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GIS-assisted Carbon Stock Assessment of Loboc-Bilar Mahogany Plantation, Bohol, Philippines

ABSTRACT

The study determined the carbon budget of the Loboc-Bilar Mahogany (Swietenia macrophylla King.) Plantation in the province of Bohol, Philippines within the months of June to October 2018. The plantation straddles two municipalities, Loboc and Bilar. It is a popular destination for local and international tourists due to its compelling tunnel-like vegetative scenery. Delineation of the plantation boundary was fine-tuned using both image digitization and ground survey. A random sampling method was applied in conjunction with Geographic Information System (GIS) software to spatially distribute sampling plots in the research area. Several carbon pools were assessed, namely: aboveground biomass, necromass or ground biomass, and belowground biomass. Allometric and other mathematical equations were used in the calculation of biomass density, stored carbon and carbon dioxide equivalents. The plantation had 29,428.03 Mg of stored carbon in the biomass distributed over a total land area of 115.21 ha, yielding an estimated stored carbon density of 255.43 Mg ha^{-1}. The monetized value of stored carbon in the whole plantation amounted to US$486,003.96.

Key words: *allometric equation, carbon budget, carbon stock, mahogany plantation*

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INTRODUCTION

The recent weather abnormalities experienced in the Philippines and around the world are indications of a changing climate (*IPCC 2001; Lasco and Pulhin 2003; Labata et al. 2012*). This has been brought by the ever increasing carbon dioxide (CO_2) concentration in the atmosphere causing global warming. Worldwide, the concentration of atmospheric CO_2 has risen in the beginning of the industrial era in 1970 from approximately 277 parts per million (ppm) to 399.4 + 0.1 ppm in 2015 (*Le Quere et al. 2016*). Initially, the atmospheric CO_2 increase above pre-industrial levels was primarily caused by the release of carbon to the atmosphere from deforestation and other land-use-change activities (*Ciais et al. 2013*). Then emissions from fossil fuels followed and became the dominant source of anthropogenic emissions to the atmosphere since around 1920 (*Archer et al. 2009*). Its relative share has continued to increase until present and may reach an alarming rate in the very near future.

Both the frequency and intensity of storms and typhoons are believed to be caused by climate change. In the Philippines, an average of 20 typhoons enter its area of responsibility and the last 10-year records reveal an increase in number and intensity leading to increased destruction and disaster. Recent examples include tropical storms Sendong (Washi), Yolanda (Haian) and Seniang, which together claimed thousands of lives, destroyed billions worth of infrastructure and agricultural crops, and devastated cities and provinces. The situation is likely to worsen because the country is the third most vulnerable in the world to climate change (*Labata et al. 2012; Cruz et al. 2017*).

Even as the country receives some of the most extreme effects of climate change, because of its vast forest reserves, it also has the seventh greatest potential among tropical countries to mitigate climate change through sequestration of the greenhouse gas - carbon dioxide (*Cruz et al. 2017*). Unfortunately, this potential is not being realized, because much forest land in the Philippines is continuously being converted into croplands for food production, without regard to the effects on local carbon pools. As forests are converted into agricultural land, they become a net source of greenhouse gas. The agriculture and forestry sectors in the Philippines contribute more than 33% of the country's total greenhouse gas emissions (*Forestry Statistics 2017*).

However, productivity does not necessitate a reduction in the carbon storage capacity of the land. For

For example, silviculture has the potential to preserve the livelihood and sustenance value of the land while increasing net carbon stocks. In fact, plantations can sometimes sequester more carbon than natural forests. *Lasco and Pulhin* (*1998*) estimated that tree plantations in the Philippines sequester carbon at the annual rate of 2.6 m t, with some plantations approaching 15 t ha^{-1} yr^{-1}. The sequestration potential of a certain tree plantation, however, varies in terms of the type of species, age, and silvicultural practices applied which can enhance the growth of trees and increase their biomass (*Lasco and Pulhin 1998*), and rotation period (*Schroeder et al. 1992*) as cited by *Racelis et al.* (*2008*).

Mahogany (*Swietenia macrophylla* King) is a fast growing tree and has been used to reforest the majority of the marginal areas in the Philippines, including the Loboc-Bilar Mahogany Plantation in Bohol. Apart from its beauty and recreational significance, the plantation is known for having enormous amount of medium and large-sized trees, typical of a forest plantation. However, the carbon stock has not yet been quantified for this plantation, which is a critical first step in determining the ecological value of plantation on climate change mitigation.

