

Estimation of Above Ground Carbon Dioxide Sequestration in a Philippine University

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ABSTRACT

In order to lessen the consequences of its carbon dioxide emissions during operations, this study attempts to evaluate the carbon sequestration capacity of trees at Bataan Peninsula State University-Main Campus using statistical and allometric equations. The university's trees were located, geotagged, and measured. The observations were converted into measurable above-ground biomass estimations using allometric formulae. The statistical linkages observed in tropical rainforests were used to construct future estimates. According to calculations, trees on university property emit between 327.67 and 680.533 tons of CO₂. Furthermore, even the most optimistic projections indicate that the potential for sequestration in the ensuing 10 years was 1 metric ton annually. In comparison, prior to the pandemic, the university's total carbon emissions were 269.57 tons of CO₂. Consequently, even if the university's operating emissions didn't rise during the following ten years, only 1% of the carbon would be sequestered. To become a carbon-neutral institution, measures must be taken to increase carbon sequestration or decrease emissions. These initiatives include comprehensive and methodical solutions to energy usage, such as the installation of energy-assessment appliances, the transition to renewable energy, energy-use legislation, and alternate modes of transportation including promoting the use of ZEVs and active transportation

INTRODUCTION

Sustainability reporting has grown in relevance in for-profit and non-profit companies over the past decade. Sustainability reporting informs decision-makers while also acting as a catalyst for organizational transformation. Furthermore, One of the objectives of the International Association of Universities is sustainable development in higher education (Jucker et al., 2015). Nations' interdependence and multilateralism in seeking a sustainable route are demonstrated in the United Nations report *Our Common Future* (Brundtland, 2011). Similar to this, the Sustainable Development Goals (SDGs), which were set by the UN General Assembly in 2015, provide precise guidelines and goals that all countries may use to address their priorities and environmental concerns worldwide. The need to prevent climate change is specifically addressed in Goal 13 of the SDGs. Raising institutional and human knowledge of climate change mitigation and enhancing their capacity to do so is one of the five aims in Goal 13 to counteract the harmful consequences of climate change (Christoff, 2018). establishing objectives and goals under the guidance of the The SDGs are a positive start toward better educating the next generation about sustainability and environmental issues.

A forecast According to Stocker et al. (2013), doubling atmospheric carbon dioxide by the middle of the next century is projected to raise the average global temperature by 0.3 to 0.7 degrees Celsius and increase the frequency of severe precipitation events. Interest in strategies to lower greenhouse gas emissions and raise public awareness of the problem has increased as a result of these predicted climate changes. Additionally, measuring the carbon sequestration of forests provides evidence of their usefulness as carbon sinks and is essential for determining how much future carbon dioxide emissions to the atmosphere may be mitigated by our forests.

Universities, according to conventional wisdom, should serve as a beacon for society; they should encourage free expression and critical thinking; they should be sustainable, honest, and inclusive. Universities have therefore been seen as organizations with important duties to help solve sustainability problems and to act as role models for society by putting sustainable plans into action, which includes keeping an eye on the detrimental effects of university operations (Adenle et al., 2017). Sustainable methods and development should be taught to college students. Universities that provide courses on sustainability must to be mindful of their students' good habits and the consequences of their actions.

The Earth's climate system is significantly impacted by greenhouse gases (GHGs), namely carbon dioxide, methane, and nitrous oxide (Superales, 2016). The most important and prevalent gas in the atmosphere is carbon dioxide (CO₂), accounting for more than half of the radiative forces as well as the greenhouse effect (Racelis et al., 2008). The forest ecosystem contributes significantly to the global carbon cycle by sequestering a significant quantity of CO₂ from the atmosphere (Vashum, 2012). Through the process of photosynthesis, trees absorb CO₂ from the environment and store it in their biomass (roots, stems, and leaves). It is estimated that the world's tropical forests were a net source of carbon (1.6 billion t) in 1990 due to anthropogenic activities such as land-use changes and

forestry, particularly tropical deforestation (Lasco, 2002). The Philippine forests, for instance, have been determined to have released Approximately 3045 tons of carbon were released into the atmosphere between 1500 and now, owing to significant deforestation.

