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Carbon Storage and Sequestration by Selected Tree Species in the University of San Carlos – Talamban Campus' (USC-TC) Nature Park, Cebu City, Philippines

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ABSTRACT

Increasing global warming as a result of an unprecedented increase in greenhouse gases in the atmosphere is a worldwide concern. Among the most important greenhouse gases in the atmosphere is carbon dioxide. The call for the reduction and sequestration of carbon dioxide is indeed very urgent. Urban greenspaces are seen to be an important player in reducing carbon dioxide. In this regard, this study looks into the carbon storage and sequestration potential by an endemic and introduced tree species in the nature park of the University of San Carlos – Talamban Campus (USC-TC), namely the molave (*Vitex parviflora*) and mahogany (*Swietenia macrophylla*). Ninety (90) individuals of molave and 90 individuals of mahogany were measured in this study. On average, molave stored 36.21 Mg C ha^{-1} while mahogany stored 207.76 Mg C ha^{-1}. Likewise, the molave sequestered carbon at a rate of 3.80 Mg C ha^{-1} y^{-1} while mahogany sequestered at a rate of 3.41 Mg C ha^{-1} y^{-1}. Conversely, older mahogany trees store more carbon than the younger molave trees. However, both old mahogany and younger molave trees do not differ in their respective annual carbon sequestration rate. Thus far, urban greenspaces, such as the nature park of the University of San Carlos–Talamban Campus (USC-TC), Cebu City, Philippines can positively help in regulating microclimate conditions in an urban setting. It is therefore recommended that old-growth forests must be preserved and new reforestation projects must consider planting endemic species like molave.
Keywords: *carbon sequestration, greenhouse gases, global warming, urban greenspace, mahogany, molave*

INTRODUCTION

The increasing global warming has led to many unprecedented effects particularly in the archipelagic nation such as the Philippines. Just recently, many parts of the country had suffered major disasters brought by strong typhoons, such as the typhoon Haiyan in 2013 (Carlos et al., 2016; Delfino et al., 2016; Tolentino et al., 2016). The risks associated with increasing global warming had been identified to include, among others, the effects of heat waves and other extreme events (e.g., flooding, droughts, strong typhoons, etc.), changes in patterns of infectious diseases, and the impacts on food yields and freshwater supplies (McMichael et al., 2008).

In addition to these imminent risks, urbanization also threatens global ecosystems via large-scale conversion of rural to urban landscapes (Seto et al. 2011). Among the greatest challenges faced by urban centers is how to adapt to the threats associated with urbanization and climate change (Campbell, 2006). Similarly, in urban areas, pollution was reported to be relatively high (Brown et al., 2006). Hence, as suggested, its greenspace plays a significant role by offering direct carbon storage which could reduce the risks of global warming (Brown et al., 1996; Nowak and Crane, 2002). At any rate, a greenspace is described as public and/or private open spaces in urban areas primarily covered with vegetation (Haq, 2011).

The role of vegetation cover, particularly in the Philippine forests, has been quantified in the national carbon dioxide budgets (Lasco and Pulhin, 2009). It is estimated that in 1998, tons per hectare of carbon dioxide (CO_2) approximately equivalent to the total Philippine GHG emissions. Lasco and Pulhin (2000) reported that Philippine forest land uses store 1091 Tg (10^{12} g) of carbon (C) and sequester 30.5 Tg C/yr while releasing 11.4 Tg C/yr through deforestation and harvesting. However, Lasco and Pulhin (2000) expected that the total C storage would decline by 8% (1005 Tg) and total rate of C sequestration will increase by 17% (35.5 Tg/yr) in 2015 due to the decline in natural forest area accompanied by an increase in tree plantation area.

In Cebu, Central Philippines, the remaining forested areas were estimated to be only one percent (ca. 14,407 has.) of its original size and are distributed as isolated patches (Mallari et al., 2001; DENR-FMB, 2010) and are continuously declining in size as development already encroached the rural forested areas. Likewise, in urban areas, where industrialization had affected their microclimate conditions, greenspaces are a haven. Urban greenspaces are found in memorial gardens and some privately-owned lands, such as the nature park in the University of San Carlos – Talamban Campus (USC-TC), Cebu City, Philippines.

The University of San Carlos–Talamban Campus (USC-TC) nature park is a secondary growth forest over limestone. It is thickly vegetated due to reforestation projects in the late 1960s, hence the vegetation inside the nature park is dominated by mahogany (Swietenia macrophylla), an introduced species. However, other tree species also were planted inside the campus, including Philippine endemics, such as kamagong (Diospyros blancoi), narra (Pterocarpus indica), and molave (Vitex parviflora), among others. With its dense vegetation, the USC-TC nature park also harbors a number of wildlife, including threatened species such as the red jungle fowl (Gallus gallus) and Philippine forest lands were a net sink of greenhouse gases (GHGs), absorbing 107 metric Cebu black shama (Copsychus cebuensis), hence the nature park is an important bird area (Parilla, 2011).

