vallesteros, A.P. Ballesteros, J.Q. Caranza and Y. Castaneto. 2021. Aboveground Biomass and Carbon Stock of Buho (*Schizostachyum lumampao* (Blanco) Merrill) in Cuyambay, Tanay, Rizal. *Journal of Agricultural Research, Development, Extension, and Technology* 3(1): 60–70.

DENR Administrative Order. 2017. *Updated National List of Threatened Philippine Plants and their Categories* (DAO No. 2017-11).

Deskis, O.Ü. 2014. Measure application version 1.4. May 10, 2014.

Dida, J.J. and C. Tiburan. 2020. Above-ground Biomass Estimation of Trees in the University of the Philippines Los Baños Campus, Philippines. Sylvatrop, *The Technical Journal of Philippine Ecosystems and Natural Resources* 30: 91–105.

Duncanson, L., J. Armston, M. Disney, V. Avitabile, N. Barbier, K. Calders, S. Carter, J. Chave, M. Herold, N. MacBean, R. McRoberts, D. Minor, K. Paul, M. Réjou-Méchain, S. Roxburgh, M. Williams, C. Albinet, T. Baker, H. Bartholomeus, J.F. Bastin, D. Coomes, T. Crowther, S.T. Davies, S. De Bruin, M. De Kauwe, G. Domke, R. Dubayah, M. Falkowski, L. Fatoyinbo, S. Goetz, P. Hantz, I. Jonckeere, T. Jucker, H. Kay, H. Kellner, N. Labireire, R. Lucas, E. Mitchard, F. Morsdorf, E. Næsset, T. Park, O. Phillips, P. Ploton, S. Puliti, S. Quegan, S. Saatchi, C. Schaaf, D. Schepaschenko, K. Scipal, A. Stovall, C. Thiel, M.A. Wulder, F. Camacho, J. Nickeson, M. Román and H. Margolis. 2021. *Aboveground Woody Biomass Product Validation Good Practices Protocol. Version 1.0.* Smithsonian Research Online. https://doi:10.5067/doc/ceoswgcv/lpv/agb.001.

Estrella, V. 2016. The Gold Working Sub-assemblage from Butuan, Northeast Mindanao, Philippines: The Archaeological Record. *Proceedings of the Society of Philippine Archaeologists*. Manila.

Fang, J., A. Chen, C. Peng, S. Zha and L. Ci. 2001. Changes in Forest Biomass Carbon Storage in China Between 1949 and 1998. *Science* 292(5525): 2320–2322. https://doi:10.1126/science.1058629.

Faris Nik Effendi, N.A., N.A. Mohd Zaki, Z. Abd Latif, M.N. Suratman, S.N. Bohari, M.Z. Zainal and H. Omar. 2021. *Aboveground Biomass and Carbon Stocks Estimation Using Allometric Equations in Tropical Forest*.

Fazilah, M., A.G. Awang Noor, M.S. Mustafa Kamal and M. Abdullah. 2013. Appraisal of Urban Trees Value Using Thyer Method. *Pertanika Journal Tropical Agriculture Science* 36(S):143–156. ISSN: 1511-3701.

Ghosh, S., R. Maity, S. Rana,M. Kamilya, S. Patra and D. Kuila. 2021. Impact of Weed Managements and Anthropogenic Stress on Quantitative Attributes of Plant Community Composition in Gopegarh Ecopark, Paschim Medinipur, West Bengal, India. *Asian Journal of Environment & Ecology* 14(4): 11–25. https://doi:10.9734/ajee/2021/v14i430213.

Guiabao, E.G. 2010. Carbon Sequestration Potential of Tree Species in the Reservation Area of Kalinga State University. *International Journal of Interdisciplinary Research and Innovations* 4: 63–68.

Jumawan, J.H., F.F.D. Tripoli, E.E.S. Boquia, K.L.M. Niez, J.A.H. Veronilla, S.A. Dellomes, R.M. Udtie, N.K. Seit, N.A. Hasi and M.J.O. Gatinao. 2015. Species Diversity and Spatial Structure of Intertidal Mollusks in Padada, Davao Del Sur, Philippines. *Aquaculture, Aquarium, Conservation & Legislation International Journal of the Bioflux Society* 8(3).

Hammer, Ø., D.A.T. Harpe and P.D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): 9. Accessed May 15 2022.

Heiskanen, J., L. Korhonen, J. Hietanen, V. Heikinheimo, E. Schäfer and P. K. Pellikka. 2015. Comparison of Field and Airborne Laser Scanning Based Crown Cover Estimates Across Land Cover Types in Kenya. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 40: 409–415.

Henry, M., N. Picard, C. Trotta, R.J. Manlay, R. Valentini, M. Bernou and Saint-André. 2011. Estimating Tree Biomass of Sub-Saharan African Forests: A Review of Available

Allometric Equations. *Silva Fennica* 45:477–569. ISSN 0037-5330.

