A Five-Year Analysis of Carbon Stock Plots in the Gordon Natural Area's Big Woods

by

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Introduction

Few old growth or mid to late successional growth forests exist that are free of human disturbance (Chokkalingam, 2001). They are fragmented and at risk of disappearing but provide valuable information regarding the nature forest structure and composition. They can also provide insight as to how current forests might grow to look (Chokkalingam, 2001) being that many millions of acres of forest in the eastern United States are secondary growth forests due to human activities mostly related to land clearing for agricultural production. These forest landscapes are in various stages of recovery (Brown, 1999). The long term consequences of agricultural activity on modern forest structure and composition are currently being investigated by many researchers.

Bellemere (2002), Flinn (2005) and Lundgren (2004) have found that historical land use has a large influence over modern species composition and structure. Flinn (2007) compared twenty pairs of primary and secondary (established 85-100yrs ago on plowed fields) forests and discovered that they were similar in many respects including tree size and number and understory light availability, however; species composition was dramatically different. Primary forests were dominated by sugar maple and beech while secondary forests were dominated by red maple and eastern white pine (Flinn, 2007). Bedison (2007) also found overall beech importance in the Hickory Creek Forest Preserve to be increasing relative to the other species. Bellemere (2002) found the sub canopy and sapling layers of primary forests to be dominated by beech and sugar maple with the canopy layer being dominated by sugar maple. Twentieth century secondary forests were found to have a greater diversity of species within the canopy and subcanopy, including sweet birch, sugar maple, black cherry, paper birch and hophornbeam Yellow birch, paper birch and black cherry were not found within the canopy layers of the primary forests (Bellemere, 2002). Rhemtulla (2009) found that a 2000 survey of forests in Wisconsin recovering from agricultural uses in the 1930's indicated a moderate recovery in tree size distribution but also evidence of biotic homogenization. Recovery in northern Wisconsin favored hardwood species over historical conifers and in southern Wisconsin forests successional species are moving in a more shade tolerant direction rather than a historical fire resistant direction (Rhemtulla, 2009). The differences in species composition and structure is clear and the Gordon Natural Area at West Chester University, West Chester, Pennsylvania provides a unique opportunity to observe a forest that consists of both primary and secondary forest stands.

The history of the Gordon Natural Area is of a forest that is both mid to late successional and secondary growth. Turner et al. reported that the earliest botanical surveys conducted of the area by William Darlington in 1837 described "rich woodlands" with oak, tuliptreee and sugar maples stands (Turner, 2007:9). Since 1935, there are no records of major disturbance, except for the chestnut blight. It was proposed that the forest is approximately 140yrs old with an even aged overstory comprised of "mid-to-late successional native hardwood species" (Turner, 2007:9). This section of the GNA is surrounded to the east, west and south west by areas of secondary growth (Figure 1). The area to the southwest, located at the southwest corner of South New Street and

Tigue Road was purchased by the University in 1967. At that time it was an abandoned cornfield and has been left to reforest. Dr. Overlease of the Biology department at West Chester University was provided with an opportunity to observe and record the change in this area for 34 years (1967-2000) (Overlease, 2011). The secondary growth area to the east has more recently been allowed to grow over, having been utilized as an orchard until least 1971, based upon the 1971 aerial photograph. With two different forest types located within one preserve, an opportunity exists to observe the change in structure and composition of new secondary growth over time to more established mid-to-late successional growth and learn how plant community's recover from human land use may be impacted by exotic species and thus change the long term forest structure and composition. The mid to late successional areas provide a baseline as to how the forest might have been should it never have been cleared for agriculture.

To observe the change in the mid to late successional area of the GNA, dbh data has been collected since 2008 on 5 plots located within 5 different topographic locations in the GNA (Figure 2). These regions include the floodplain, lower mid-slope, mid-slope, upper mid-slope and the ridgeline. This is a review of 5 years of data collection to help establish a baseline for plant community, structure, biomass and carbon stock for a mid-to-late successional hardwood forest.

Methods

The study site consists of 5 circular plots located at the Gordon Natural Area on South Campus of West Chester University, West Chester PA. Each plot is 0.1271ha in size. The five areas are located within different topographc positions: ridgetop, upper midslope, midslope, lower midslope and floodplain. Data for trees within 20meters of the center of the plot and over 5dbh in size were collected. Data included azimuth of tree, distance of tree from the center of the plot, dbh and tree species. Azimuth was collected using a compass, distance to tree was measure using a 100 meter measuring tape and dbh was collected with dbh tape. Data for each plot was collected over 5 years, 2008-2012; however data for the flooplain plot was not collected in 2008 and 2010.

The 5-year collection of tree data from the Gordon Nature Area (GNA) was compiled and organized in Microsoft Excel. For each year of data, 2008-2012, carbon stock of trees 5cm DBH and greater was determined. Methodology for determining carbon stock of the plots was based on guidelines published by the US Forest Services in Measurement guidelines for the sequestration of forest carbon (Pearson, T.R.H. et al, 2007). Total Carbon Stock 2008, 2009, 2010, 2011 and 2012 was statistically analyzed with ANOVA one-factor. The sample collections had labeled (1) ridge-top, (2) upper-slope, (3) mid-slope, (4) lower-slope, and (5) floodplain. Two collection years, 2008 and 2009, had labeled the order ascending instead of descending. The results were arranged to match the descending order, starting with ridge-top as plot 1. Additionally, 2008 and 2010 data did not include a sample collection from floodplain plot. A second ANOVA statistical analysis of the data was completed between 2009 and 2012 total carbon stock. Two factor ANOVA without replication including factors of years (2009 vs. 2012) and plots (1-5).

