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Above ground biomass and carbon stock estimation of Arroceros Forest Park "The Manila's Last Lung" using geographic information system (GIS)

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Key words: Aboveground biomass, Arroceros forest park, Carbon sequestration, Carbon stock

Abstract

In an area where urbanization is rapidly growing, carbon is slowly sequestered which clogs the ozone layer. With forest biomass, carbon is easily sequestered and stored by trees. This research focuses on the potential carbon storage of the Arroceros Forest Park, one of the last lungs of the metropolis located in the heart of the National Capital Region, Manila, Philippines. Trees with ≥10 cm diameter at breast height (DBH) were inventoried, from two (2) hectare area of site. These trees were used in the estimation of the biomass and carbon stock. The Power-Fit Equation from Banaticla (insert year), $Y = 0.342$ (DBH (exp (0.73))) was used in the study. Results showed that *Swietenia macrophylla* dominated the park. Species with highest contribution of biomass and carbon is the *Swietenia macrophylla* with value of 149.55t/ha. The carbon formed from this was 45%, and estimated carbon stock present is 30.59Ct/ha. Total aboveground biomass and carbon stock in the forest park is estimated at 640.21t/ha, and 130.95Ct/ha, respectively. Provided the carbon stock estimate, this could give more importance to Arroceros Forest Park in carbon sequestration. Site must be protected and enhanced to promote the important role of green spaces in Metro Manila.

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Introduction

Forest has a massive role in the ecosystem. It is composed of trees that function as a sink for the carbons available in the atmosphere. This is also important to human beings as it produces oxygen that is essential to life. Through continuous collection of carbons from the atmosphere, without disturbances that will compromise the function of trees and forest, average global temperature will slowly decrease.

Without forests negative impact such flash floods and sudden increase in the global temperature would likely to occur. Due to industrialization and modernization, agricultural areas were prioritized and forested areas were converted, corals were decolorizing and degrading from the absorption of toxic liquid wastes found in the oceans and seas (Dam, J.W., *et al.,* 2011). Another threat to the environment was the conversion of forest lands to establishments for the creation of different kinds of technologies for efficient production.

On the other hand, urbanization leads to production of different kinds of ways to efficiently work developmental projects and environmental research such field as *Geographic Information System* and *Remote Sensing*. This innovation helps the forestry adapt to modern approach of environment. Urban establishments also use the green architecture, different recreational parks and ecotourism sites were formed for controlling the microclimate of the environment as well tourist attraction.

Carbons formed due to the process of the carbon cycle, the interconnected process in the environment, of carbon atoms, with its component; the atmosphere, the terrestrial biosphere, ocean, sediment as well as the earth's interior (Encyclopaedia Britannica, 2019). According to the Royal Society of Chemistry (2020), Carbon, with an atomic number of six (6) had an atomic weight of 12 u, is widely distributed in every part of the planet. This element was considered to be one of the important elements discovered on the planet. Also, it is fourth in terms of abundance in the universe through mass and was the second most abundant element to be found in the human body.

In spite of pollution from the carbon, Committee on Climate Change performs different activities in order to demote the use of technologies that harms the environment such as United Nations Framework Convention on Climate Change (UNFCCC) a forum composed of 195 countries in 1992 focuses on areas of mitigation of greenhouse gas emissions, reporting of national emissions, adapting to climate change, and financing the developing countries that promote climate action. Another activity is the Kyoto Protocol, wherein 37 industrialized countries committed to lowering their greenhouse gas emission to five percent, in the same manner, the United Kingdom voluntarily reduced their greenhouse gas emissions to 12.5% from the year 2008 to 2012. In addition, in December 2015 the committee continues negotiations that lead to the Paris Agreement compose of 160 UNFCCC parties including China, the United States, and the European Union. The main goal of the Agreement is to lessen greenhouse gas emissions and reduce the global average temperature from two degrees and below.