Although Few attempts have been undertaken to investigate the potential of trees in urban areas for carbon sequestration, despite the fact that the importance of forested areas in this regard is widely acknowledged and documented. To understand and highlight the importance of urban green spaces in reducing carbon emissions at the local level, it is imperative to look at the carbon sequestration capability of urban environments. There is ample area on large university campuses for urban tree plantings, which might be a practical way to slow down climate change. It is helpful to know how much carbon an urban green space can absorb since it might help a business or organization offset its emissions and value its green space areas.

Because of the implications The Philippines has carried out a thorough investigation on carbon budgets in forest ecosystems in order to better understand how forests contribute to global climate change (Pascua et al., 2021). However, the nation's present knowledge of the capacity of various plantation species, particularly in urban areas, to sequester carbon is severely lacking. Therefore, by calculating the amount of carbon stored in the above-ground biomass of tree species, this study aims to evaluate the overall carbon stock potential of trees at Bataan Peninsula State University.

LITERATURE REVIEW

According to the Intergovernmental Panel on Climate Change (2006), there are five main carbon pools in a terrestrial ecosystem that include biomass: above-ground biomass, below-ground biomass, deadwood, litter, and soil organic matter (Eggleston et al., 2006). Therefore, there are three ways that urban green spaces might lower atmospheric carbon. In order to produce biomass, or plant growth, autotrophs first take up carbon dioxide from the atmosphere. Some of this carbon dioxide is then released back into the atmosphere, while the remainder is stored in plant tissues both above and below ground. Therefore, all autotrophs produce biomass from atmospheric carbon dioxide, but trees are believed to be the main carbon sinks or sponges. Trees that absorb carbon keep it for a longer amount of time using a little escape into the atmosphere. Tree life duration, growth rates, and maturity size all have a significant impact on annual rates of carbon sequestration (Nowak et al., 2002). The biomass either becomes soil carbon or enters the food chain shortly after the trees die. Furthermore, soils contribute significantly to carbon storage. Since litter and woody debris only make up a small percentage of overall carbon stocks, they do not represent a major carbon pool. Third, urban greenery reduces the requirement for cooling by providing shade and evapotranspiration, as well as the demand for heating living areas by lowering wind speed. This significantly decreases the need for fossil fuels for energy generation, therefore offsetting carbon emissions (Suryawanshi et al., 2014).

Green areas are an essential component of a college or university experience. Aside from improving the aesthetics of a college or university campus, green areas foster community development (Matloob et al., 2014), serve as a stress-relieving medium (Seitz et al., 2014), serve as a venue to establish the institute's identity, encourage public health, and provide spiritual experiences (Roman et al., 2017).

Additionally, green spaces offer a range of ecosystem services that are essential to achieving colleges' and universities' sustainability objectives. In this regard, one potentially significant way to reduce the overall carbon footprint of colleges and universities is through the yearly carbon accumulation and sequestration in campus trees globally. This is especially important for schools and universities as the Philippines aims for carbon neutrality (ADB, 2017).

Several studies have been conducted in the Philippines and other countries to characterize the ecological services supplied by urban tree canopy (Roman et al., 2017; Pansit, 2019). However, just a The role of carbon stored and sequestered in trees on college and university campuses in mitigating or reducing their carbon footprint has not received much attention in research.

Bassett (2015) found that trees on the University of Pennsylvania campus saved \$51,871 in building heating/cooling costs and retained 715 t of carbon (Bassett, 2019). At Auburn University in Alabama, USA, Martin et al. (2013) determined how much carbon was stored in managed landscapes (6.7 t/hectare) and uncontrolled landscapes (41.9 t/hectare) (Martin et al., 2012).

