Carbon Storage Potential of Mahogany (*Swietenia* spp.) Forest in Cavite State University, Philippines: A Basis for a Carbon Mitigation Plan

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ABSTRACT

A tropical forest has a valuable role in relation to climate change being a source and sink of carbon. The study created a distribution map of mahogany found trees (*Swietenia macrophylla*) in Cavite State University; determined the morphometrics of mahogany trees in the university in terms of diameter at breast height (DBH) and height; determined the total carbon storage of mahogany trees in the university; determined the factors affecting carbon sequestration of the mahogany; and created a proposed carbon mitigation plan for the utilization and management of mahogany trees in the university. The height and diameter at DBH of all mahogany trees were measured. Allometric equation was used to calculate the carbon storage of mahogany trees. The location of mahogany trees was determined using Global Positioning System device. There are 3,402 mahogany trees inside the university. Majority of the mahogany trees have a diameter of 30 cm and there are 712 mahogany trees that have DBH below 30 cm. Mahogany forest covers about 7.32 ha of the total land area (76.19 ha.) of Cavite State University and it cumulatively stored carbon amounting to 1,960.79 Mg C ha^{-1}. The height of mahogany greatly affected the carbon sequestration of mahogany trees since the growth of the tree indicates increasing biomass, thus, carbon is being stored in the body of the tree. CvSU contributed in carbon mitigation since there is a high density of forest found inside the campus.

Keywords: *carbon sequestration , carbon storage, morphometrics*

INTRODUCTION

Climate change is one of the concerns of the world today. Global surface temperature has increased by more than 0.8 °C since 1980 and average temperature has exceeded in the last century average every year (Global Change, 2017). Anthropogenic activities like burning of fossil fuels such as coal, oil, and gas, have caused an increase in the level of carbon dioxide (CO_2) in the atmosphere. Potential impacts of climate change include sea-level rise, increased wildfires, floods, droughts, tropical storms; change in amount, timing, and distribution of rain, snow and runoff; and disturbance of coastal marine and other ecosystems (Sunquist *et al.,* 2008). Moreover, carbon dioxide level increased by 46 percent in over 250 years (Hindustantimes, 2019), thus, mitigation and efforts, small or big scale, must be done in order to reduce the impacts of climate change. The Intergovernmental Panel on Climate Change (IPCC) emphasized that the impacts of 2.7 degrees Fahrenheit of global warming are far greater than the expected. This rise in the global temperature could happen within 11 to 20 years with the continuous emission of carbon dioxide (Leahay, 2018).

Carbon sinks on Earth like tropical forest play a significant role in harvesting large amounts of carbon from the atmosphere and has a big contribution in relation to climate change being a source and sink of carbon (Lasco & Pulhin, 2003; Ussiri & Lal, 2017). Carbon sequestration, a process by which atmospheric carbon dioxide is taken by plants through photosynthesis and eventually stored in the biomass and soils. Tree biomass stores carbon through photosynthesis, therefore deforestation lessen the number of carbon storage, that can reduce and slow down the process of global warming (Reicosky, 2008). Tropical forests contain about 25 percent of the world's carbon and the forest region of the world adds another 20 percent of the world's carbon (Yale University, 2019). Thus, managing forest resources and protecting these from anthropogenic activities were recommended to achieve environmental sustainability (Sheikh & Kumar, 2010).

The Philippine forest ecosystem have always been the source and sink of carbon. The Philippine forest land have a great possibility to sequester and store carbon due to its immense and abundance of vegetation (Lasco *et al*., 2004). In one of the studies in the Philippines, carbon storage of mahogany has been evaluated, since this species was used in reforestation program in the country. The Mt. Makiling Forest Reserve in Laguna has a mahogany transplantation and its carbon storage after a decade was evaluated to determine its contribution in climate change mitigation (Racelis *et a*l., 2019).

Cavite State University (CvSU) Don Severino de las Alas Campus is situated at Barangay Bancod, Indang, Cavite. CvSU has an area coverage of 76.19 hectares. The most abundant tree found inside the university is mahogany with 1,679 trees as of 2017 (CvSU-Environmental Performance Report & Management Plan, 2017). Mahogany (*Sweitenia macrophylla*) trees produce wood that is dense, and the tree that can hold its own in strong winds and makes it useful as a street tree (Spengler, 2019). Mahogany was first imported to Europe in 1724, and soon became known because of its different characteristics (Britannica, 2019) and can grow rapidly until it dominates an area by inhibiting the growth of other species or allelopathy, usually the native species (Bareja, 2012).