Idso, C.D., S. Idso and R. Balling. 2001. An Intensive Two–week Study of an Urban CO_2 Dome in Phoenix, Arizona, USA. *Atmospheric Environment* 35(6):995–1000. https://doi:10.1016/S1352-2310(00)00412-X.

IPCC (The Intergovernmental Panel on Climate Change). 2006. Guidelines for National Greenhouse Gas Inventories Vol. 4. In S. Eggelstons, L. Buendia, K. Miwa, N. Todd & K. Tanabe (Eds.). Hayama, Japan: *Institute for Global Environmental Strategies (IGES).*

Kordowski, K. and W. Kuttler. 2010. Carbon Dioxide Fluxes Over an Urban Park Area. *Atmospheric Environment* 44:2722–2730. https://doi:10.1016/j.atmosenv.2010.04.039.

Labata, M.M., E.C. Aranico, A.C. Tabaranza, J.H.P. Patrici and R.F. Amparado, Jr. 2012. Carbon Stock Assessment of Three Selected Agroforestry Systems in Bukidnon, Philippines. *Advances in Environmental Sciences International Journal of the Bioflux Society* 4(1).

Lagbas, A. 2019. Social Valuation of Regulating and Cultural Ecosystem Services of Arroceros Forest Park: A Man-made Forest in the City of Manila, Philippines. *Journal of Urban Management* 8(1): 159–177. https://doi.org/10.1016/j.jum.2018.09.002.

Larson, L.R. and J. A. Hipp. 2022. "Nature-Based Pathways to Health Promotion: The Value of Parks and Greenspace." *North Carolina Medical Journal* 83(2): 99–102. https://doi.org/10.18043/ncm.83.2.99.

Lasco, R.D., K.G. MacDicken, F.B. Pulhin, I.Q. Guillermo, R.F. Sales and R V.O. Cruz. 2006. Carbon Stock Assessment of a Selectively Logged Dipterocarp Forest and Wood Processing Mill in the Philippines. *Journal of Tropical Science* 18(4):166–172.

Lasco, R.D., I.Q. Guillermo, R.V.O. Cruz, N.C. Bantayan and F.B. Pulhin. 2004. Carbon Stocks Assessment of a Secondary Tropical Forest in Mt. Makiling Forest Reserve, Philippines. *Journal of Tropical Forest Science* 16(1): 35–45.

Lin, J., D. Chen, W. Wu and X. Liao. 2022. Estimating Aboveground Biomass of Urban Forest Trees with Dual-source UAV Acquired Point Clouds. *Urban Forestry & Urban Greening* 69: 127521. https://doi.org/10.1016/j.ufug.2022.127521.

Lumbres, R.I.C., D.F.C. Soriano, N.F. Doyog, R.A. Raterta, S.C.Villarta Jr. and Z.G. Baoanan. 2023. Biomass and Carbon Stock Assessment of Trees in the Lowland Evergreen Forest of Mt. Iraya, Batanes, Philippines. *Philippine Journal of Science* 152(1): 269–276. ISSN 0031-7683.

Macaraig, J.E.D., J.J.V. Dida and N.C. Bantayan. 2021. Above Ground Biomass and Carbon Stock Estimation of Arroceros Forest Park "The Manila's Last Lung" using Geographic Information System (GIS). *Journal of Biodiversity and Environmental Sciences* 18(1): 17–24.

Mahmood, H.M. and K.H. Mahdi. 2021. Modern Technologies as Urban Management Tools that Work to Sustain and Develop Urbanization in Cities. *Journal of Physics: Conference Series 1773.* https://doi:10.1088/1742-6596/1773/1/012034.

Membrebe Jr. Z., A.J.G. Santos, J.C.C. Valeros and A.A. Ancheta. 2017. Urban Forest Park as Eco-Space for Liveable City: Arroceros Forest Park, Manila, Philippines. *International Journal of Real Estate Studies* 11(4).

Mildrexler, D.J., L.T. Berner, B.E. Law, R. Birdsey and W. R. Moomaw. 2020. Large Trees Dominate Carbon Storage in Forests East of the Cascade Crest in the United States Pacific Northwest. *Frontier For Global Change* 3. https://doi.org/10.3389/ffgc.2020.594274.

Millward, A.A. and B. Sabir. 2011. Benefits of a Forested Urban Park: What Is the Value of Allan Gardens to the City of Toronto, Canada? *Landscape and Urban Planning* 100: 177–188. https://doi.org/10.1016/j.landurbplan.2010.11.013.

Mueller-Dumbois, D. and H. Ellenburg. 1974. *Aims and Methods of Vegetation Ecology. NY: The standard Textbook of Vegetation Ecology*. A Reprint (2002) is available from The Blackburn Press, Caldwell, New Jersey.Wiley and Sons: ISBN: 1-930665-73-3.