According to 1,584 t of carbon were found in 4,139 trees on a New Zealand university campus, according to de Villiers et al. (2014). Additionally, it was found that only around 6% of the university's overall carbon emissions could be reduced by carbon stored in trees during the following ten years.

On the study done at the University of Georgia, it was estimated 73.0 percent (5,049 trees), 32.3 percent (2,236 trees), and 0.7 percent (50 trees) of the 6,915 trees in the study region are native, understory, and invasive trees, respectively (Fox et al., 2020). Trees store 3,450.4 t of carbon overall, with a standard deviation of 65 t. The annual sequestration rate is around 65 t. In comparison, the yearly carbon absorbed by assessed trees over a 10-year period would only account for 1% of the university's GHG emissions for just a year.

According to research conducted in April 2021, There are 285 individuals of 34 different tree species at the Isabela State University Wildlife Sanctuary (ISUWS), which has a total carbon stock of 47.50 t/ha and 164.09 t/ha of stored CO₂ (Pascua et al., 2021). The study finds that *Alstonia scholaris* has the highest amount of above-ground biomass (AGB), with a mass of 20.97 t/ha and a carbon stock of 9.44 t/ha, followed by *Samanea Saman*, which has a mass of 13.40 t/ha and a carbon stock of 6.03 t/ha.

This study seeks to add to the existing literature by calculating the total carbon stored and yearly sequestered in trees located on the Main campus of Bataan Peninsula State University, an urban university located in Balanga City, Bataan in Central Luzon. The primary objective is to describe and measure all of the living trees on the university's main campus in order to determine the overall yearly carbon sequestration capability. The research emphasizes the importance

of trees in tackling the carbon reduction challenges faced by Philippine colleges and institutions. Additionally, this study places the importance of trees in particular and green areas in general in the continuing global push toward sustainable colleges and campuses

METHODOLOGY

Estimating Determining the environmental sustainability and productivity of the area depends heavily on the amount of biomass that has accumulated in the urban plant ecosystem. Additionally, it gives us a sense of the amount of carbon dioxide that can be released when plants and trees are burned or felled. Biomass estimations are primarily responsible for estimating the amount of carbon dioxide that an urban area can absorb from the atmosphere. For many applications, including as urban planning, monitoring carbon stock changes, and comprehending the global carbon cycle, precise biomass estimations are essential. Field calculations can be used to determine biomass. measurements, remote sensing, and GIS techniques (de Villiers et al., 2014; Cox, 2012).

The most often used method for calculating biomass is the use of allometric equations. Allometric equations are developed and used to forest inventory data in order to estimate the biomass and carbon stocks of forests. Generic biomass forecast equations for different forest types and tree species have been developed by several scholars (Xiao et al., 2004, Nelson et al., 1999). By establishing a connection between several tree physical characteristics, such as diameter at breast height, height of the tree trunk, overall height of the tree, crown diameter, tree type, and so on, allometric equations for biomass estimation are produced. Biomass estimations for specific locations and large-scale global and regional comparisons are provided using equations developed for individual species and species mixes.

Creating a program to help with carbon sequestration estimates is one of the study's main goals. This Excel spreadsheet-based tool offers a menu-driven interface for figuring out how much carbon is absorbed and stored by different types of trees in the Philippines.

Carbon dioxide sequestration rates can vary substantially based on assumptions made about tree growth rates, which are heavily influenced by climate and irrigation. Because the Philippines is known to be tropical, the researchers aim to utilize growth rates based on species and age or size of tree in their investigation.

Brown (Pascua et al., 2021), MacDicken (Macdicken, 1997), Ketterings (Ketterings et al., 2001), and Chave et al. (2014) allometric equation will be used to calculate the above-ground biomass (AGB) of the tree species. The carbon stock of the tree will be calculated by multiplying the calculated AGB by 45 percent (Equation 5), which is the average carbon content of wood samples obtained from secondary forests in various places around the Philippines (Lasco et al., 2000). The weight of CO₂ sequestered, on the other hand, will be calculated by multiplying the tree's carbon store by 3.67 (Equation 6), which is the carbon-to-carbon dioxide ratio (Tagupa et al., 2010).