The carbon stock for each species for each plot was also determined for the 2009 and 2012 tree survey. The 2008 and 2010 were not included because data was not collected for the floodplain plot. Additionally, it was decided that a change in trees species carbon stock would be more notable between several years rather than sequential years. It was thought it might be useful to look at the change in carbon stock for each species of trees within each plot and gain insight as to how the tree species carbon stock changes over time.

Importance values for the understory and overstory of the 2009 and 2012 tree survey was also done. The 2008 and 2010 were not included because data was not collected for the floodplain plot. Additionally, it was decided that a change in importance values would be more notable between several years rather than sequential years. Understory trees were considered trees less than 10cm dbh; trees 10cm dbh and greater were considered overstory trees. Importance values for each identified tree species were determined by calculated the relative density, relative frequency and relative coverage and adding them together.

Historical aerial photographs for 1937, 1958 and 1967 were obtained from Penn Pilot online (http://www.pennpilot.psu.edu/). The aerial photographs provided insight as to change in land use and forest cover at the GNA.

Results

The 5-year carbon sequestration is not significantly different through 2008 to 2012. ANOVA result has a p-value= 0.98. It should be noted that 2008 and 2010 did not include floodplain plot in the data analysis which may have caused a skewed result in the ANOVA analysis. There is no significant difference between sample collections within the 5-year period and total carbon stock. .

A two factor ANOVA without replication, with collection years 2009 versus 2012, result is p-value of 0.000448 (5 plots) and p-value = .34 (sample collection year). This analysis searches for a difference in total carbon stock with collection year and a difference in total carbon stock with 5 plots. Further analysis would be to obtain the missing 5th plot data in 2010 and 2008 data (if available). Alternatively analysis could be run on all five years with only four plots, excluding the floodplain plot.

Carbon stock per species per plot was also calculated for 2009 and 2012 (Figures 3-7). Comparing the change in species within plots would be useful in determining change over time in species within each plot. In the floodplain, the tulip tree (*Liriodendron tulipfera*), red maple (*Acer rubrum*), American beech (*Fagus grandifolia*) and oaks (*Quercus* spp.) were the dominant species. The tulip tree had a carbon stock value of 49.84 in 2009 and 56.87 in 2012. Red Maple had a carbon stock of 33.77 in 2009 and 37.54 in 2012. Beech had a carbon stock of 24.71 in 2009 and 29.52 in 2012. Oaks had a carbon stock of 23.9 and 23.5. Oaks were the principal species in the lower midslope plot, with a carbon stock value of 101.66 in 2009 and 102.77 in 2012. Tulip trees and beech trees were also important with the tulip tree having a carbon stock of 56.39 in 2009 and 41.14 in 2012 and the beech having a carbon stock of 21.29 in 2009 and 19.85 in 2012. In the midslope oaks and tulip trees were the dominant species. Tulip trees had a carbon stock value of 122.7 in 2009 and 120.87 in 2012. Oaks had a carbon stock of 101.66 in 2009 and 94.63 in 2012. At the midslope plot the tulip tree was the principal species with a carbon stock of 180.76 in 2009 and 182.06 in 2012. Oak was the next closest in importance with a carbon stock of 69.63 in 2009 and 53.74 in 2012. The tulip tree was the single dominant tree in the ridgetop plot with a carbon stock value of 314.55 in 2009 and 291.05 in 2012.

Importance values (Figures 8 and 9) indicated that American Beech continues to be of significant importance within the understory of the GNA with an importance value of 1.63 in 2009 and an importance value of 1.85 in 2012. The tulip tree is the dominate tree in the overstory with an importance value of 0.97 in 2009 and an importance value of 1.03 in 2012. It should be noted that after the beech, the invasive Norway maple is also an important species within the understory with an importance value of 0.51 in 2009 and 0.46 in 2012. It is also a tree found within the overstory with and importance value of 0.45 in 2009 and 0.34 in 2012. Additionally the total carbon stock for the Norway maple demonstrates the same trend. The total carbon stock of the Norway maple in 2009 was 41.43 and in 2012 it was 28.03.

Discussion

The first statistical analysis is one factor ANOVA with the factor as sample collection year. Every year the carbon stock is analyzed with a result of no significant difference of calculated Confidence Intervals (CI). The ANOVA analysis has a similar result of 5 year carbon stock totals with p-value > .05. This finding supports the individual year CI. The carbon stock totals do not differ in high enough values between plots. The elevation does not change tree species and vegetation. The two factor ANOVA includes sample collection year and the 5 plots as factors in carbon stock differences over time.

The two factor ANOVA result has two p-values, (1) factor of sample collection year and (2) 5 plots. The result from collection year is similar to previous CI and one factor ANOVA analysis with a p-value > .05. However, the analysis result with the basis on 5 plots is a p-value < .05. This may contribute to comparing 2009 versus 2012 with 3 years for the forest to change. The GNA forest composition may be changing in a slow-rate. This supports the possibility the GNA forest composition is changing only in a slow rate and not analyzable year to year. Continuing yearly data analysis and further data analysis may support slow rate forest composition changes.