Thus, this study was conducted primarily to assess the current carbon budget of the Loboc-Bilar Mahogany Plantation. Specifically, the study intended to apply quantitative and systematic methodology for biomass and carbon estimation with the application of GIS; quantify the biomass and its stored carbon in all carbon pools using allometric and mathematical equations; and finally monetize the stored carbon in the whole plantation.

MATERIALS AND METHODS

Study Site. The carbon accounting study was conducted in a three km stretch of mahogany stand along the boundaries of the municipalities of Loboc and Bilar in the province of Bohol, Philippines (**Figure 1**). Initiated more than half a century ago, Loboc-Bilar mahogany plantation was established through a series of reforestation projects of the then Bureau of Forestry, now Department of Environment and Natural Resources (DENR), and the barangay and municipal local government units, to replace native trees lost from widespread slash-and-burn farming. This reforested area has now become a tourist destination and is home to the Green Tunnel of Bohol which traverses the forest via the national road. The forest stand is located at 9°40’ North and 124°06’ East, about 45 km away from Tagbilaran City and lies at the southern part of Bohol province. The plantation has a total land area of 115.21 ha with elevation ranging from 250 to 350 meters above sea level (masl) and its topography is characterized by moderately rolling terrain with a sandy clay loam type of soil. The area has tropical monsoon climate which belongs to the Climatic Type IV under the Corona Classification. This means that rainfall is more or less evenly distributed throughout the year (*Reyes and Ludevese 2015*). The mahogany plantation, including the rest of the Loboc Watershed, has an annual mean rainfall and temperature of 2,000 mm and 24°C, respectively (*Reyes and Bethune 2017*).

Preliminary Activities

On-Screen Digitization. The canopy color of mahogany plantation is distinct from the surrounding forest vegetation. Google Earth Pro reveals the plantation as a vegetation with distinct dark green color (**Figures 1** and **3**) signifying a unique spectral signature. This makes it easier to perform on-screen digitization of the plantation span. The output of digitization was saved as gpx and kml files for ground truthing using GPS receivers and further GIS processing in desktop computer, respectively.

Ground Truthing and Plantation Boundary Delineation. Ground survey was conducted to determine the real extent of the plantation boundaries. The gpx files stored in GPS receivers were used as guide in the delineation of plantation extent. GPS tracks were saved and imported in the GIS platform. Harmonization of the outputs of on-screen digitization and survey tracks was carried out until fine-tuned plantation boundary was determined. The Loboc-Bilar mahogany plantation was found to have a total land area of 115.21 ha.

Determination of Plot Locations. Selection of survey locations of 100 sampling plots was performed using several functionalities in ArcGIS. Following the principle of random sampling, “create random points” in ArcGIS was used to distribute the plots without bias. This ensured that survey plots well represent the stand structure in the study area taking into consideration the terrain particularly the relative position along the hills and flats including the distance in between them. (**Figure 3**).

Sampling Plot Design. The nested plot design used in this study was modified from the sampling plot designs employed by *Hairiah et al.* (*2001a and 2001b*), *Chave et al.* (*2005*), *Racelis et al.* (*2008*), *Hairiah et al.* (*2011*), *Reyes et al.* (*2011*) and *Walker et al.* (*2012*) with the intention of spreading as many plots as possible within the plantation.

