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Comparison of Carbon Stocks & Importance Values in correlation with past land use in the Gordon Natural Area

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Abstract

Purpose

The study aims to find results on how two different past land uses affected the present day forest structure and composition of a fragmented forest. Studying Pennsylvania's fragmented forests will become increasingly important as those forests are threatened by urban sprawl and their positive effects are being jeopardized.

Location

We studied the forest composition and structure of the Gordon Natural Area in southeastern Pennsylvania, 25 miles west of Philadelphia. The study area represents a fragmented second-growth forest reserve with a history of different land uses. It has been cleared for commercial logging and farming like the majority of Pennsylvania's woodlands in the 18th century.

Methods

We measured the abundance of trees with a DBH greater than 5 cm and less than 74 cm in eight randomly selected plots (0.1257 ha). For each plot we calculated the total carbon stock, mean carbon stock and the importance values for each species. Importance values were used for NMS-tests, utilizing Sorenson's Distance Measure in PC-Ord. Also, the richness for each plot was determined by total number of tree species found in the plot.

Results

Leriodendron tulipfera was dominant in the overstory throughout. *Fagus grandifolia* dominated the understory in the old woodlot while *Leriodendron tulipfera* did in the former apple orchard.

Mean Carbon stocks revealed small statistical correlations between individual plots but nothing overall regarding all four wood plots versus all four apple orchard plots.

NMS tests revealed *Liriodendron tulipfera, Quercas rubra* and *Fagus grandifolia* all to be statistically significant on both axes and each were clustered based on past land use.

Conclusion

This study supports the idea that past land uses effects present day forest composition, structure and richness. It also found a possible correlation between abundance of invasive species and different past land uses.

Keywords

Human interference, land use, Pennsylvania, preservation site, fragmented forest

Introduction

Pennsylvania's forests have experienced a dramatic change over the last 300 years. With the arrival of the first colonists, old-growth forests were transformed to open pasture and farm land. Subsequently, the majority of the remaining forests suffered from the log boom that swept Pennsylvania until the practice moved westward to the Great Lakes in the early 19th century. This marked the halt of centuries of deforestation and allowed forest recovery in most regions of the state, creating second-growth forests that cover 60% of the state, yet are different from those that had covered the lands before European colonization (DCNR 2005).

Today Pennsylvania's second growth forests are threatened by urban sprawl, especially in the state's more densely populated regions. The amount of woodlands being lost to those sprawling patterns per day has tripled over the last 30 years, leaving the state with fragmented forests that are prone to the threat of invasive species (DCNR 2005). Thus, protecting the remaining forests for their positive and beneficial effects is becoming increasingly important, as those forests are storing carbon, absorb storm water and supply natural escapes in the manner of outdoor recreation (Board on Agriculture 1991).

Various studies have linked past human interference, such as logging and farming, to changes in present forest composition (Foster 1992). Furthermore, studies have found a connection between past land use and the abundance of invasive species (Niering 1998).

Studying Pennsylvania's fragmented forests, such as the Gordon Natural Area, represents a high priority as it gives valuable results in how to manage and preserve those woodlands for future generations.
The Gordon Natural Area (GNA) is located in Pennsylvania's densely populated southeast, just south of West Chester in Chester County (39° 58' N, 75° 34' W) (Fig. 1, 2 GNA Map). It is situated in the Brandywine Watershed, which falls into the Humid Continental Climate Zone with an annual precipitation of about 45 inches and an average temperature of 52 degrees Fahrenheit (Brandywine Conservancy 2004). The Gordon Natural Area represents a preservation site, which is enclosed by residential development and has been

protected since 1973. It is comprised of three major land areas – The Ridge, The Floodplain Wetlands and The Southeastern Parcel (Department Biology, West Chester University). The GNA is a second-growth forest, which grounds had been previously cleared and used for farming. Also, the forest was commercially used as a woodlot (Matlack 1997). The GNA serves as a study site for West Chester University, yet only a few studies have been conducted that observe the forest's composition while accounting for different past land use of the preservation site. Thus, this pilot study is trying to extend on past research by including the sites of a previous apple-orchard while still including the old woodlot. The study is trying to find possible correlations between past land use and present day forest structure as well as composition.