Elevation and topographic location contribute to carbon stock differences in forest composition. Elevation differences between the plots are (floodplain verses ridgetop) can contribute to difference species composition and carbon stock differences; however the difference in elevation within the GNA was not found to be significant. There is no difference between the five established plots within the GNA. Even though there is no significant difference, the floodplain plot has a wider range of tree species than the higher elevations elevation plots. The tulip tree was the single dominant species in the ridgetop plot; however, while it was also the dominant species in the floodplain plot; it was not the single dominant species. Red maple, American beech and oaks were also dominant species on the floodplain.

Beech is the principal species within the understory in the GNA. Beech is a shade tolerant tree (Poage, 1993) so in a mid to late successional forest with an extensive overstory it is not surprising that beech is the dominant species. Bedison (2007) found that in the hardwood forests of the Adriondacks are dominated by beech and that the overall importance of beech to be increasing relative to other species over the 20 year period studied. Chokkalingam (2001) found that in the old growth forests of the northeast US saplings were mostly beech. Primary forests in central New York forests were dominated by sugar maple and beech (Flinn, 2007).

The tulip tree is the dominate species in the overstory of the GNA. The tulip tree is a shade intolerant tree and is most successful as a canopy tree (Burns, 1990). It is often a pioneer species in clear cut and abandoned agricultural fields and with its abundance in the overstory was mostly likely an early tree in the GNA. The importance value of the tulip tree in the overstory in 2009 was 0.97 while the in the understory in was 0.0. In 2012 in the overstory its importance value was 1.03 and in the understory is was 0.28.

The importance value of the invasive Norway maple is decreasing in both the understory and overstory. The total carbon stock of the Norway maple supports this change as the total carbon stock of the Norway maple for all five plots is also decreasing. The total carbon stock of the Norway maple in 2009 was 41.43 and in 2012 it was 28.03. With the Norway maple being an invasive species this is good news for the GNA. It will be important to continue monitor this trend for the Norway maple as part of maintaining the overall health of the GNA and reducing the impact of invasives within the GNA.

It is prudent to continue to collect this data as it has provided much information regarding changes in carbon stock and species composition and structure. With this we will be able to continue monitoring these trends and observe how the structure and composition of the GNA changes over time. Additionally it will continue to provide information to compare to the new areas of secondary growth in the GNA currently recovery from agricultural use.

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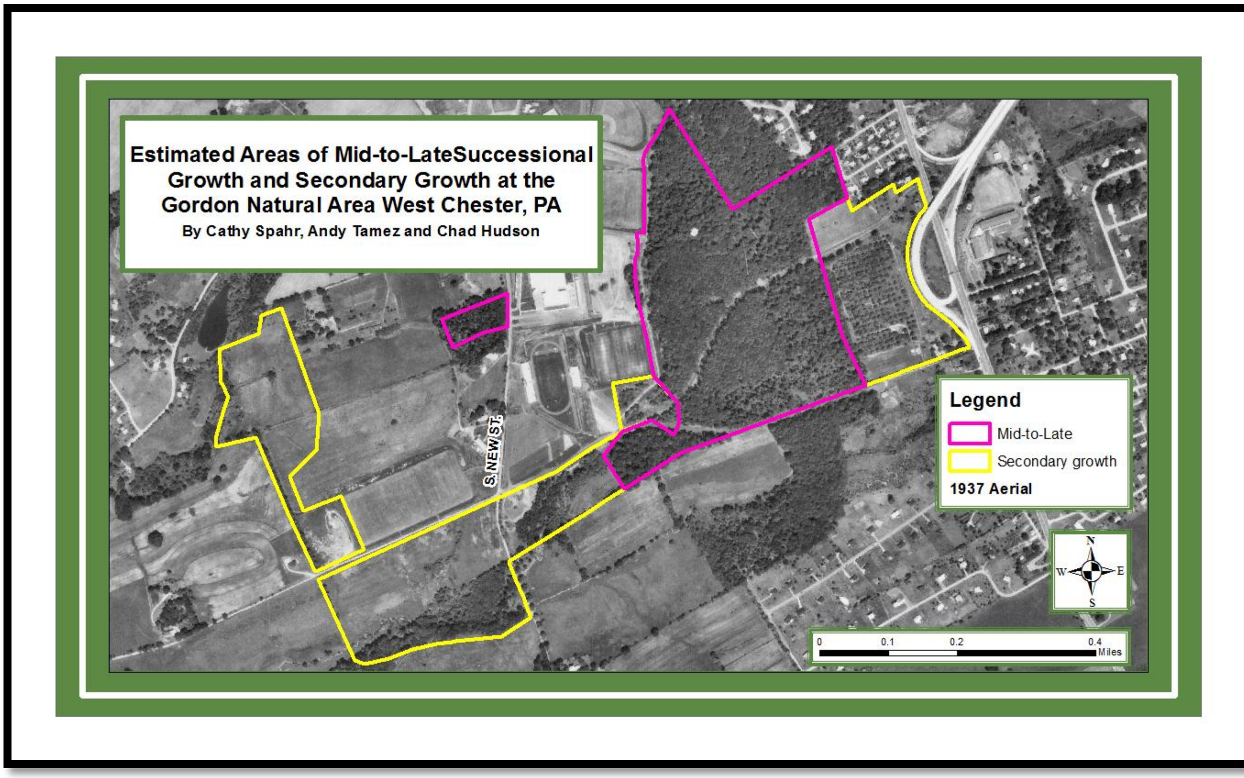

Figure 1: Proposed areas of secondary and mid-to-late successional growth in the GNA. Aerial from 1937 shows what areas were forested and agriculture.