Objectives of the Study

The study primarily aimed to determine the carbon storage potential of mahogany forest found in Cavite State University.

Specifically, this study aimed to:

1. Create a distribution map of mahogany tree in the university;
2. Determine the morphometrics of mahogany trees in the university in terms of diameter at breast height (DBH) and height;
3. Determine the total carbon storage of mahogany trees in the university;
4. Determine the factors affecting the carbon sequestration of mahogany trees in the university; and
5. Create a proposed carbon mitigation plan for the utilization and management of mahogany trees in the university.

METHODOLOGY

Study Area

Cavite State University (Figure 1) has an area coverage of 76.1891 hectares. The university is located in Indang, Cavite with a geographical location of 14°11'55.60'' N and 120°52'51.63' E (CvSU-EPRMP, 2017).

Mapping of mahogany plantations in Cavite State University

A GPS device was used to get the coordinates of the mahogany trees in the university. ArcMap 10.4 was used to map the location of the distribution of mahogany trees in the university.

Tree categorization and classification

This study has covered all the mahogany trees that can be found in the study area. The trees were categorized based on their diameter at breast height (DBH) whether they are sapling (<10cm), poles (10-30cm), and standard (>30cm) (Maclauchlan, 2009).

Diameter at breast height (DBH) measurement

To determine the DBH of the trees, 1.3 m was measured above the soil surface, except when the trunk has irregularities. When there are two trunks, the DBH was measured as the average of