Fig. 1 GNA Map

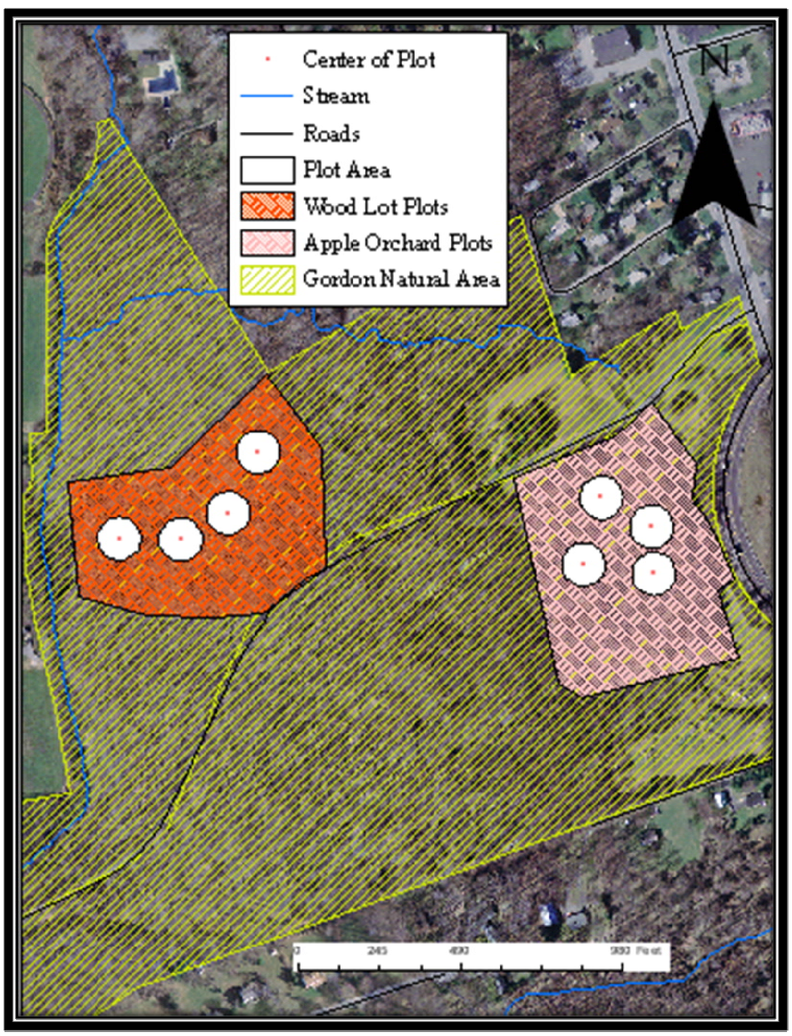


Fig. 2 GNA Map

Methods

Data Collection

Eight 0.1257 ha circular plots were located in the Gordon Natural Area. Four were randomly located on historical woodlot grounds (plots 000 – 003) while four were randomly located on a former apple orchard (plots 004 – 007) (Hertel). Past land use (apple orchard and commercial logging on woodlot) was identified through a 1937 Strategic Plan map for West Chester and through interviews with Dr. Hertel, a professor of Biology at West Chester University (Fig. 3 Strategic Map) (Strategic Map, Hertel). Trees were identified, measured and analyzed when DBH > 5 cm and < 74 cm. The removal of large outliers was to reduce exaggerated data. The DBH measurements provided the basis to calculate basal area, frequency, coverage, density, carbon stocks and importance values. Shrubs and vines were omitted from the sampling.

Calculations/Statistical Analysis

Canopy structure was divided by DBH's < 10.5 cm being classified as the understory and DBH's > 10.4 cm being classified as the overstory. Overstory and understory structure was compared in simple size class diagrams. Aboveground biomass and density was calculated to obtain the aboveground carbon stock. Belowground biomass and density was calculated to obtain belowground carbon stock. Total carbon stock equaled aboveground and belowground carbon stock in tonnes/Carbon per hectare. Mean carbon stock was calculated with a +/- 95% confidence interval.

Basal area was calculated for each individual tree as BA = PI * [(DBH/2) ^ 2]. Total basal area was calculated twice. Once as the sum for all of the same species despite plot location and a second time as the sum for all the same species in each individual plot. The former was used in calculating understory and overstory importance values while the ladder served in calculating individual plot importance values, both for each species. Importance values in each respective use equaled the sum of relative density, relative frequency and relative coverage.

Richness was calculated as the total number of tree species found in a plot. We created a land use variable in which each plot was assigned a 1 or 2 where 1 = Old woodlot and 2 = former Apple Orchard. NMS tests were run using Sorenson's Distance Measure in PC-Ord (McCune). The main matrix contained the importance values for tree species in each separate plot and was overlayed with a second matrix containing richness and land use.