Furthermore, through forest biomass, different parts of the tree such as the trunk, bark, leaves, branches, and needles, carbon are easily sequestered and stored trees. In addition, elements such as carbon are very essential in plants and will be recycled to be used in the process called Photosynthesis, which produces glucose and oxygen. The biomass depends on the size of the forest area Due to this particular reason, forest land conversion is one of the most dangerous things that humans should not have done because without forest lands, there would not be a huge machine that could face the dangerous typhoons such as Yolanda. Also, this inappropriate action could lead to a loss of macronutrients of the soil, as well as micronutrients, and infertility of the particular burned area (Buttler, R. 2012).

However, carbon stock estimation is the assessment of the forest biomass in terms of carbon. Also, carbon stock estimation would tell if a certain forest area has become a huge success in carbon sequestering for an environment (Vashum, K, T, 2012). The objective of the study is to calculate the aboveground biomass and carbon stock of the Arroceros Forest Park, Manila.

Materials and methods

Study Area

The City of Manila and Winner Foundation signed a memorandum of agreement on leasing a site for Nature Park as a development project of the private environmental group supported by the first lady Amelita Ramos which was considered as the "Manila's Last Lung", the Arroceros Forest Park, developed in 1993 was designed Wilfredo Dizon, a landscape architect, found in the Central Terminal of Manila, with coordinates of 14°35′39″North and 120°58′55″East. It is a riverside park, located at the central district of Ermita in the Antonio Villegas Street of Barangay 659-a (Lopez, A. 2007). This Forest Park has an area of 21,428 square meters, 2.2-hectare urban forest. This urban forest is the home of the six different avian species namely Yellow-Vented Bulbul (*Pycnonotus goiavier*), Long-Tailed Shrike or Rufous-Backed Shrike (Lanius schach), Zebra Dove (*Geopelia striata*), Pied Fantail (*Rhipidura nigritorquis*), Pacific Swallow (*Hirundo tahitica*), and the Brown Shrike (*Lanius cristatus*) (Liuag, N. 2003). In addition, this park has 41 different kinds of forest tree species, some of which were *Acacia auriculiformis, Acacia mangium, Agoho,* African tulip, Anahaw, Eucalyptus, Fire Tree and such (Roces, A. February 11, 2003).

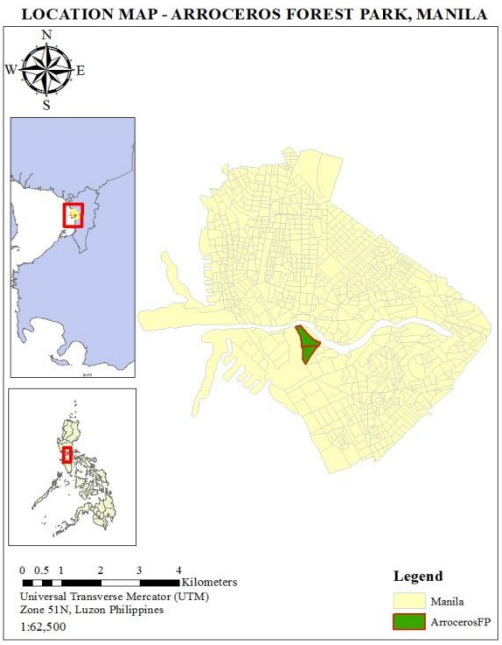

Fig. 1. Location Map of Arroceros Forest Park. Source (GIS Derived).

Procedure of Inventory and Data Collection

The samples of the research will be taken directly from the site, Arroceros Forest Park. The sampling method will be a complete sampling of the entire forest park since this park has an area of two (2.2) hectares only. The duration of data collection was one month. Trees with ≥ 10 cm DBH were the data gathered from the Arroceros Forest Park. Measurement of diameter at breast height, total height, and identification of tree species, and its' age, must be collected in order to generate aboveground biomass for carbon stock estimation. The area to be inventory will be all the standing tree species inside the whole forest park (Fig. 2). Species must be greater than or equal to 10 centimeters diameter at breast height. The irregular shape of the forest park has four corners and its total area in hectares (2.2 ha).