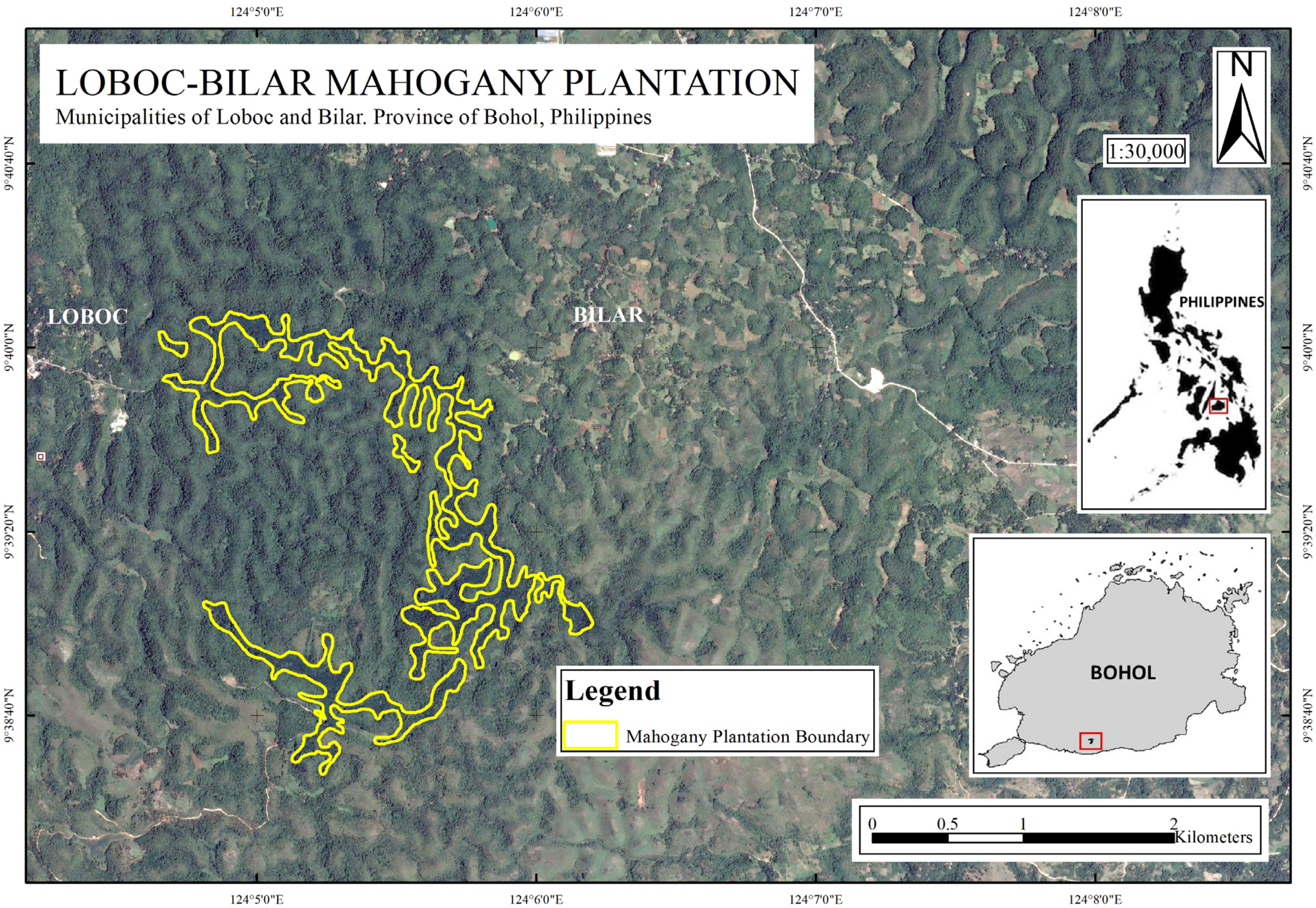

Figure 1. Google Earth map showing the location of the Loboc-Bilar mahogany plantation, Bohol, Philippines (in yellow color).

Field Survey

Field Data Collection. Trees, regardless of species, with diameter at breast height (DBH) of >30 cm were recorded in a 20 x 20 m plot. Trees and other woody plants with DBH of 5-30 cm were sampled from within a smaller 5x5 m plot. Within the 5x5 plot, understorey vegetation, litter, and soil were assessed in four smaller plots of 1x1 m each.

Non-destructive sampling was applied in the 20 x 20 m and 5 x 5 m plots, while destructive sampling was employed in the smallest plots. Fresh and oven-dry weights were recorded in all harvested specimens. In particular, composite soil samples were collected with an aid of a soil auger at the centermost part of smallest plots for per cent organic matter (OM) analysis. Organic carbon (OC) was computed as a fraction of OM. Density sampler, on the other hand, was used to collect core soil samples for bulk density calculation. The average soil depth in the study was about 0.35 m, thus, soil collection using an auger was not difficult. Snags and fallen dead branches were regularly collected for firewood by nearby community residents, thus, were not included as part of the necromass or ground biomass (**Figure 2**).