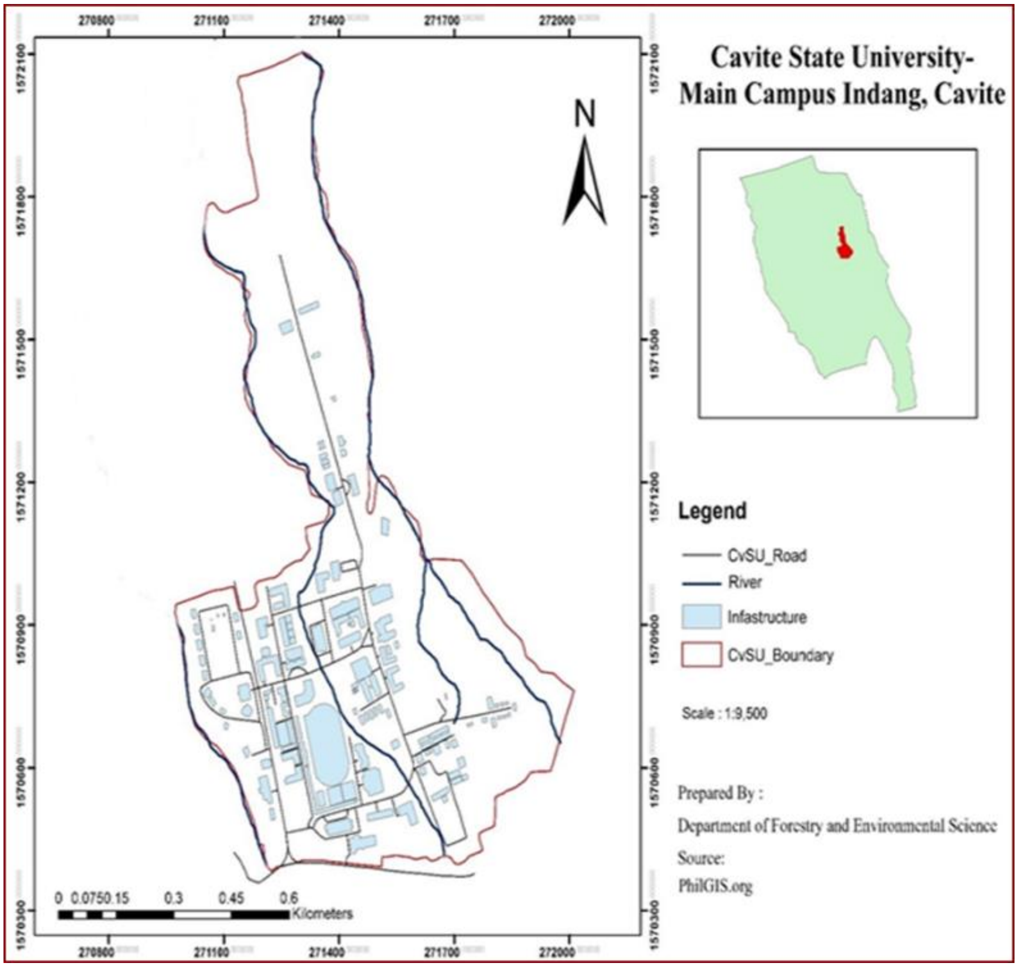

Figure 1. Cavite State University - Don Severino de las Alas Campus
Indang, Cavite (CvSU-EPRMP, 2017)

the two trunks. Tape measure was used to obtain the DBH (Hairiah *et al*., 2001).

Tree height measurement

A rangefinder was used to determine the angle to the tip of the tree based on a fixed distance from the sampled tree. The tree height can be determined according to the scale reading on the clinometer (Hairiah *et al*., 2001).

Computation of aboveground biomass (AGB) of Tree

The biomass was estimated using allometric equation. Aboveground biomass was calculated by multiplying the bio-volume to the green wood density of the species. Tree bio-volume (T_{BV}) value was calculated by multiplying the diameter and height of the tree species to factor 0.4.

$$\text{Tree Bio-volume } (T_{BV}) = 0.4 \times (D)^2 \times H$$

$$\text{Aboveground Biomass (AGB)} = \text{wood density} \times T_{BV}$$

where:

T_{BV} = Tree bio-volume

AGB = Aboveground Biomass

D = diameter

H = height

whereas:

Diameter in meter (D) = GBH/π

H = height (meter)

Wood density was obtained from the Global Wood Density Database (Dryad, 2009). The standard average density of 0.6 g/cm^3 is applied whenever the density value is not available for the tree species (Zanne *et al.,* 2009)**.**

Computation of belowground biomass (BGB)

The belowground biomass was calculated by multiplying the aboveground biomass by 0.26 factors as the root and shoot ratio. It excludes fine roots having < 2mm diameter (Hangarge et al., 2012).

Belowground Biomass (BGB) = AGB x 0.26

where:

BGB= belowground biomass

AGB= aboveground biomass

Computation of total biomass

The total biomass was calculated by adding the aboveground biomass and belowground biomass (Sheikh et al., 2011).

Total Biomass = AGB + BGB

where:

BGB= belowground biomass

AGB= aboveground biomass

Estimation of carbon on trees

According to Pearson, Brown, & Birdsey (2005), generally, 50 percent of the biomass of trees is considered as carbon.

Carbon storage = total biomass x 50%

Computation of tree biomass density and carbon stored was calculated using the following equations (Lasco & Pulhin, 2003):

Tree Biomass Density= tree biomass/ sample area in hectare

Carbon Stored (MgC^{ha-1}) = tree biomass density x Carbon content

where:

MgC^{ha-1} =Tonne

Statistical analysis

The non-linear models were used to determine the carbon sequestration potential of mahogany trees in Cavite State University. The basic biomass model consists of estimating the components of the model.

Nonlinear: Y= $X^{\beta} + \varepsilon$

where:

Y = observed tree biomass

X = predictor variable (diameter, height)

β = model parameter

ε = error term

RESULTS AND DISCUSSION

Mahogany Trees in Cavite State University

Cavite State University - Don Severino de las Alas Campus has a wide distribution of mahogany trees with a total cover of 7.32 hectares (Figure 2). The mahogany trees dominated the riparian area within the vicinity of the university. There are 3,402 mahogany trees based on the conducted total enumeration of mahogany trees (Table 1). The enumerated trees are classified based on their diameter at breast height; 2,690 trees have a diameter of 30cm and 712 trees have DBH below 30cm (Figures 2 and 3).

Diameter at Breast Height and Height of the Mahogany Trees

Table 2 shows the structural parameters of the morphometric profile of mahogany trees. The morphometrics of trees predict the carbon storage of a tree.