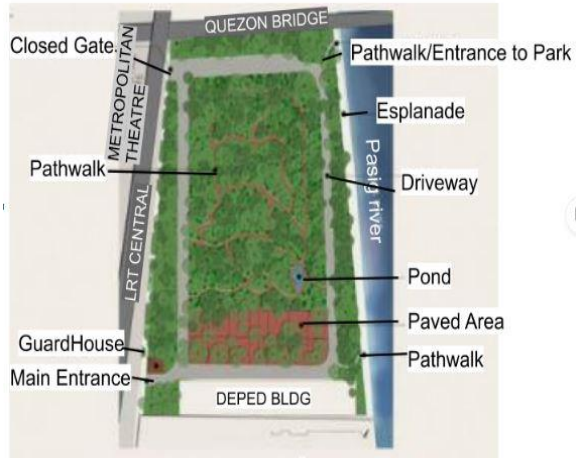

Fig. 2. Components of the Arroceros Forest Park.

Data Analysis

In analyzing the data, instead of using the equation from Brown, the estimated values would be analyze with the help of the formula from the studies of Banaticla for her allometric equation, the Power-Fit. Despite the estimation, Brown's general equation (1997) for biomass estimation overestimates the actual value of biomass because the formula was used in the local studies 170 diverse tree species while using the destructive sample to estimate the three tropical moist forest regions (Ketterings *et al.,* 2001; van Noordwijk *et al.,* 2002 as cited in Labata M. M., *et al.,* 2012).

$$Y\ (kg) = \exp\{-2.134 + 2.53 * \ln * D\}$$

Where: exp {...} = "raised to the power of"
ln = "natural log of (...)"
Y = biomass per tree in kg
D = diameter at breast height (1.3m) in cm

Using the DBH, the formula used in getting the biomass is Banaticla's Power Fit Equation.

$Y=0.342D^{2.073}$

Where Y: biomass of the tree in kg
D: diameter at breast height

Also generated maps from the software, Google Earth, Envi, and ArcMap, these three will help in easily providing information and illustration about the said aboveground biomass as well as the carbon stock in the park.

Results

Inventory Data

The fig. 3 shows the ten (10) DBH, in centimeters, class in the Arroceros Forest Park. Furthermore, in the graph of the count of species found in the forest park, *Swietenia Macrophylla* King dominates the Arroceros Forest Park (Fig. 4). Out of 226 inventory trees, 42 trees were *Swietenia Macrophylla* King. Furthermore, *Pterocarpus indicus* Willd. Forma *indicus* was the next top species in the forest park. This species has a total count of 28. Another species that has more counts than the other species is the *Vitex parviflora* Juss. with a total count of 26 trees.

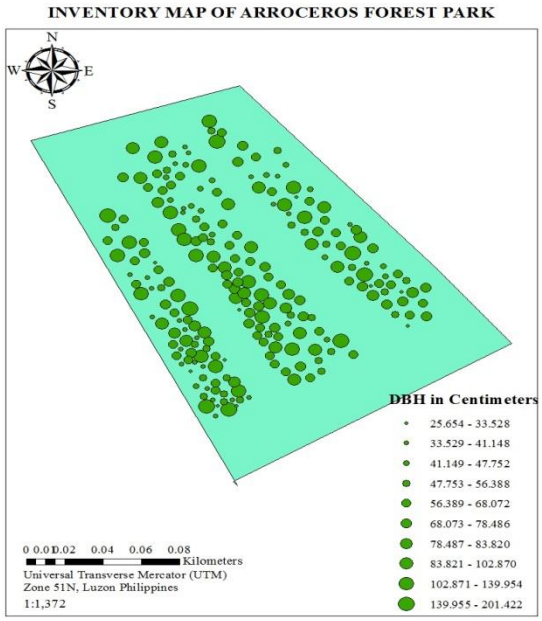

Fig. 3. Inventory Map of Arroceros Forest Park.

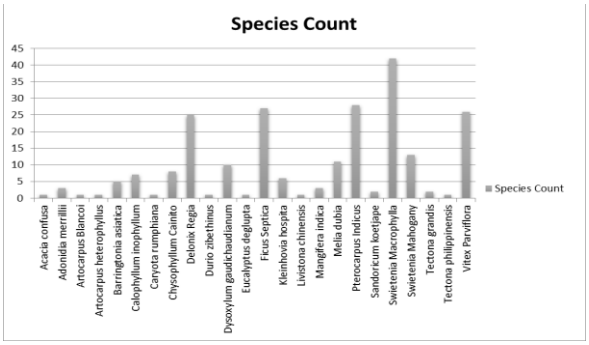

Fig. 4. Count of Species in Arroceros Forest Park.