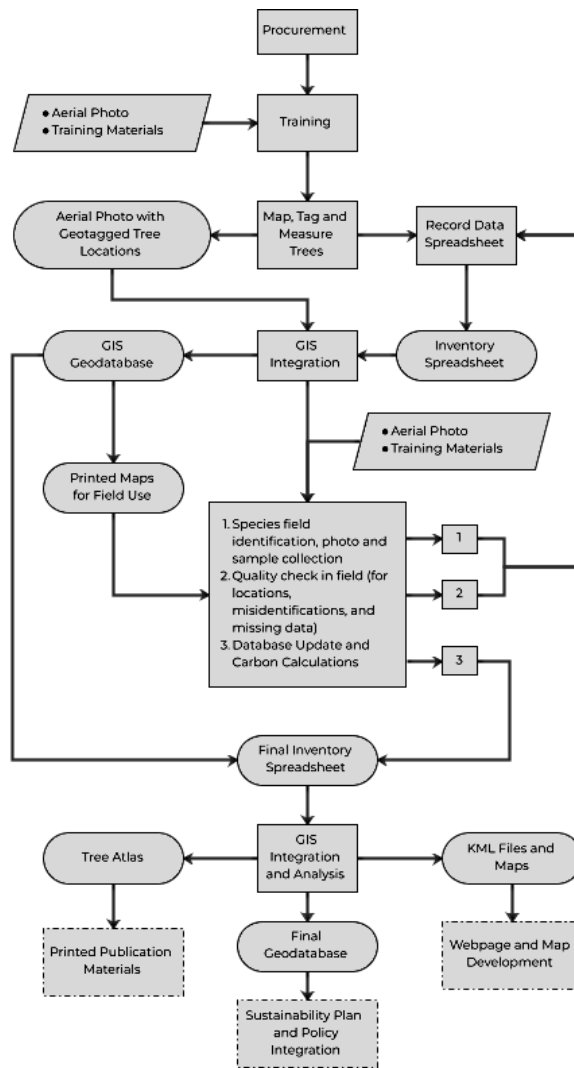


Figure 1. Flowchart Showing the Tree Inventory Process Using a GIS

Equation 1. Brown's Allometric Equation (Chave et al.,2014).

$$AGB = 34.4703 - 8.0671D + 0.6589D^2$$

Equation 2. MacDicken's Allometric Equation (Chave et al.,2014)..

$$AGB = 0.066D^{2.59}$$

Equation 3. Ketterings's Allometric Equation (Chave et al.,2014)..

$$AGB \text{ (kg)} = 0.0673 \times (\rho D^2 H)^{0.976}$$

Equation 4. Chave's Allometric Equation (Chave et al.,2014)..

Where:

AGB = the above-ground biomass in kg.

D = the measured diameter at 1.3 m above the ground in cm

H = the measured height in m

ρ = the tree mean density per specie as estimated by FAO in g.cm-3

$$C = AGB * 45\%$$

Equation 5. Determination of Carbon Stock (Lasco et al.,2000).

Where:

C = carbon stock

AGB = computed above-ground tree biomass

45% = carbon content of tree biomass

$CO_2 = C * 3.67$

Equation 6. Determination of CO₂ Sequestered (Tagupa et al.,2010).

Where:

CO₂ = carbon dioxide sequestered by tree species in their entire lifetime

C = carbon stock of tree species

3.67 = ratio of CO₂ to C

Tree growth rates will be estimated using de Villiers estimated growth rates (de Villiers et al., 2014). The trees were classified, as having different growth rates for each age group. Each year, ages were incremented and tree growth rates from Table 1 were applied. For Ages 0-10, the estimated growth rate was 0.4cm/year in its diameter and 0.6m/year in its height. For, Ages trees were added 0.38 cm on diameter and 1m in its height. For ages 40 and above, on the other hand, the annual carbon stock was assumed to be nearly constant (Leoni et al.,2011). Thus, diameter and height values will not be incremented.

