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Aboveground Biomass and Carbon Stock in an Urban forest within the St. Thomas University Campus, Miami Gardens

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Abstract

The world's forests play a pivotal role in the mitigation of global climate change, since by photosynthesis trees remove CO_2 from the atmosphere and store carbon in their biomass. Particularly, tropical forests have assumed increasing importance in international efforts to mitigate climate change due to their capacity to store carbon and because of the significant emissions that their destruction causes. The urban environment presents important considerations for global climate change, considering that over half of the world's population lives in urban areas. We conducted this project in the St. Thomas University Campus forest, in Miami Gardens, north of the city of Miami, Florida, U.S.A., as a part of the Summer Research Seminar course we developed in years 2019 and 2020, with the purpose of calculating the amount of Biomass that the forest produces. We measured the Perimeters of hardwood tree species in centimeters using a Tailor's Tape as a first step to determining their biomass. We then transformed Perimeters into Diameters, and with Diameters at Breast Height (DBH), we calculated biomass and carbon stock utilizing an allometric equation by Brown and Iverson, particularly one with the highest Determination Coefficient among those analyzed for this purpose (R^2= 0.94). Total Biomass based on our measurements is 561,428.30 Kg (= 561.43 Mg or 17.54 Mg Ha^{-1}). Total Carbon Stock stored is 280,714.17 Kg (= 80.71 Mg or 8.71 Mg Ha^{-1}). These results may serve as beneficial assets to encourage the calculation of Biomass/Carbon stock of tree species, and to foster reforestation projects by academic and public institutions.

Keywords

biomass, carbon capture, trees, university campus forest, Miami Gardens, South Florida

Introduction

The world's forests are a fundamental component of ongoing efforts to control global climate change. Through the process of photosynthesis, trees remove CO_2 from the atmosphere and store carbon in their biomass (Köhl, Neupane, & Lotfiomran, 2017). Tropical forests are especially significant due to their capacity to store vast quantities of carbon and because of the significant CO_2 emissions that their destruction consequently yields (Malhi & Grace, 2000; Gibbs, Brown, Niles, & Foley, 2007).

The urban environment presents another important consideration for global climate change initiatives. Over half of the world's population live in urban areas (Population Reference Bureau, 2012). The term "urban forest" refers to all trees within a densely populated area, including trees in parks, on street ways, and on private property. Urban forests present important considerations for global climate change, since they operate as "carbon sinks" that significantly contribute to the effort of reducing carbon in the atmosphere (Safford et al., 2013); that is the case of the St. Thomas University (STU) forest.

Biomass estimation is the most widely followed approach for determination of carbon sequestration potential in terrestrial ecosystems (Brown, 1997; Brown, Gillespie, & Lugo, 1989; Chambers, dos Santos, Ribeiro, & Higuchi, 2001). Although several researchers have used tree height, trunk diameter [i.e., diameter at breast height (DBH)], and wood density as independent variables for estimating tree aboveground biomass (AGB), the allometric relationship between AGB and DBH has proved to be the best fit for tree biomass estimation in several forests (Brown, 1997; Brown et al., 1989). Since AGB of trees contains a large fraction of the total forest carbon stock, most studies on forest carbon budget have focused only on tree AGB estimation (Baishya & Barik, 2001).

We have not found information published on the calculation or biomass and carbon stock in the region of South Florida, other than an article with data on local common trees (Perez, 2019).

We conducted the project in the STU campus forest, in Miami Gardens, to the north of the city of Miami, Florida, U.S.A., as a part of the 2019 and 2020 Summer Research program within STU, with the purpose of calculating the amount of Biomass and Carbon Stock produced by the campus urban forest. This forest is one of the few natural forest patches remaining in the southern Florida Peninsula outside of Preserves, and is probably the only one remaining in the Miami-Dade County area.

Material and Methods

Study Site

The Saint Thomas University forest, is located to the north side of the campus and has an area of 32.1 Ha. Species composition is basically hardwood species (*Pinus elliotti*, *Casuarina equisetifolia* and *Quercus virginiana*), Palm trees, vines, herbs, and ferns, the latter making up the understory.