On the other hand, *Delonix regia* (Box. ex Hook) Raf. has the highest recorded height in the forest park with 13.74 meters on average. Another species with an outstanding height is the *Barringtonia asiatica* (L.) Kurz with 13.50 meters on the average. Furthermore, *Adonidia merilli* (Becc.) is next to the *Barringtonia asiatica* (L.) Kurz, with 12.97 meters of height.

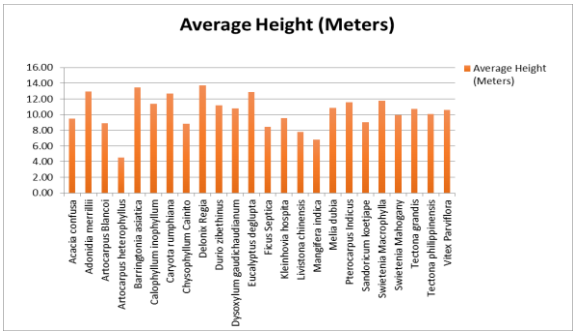

Fig. 5. Height of Species in the Forest Park (Meters).

Furthermore, the *Calophyllum inophyllum* (L.) has the largest Diameter at Breast Height recorded, on the average, in the forest park with 98.12 centimeters. Another species that has a large DBH is the *Delonix regia* (Box. ex Hook) Raf. with 84.99 cm and the *Pterocarpus indicus* Willd. Forma *indicus* with 84.77 centimeters.

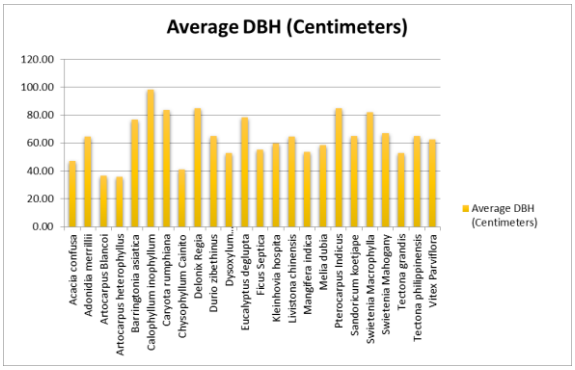

Fig. 6. DBH of Species in Forest Park (Centimeters).

Aboveground biomass of Forest Park

Swietenia macrophylla King has the most biomass produced out of the 24 flora species found in the forest park, with 149,545.70 kg. Another species is the *Pterocarpus indicus* Willd. Forma *indicus*, out of the 28 species found it has 129,429.18 kg of biomass in the forest park. The total above-ground biomass in the Forest park is 640,206.21 kg. Furthermore, according to Lasco R.D., & Pulhin F.B.(2000) in the study about the Forest Land Use Change in the Philippines and Climate Change Mitigation from the samples collected in several locations in the Philippines. The default value of 45% was used in order to quantify the carbon present in the aboveground biomass of the forest park. 45% was the mean value of the carbon content of the wood sample in the study of Lasco R.D., & Pulhin F.B.

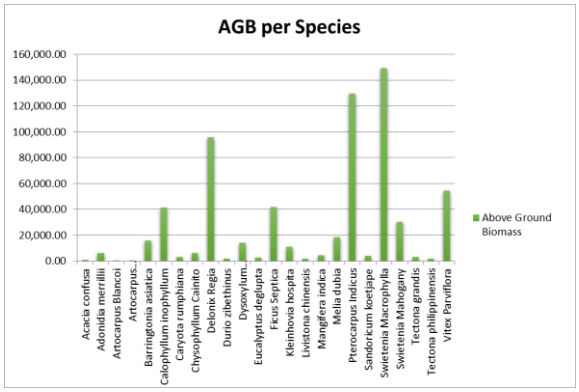

Fig. 7. Graph per species of ABG using the Power – Fit Equation.