Mullet, E.K., G.H. Lacorte, R.M. Hamiladan, C.E. Arabit, S.O. Cuales, L.G. Lasutan, N.J. Alagos, H.G. Kamantu, K.J. Protacio and J.H. Jumawan. 2014. Assessment of Mangrove Species and its Relation to Soil Substrates in Malapatan, Sarangani Province, Philippines. *Journal of Biodiversity and Environmental Sciences* 5(4): 100–107.

Mulyani, Y.A., M.D. Kusrini, A. Mardiastuti, R. Oktavian and A. Kaban. 2021. The Use of Weeping Fig Ficus benjamina by Wildlife in Campus Area of Dramaga, Bogor, Indonesia. IOP Conf. Series: *Earth and Environmental Science* 948: 012012. https://doi:10.1088/1755-1315/948/1/012012.

Natividad, E.M., V.S. Hingabay, H.B. Lipae, E.A. REquieron, A.J. Abalunan, P.M. Tagaloguin, R.S. Flamiano, J.H. Jumawan and J.C. Jumawan. 2015. Vegetation Analysis and Community Structure of Mangroves in Alabel and Maasim Sarangani Province, Philippines. *ARPN Journal of Agriculture and Biological Science* 10(3). ISSN 1990-6145.

Nie, J. and S. Liu. 2023. Incorporated Neighborhood and Environmental Effects to Model Individual-Tree Height Using Random Forest Regression. *Scandinavian Journal of Forest Research* 1–11.

Orella, J., D.R. Africa, C.H. Bustillo, N. Pascua, C. Marquez, H. Adornado and M. Arguilos. 2022. Above-and-Belowground Carbon Stocks in Two Contrasting Peatlands in the Philippines. *Forest* 13(2):303. https://doi.org/10.3390/f13020303.

Origenes, M.G. and R.L. Lapitan. 2021. Carbon Stock Assessment Through Above-ground Biomass of Trees at Different Forest Composition in Mt. Malindawag, Lubilan, Naawan, Misamis Oriental, Philippines. *International Journal of Forestry, Ecology and Environment* 3(1): 100–113. https://doi:10.18801/ijfee.030121.11.

Orwa, C., A. Mutua, R. Kindt, R. Jamnadass and A. Simons. 2009. *Agroforestree Database: A Tree Reference and Selection Guide version 4.0*. World Agroforestry Centre, Kenya. https://www.worldagroforestry.org/output/agroforestree-database accessed on 05-02-2024.

Pansit, N.R. 2019. Carbon Storage and Sequestration Potential of Urban Trees in Cebu City, Philippines. *Mindanao Journal of Science and Technology* 17.

Parilla R.B., K.M.P. Tamos and F.R.O. Jawad. 2018. Carbon storage and sequestration by selected tree species in the University of San Carlos – Talamban Campus' (USC-TC) Nature Park, Cebu City, Philippines. *CNU Journal of Higher Education* 12: 15–20.

Pasiecznik, N. 2020. Acacia mellifera (blackthorn). *CABI Compendium*. https://doi.org/10.1079/cabicompendium.2328.

Paudel, S. and S.L. States. 2023. Urban Green Spaces and Sustainability: Exploring the Ecosystem Services and Disservices of Grassy Lawns Versus Floral Meadows. *Urban Forestry & Urban Greening* 84: 127932. https://doi.org/10.1016/j.ufug.2023.127932.

Rahman, M.M., S.H. Rahman and M. Al Amin. 2021. Role of Forest Tree Species in The Carbon Storage of the Kaptai National Park, Bangladesh. *Bangladesh Journal Botany* 50(2): 365–371. https://doi.org/10.3329/bjb.v50i2.54094.

Raga-as, M. , Tano, R. , Polaron, F. , Saladar, R. , Bohulano, N. , Morales, J. , Gregorio, E. and J. Nacionales. 2022. Aboveground Blue Carbon Stock Assessment of Bakhawan Eco-Park Mangrove Plantation in New Buswang, Kalibo, Aklan, the Philippines. Open Journal of Ecology, 12, 773-787.https://doi.org/10.4236/oje.2022.1212045.

Racelis, E.L., D.A. Racelis and A.C. Luna. 2019. Carbon Sequestration by Large Leaf Mahogany (*Swietenia macrophylla* King.) Plantation in Mount Makiling Forest Reserve, Philippines: A Decade After. *Journal of Environmental Science and Management* 22(1): 67–76. ISSN 0119-1144.

Saatchi, S.S., N.L. Harris, S. Brown, M. Lefskyd, E.T.A. Mitcharde, W. Salas, B.R. Zutta, W. Buermann, S.L. Lewis, S. Hagen, S. Petrova, L. White, M. Silman and A. Morel. 2011. Benchmark Map of Forest Carbon Stocks in Tropical Regions Across Three Continents. *PNAS* 108(24): 9899–9904. https://doi.org/10.1073/pnas.1019576108.