Measurements

To determine aboveground Biomass, we measured the Perimeters of all hardwood trees of the forest in centimeters using a Tailor's Tape. In other words, we conducted a Census. In total, we measured 511 trees calculating Diameter at Breast Height (DBH) above 10 cm and at a height of 130 cm from the ground.

Figure 1
Measurement of perimeters on trees, conducted at breast height
Permission granted by co-author Stevenson Cottiere for use of his image.

Calculation of Biomass

We transformed Perimeters into Diameters (DBH), and with Diameters, we used the formula below to calculate biomass according to Brown and Iverson (1992), and Milena and Kanninen (2005).

P= π DBH (Diameter at Breast Height, 130 cm, Fig 1), so:
DBH = P/ π
Biomass (Kg/tree) = 21.297 – 6.953 (DBH) + 0.740(DBH)^2

The Brown and Iverson (1992) formula is not only recommended for the calculation of Biomass in hardwood trees by various authors (summarized in CATIE, n.d.) but also is the formula that provided the highest Determination Coefficient, of the ones analyzed for this purpose (R^2= 0.94).

We calculated Biomass in Kg, and we expressed it in Kg ha^{-1}, for clarity, but it is usually expressed as Mg ha^{-1} (Megagrams, 1 Mg= 1 Ton), in the scientific literature (Segura & Kanninen, 2005; Becknell et al., 2012; Donkor et al., 2016).

Calculation of Carbon Stock

We calculated the aboveground biomass carbon stock by assuming that the carbon content is nearly 50% of the total aboveground biomass (Eggelston, Buendia, Miwa, Ngara, & Tanabe, 2006).

CO_2 = Biomass x 0.47

Statistical Analysis

We conducted an ANOVA test to determine significant differences in biomass among the species in the forest: *P. elliotti*, *Q. virginiana*, and *C. equisetifolia,* following Sokal and Rohlf (1981). We met the assumptions of Normality and Homogeneity of Variances and calculated ANOVA using an extension of Microsoft Excel. We calculated Average, Maximun, Minimun, and Standard Deviation for each dataset as basic statistic indicators to characterize the population.

Studied Species

C. equisetifolia is commonly known as Ironwood, Beefwood, or Bull-oak and is known as one to be one of most invasive species in south Florida, due to its ability to self plant and, once already established, most likely will inhibit native species to grow (Australian Pine, n.d., Elfers, 2017). *P. elliottii*, also known as Slash pine (Figure 2), is a species native to South East United States (US), which highlights even more its importance and conservation status (Slash Pine, 2018; Earle, 2019).

Figure 2
Pinus elliottii characteristic bark scaling

Q. virginiana, commonly known as Southern Live Oak, is native to the southeastern US. The Live Oak is a massive and wide spreading tree that grows up to 12 meters high and can have a diameter of over 30 m. It often is draped in Spanish moss. It is a species that very well withstands the strong winds of hurricanes, which makes it ideal for South Florida (Southern Live Oak: The Majestic Tree, 2015; Othman, 2019).