Carbon Stock of the Forest Park

Biomass is directly proportional to the Carbon Stock estimate. In Fig. 8, *Swietenia macrophylla* King has the highest carbon stock with 30.59t C/ha whereas the total carbon stock in the forest park is 130.95t C/ha.

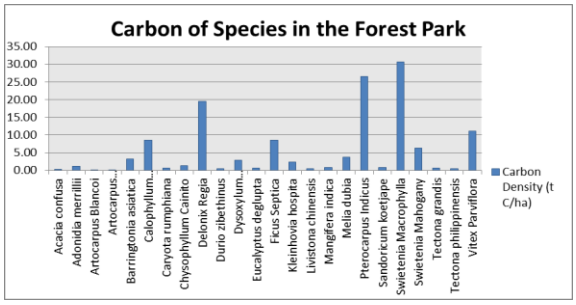

Fig. 8. Graph per Species of Carbon using Power–Fit Equation.

Table 1. Summary of top three species with highest values for Carbon Stock.

Species Identity	ABG (Tonne)	Tree Biomass Density (t/ha)	Mean Annual Increment (t C/ha/yr)	Carbon Density (t C/ha)
Swietenia Macrophylla	149.55	67.98	1.18	30.59
Pterocarpus Indicus	129.43	58.83	1.02	26.47
Delonix Regia	95.72	43.51	0.75	19.58

Discussion

Swietenia macrophylla King dominates the forest park because of its availability in the area, This species was first introduced in Manila as park trees from unknown origins during 1907 (Ponce 1993 as cited by Abarquez, A. *et al.,* 2015). Furthermore, 1002 mahogany seeds from the Royal Botanic Gardens of India was received by the College of Forestry and Natural Resources, UPLB (Abarquez, A. *et al.,* 2015).

Most of the sources of seeds in the urban areas were an exotic one and this particular species does not need to adapt to the characteristic of the soil because our soil here in the Philippine Setting has high sources of nutrients, one main reason is the high biodiversity of flora in the Philippine Setting (McNeely *et al.*, 1990 as cited in Lasco *et al.,* 2008).

Despite the lack of data about the soil characteristics of the forest part, about filed up the soil, and about the land cover of the forest park, the built-up area surrounding the forest park and a Pasig river did not affect the health of this forest park (Fig. 9 and 10).

Proof that Pasig River did not affect the health of forest park is the abundance of tree species found inside 2.2 hectares fence protected park with an ecological trail for the people who wants to visit the park (Santos Jr, R. 2019).

Although not related to the species composition, the presence of bird species such as pied fantails, Yellow-vented bulbuls, brown shrike, and common kingfisher, etc. with unidentified snakes inside the park makes it diversity rich in both flora and fauna (Lagbas AJ 2018).

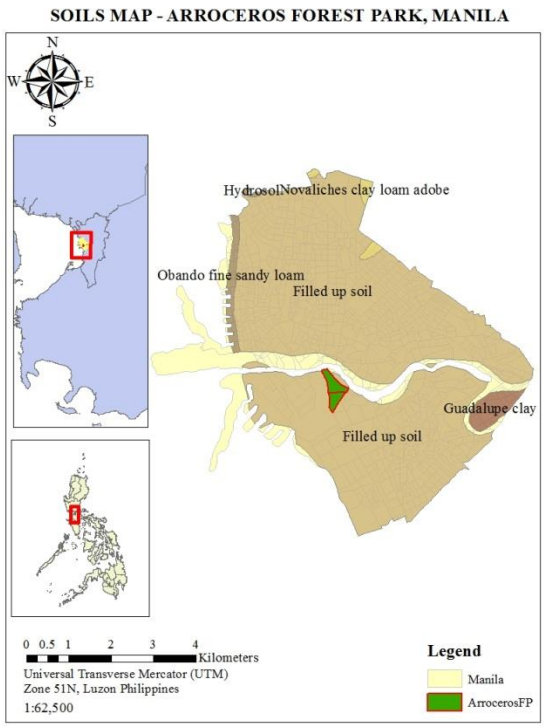

Fig. 9. Soils Map of Arroceros Forest Park.