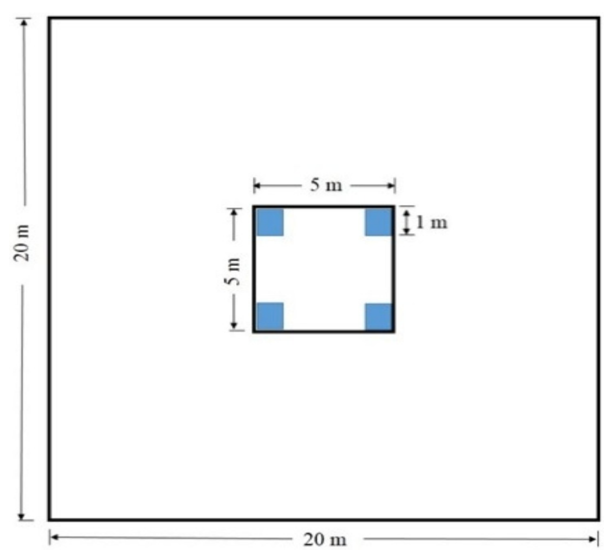

Figure 2. Nested plot design for sampling carbon (C) pool.

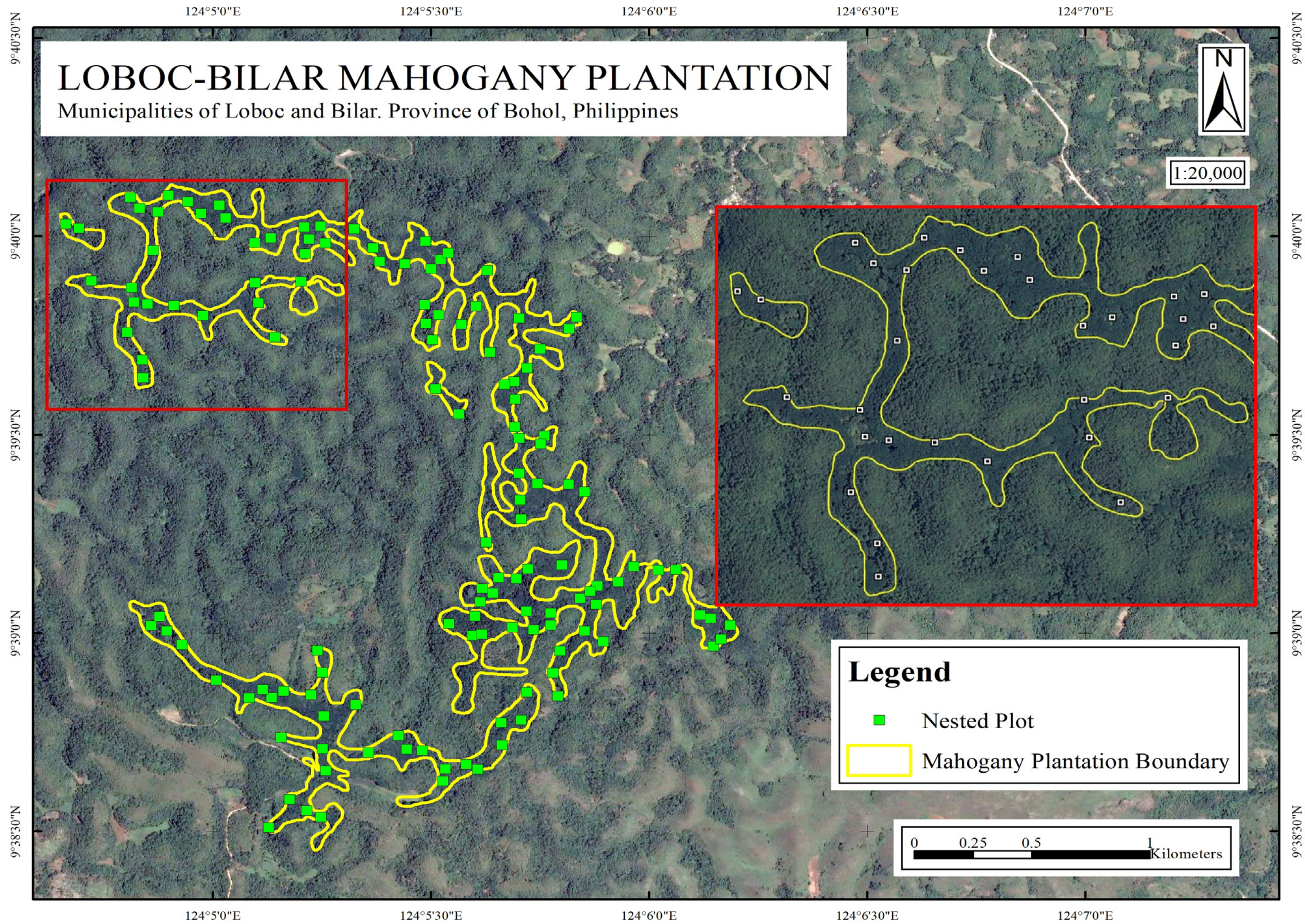

Figure 3. Google Earth map of Loboc-Bilar mahogany plantation, Bohol, Philippines showing locations of randomly assigned sampling plots.