Each tree species plays an important role in carbon sequestration. The mahogany tree is the most abundant tree based on the CvSU Environmental Performance Report and Management Plan (2017). Being dominant, mahogany absorbs high amounts of carbon dioxide compared to other tree species that has low population. The amount of carbon stored in a forest is based on the size and the age of the tree; the older trees have low rate of carbon sequestration (Sheikh & Kumar, 2010).

Biomass of Mahogany Trees

Forest biometrics increase the demand for the accuracy and precision in quantitative approaches for computing the carbon sequestration potential. Biometric is important for forest measurement as tool of forestry science (Oregon State University, 2011). Half (50%) of the biomass of trees is considered as carbon

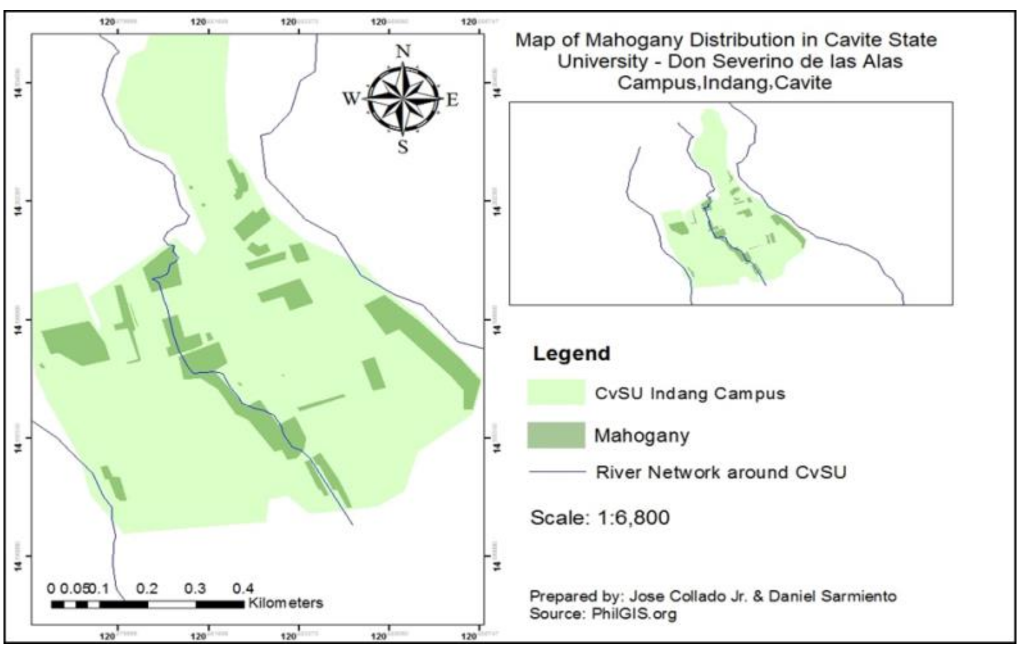

Figure 2. Map of mahogany distribution in Cavite State University-Don Severino delas Alas Campus, Indang, Cavite

according to Pearson, Brown, & Birdsey (2005) as cited by Suryawanshi, Patel, Kale, & Patil (2014). Table 3 shows the forest biometrics of mahogany trees. The aboveground and belowground biomass of trees account for the total carbon stored by the mahogany trees.

Initiative of the university in conserving trees within the campus is essential and CvSU's efforts in planting trees inside the campus lead to a total carbon storage of 1,960.79 Mg C ha^{-1}. In a study conducted at the Mt. Makiling Forest Reserve in Laguna, Philippines, the mahogany plantation present in the area has a total carbon storage of 542.58 Mg C ha^{-1} for the 387 trees inventoried (Racelis et al., 2019). Similarly, in other countries like Taiwan, the man-made forest present in the area was evaluated based on its carbon storage and the study showed that the Taiwan red cypress forest has a total carbon storage of 68.85–96.81 Mg C ha^{-1} and Japanese cedar has a total carbon storage 101.14–164.80 Mg ha^{-1} (Yen and Wang, 2013). Carbon storage cannot be materialized or monetized, thus it is