Table 1. Tree Growth Rates

Age range	Incremental diameter (cm)	Incremental height (m)
0-10	0.4	0.6
11-40	0.38	1
40 Above	Nearly constant	Nearly constant

RESULT AND DISCUSSION

The survey on the campus was done in March 2022. A total of 109 trees were measured, identified, and tagged. It was identified that the trees comprise 22 major species which varied across six survey plots. A computational tool built on MS Excel was developed and used for the various allometric calculations. The total weight of carbon in the trees was around 95.54 to 185.43 tons. Thus, trees in the university would have sequestered at least 320.67 tons of carbon dioxide in the most conservative estimates throughout its lifespan. Using growth rates from existing studies on tropical rainforests (Laing et al.,2021), the trees are expected to have sequestered an average of 553.68 tons of carbon dioxide in their lifetime.

Current Carbon Sequestration Per Allometric Equation

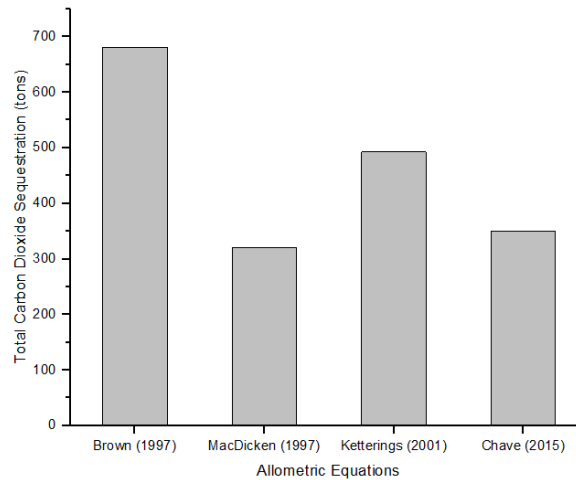


Figure 2. Comparison of Total Carbon Dioxide Sequestered by Trees in the Campus by the different Allometric Equations

The above-ground biomass of the campus was calculated using the available allometric equations in the current studies. This resulted in varying values for the sequestered carbon dioxide. Using Brown's equation (Nelson et al., 1999), the total sequestered carbon dioxide yielded 680.53 metric tons which is more than twice Mac Dicken's (Macdicken, 1997) estimate of 320.67 metric tons. This is due to uncertainties introduced by different climates from which the allometric equations were fitted. Moreover, Mac Dicken's equation used a second-degree polynomial fitting. Although this would create a greater accuracy at smaller heights, it introduces lower values for trees larger than 40cm in diameter. Calibrated allometric equations for the tropics, Ketterings et. al (Ketterings et al., 2001) and Chave, et al (Chave et al., 2014), resulted in median values with 492.42 and 350.62 metric tons respectively. Kettering's equation was calibrated in a pantropical location which includes the study area. This greatly improved the accuracy of the calculations in terms of climate appropriation. On the other hand, Chave offered equations with height and density as independent variables to create a more species-specific result.