On the other hand, as presented by Bolund and Hunhammar (1999) that on average, 85% of air pollution in urban areas can be filtered by a greenspace. It is within this context that this study looked at the potential of the USC-TC nature park, as an urban greenspace to sequester carbon. This study also serves as a model to show the potential contribution of an urban greenspace in highly urbanized centers in mitigating the harmful effect of increasing global warming. According to Montagnini and Nair (2004), there have been few studies that investigated the relative efficiency of exotic and endemic species in terms of their carbon storage and sequestration potentials. Likewise, similar studies in this region of the country are lacking. The carbon storage and sequestration potentials between native and exotic species could provide guidance on sustaining the urban greenspaces as well as in planning reforestation projects. Thus, this study looked at the amount of carbon stored and sequestered by a population of an introduced/exotic tree species, mahogany (Swietenia macrophylla), and a population of a Philippine endemics, molave (Vitex parviflora), thriving in the nature park.

MATERIALS AND METHODS

Description of the Study Site

The University of San Carlos – Talamban Campus (USC-TC) is located in Nasipit, Talamban, Cebu City, around 5 kilometers north of the city proper (Fig. 1). The university has a total land area of ca. 100 hectares and one-third of which was designated as a nature park. The local climate condition in the area is Climate type III according to Modified Corona Classification, wherein wet and dry seasons are not very pronounced.

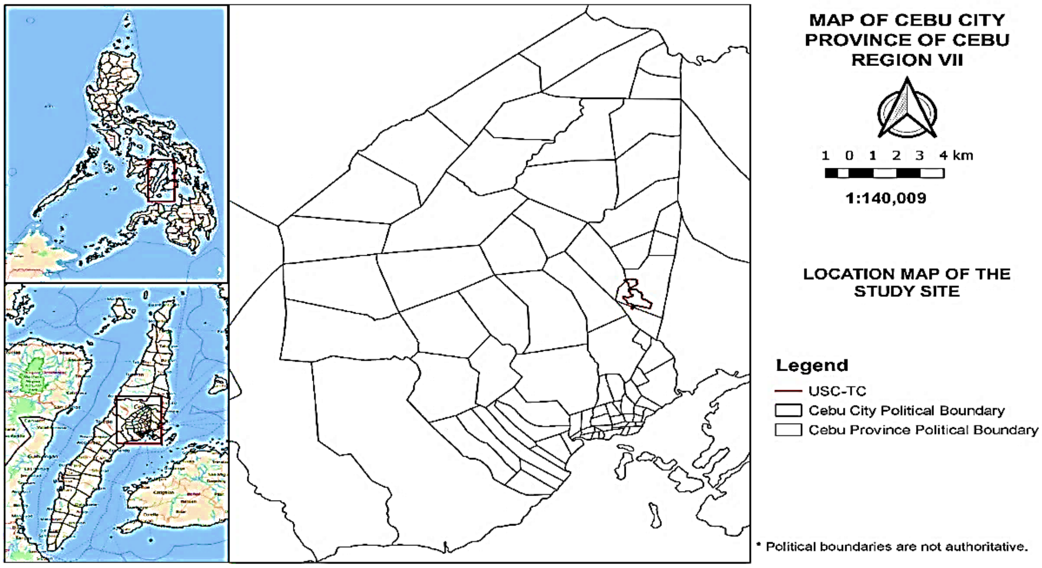

Figure 1. Location map of the study site – University of San Carlos-Talamban Campus, Cebu City, Philippines

Data Collection

Selection of tree species

Among the trees found in the USC-TC nature park, the study focused only on comparing two species namely, mahogany (Swietenia macrophylla) and molave (Vitex parviflora). They are among the abundant species in the nature park. Albeit other endemic species were encountered, their number is not sufficient enough for the purpose of the study as compared with molave.

Field Survey

Ninety (90) individuals of mahogany (S. macrophylla) and 90 individuals of molave (S. parviflora) were sampled inside the USC-TC nature park. The height and trunk diameter at breast height (dbh) of the individual tree species, i.e., height > 1m, were measured. Tree basal area, tree age, the tree above ground biomass, tree biomass density, carbon stored by the tree, and its annual carbon sequestration rate were computed.

Computations

Tree biomass. Tree biomass was computed following Chave et al. (2014), which was found to be the best-fit pantropical model and performed well across forest types and bioclimatic conditions:

$$AGB_{est} = 0.0673 \times (\rho D^2 H)^{0.967} \quad \textbf{Eq. 1}$$

where

AGB_{est} = estimated tree above ground biomass in Kg
ρ = wood specific gravity in g m^{-3}
D = tree trunk diameter at breast height (dbh) in cm
H = total tree height in m

For wood specific gravity of the trees, the values were taken from Wood Species Database (www.wagnermeters.com), e.g., the wood specific gravity of mahogany is 0.47 g m^{-3} while that of molave is 0.68 g m^{-3}.