Results

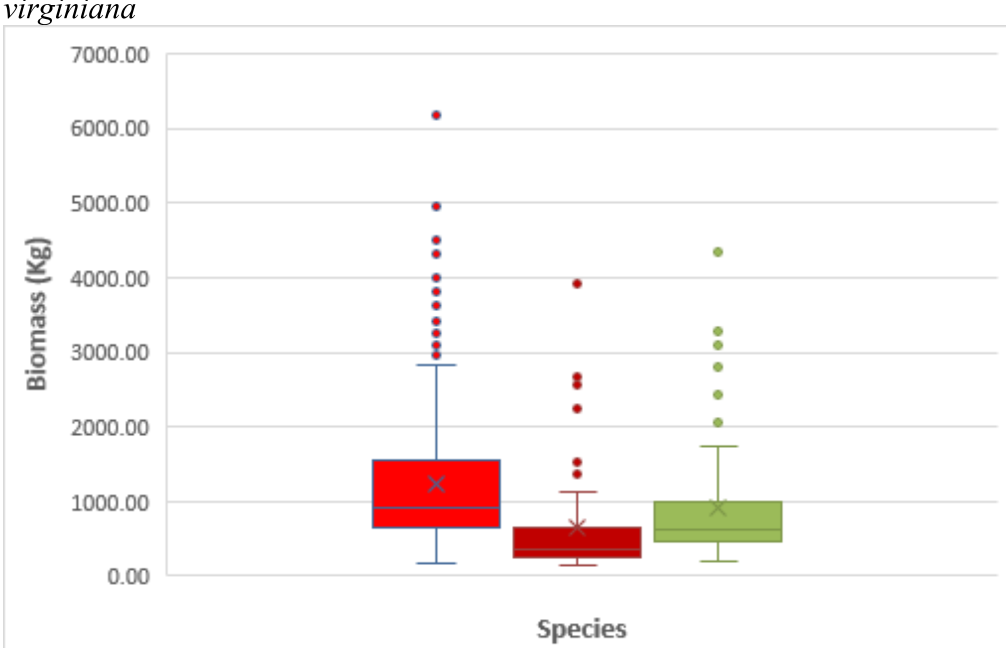
Total Biomass

Total Biomass calculated from all tree species in the STU forest was of 561.43 Mg or 17.54 Mg Ha^{-1} (Mean 1098.70, SD 881.78, Range 134.97-6,169.62, N= 511), or 561,428.30 Kg (Table 1). Figure 3 represents represents total Biomass broken down by species.

Table 1
Calculated Total Biomass for all tree species

Statistics	Values
Sum (kg)	561,428.30
Average (kg)	1,098.69
Min (kg)	134.97
Max (kg)	6,169.62
St. Dev.	881.78
N	511

Figure 3
Total Biomass for all tree species. From left to right species are P. elliotti, C. equisetifolia, and Q. virginiana

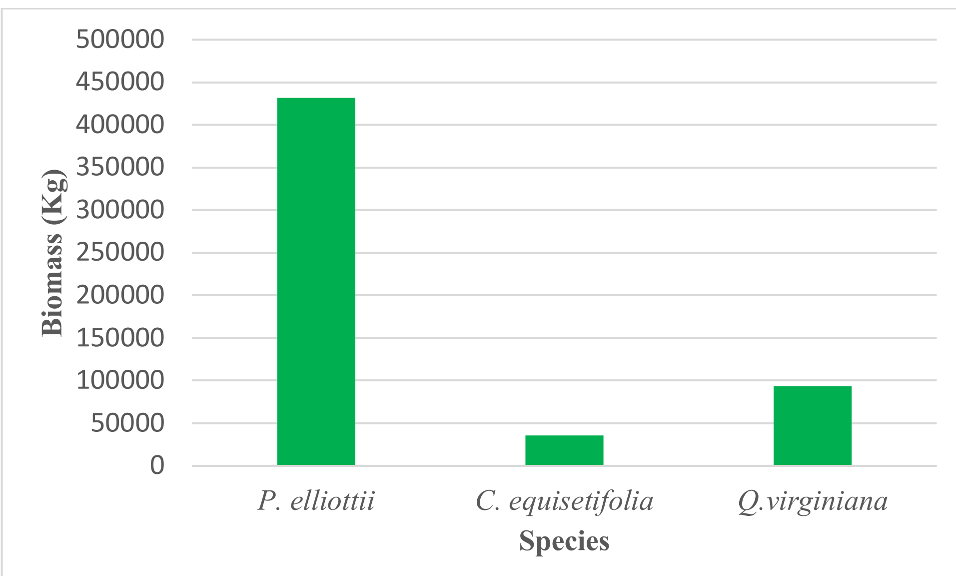


In Table 2 and Figure 4, we present comparisons among species. Biomass results for *Q. virginiana* were significantly lower than those of slash pine populations occurring in the campus forest, even though both trees can reach similar heights and trunk diameters ($F= 16.70$, $p< 0.05$). Whether this is due to the age of the respective trees or a result of *Q. virginiana*´s propensity for growing close together and, thus, possibly compromising individuals' access to soil nutrients, is not certain. Live-oak-dense zones were considerably sparse on other plant species, except for some clusters of oyster plants (*Tradescantia spathacea*), an invasive species.