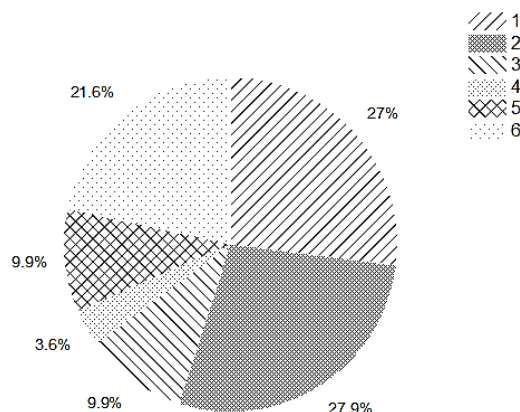


Figure 3. Tree Distribution per Area

Per Area

The campus was divided into 6 distinct areas to efficiently facilitate the survey. Figure 4.2 shows the total carbon sequestration of every area in the campus. Note that although more trees have been measured in Area 1 (Figure 4.3), it contains around half the of the Total Carbon Sequestered in Area 6. This is due to the comparatively larger sizes of trees found in Areas 2 and 6. Thus, Area 2 and Area 6 contain more than 250 metric tons of carbon; which means there is more carbon in those areas than the sum of all the remaining areas.

Table 2. Total Carbon Sequestered Per Species

Species	Count	Total Carbon Sequestration (metric tons)
Swietenia macrophylla	31	67.60
Albizia saman	3	62.01
Artocarpus heterophyllus	7	52.30
Syzygium cumini	9	51.87
Anacardium occidentale	9	32.04
Eucalyptus deglupta	8	30.74
Acacia mangium	7	30.47
Mangifera indica	11	29.39
Cassia siamea	2	27.58
Azadirachta indica	4	21.09
Chrysophyllum cainito	2	19.34
Plumeria acuminata	2	10.35
Pterocarpus indicus	2	9.32
Intsia bijuga	1	5.51
Muntingia calabura	1	4.42
Cocos nucifera	4	3.75
Cananga odorata	1	1.34
Artocarpus altilis	1	0.72
Manilkara kaukii	1	0.65
Paraserianthes falcataria	1	0.27

Araucaria cunninghamii	1	0.15
Manilkara zapota	1	0.13

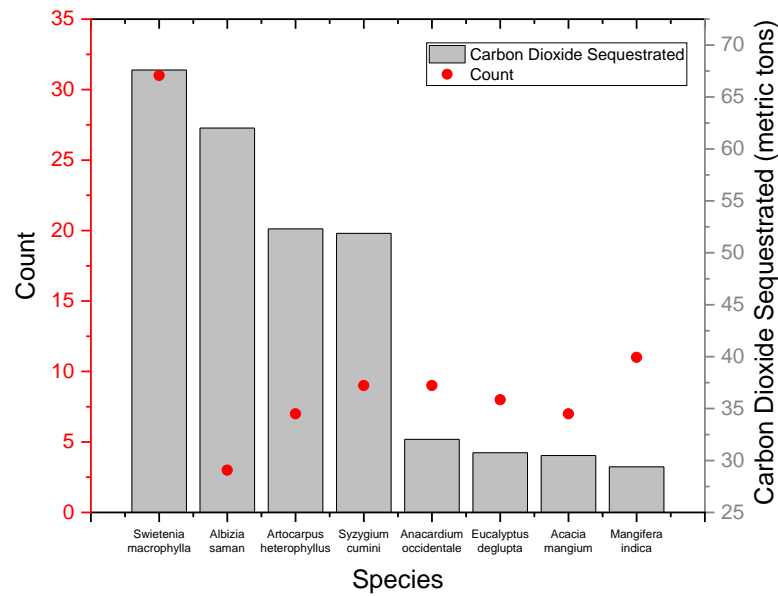


Figure 4. Total Carbon Sequestered Per Species of the 80% Percentile **By Species**

Among the tree species, *Swietenia Macrophylla* or Mahogany sequestered more than 67 metric tons of carbon dioxide, and the most sequestration among the tree species. This is evident provided that it contains more than 28% of trees in the campus. In comparison, *Albizia Saman* or *Acacia* sequesters only 5 metric tons less than *Swietenia Macrophylla* despite having the lowest number of trees in the 80th Percentile (Figure 4). This entails that *Acacia* trees sequester almost 10 times as Mahogany Trees.