Salvaña, F.R., C.J. Dacutan, C.C. Mangaoang and B.L.P. Bretaña. 2019. Comparison of Aboveground Biomass Estimation in Two Forest Types Using Different Allometric Equations. *Journal on New Biological Reports* 8(3):155–163. ISSN 2319-1104.

Senbeta, F.W. 2006. Biodiversity and Ecology of Afromontane Rain-Forests with Wild Coffee Arabica L. Populations in Ethiopia. Ecology and Development Series No. 38, Bonn: Center for Development Research, University of Bonn.*Open Journal of Forestry* 8(4).

Seto, K.C. and J.M. Shepherd. 2009. Global Urban Land-use Trends and Climate Impacts.

Current Opinion in Environmental Sustainability 1:89–95. https://doi.org/10.1016/j.cosust.2009.07.012.

Sintayehu, D.W., A. Belayneh and N. Dechassa. 2020. Aboveground Carbon Stock is Related to Land Cover and Woody Species Diversity in Tropical Ecosystems of Eastern Ethiopia. *Ecological Processes* 9(37). https://doi.org/10.1186/s13717-020-00237-6.

Vasagadekar, P., Gargate, A., Patil,Y. and P. Raut. 2023. Carbon Sequestration Potential of Trees from Urban Green Spaces of Kolhapur City, Maharashtra, India. Environmental and Socio-economic Studies,11(3) 22-32. https://doi.org/10.2478/environ-2023-0014.

Vashum, K. T. and S. Jayakumar. 2012. *Methods to Estimate Above-Ground Biomass and Carbon Stock in Natural Forests - A Review. Journal of Ecosystem and Ecography* 2:4. http://dx.doi.org/10.4172/2157-7625.100011S.

Wang, H., Y. Feng and L. Ai. 2023. Progress of Carbon Sequestration in Urban Green Space Based on Bibliometric Analysis. *Frontiers Environmental Science* 11:1196803. https://doi.org/10.3389/fenvs.2023.1196803.

Wang, Y., M.X. Lehtomäki, J. Liang, A. Pyörälä, A. Kukko, J. Jaakkola, Z. Liu, R. Feng, C. Chen and J. Hyyppä. 2019. Is Field-measured Tree Height as Reliable as Believed – A Comparison Study of Tree Height Estimates from Field Measurement, Airborne Laser Scanning and Terrestrial Laser Scanning in a Boreal Forest. ISPRS Journal of Photogrammetry and Remote Sensing 147: 132–145. https://doi.10.1016/j.isprsjprs.2018.11.008.

Wilkes, P., M. Disney, M.B. Vicari, K. Calders and A. Burt. 2018. Estimating Urban Above Ground Biomass with Multi-scale LiDAR. *Carbon Balance Manage* 13(10). https://doi.org/10.1186/s13021-018-0098-0.

Winterberger, K.C. and F.R. Larson. 1988. Measuring Crown Cover in Interior Alaska Vegetation Types. *American Society for Photogrammetry and Remote Sensing* 54(3): 385–387.

Woodward, A., A. Hinwood, D. Bennett, B. Grear, S. Vardoulakis, N. Lalchandani, K. Lyne and C. Williams. 2023. Trees, Climate Change, and Health: An Urban Planning, Greening and Implementation Perspective. *International Journal of Environmental Research and Public Health* 20(18). https://doi.org/10.3390/ijerph2018679.8.

Xiao, J., L. Chen, T. Zhang, L. Li, Z. Yu, R. Wu, L. Bai, J. Xiao and L. Chen. 2022. Identification of Urban Green Space Types and Estimation of Above-Ground Biomass Using Sentinel-1 and Sentinel-2 Data. *Forests* 13: 1077. https://doi.org/10.3390/f13071077.

Zafriakma, N., N.S. Masran, D.D. Ahmad, M.I. Nazli, R. Zakaria, M.F.A. Karim, M.F.A. and N.A. Amaludin. 2020. Preliminary Study on Tree Species Composition, Diversity and Biomass of Dipterocarpus and Hopea Genera of Bukit Bakar Forest Eco Park, Machang, Kelantan. IOP Conference. Series: *Earth and Environmental Science* 549. https://doi:10.1088/17551315/549/1/012037.

Zhao, D., J. Cai, Y. Xu, Y. Liu. and M. Yao. 2023. Carbon Sinks in Urban Public Green Spaces Under Carbon Neutrality: A Bibliometric Analysis and Systematic Literature Review. Urban Forestry and Urban Greening, 86: 128037. https://doi.org/10.1016/j.ufug.2023.128037.