Table 2
Comparison among the three studied species

P. elliottii		*C. equisetifolia*		*Q. virginiana*	
Sum (kg)	432,035.27	Sum (kg)	35,536.16	Sum (kg)	93,856.92
Average (kg)	1,237.92	Average (kg)	612.69	Average (kg)	902.47
Min (kg)	179.45	Min (kg)	134.97	Min (kg)	189.72
Max (kg)	6,169.62	Max (kg)	3,910.82	Max (kg)	4,452.03
St. Dev.	893.49	St. Dev.	697.057	St. Dev.	803.9
N	349	N	58	N	104

Figure 4
Comparison of biomass among species in the forest



Total Carbon Stock

The total Carbon stock calculated is 263.27 Mg (Mean=87,755.56 SD=419.94, Range=186,354.58, N=511) or 8.20 Mg Ha^{-1}, or 280,714.17 Kg (Table 3). Table 4 presents the contribution from each species.

Table 3
Calculated total carbon stock for all tree species

Statistics	Values
Sum (kg)	263,267.56
Average (kg)	87,755.85
Min (kg)	16,702
Max (kg)	203,056.58
St. Dev.	419.94

Table 4
Carbon stock in each of the three studied species

P. elliottii		*C. equisetifolia*		*Q. virginiana*	
Sum (kg)	203056.6	Sum (kg)	16702	Sum (kg)	43508.98
Average (kg)	581.82	Average (kg)	287.96	Average (kg)	422.42
Min (kg)	84.34	Min (kg)	63.44	Min (kg)	89.17
Max (kg)	2899.72	Max (kg)	1838.08	Max (kg)	2092.45
St. Dev.	419.94	St. Dev.	327.62	St. Dev.	379.26

Discussion

Biomass: Becknell et al. (2012), in their study on seasonally dry tropical forests (SDTFs), obtained a biomass 39 to 334 Mg ha^{-1}, which is a much higher amount than the one obtained in our study, but it may be because the campus forest has wide gaps, with no trees. In a tropical dry forest in northwestern Mexico, Navar (2008) obtained 73 Mg ha^{-1} for total above ground biomass, although he used not only the DBH but also the trunk specific gravity, which is added to the DBH. His data was obtained from 637 trees. Other results are not comparable because they encompass not only AGB but also BGB, such as the ones from Donkor and others (2016).

In regards to the species, Wang and Tumwebaze (2013) provide information on the Biometry of *C. equisetifolia* from other countries like China and Uganda, where this species is considered an introduced species. In Table 5, we present basic statistical values that we used to calculate the Biomass for those individuals. We should mention that various authors have called into question the hypothesis of a unique explicative variable based on tree size (i.e., tree diameter) to estimate biomass. Better biomass estimates include tree height as an additional size covariate (Brown et al., 1989; Chave et al., 2005). However, we agree with Segura and Kanninen (2005), who recommend the use of models where only DBH is used to determine tree biomass. This has a practical advantage because most of the inventories include DBH measurements; moreover, DBH is easy to measure accurately in the field. Models that incorporate Height are in many cases not practical because the measurement of this variable is difficult to carry out with high accuracy, particularly in dense forests (Segura & Kanninen, 2005).