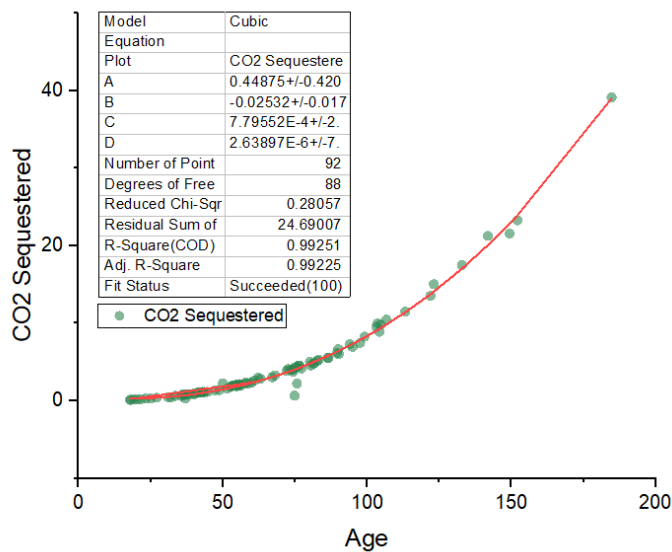


Figure 5. Cubic Polynomial Fitting for Age and CO2 Sequestration

By Ages

Trees Sequester at varying rates throughout its lifespan. Figure 4.5 shows the total carbon dioxide sequestered of Trees in the campus with respect with its age. The trees follow a third-degree polynomial curve, having a high correlation with an r-squared value of 0.99.

Predicted Carbon Sequestration from 2020 to 2030

Carbon sequestration was predicted using growth rates from de Villiers (de Villiers et al., 2014) as shown in Table 4.1. As tree ages beyond 40, it is expected to decrease its growth rate significantly to a halt. This would indicate a decreasing carbon dioxide sequestration annually. As more and more trees reach above 40 years old. As indicated in Figure 4.6, currently there is only 20% of trees in the campus still actively contributing to carbon dioxide sequestration. Thus, if no new trees are planted, the carbon sequestration inside the campus would curve to a halt in the next 8 years as indicated in Figure 6.