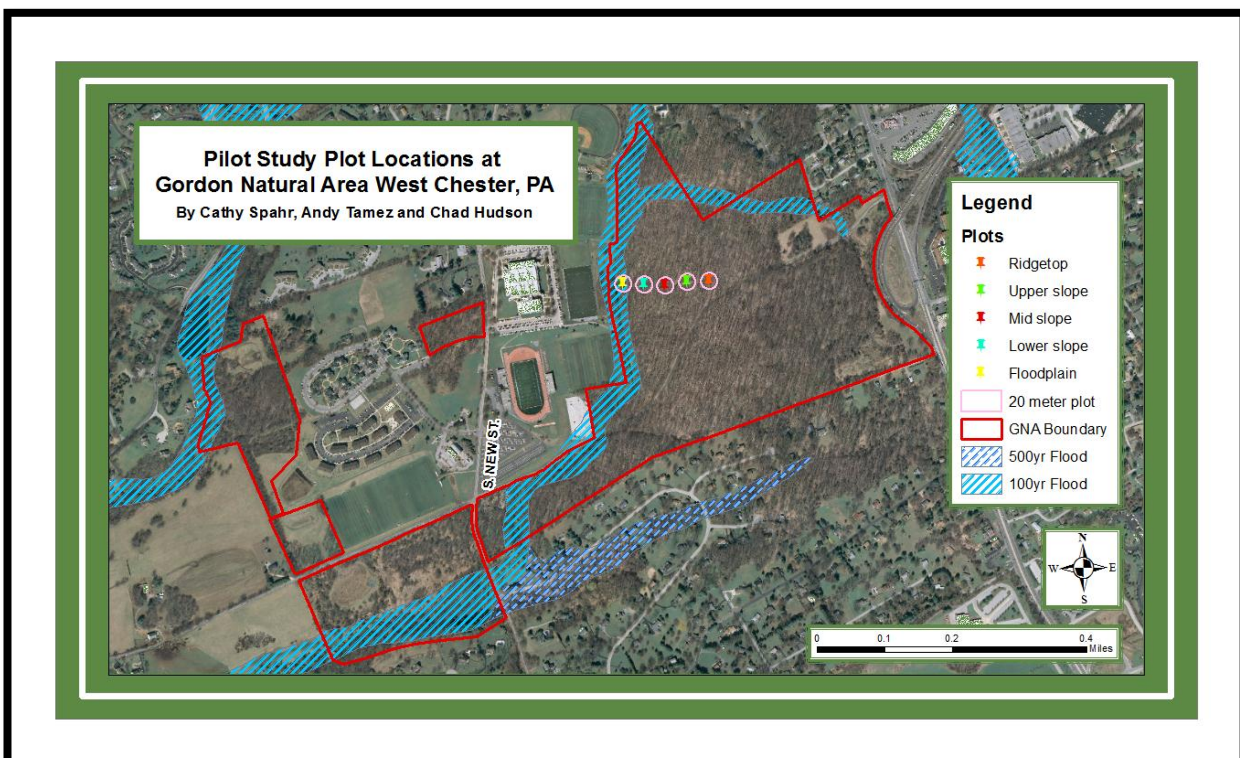

Figure 2: Plot locations at the Gordon Natural Area, West Chester, PA

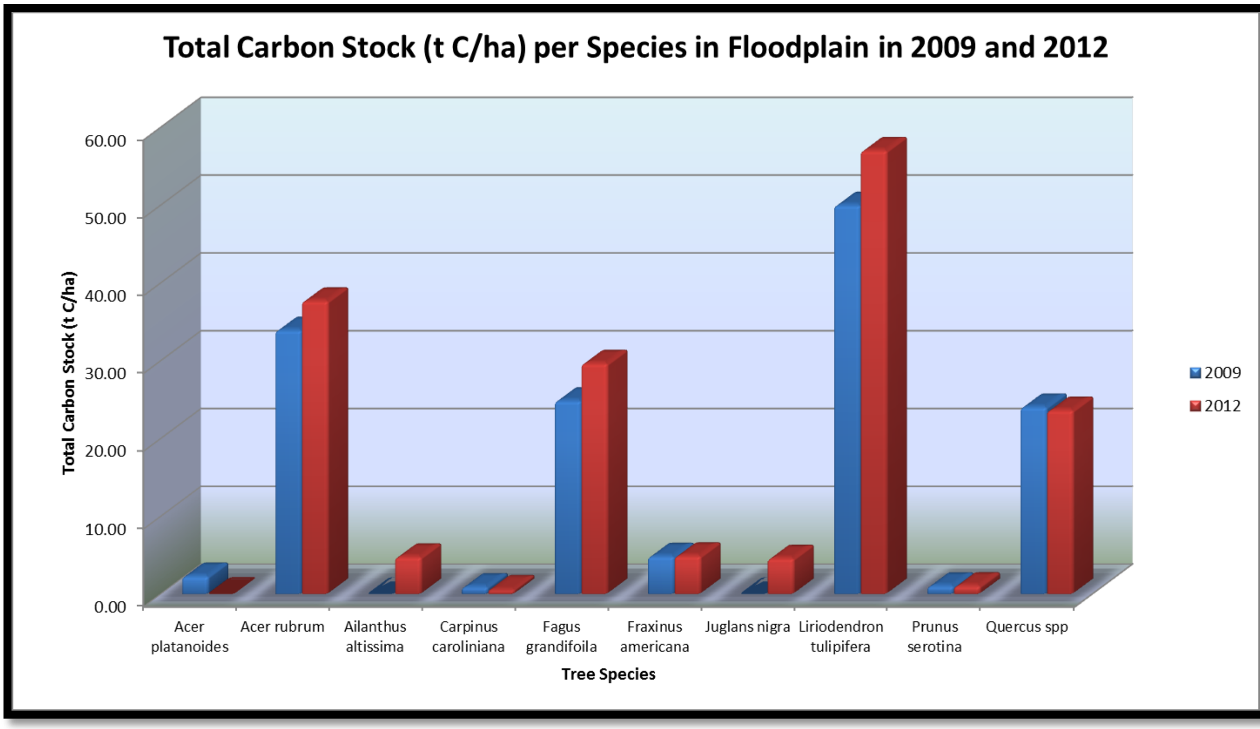