Stand Structure. There were 2,345 saplings, juvenile, and matured trees recorded in the study site, 1,718 individuals were mahogany trees at an average of 6 large mahogany trees per plot. Mahogany trees had an average diameter at breast height (DBH) of 36.7 cm with a mean total height (TH) of 18.4 m. Other tree species, on the other hand, had an average DBH of 10.1 cm and a mean TH of 6.6 m. The largest DBH tree recorded within the stand was 91.2 cm. The stand had a density of 586 trees ha^{-1} and an average basal area of 37.0 m^{-2} ha^{-1}. No silvicultural treatments have been applied except on bucking of fallen trees blocking the road and salvage cutting of leaning trees hazardous to passing vehicles, walking by-passers and/or tourists. Portions of the stand were utilized as enrichment planting sites for the National Greening Program (NGP) of DENR-CENRO Tagbilaran City, Bohol.

Data Analysis:

Allometric equations were used in this study to estimate the above-and-belowground biomass from field measurements. Above-ground biomass (AGB) equations for mahogany and other tree and shrubs species were adopted from *Brown et al.* (*1996*) and *Brown* (*1997*). Belowground biomass (BGB) equation, on the other hand, was obtained from *Pearson et al.* (*2005*). The resulting unit of measure using the equations was in kilogram (kg) and then was converted to ton or megagram (Mg). Computation was done per hectare basis and finally expanded to the total area of the plantation.

A conservative estimate of 45% Megagram (Mg) of C biomass dry weight for the carbon content was used based on the studies of *Lasco and Pulhin* (*2000 and 2006*) and *Lasco et al.* (*2004*), in which carbon content ranged from 40% to 55%. Soil carbon was taken as a fraction of the % OM content in the soil.

Monetary value of carbon was calculated by determining the product of total carbon content, carbon dioxide-to-carbon ratio and the market value of CO_2 in ton or Mg. The formula to determine the carbon dioxide-to-carbon ratio and the average CO_2 pricing of US$10 per Mg of CO_2 were taken from World Bank and Ecofys (2018).

The formulas used in the calculation are as follows:

A. Above-ground Biomass (AGB)
1. Tree Biomass (TB)
a. Trees and Shrubs with DBH ranging from 5 - 60 cm

$$TB = EXP(-2.134+2.530*LN(DBH))$$

b. Trees with DBH over 60 cm

$$TB = 42.69-12.8*DBH+1.242*(DBH)^2$$

$$\text{Total TB (TTB) in Mg ha}^{-1} = \frac{\sum \text{TBs of all trees in a plot (ton)}}{\text{Area of the plot (m}^2\text{)}} \times \frac{10{,}000 \text{ m}^2}{1 \text{ ha}}$$

2. Understorey/Herbaceous Vegetation Biomass (UHVB)

$$\text{Total UHVB} = \frac{\sum(ODW_{UHV}/\text{area g m}^{-2}) \times 10{,}000 \text{ m}^2 \text{ ha}^{-1}}{10^6 \text{ g ton}^{-1}}$$

where: ODWUHV = oven dry weight of understorey/herbaceous vegetation

Therefore, AGB = Total TB + Total UHVB

B. Necromass / Ground Biomass (GB)
Floor Litter (FL)

$$\text{Total FL} = \frac{\sum(ODW_{FL}/\text{area g m}^{-2}) \times 10{,}000 \text{ m}^2 \text{ ha}^{-1}}{10^6 \text{ g ton}^{-1}}$$

where: ODWFL = oven dry weight of floor litter

C. Below-ground Biomass (BGB)
Root Biomass (RB)

$$BGBRB = EXP(-1.0587+0.8836*LN(AGB))$$

D. Carbon Content (CC)
1. Above-ground Carbon (AGC)

$$AGC = AGB * 45\%$$

2. Ground Carbon (GC)

$$GC = FL * 45\%$$

3. Below-ground Carbon (BGC)

$$BGC = (BGB * 45\%) + SOC$$

4. Soil Organic Carbon (SOC)

$$SOC = \text{Weight of the soil (Mg ha}^{-1}) \times \% \text{ SOC}$$

where: weight of the soil = bulk density (g cm^{-3}) x soil volume (Mg ha^{-1}/g cm^{-3})
bulk density (g cm^{-3}) = soil dry weight (g)/ volume of density sampler (cm^3)