Table 5

Comparison of values of diameter and biomass of C. equisetifolia from the STU forest and those reported in the scientific literature

Diameter	*Casuarina* Local	*Casuarina* China	*Casuarina* Uganda
Mean (cm)	38.3	23.12	18.95
Max (cm)	246.37	36.3	26.2
Min (cm)	11.62	15.6	11.4
St. Dev.	37.24	5.092	5.04
Biomass	*Casuarina* Local	*Casuarina* China	*Casuarina* Uganda
Mean (kg)	612.69	3816.1	2546.14
Max (kg)	3,910.82	9519.8	4918.8
Min (kg)	134.97	1569.8	903.7
St. Dev.	697.057	N/A	N/A

We found that the mean values for our local individuals are much higher than those the scientific literature reported, which is probably because mostly adult individuals make up the St. Thomas University forest, unlike those studied in other countries that are most likely juveniles.

Douterlungne et al. (2013) found an average biomass accumulation in two-year-old monocultures of *Inga, Ochroma, Trichospermum,* and *Guazuma* of 6.60, 30.80, 47.62, and 48.12 Mg ha^{-1}, respectively.

Carbon Stock: In recent years, scientists are giving much attention to biomass estimation of tropical forests because researchers consider the change in biomass as a vital component of climate change (Richardson & Oosterom, 2013). Biomass determines potential carbon emissions due to deforestation, forest degradation, and conversion of natural forest lands. Therefore, accurate biomass estimation is necessary for better understanding of deforestation and forest degradation impacts on global warming and environmental degradation (Richardson & Oosterom, 2013). Natural forests accumulate a large quantity of carbon, and when these forests are cleared, the carbon is converted to carbon dioxide into the atmosphere (Chave et al., 2004).

Carbon Dioxide (CO2) is the greenhouse gas with the greatest impact on climate change. Global CO2 emissions increased at an annual rate of 2.6% between 1960 and 2011, almost quadrupling from 9.4 billion tons to 34 billion tons. This strong increase is mainly due to the increase in the use of fossil fuels and to the changes in the use of land represented by deforestation, population growth, and urban expansion, among others.

As the IPCC Report on land use (IPCC, 2000) explained, carbon exchange between terrestrial ecosystems and the atmosphere occurs naturally through the processes of photosynthesis, respiration, decomposition, and combustion. This situation is altered when human activity changes the use of land through, for example, forest logging. Conversely, newly planted or regenerating forests can absorb carbon for 20 to 50 years or even longer, depending on the species and conditions of the site. Both vegetation and soils absorb carbon (IPCC, 2000). The forests with the highest carbon storage in the world are boreal and tropical (Herreros et al., 2012). This information is very important, since estimates of carbon fluxes from deforestation, land cover change, and other disturbances depend on knowing the forest carbon stock before disturbance (Houghton, 1991).

The carbon pool of a forest ecosystem varies with age (Kurz & Apps, 1995; Clark et al., 2004). While young and middle-aged forest stands act as active carbon sinks (Valentini, Matteucci, & Dolman, 2000), old stands are moderate to small carbon sinks or even carbon sources, depending on the forest type and species composition (Malhi, Baldochi, & Jarvis, 1999; Kohl, 2003; Law, Sun, Campbell, van Tuyl & Thornton, 2004; Desai, Bolstad, Cook, Davies, & Carey, 2005). The diameter of the STU campus forest trees suggests it is probably a middle-aged forest, when we compare its biomass and carbon with some other examples from the literature; however, in the context of Climate Change mitigation we believe it is a great opportunity for the city and the county to have a carbon sink such as this.

The total carbon stock of the STU forest of 263.27 Mg (Mean=87,755.56 SD=419.94, Range=186,354.58, N=511) or 8.20 Mg Ha-1, or 280,714.17 Kg, provides evidence of the importance of urban forests for climate change mitigation, and suggests that we can consider South Florida native hardwood trees such as Q. virginiana as one of the most important species to grow in this area in order to address this issue of local and global importance.

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Discussion Questions

1. Why are Urban Forests, Parks, and street Trees relevant?

2. Why is it important to preserve native trees like *Pinus elliottii*, and *Quercus virginiana*?

3. On what basis would you select a tree species that contributes the most to climate change mitigation?

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