Figure 3: Total Carbon Stock per species in Floodplain plot

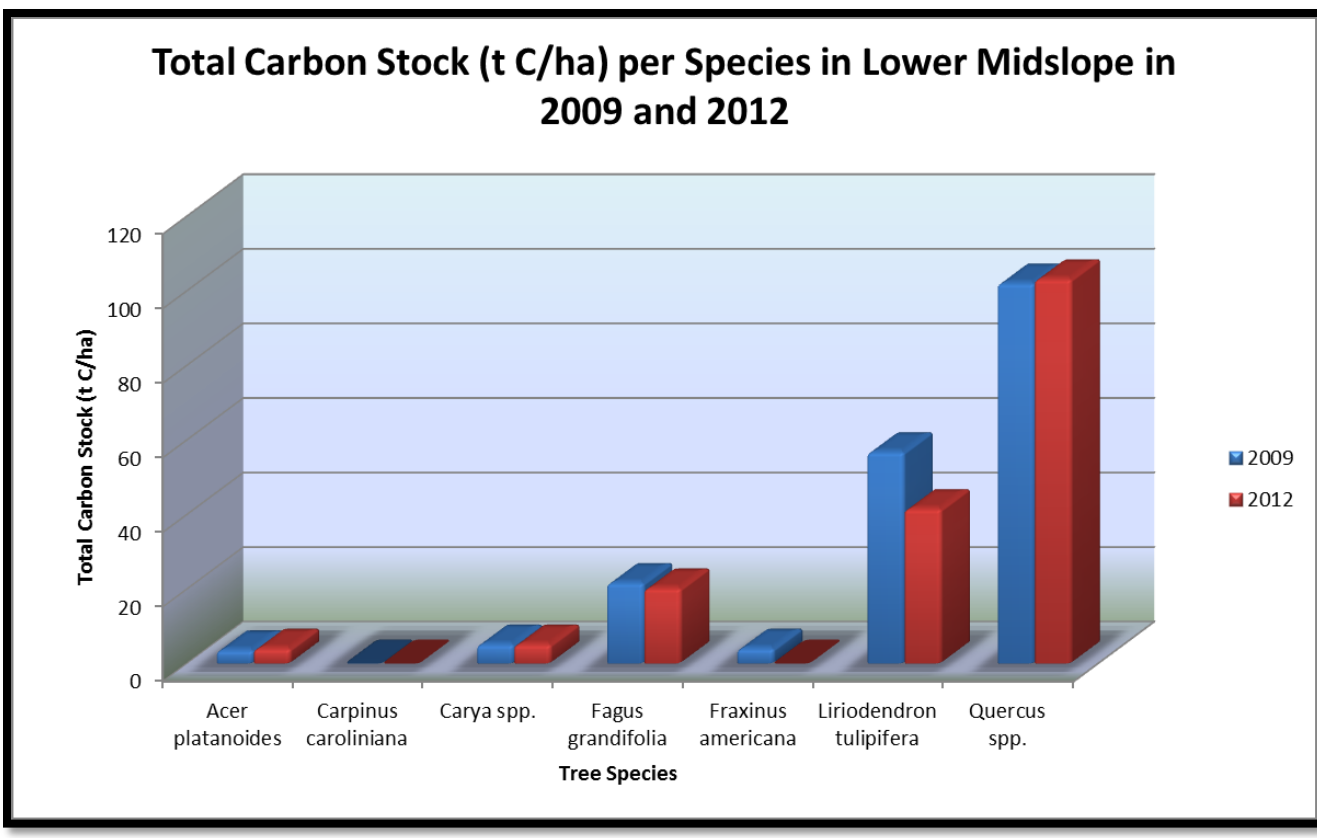

Figure 4: Total Carbon Stock per species in Lower Midslope plot