Therefore, Total CC = AGC + GC + BGC

E. Carbon Dioxide Content (CDC)

$$CDC = \text{Total CC} * CO_2\text{-Carbon Ratio}$$

where: CO_2-Carbon Ratio = 44/12 or 3.67

RESULTS AND DISCUSSION

Biomass and Stored Carbon

There were five carbon pools appraised in the study categorized into three major groups: aboveground biomass (tree & shrub and understorey); necromass or ground biomass (floor litter) and belowground biomass (root and soil). Among these carbon pools, aboveground biomass had the highest computed biomass and carbon stock of about 438.81 Mg ha^{-1} and 197.46 Mg ha^{-1}, respectively (**Table 1**). It was followed by belowground biomass and necromass or ground biomass with accounted carbon budget of 55.03 Mg ha^{-1} and 2.94 Mg ha^{-1}, respectively. The total computed biomass was 520.11 Mg ha^{-1} which gave a total carbon budget of 255.43 Mg ha^{-1}. This included the 21.38 Mg ha^{-1} of organic carbon derived from the soil carbon pool.

The result conformed with the findings of *Racelis et al.* (*2008*) in Mt. Makiling, Luzon, Philippines that mahogany plantation with trees of almost similar age group, large girth (~50 cm, average dbh) and dense stocking would have over 500 Mg ha^{-1} of biomass. Mahogany plantation in Mt. Makiling, in particular, had computed biomass and carbon stock of 605.24 Mg ha^{-1} and 542.05 Mg ha^{-1}, respectively. However, unlike the present study, the major source of carbon stock in the mahogany plantation at Mt. Makiling was its soil organic carbon pool, perhaps because of its richer soil property which is derived from volcanic parent material. The mahogany plantation in the present study has a poor quality and shallow depth soil, a characteristic of soil coming from a limestone parent material, thus consequently, its soil carbon pool would have lower SOC value.

Table 1. Computed biomass and carbon budget (Mg ha^{-1}) in different carbon pools.

Carbon Pool	Biomass Density (Mg ha^{-1})	Stored Carbon (Mg ha^{-1})
Aboveground Biomass		
a. Tree and shrub	437.41	196.83
b. Understorey	1.40	0.63
Sub-total	438.81	197.46
Necromass/Ground Biomass		
a. Floor litter	6.53	2.94
Sub-total	6.53	2.94
Belowground Biomass		
a. Root	74.77	33.65
b. Soil		21.38
Sub-total	74.77	55.03
Total	520.11	255.43

The results further support the observations made by *Brown et al.* (*1986*) that the net productivity values of plantations are higher than other vegetation types, even secondary and mature forests. Preceding studies conducted in the province of Bohol, Philippines reveal consistent findings that plantations (e.g., oil palm, yemane, teak, rubber and mahogany) would have higher biomass and stored carbon values of more than 600 Mg ha^{-1} and 300 Mg ha^{-1}, respectively (*Reyes and Ludevese 2015; Reyes et al. 2011*). These computed values were found more than three to four times higher than that of other land uses such as secondary forests, agroforestry, mangrove stands, grasslands, and croplands (*Reyes and Ludevese 2015*). This is attributed mainly to higher tree density (close spacing) in the established plantations, apart from relatively uniform ages and girth sizes. The study of *Camacho et al.* (*2011*), for instance, described the 40-year old mangrove plantation in Banacon Island, Bohol to have a stored C of 370.7 Mg ha^{-1} more than twice the amount of stored C of natural mangrove stands, 145.6 Mg ha^{-1}.

However, these observations are not always true. *Lasco and Pulhin* (*2003*) reported carbon stocks of other plantations in Mt. Makiling had values ranging from 125.6 to 287.5 t ha^{-1}. Other literatures even revealed lower carbon stocks in other provinces in the Philippines (*Lasco and Suson 1999; Lasco et al. 1999; Lasco and Pulhin 2000; and Lasco and Pulhin 2009*) and in other countries (*Arevalo et al. 2009; Kaul et al. 2010; and Potter 2010*).