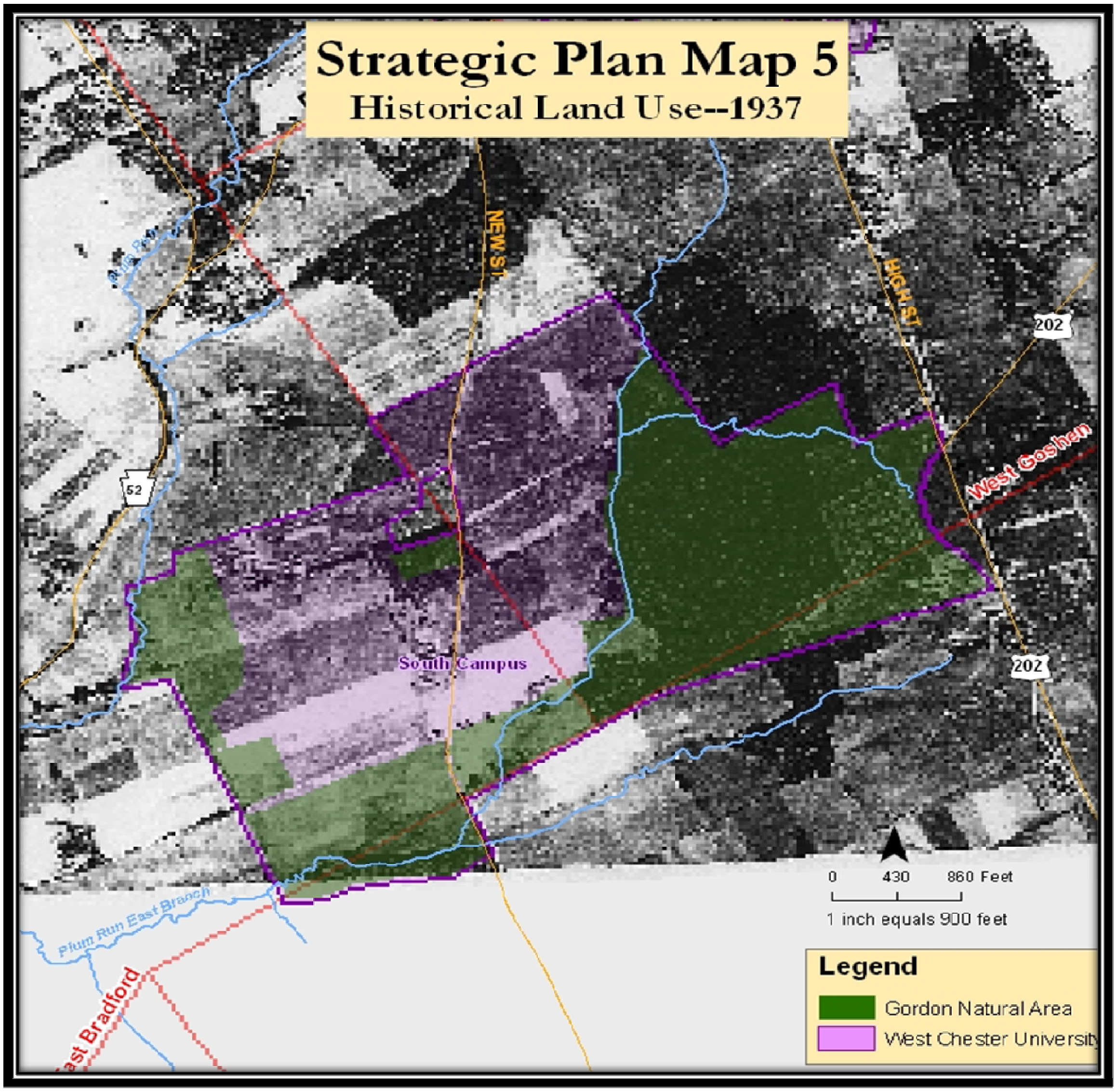


Fig. 3 Strategic Plan Map 1937

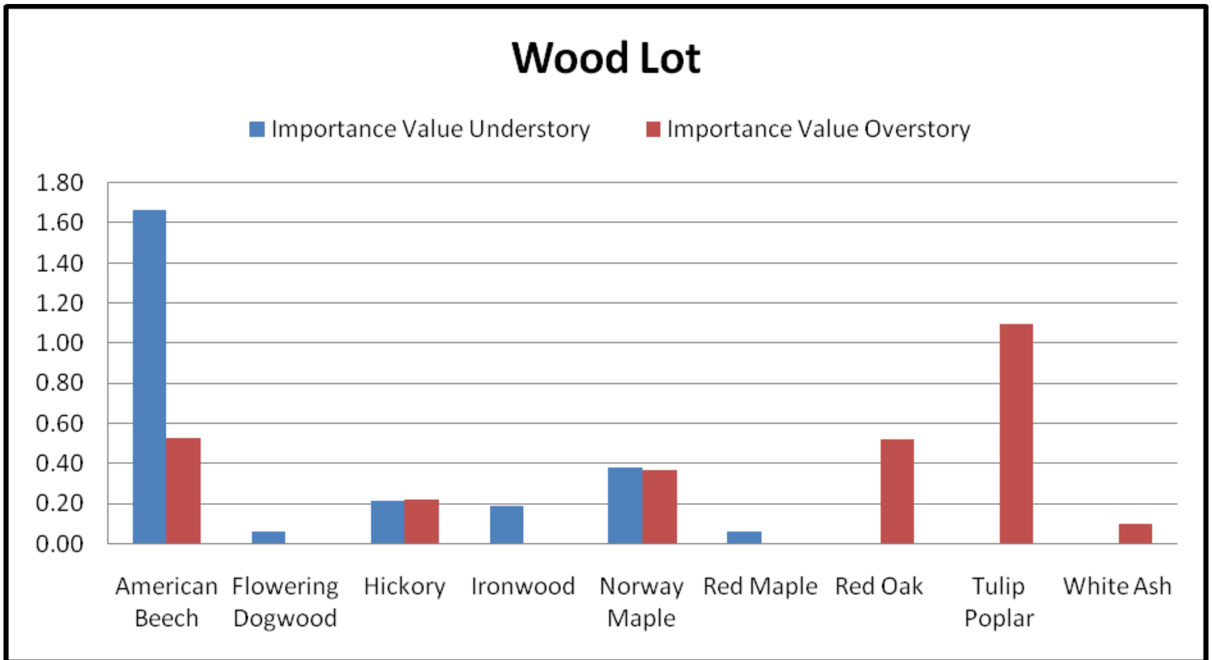
Results

A total of 418 trees consisting of 12 different species were found; 286 trees consisting of 9 species in the old woodlot and 132 trees consisting of 7 species in the former apple orchard. Tulip Poplar (*Liriodendron tulipfera*) was most prevalent in the overstory, with importance values of 1.13 in the old woodlot and 1.83 in the former apple orchard and with basal areas of 154,068 cm^2 and 134,937 cm^2 (Fig. 3 IV under/over). American Beech (*Fagus grandifolia*), Red Oak (*Quercas rubra*) and Norway Maple (*Acer platanoides*) had a strong presence in the old woodlot overstory behind *Leriodendron tulipfera* with importance values of 0.56, 0.55 and 0.40 and basal areas of 15,654 cm^2, 59,671 cm^2 and 7,790 cm^2 respectively. In the overstory of the former apple orchard on the other hand, White Ash (*Fraxinus americana*) and Box Elder (*Acer negundo*) had a small presence in regard to the *Leriodendron tulipfera* with importance values of 0.36 and 0.34 and basal areas of 13,105 cm^2 and 6,032 cm^2 (Fig. 4).