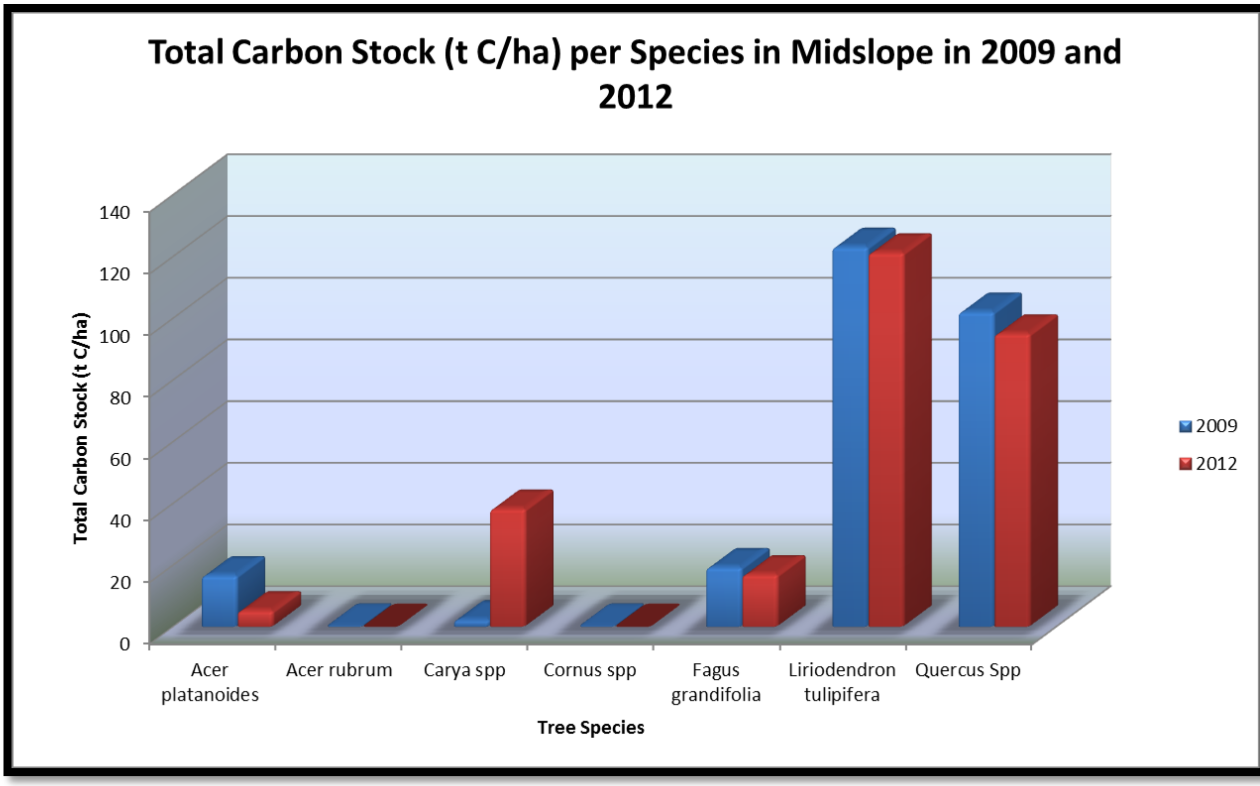

Figure 5: Total Carbon Stock per species in Midslope plot

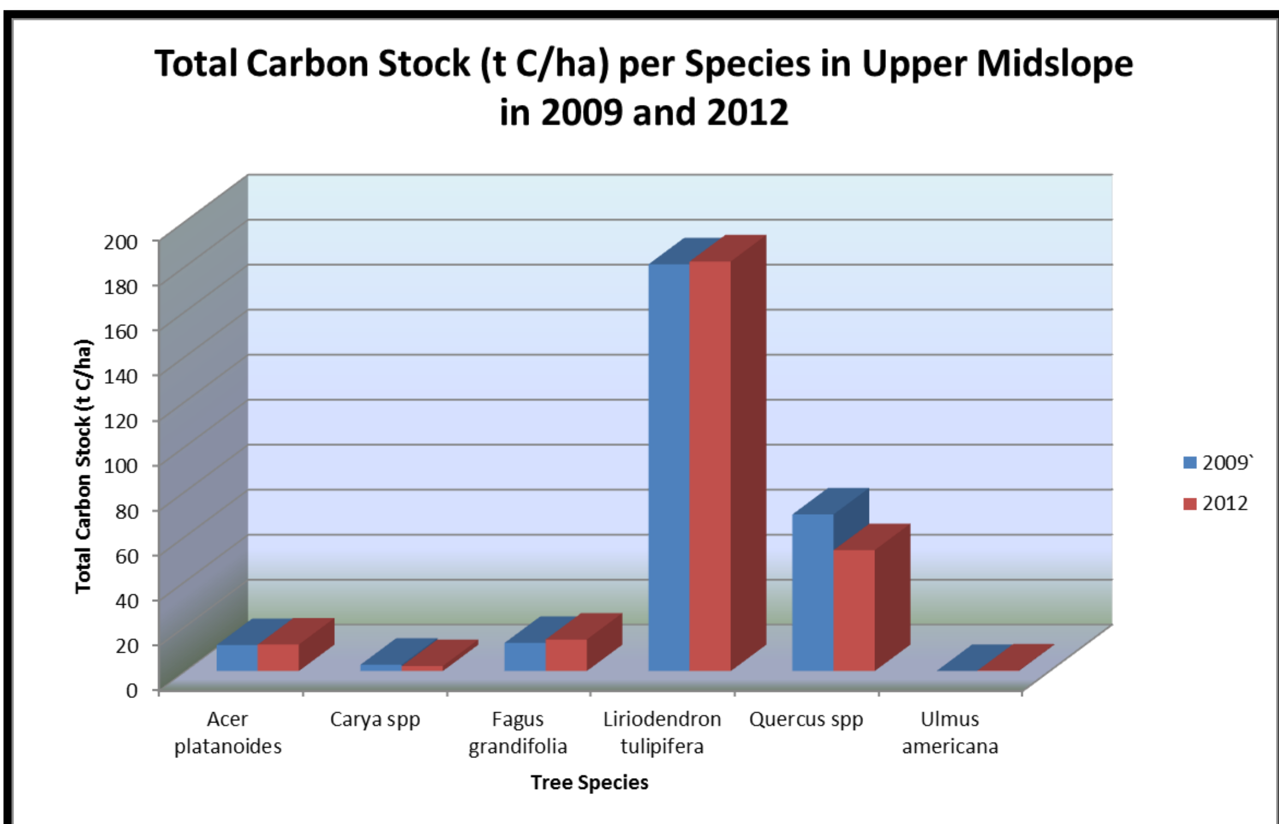

Figure 6: Total Carbon Stock per species in Upper Midslope plot