Tree biomass density and carbon stored. Tree biomass density (TBD) and carbon stored were calculated using Labata equation (Labata et al., 2012), with a default value of 45% being used to determine the carbon stored in tree biomass, i.e., an average carbon content of wood samples collected from secondary forests from several locations in the Philippines (Lasco and Pulhin 2000):

$$\text{TBD (Kg ha}^{-1}) = \text{AGB (Kg) / Sample area in hectare} \quad \textbf{Eq. 2}$$

$$\text{Carbon stored (Kg C ha}^{-1}) = \text{Tree biomass density} * \text{C content} \quad \textbf{Eq. 3}$$

Tree basal area. To describe the average amount of an area occupied by a tree, the tree basal area is calculated using the following formula:

Tree basal area (TBA) = $(\pi D^2) / 4$

where

D = tree trunk diameter at breast height (dbh) in cm
$\pi = 3.1416$

Tree age estimates. Age of trees was estimated using the formula published by the International Society of Arboriculture (www.thelivingurn.com):

Tree Age = D x GF **Eq. 4**

where

D = tree trunk diameter at breast height (dbh) in cm
GF = tree growth factor

For the growth factor of the trees, the values were adapted from the study of Schneider et al. (2013), e.g., the growth factor of mahogany is 1.25 while it is 0.91 for molave.

Annual sequestration rate (ASR). On the other hand, the annual carbon sequestration rate was adjusted following the method established by Nowak & Crane (2002):

ASR (Mg C ha^{-1} yr^{-1}) = Carbon stored (Mg C ha^{-1}) /Tree Age
Eq. 5

RESULTS AND DISCUSSION

On average, carbon stored by molave is significantly lower compared with the carbon stored by mahogany (Table 1). The plausible reason for this difference could be due to the average age difference between molave and mahogany trees in the nature park, i.e., mahogany is relatively older than molave. This finding is consistent with the findings of Köhl et al., (2017), that carbon storage is comparatively low at younger tree ages than older tree ages.

On the other hand, the results also showed that the average ASR between molave and mahogany do not differ ($p = 0.381$) (Table 1). This implies that the rate of annual carbon sequestration is not correlated with ages and sizes of trees. Sequestration rate could be influenced by some other factors. Trees sequestered carbon in order to sustain their physiologic and metabolic needs (Unwin and Kriedemann, 2000). It is also at younger stages in the life cycle of plantations that maximum sequestration rate is taking place (Unwin and Kriedemann, 2000). Moreover, Schneider et al. (2012) reported that certain native species performed better than introduced species especially when grown in open areas. Thus, the nature of trees, i.e., being endemic or introduced, might be a crucial factor for the rate of carbon sequestration.

Table 1. The computed above-ground biomass, total biomass density, carbon stored, tree age, and annual sequestration rate of molave and mahogany in the USC-TC nature park

Species	AGB (in kg) mean (± SE)	TBD (in Mg ha^{-1}) mean (± SE)	C Stored (in Mg C ha^{-1}) mean (± SE)	Tree Age (in years) mean (± SE)	ASR (in Mg C ha^{-1} y^{-1}) mean (± SE)
Molave	53.16 (± 6.54)	80.48 (± 9.90)	36.21 (± 4.45)	8.57 (± 0.36)	3.80 (± 0.405)
Mahogany	860.05 (± 107.00)	461.69 (± 57.7)	207.76 (± 26.00)	49.46 (± 2.33)	3.41 (± 0.198)

Overall, the USC-TC nature park has an average stored carbon of 167.13 Mg C ha–1. This amount is comparable to the carbon stock of agroforestry systems, particularly of mixed multistorey systems (Labata et al., 2012). Thus, the potential of USC-TC nature park as a carbon sink should not be overlooked.

CONCLUSION

In an urbanized area, where carbon dioxide is increasingly accumulating in the air, carbon sequesters are very much needed. Urban greenspaces, such as the USC-TC nature park, is a potential solution to this problem. This potential of urban greenspaces had been demonstrated by the USC-TC nature park. With a relatively small area, the USC-TC nature park and its trees have been found to store and sequester a significant amount of carbon that is comparable to large agroforest systems. Hence, the presence of urban greenspaces and their role in climate mitigation must not be discounted.

In this regard, urban greenspaces must be developed and established in strategic locations within urbanized centers for their important role in the microclimate regulation in the city of Cebu, Philippines. Likewise, existing greenspaces, such as USC-TC nature park, and the like, should be sustained and enhanced. Conversely, urban greenspaces should be streamlined and be an indispensable component in urban planning and design. Furthermore, it is highly reiterated that old-growth forests with their old-growth trees must be protected and cutting of trees in these forests must be stopped. Similarly, removing old introduced species from the landscape will, too, have detrimental effects, in terms of climate change mitigation, as demonstrated by the potential of old mahogany (Swietenia macrophylla) trees in the USC-TC nature park.

Nevertheless, with regards to future reforestation projects, it is still recommended to better plant native species of trees, such as molave (Vitex parviflora) than exotic ones. On the other hand, future studies should look into how socioeconomic issues influence the success of establishing greenspaces in an urban landscape.

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