Fagus grandifolia dominated the old woodlot understory with an importance value of 1.76 with a small presence of *Acer platanoides* and Shagbark Hickory (*Carya ovata*) with importance values of 0.47 and 0.30 respectively. Again, the former apple orchard differed with *Leriodendron tulipfera* and *Acer negundo* being the only two species present in the understory with importance values of 1.72 and 0.95 (Fig. 4). Honeysuckle (*Lonicera sp.*) and Oriental Bittersweet (*Celastrus orbiculatus*) are noted, but not measured, as being dominantly present in the apple orchard but not in the woodlot plots.

Total Carbon Stocks ranged from the 106.32 t C/ha in plot 8 to the 327.85 t C/ha in plot 1 (Table 1 TCS chart). Mean Carbon Stock was calculated with a +/- 95% confidence interval. Means ranged from 2.56 to 9.24 t C/ha and after +/- intervals, ranged from 1.47 t C/ha to 11.32 t C/ha with no single plot being statistically significant from all other plots (Table 2 MCS chart). However, the old apple orchard plot six was statistically significantly larger then all of the wood plots and apple orchard plot eight with a mean ranging from 7.17 t C/ha to 11.32 t C/ha. Apple orchard plot four was statistically significantly smaller then woodlot plots five and six with a mean only ranging from 1.48 t C/ha to 3.64 t C/ha.