Table 1. Tree categorization

TREE CATEGORIES	NUMBER OF TREES	PERCENTAGE
Sapling > 10cm	601	17.67%
Poles 11 - 29cm	1,977	58.11%
Standard < 30cm	824	24.22%
TOTAL	**3,402**	**100%**

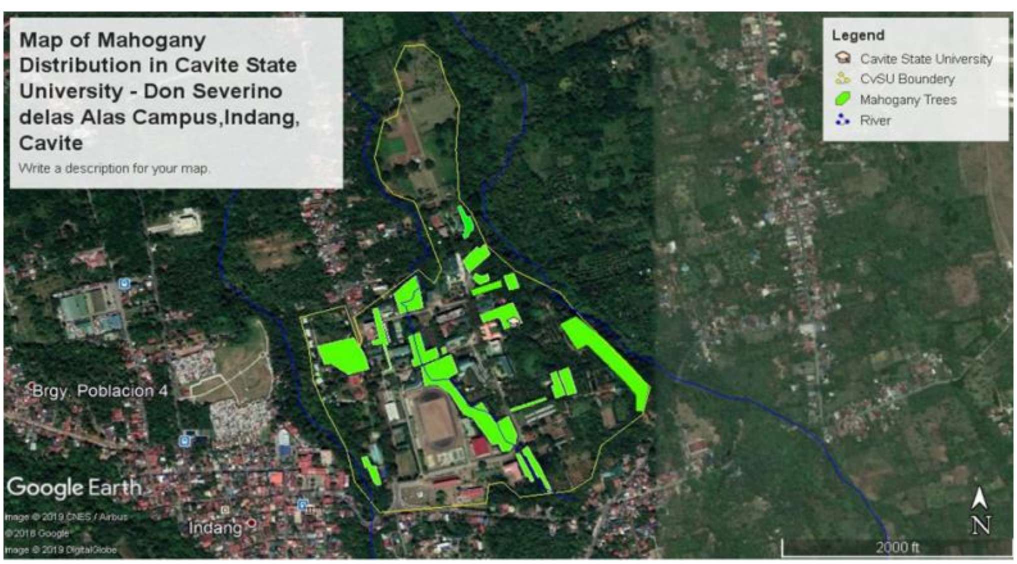

Figure 3. Map of mahogany distribution in Cavite State University-Don Severino delas Alas Campus, Indang, Cavite (Google Earth Pro)

Table 2. Morphometric profile of mahogany trees in Cavite State University

STRUCTURAL PARAMETER	MEAN ± STANDARD DEVIATION
Diameter at Breast Height (cm)	21.16 ± 9.99
Height (m)	8.20 ± 2.95
Tree volume (kg cm2)	1467.47 ± 117.93

Table 3. Carbon sequestration of mahogany-dominated vegetation

FOREST BIOMETRICS	TOTAL
Total Biomass	Tonnes
Aboveground Biomass	3,778,568.32
Belowground Biomass	982,427.76
Tree Biomass Density	650.41
Carbon Content	2,380.50
Carbon Storage	1,960.79

undervalued; However, a tree census could form the basis for carbon management program (De Villiers, 2014).

Carbon Sequestration Modelling

Figure 4.0 and 4.1 show the nonlinear model of the diameter at breast height and height of the mahogany to its biomass. The graphs show that the height of the trees predicts its biomass more than the DBH does. Thus, the carbon sequestration of trees is highly affected by the height of the tree rather than the diameter at breast height which is contradicting with the consistent findings of other studies which show that DBH is the predictor of carbon storage of trees. This is evident in the study of Afzal & Akhtar (2013) where DBH is proved to be a highly significant factor affecting carbon sequestration in a tree. In view of advances in describing productivity of trees, no consensus exists about the nature of productivity at the scale of the individual tree (Stephenson et al., 2014). However, it is still evident that the growth of the trees including height, ring width, and basal increment contribute to carbon storage of trees (Sillett et al., 2010), thus, larger trees fix large amount of carbon than the smaller trees (Stephenson et al., 2014).

Table 4 shows the regression model diagnostics. This model formulates assumptions and investigates whether or not there are observations with a large analysis. Carbon sequestration based on DBH was 15, 015 and the carbon sequestration based on the height was 3, 733. Based on the value of Akaike Information Criterion (AIC), height has a lower value than DBH. Therefore, the higher the height of the tree, the higher its carbon sequestration.