Lasco and Pulhin (*2009*), however, added that improvement in the biomass mean annual increments (MAI) of these plantations may be achieved if proper silvicultural operations such as fertilizer application, soil augmentation and enrichment planting are applied.

Same with the previous studies (*Lasco and Suson 1999; Lasco et al. 1999; Lasco and Pulhin 2000; Gevana et al. 2008; Gevana and Pampolina 2009; Lasco and Pulhin 2009; Gevana et al. 2013; Reyes and Ludevese 2015; Reyes et al. 2011*), the tree and shrub biomass or the overstorey in the present study plays a major role in sequestering much of the CO_2 in the atmosphere. The biomass density and its corresponding stored carbon value were larger than the other carbon pools. This is because the standing biomass of trees can store large amount of carbon, magnified by a higher density per unit area in a forest plantation setting.

Contrary to this observation, *Racelis et al.* (*2008*) reported that belowground biomass of both mahogany and dipterocarp plantations in Mt. Makiling had slightly higher carbon stocks than tree biomass mainly because of the large amount of organic carbon in the soil. This is consistent with the findings of *Lasco and Pulhin* (*2006*) from the studies conducted in the Philippines that over 50% of the total carbon stored by forest is contained in soil. *Watson et al.* (*2000*) as cited by *Racelis et al.* (*2008*) also revealed that soil component can also contain much carbon as vegetation. Accordingly, the carbon in soil has a slower turnover rate and is more protected from disturbance than that in aboveground vegetation. In addition to this, *Lasco et al.* (*2004*) and *Chen et al.* (*2013*) disclosed that soil organic carbon may also increase over time as vegetation sheds organic matter and leaches in the soil periodically. *Labata et al.* (*2012*) also reported similar findings that soil carbon pool in the three selected agroforestry systems in Bukidnon, Philippines had the highest carbon content among all other carbon pools. This was also proven by *He et al.* (*2013*) in their study on monoculture and mixed-species plantations in Subtropical China, where most of the concentrations of carbon are found in the upper 20-cm of the soil pool.

Among all major carbon pools in all references at hand, necromass or ground biomass had the lowest computed stored carbon. This is even more evident in the present study since snags and dead woody branches on the forest floor were not included in the data collection. As observed during the conduct of the study, these were regularly collected by nearby community residents. The municipal local government units of Bilar also manages to cut leaning hazardous dead trees along the road and buck fallen logs which serve as obstruction primarily to prevent impending road accidents.

Total Biomass, Stored Carbon and Carbon Dioxide Equivalent

Extending the values to the entire 115.21-ha plantation revealed a total biomass of 59,921.87 Mg which is about 29,428.03 Mg of stored carbon (**Table 1**). Using the carbon to carbon dioxide ratio of 3.67, the total carbon dioxide equivalent was computed to be 48,600.40 Mg (**Table 2**).

The results portrayed a direct relationship among biomass density, stored carbon and carbon dioxide equivalent. *Racelis et al.* (*2008*) performed correlations between diameter at breast height and biomass density and stored carbon for both mahogany and dipterocarp plantations and found very significant strong positive correlations among all parameters considered. *He et al.* (*2013*) also implemented similar analysis and determined strong direct relationship between biomass and carbon among monoculture and mixed-species plantations in Subtropical China. In the same year, Chen et al. did more complicated analysis for Chinese fir stands at different developmental stages and found that biomass C pool increased linearly from 2 to 40 years old with no further significant increase beyond the age of 40 years.

Monetary Value of Stored Carbon

The total monetized value of stored carbon based on the computed carbon dioxide equivalent amounted to US$486,003.96 (**Table 3**). A large portion of this value, US$375,714.35, was contributed by the above-ground biomass. Tree and shrub carbon pool, in particular, had a monetized value of US$374,515.65, while US$119.87 was only attributed to the understorey. The least valued carbon pool, given the smallest computed carbon dioxide equivalent, was the ground biomass or floor litter with a monetized value of US$559.11.

Table 2. Total computed biomass, carbon budget and carbon dioxide equivalent in different carbon pools.