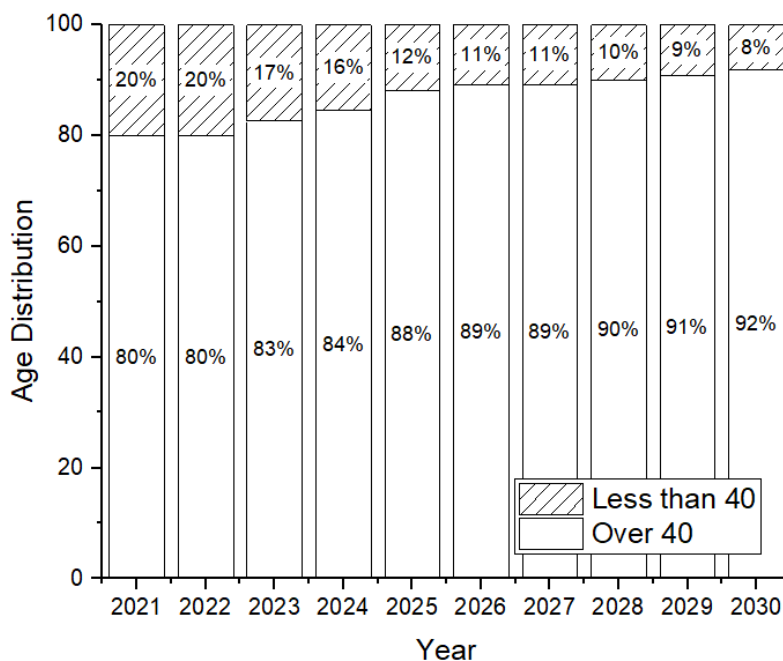


Figure 6. Age Distribution of Ages Above and Below 40 Years Old on the Campus

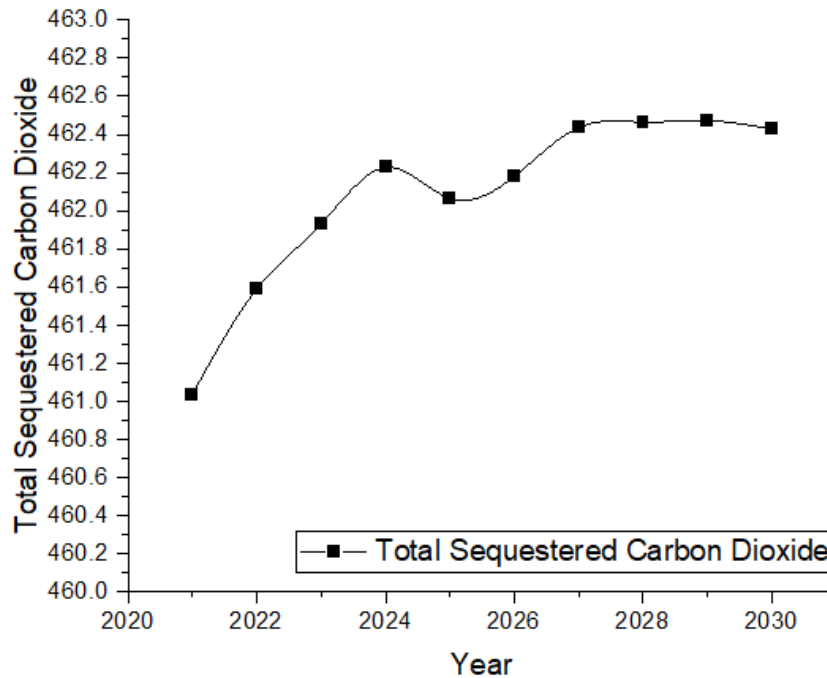


Figure 7. Total Carbon Dioxide Sequestered from 2020 to 2031 as Calculated Using the Growth Rate Using de Villiers

CONCLUSION ND RECOMMENDATION

The total carbon dioxide sequestered by the tree vegetation in Bataan Peninsula State University-Main Campus was estimated. Using tree growth rates equations, the potential annual carbon dioxide sequestration in the campus was calculated. To estimate current biomass, allometric equations for tropical rainforests were used. Then, Equation 5 and Equation 6 were used to estimate the corresponding total carbon dioxide sequestered from biomass. The circumference and height measurements of 109 trees were determined and tree ages were estimated. It was found that the trees sequestered around 461 metric tons of carbon dioxide in their lifetime. Applying growth rates, the carbon dioxide sequestration in the university is slowing down to a halt with only another 2 metric tons expected to be sequestered in the next decade. This is less than 1% of the total projected carbon emissions of the university. Thus, environmental initiatives centered on tree planting and carbon dioxide sequestration are encouraged.

The Bataan Peninsula State University Main Campus, Philippines has a relatively small area allowing for a limited number of planted vegetation. This indicates a modest carbon dioxide sequestration compared to other campuses. Hence, efforts around carbon dioxide sequestration such as tree planting and tree census will help the university's environmental health. A university-wide carbon management program will help monitor such initiatives help the university garner accolades on environmental research and protection and ultimately enhance the university's environmental reputation. Moreover, the established Office of Environmental Sustainability is strategically inclined to lead the university into implementing initiatives that holistically and strategically utilize its ecological resources.

FURTER STUDY

Further studies on tree growth rates and species-specific growing conditions can guide future initiatives on carbon sequestration. Improvement in the tree records and allometric estimates will show the greatest increase in the accuracy of this study. Moreover, this study can still be improved by accounting for growth requirements and climactic conditions to improve the accuracy of the annual sequestration estimates. Modern GIS techniques on elevation and terrain analysis can also be utilized to exceed the spatial limitations of this research. Through this, we will be able to create a more accurate picture of the health of our environment, the impact of our initiatives, and capacity of our ecological spheres to mitigate the impacts of climate change.

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