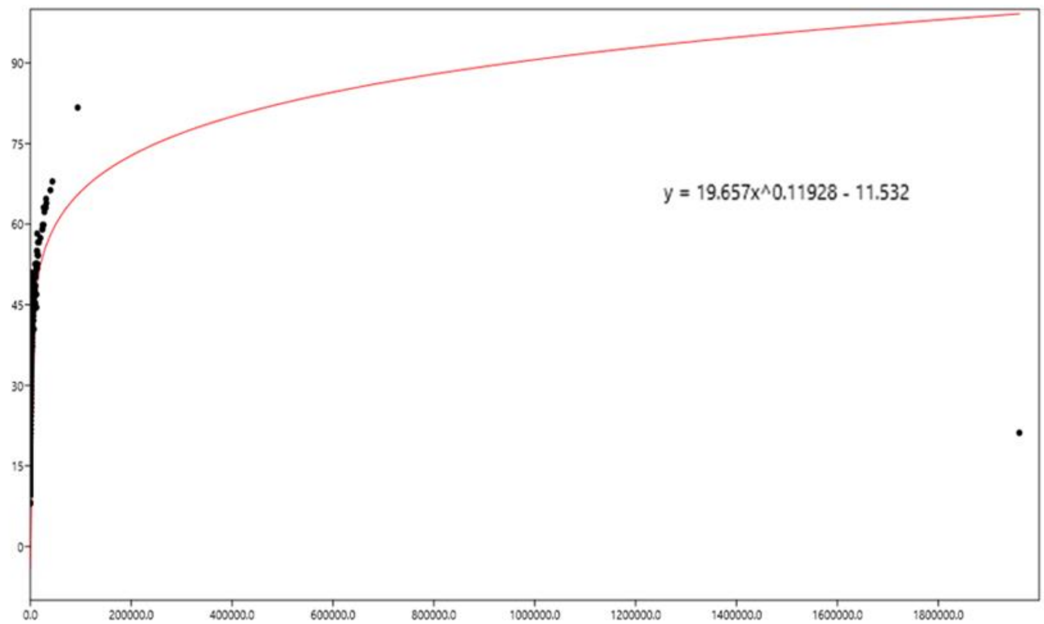

Figure 4.0. Nonlinear Model of the Carbon Sequestration vs. DBH of Mahogany

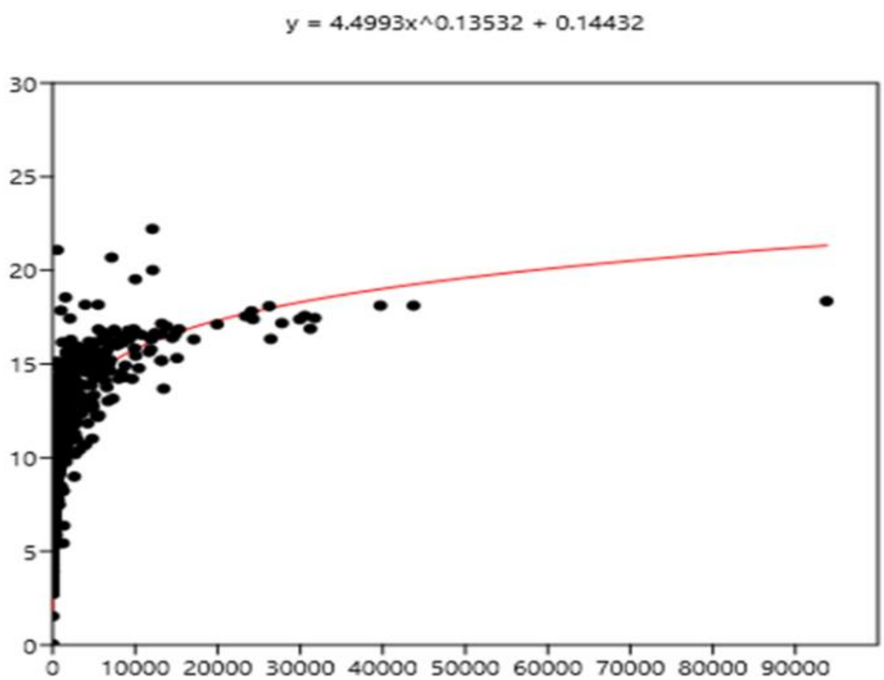

Figure 4.1. Nonlinear Model of the Carbon Sequestration vs. Height of Mahogany

Table 4. Regression model diagnostics

MODEL	AKAIKE INFORMATION CRITERION (AIC) VALUE
1 (Carbon Sequestration-DBH)	15015
2 (Carbon Sequestration-Height)	3733

*Lesser AIC means robust or best model.