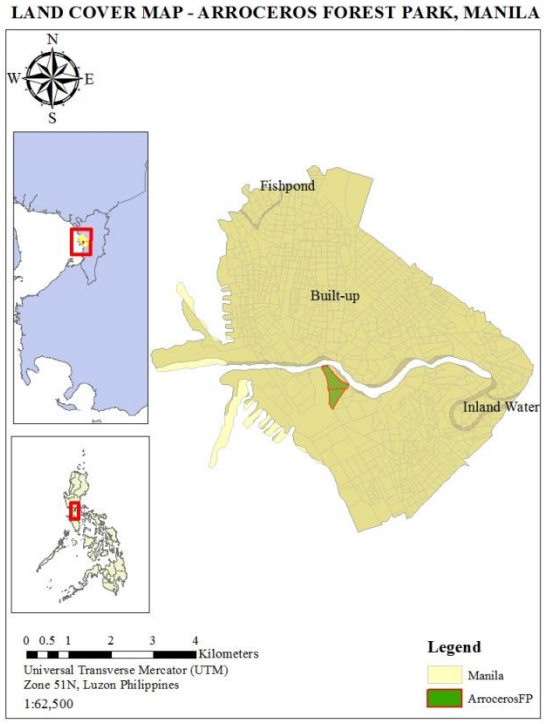

Fig. 10. Land Cover Map of Arroceros Forest Park.

In addition, the big leaf characteristic of this species fits in a heat centered area due to the presence of stomata in the leaf of the plants (Dai *et al.*, 2004). The greater size and number of the leaf the plants, the more stomata can store the carbon dioxide available in the area as well as in the neighboring areas. Furthermore, the presence of the water body, Pasig River, in this urban area alleviates the heat temperature. As cited in the study of Gupta, N. *et al.* (2019) from the case of Ahmedabad and Chandigarh cities in India, results show that the fall of temperature was seen near the bank of the river of about 0.69˚C for the summer and 0.65˚C for the winter. The study also discusses the importance of the water body despite its low quality which could also be observed on the qualities of the Pasig River based on its color.

In the aspect of height, the *Delonix regia* (Box. ex Hook) Raf. from the family of Fabaceae, there are few reasons why *Delonix regia* (Box. ex Hook) Raf. was the tallest tree species in the forest park. One is the environment, this species was found to be exotic in the Philippines and one of the characteristics of exotic species were out-scaling the native ones in their home soil since Philippine has one of the richest soil as what could have been correlated with the floral biodiversity in the Philippines (McNeely *et al.*, 1990 as cited in Lasco *et al.*, 2008). Also, *Delonix regia* (Box. ex Hook) Raf and other species in the forest park follows the carbon produced near the roads for these molecules were the ones needed for Photosynthesis in the process of light (Boardman NK, 1977).

For the Diameter at Breast Height, *Calophyllum inophyllum* (L.) one of the species found in the mangrove areas. Also one of the characteristics of this species, and the other mangrove species, is the large stem diameter which is a good indicator of great biomass formed which could be converted into carbon stock. Furthermore, soil organic carbon existing in the mangrove areas are high due to the presence of highly nutritious soil for the protection of the mangrove areas and tree species from the windbreaks and oceans (Friday JB *et al.*, 2006)

Since the research was pioneer in the forest park, comparison was not necessary. Also the the downside of using the allometric equations for both Brown and Banaticla is the loss of range to determine if a certain area sequesters low, medium, or high enough for a 2.2-hectare forest park.

Conclusion

The research focused on the potential of the Arroceros Forest Park located in Manila, Philippines, as one of the country's most populated and polluted areas, in storing and sequestering carbon. The Arroceros Forest Park is considered as the "Last Lung of Manila" with a 2.2-hectare area Over the last 26 years of existing, the forest park sequesters carbon of an amount 5.04t C/ha/yr. Despite the formulation of values, lack of studies relation to the scale of how more or less the aboveground biomass and carbon stock estimate is. Furthermore, the use of drones and accurate technologies must be used for large scale forest for efficient working.

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