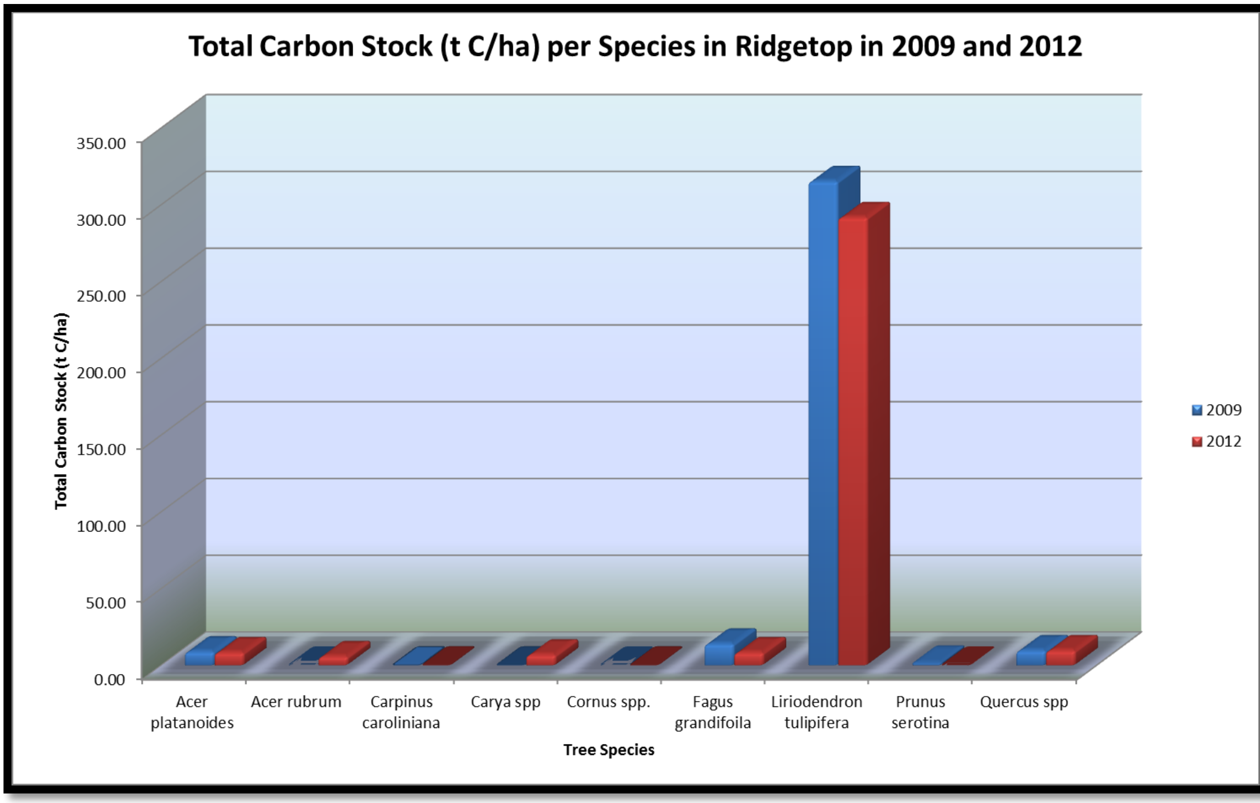

Figure 7: Total Carbon Stock per species in Ridgetop plot

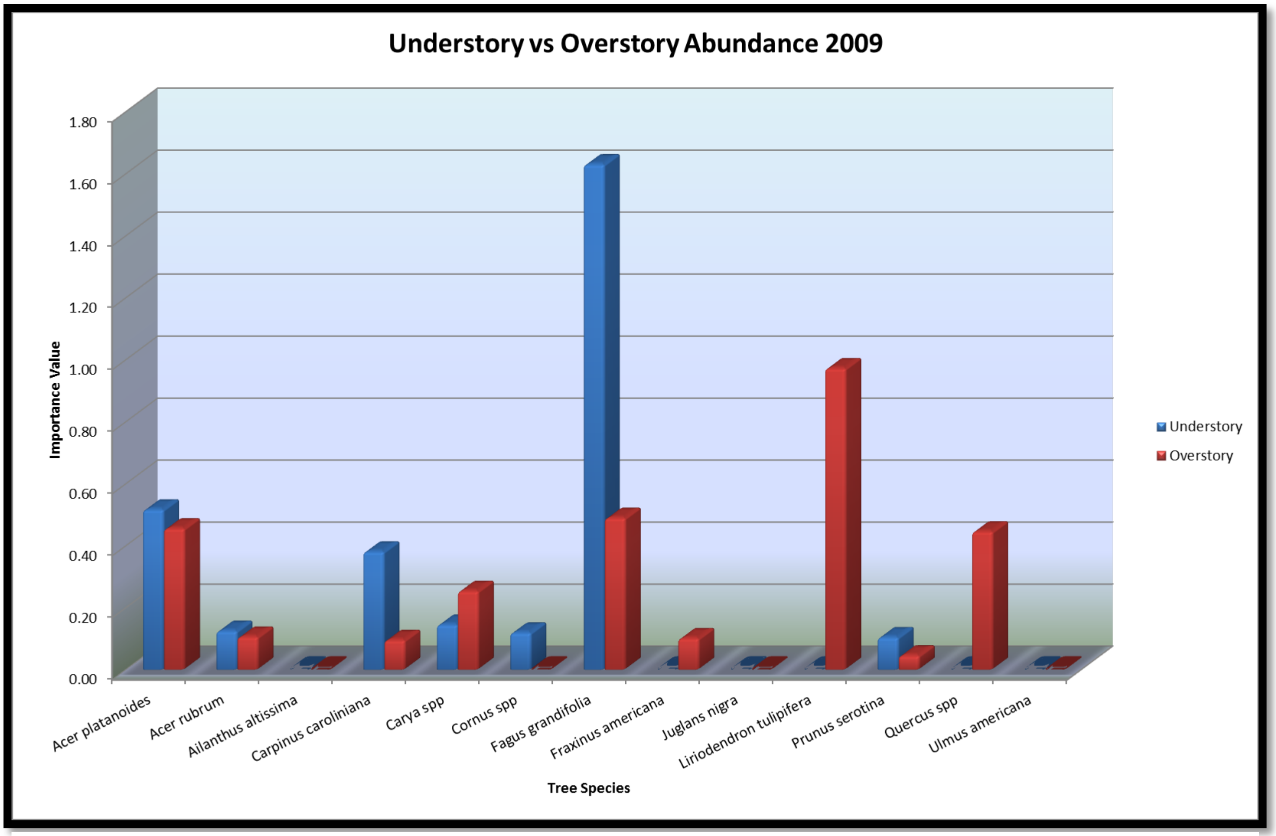