Carbon Pool	Biomass Density (Mg ha^{-1})	Stored Carbon (Mg ha^{-1})	Carbon Dioxide (Mg)
Aboveground Biomass			
a. Tree and shrub	50,394.01	22,677.30	37,451.57
b. Understorey	161.29	72.58	119.87
Sub-total	50,555.30	22,749.89	37,571.44
Necromass/Ground Biomass			
a. Floor litter	752.32	338.54	559.11
Sub-total	752.32	338.54	559.11
Belowground Biomass			
a. Root	8,614.25	3,876.41	6,401.90
b. Soil		2,463.19	4,067.96
Sub-total	8,614.25	6,339.60	10,469.85
Total	59,921.87	29,428.03	48,600.40

Note: Carbon to Carbon Dioxide Ratio = 44/12 or 3.67
(Source: *World Bank and Ecofys* [*2018*])

Table 3. Monetary value of stored carbon in different carbon pools.

Carbon Pool	Biomass Density (Mg ha^{-1})	Monetary Value (US$)
Aboveground Biomass		
a. Tree and shrub	37,451.57	374,515.65
b. Understorey	119.87	1,198.70
Sub-total	37,571.44	375,714.35
Necromass/Ground Biomass		
a. Floor litter	559.11	5,591.06
Sub-total	559.11	5,591.06
Belowground Biomass		
a. Root	6,401.90	64,018.97
b. Soil	4,067.96	40,679.58
Sub-total	10,469.85	104,698.54
Total	48,600.40	486,003.96

Note: 1 Mg of CO_2 = US$10.00 (Source: *World Bank and Ecofys* [*2018*])

Environmental services, like carbon sequestration provided by mahogany plantations, are seldom appreciated unless these are presented in monetary values. Often, plantations are commercially valued based on the direct benefits that these can provide to people, for instance timber, medicine or edible fruits.

Noticeably, the higher the value of carbon dioxide equivalent derived from the stored carbon, the higher its monetary value. Consequently, an increase in biomass density through enrichment planting or reforestation would have a considerable increase in the stored carbon over the years and thus its monetized value (**Table 3**).

At present, carbon markets are becoming more and more available to plantation owners and public forest management institutions. The only problem besetting these groups is on how incentives are to be accessed, apart from the voluminous requirements needed for the application. Nevertheless, incentivizing carbon sequestration initiatives would somehow promote participatory conservation especially if nearby communities will be involved.

CONCLUSIONS AND RECOMMENDATIONS

The Loboc-Bilar Mahogany Plantation stores 255.43

Mg ha^{-1} of carbon, for a total of 29,428.03 Mg ha^{-1} of carbon. Its monetized value amounted to US$486,003.96. Among the different carbon pools appraised, aboveground biomass, particularly trees and shrubs, had the highest amount of carbon stock. The remaining carbon pools, understorey, floor litter, root, and soil carbon pools, were relatively small compared to the carbon storage capacity of the overstorey. This finding highlights the importance of the mahogany overstorey as it contributes a significant portion of the carbon pool within the plantation. Protection of these trees from poachers should be the foremost concern, since apart from being the largest sink of carbon, they give aesthetic and recreational beauty in the area.

Aside from *Swietenia macrophylla*, there were other plant species that survived underneath the plantation. Management practice at the Loboc-Bilar Mahogany Plantation could expand the occurrence of secondary species to further increase the total carbon stock of the plantation. Revegetation of open gaps, either using mahogany or any other local species, could be a starting activity. Based on the findings of this present study, stored carbon is highly dependent on the biomass density and so an increase in the vegetation would have a considerable increase in the carbon stock over time.

A follow-up study should be conducted to measure the rate at which the Loboc-Bilar Mahogany Plantation sequesters carbon. This value could then be compared to the net storage fluxes of the Philippines to assess the plantation in the context of the contribution of the Philippines to global climate change.

Plantations with other species can produce fruits, seeds, and other non-timber products in addition to their timber. Once the economic value of the carbon stock is fully assessed, mixed-use-harvest values should be assessed for fruit bearing trees to develop a model of complete economic value to the area.

The objectivity of GIS sampling procedure and the simplified field survey method applied in the present study imply immediate utility and replications in other plantations and vegetation types. The use of GIS and field survey instruments like GPS receivers reduces subjectivity of and committing sampling errors from purposive sampling technique. Integrated to GIS, statistical relationships of biomass and stored carbon with several factors affecting C storage within each pool may be investigated in succeeding researches. Different modeling techniques such as simple linear regression, multiple linear regression and boosted regression tree models may also be tested and compared for various factor sets.

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