Proposed Carbon Mitigation Plan

This plan is proposed to evaluate the different options on how to utilize the mahogany trees found inside the university since it is considered now as an invasive alien species (IAS). Table 5 shows that the best option for carbon mitigation plan is Plan B, to cut all mahogany trees for furniture production. Based on the impact categorization, Plan B will provide a livelihood from furniture. Moreover, there will be minimal emission of carbon and high economic benefit. Furniture making preserves the body of the tree and prevent release of carbon into the atmosphere. Plan A is almost the same as Plan B, but instead of making furniture, it just produced logs for other purposes. Plan C, charcoal production is not recommended as an option for carbon mitigation plan since it releases a high amount of carbon back to the atmosphere.

CONCLUSIONS

Based on the results, the following conclusions were drawn:

1. The university has a wide distribution of mahogany trees with a total cover of 7.32 hectares.
2. There are 3,402 mahogany trees based on the conducted total enumeration of mahogany trees. The enumerated trees are classified based on their diameter at breast height; 2,690 trees have a diameter of 30cm and 712 trees have diameter below 30cm.
3. Mahogany forest covers about 7.32 ha of Cavite State University and it stored carbon amounting to 1,960.79 tons. These trees served as carbon sinks in the university, thereby contributing to climate change mitigation. Cavite State University houses different species of trees and eventually be a carbon sink.
4. Carbon sequestration modelling through non-linear modelling shows that the height of the mahogany tree affects the tree biomass.
5. Carbon mitigation plan for mahogany forest is essential for decision making. Charcoal production as an option in carbon mitigation is not advisable to do since it releases high amounts of carbon back to the atmosphere since it involves combustion process. Moreover, this option has a low economic benefit. Cutting all mahogany trees for furniture production is the most recommended. It will provide a livelihood from furniture and shall cause minimal emission of carbon and high economic benefit.

RECOMMENDATIONS

It is recommended that the carbon storage assessment of all the trees found inside Cavite State University be conducted to determine their potential as good carbon sinks that can help

OPTION	SET UP REQUIREMENTS	EXECUTION	ESTIMATED BUDGET	EXPECTED ACTION	PRESENCE OF CARBON EMISSION	IMPACT
Plan A- Cut all mahogany trees for log production	Tools -manpower -power saw	1-3 months	Php 100,000	Sell the logs	Yes	Minimal emission of carbon to the atmosphere; high capital cost; less economic benefit
Plan B- Cut all mahogany trees for furniture production	Tools -manpower -power saw	1-3 months	Php 100,000	Make a furniture and sell	Yes	Minimal emission of carbon to the atmosphere; high capital cost; higher economic benefit
Plan C- Charcoal production out of all mahogany trees	Tools -manpower -power saw	3-6 months	Php 50,000	Produce charcoal and sell	Yes	Higher emission of carbon to the atmosphere; low capital costs; less economic value
Plan D- Planting of mahogany	Tools -manpower	1-2 months	Php 20,000	Become more invasive	No	No emission of carbon to the atmosphere; low capital cost; no return of investment
Plan E- let the mahogany tree grow		None	None	Become more invasive	No	No emission of carbon to the atmosphere; no capital cost; no return of investment

Impact categorization: best- green; good- yellow; fair- red mitigate climate change. It is also suggested that the carbon mitigation action plan be considered for decision making regarding the utilization of mahogany trees inside the university since it is considered as an invasive species. Cavite State University must continue planting trees inside the campus and plan tree planting activities wisely to avoid conflict with the future plans of the university. CvSU must not use invasive alien species in tree planting activities instead plant native and endemic trees. Moreover, planting trees must be practiced by different institutions to contribute in combating climate change as a global challenge.

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