Figure 8: Understory vs Overstory Abundance of all five plots in 2009

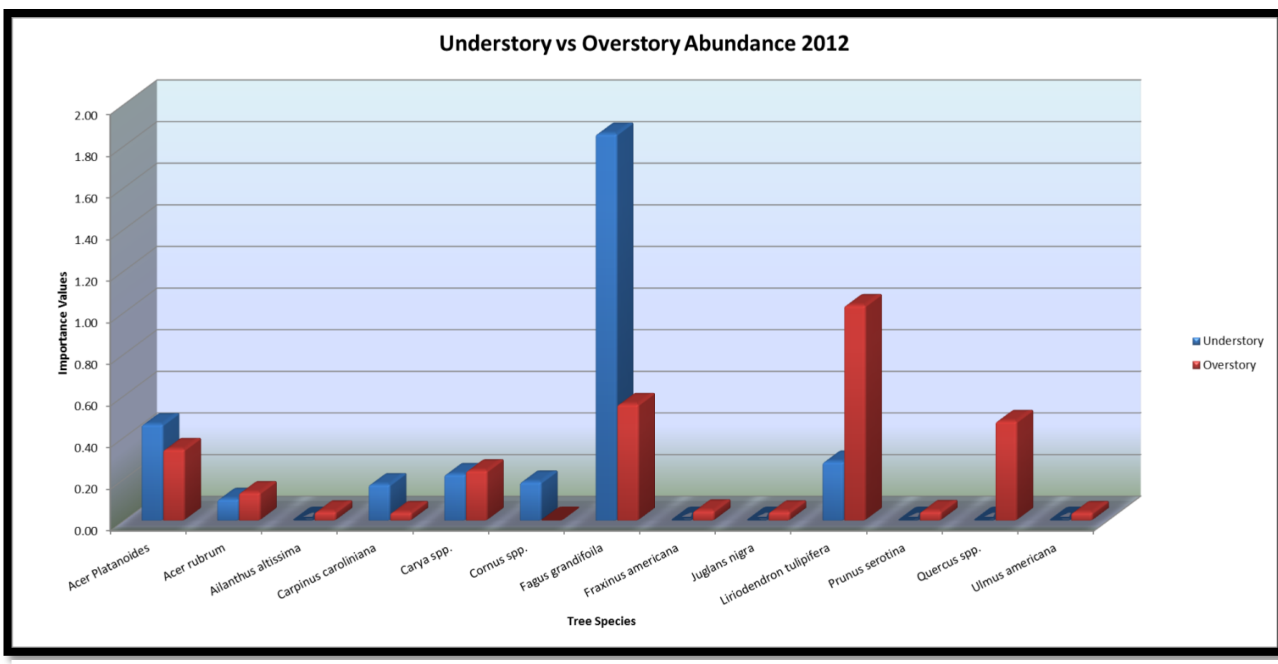

Figure 9: Understory vs Overstory Abundance of all five plots in 2012