NMS tests reveal *Liriodendron tulipfera, Quercas rubra* and *Fagus grandifolia* to be significant on both axes (Table 3). The stress test resulted in a *p* value of 0.12 (Table 3). Richness was significantly related to species importance values in each plot, on both axes, with Kendall Tau values of 0.946 and 0.727 (Fig. 5, Table 4 Richness). Past land use influenced clustering of graph locations with all four woodlot plots appearing in the upper right quadrant and all four apple orchard plots appearing in the lower left quadrant (Fig. 6 Land Use). *Quercas rubra* and *Fagus grandifolia* significantly cluster in the woodlot plots while *Liriodendron tulipfera* significantly cluster in the orchard plots (Fig. 7, 8 & 9). The remaining nine species lacked significant correlations on either axes.



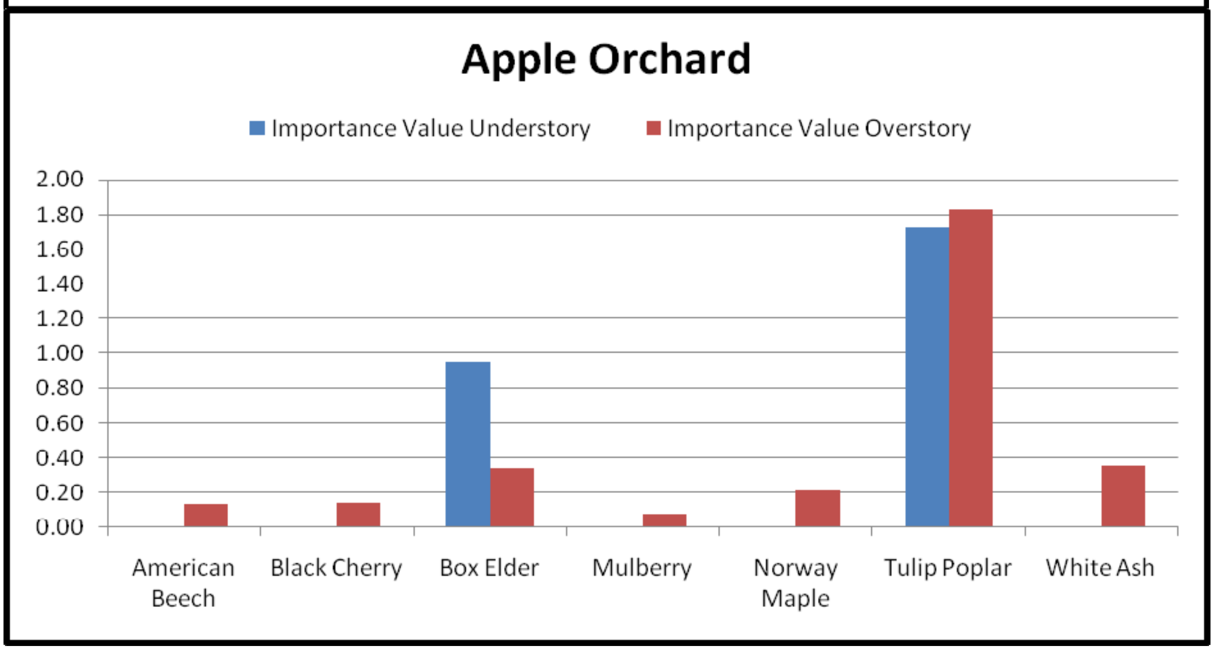


Fig. 4 Importance Values Woodlot and Apple Orchard

Plot	Aboveground Carbon Stock of Standing Live Trees (tonnes Carbon/hectare)	Belowground Carbon Stock of Standing Live Trees (tonnes Carbon/hectare)	Total Carbon Stock of Standing Live Trees (tonnes Carbon/hectare)
1	245.23	82.62	327.85
2	214.31	71.90	286.21
3	192.59	63.75	256.33
4	140.63	48.83	189.46
5	143.82	49.44	193.26
6	243.14	80.39	323.53
7	105.02	35.96	140.98
8	78.18	28.14	106.32

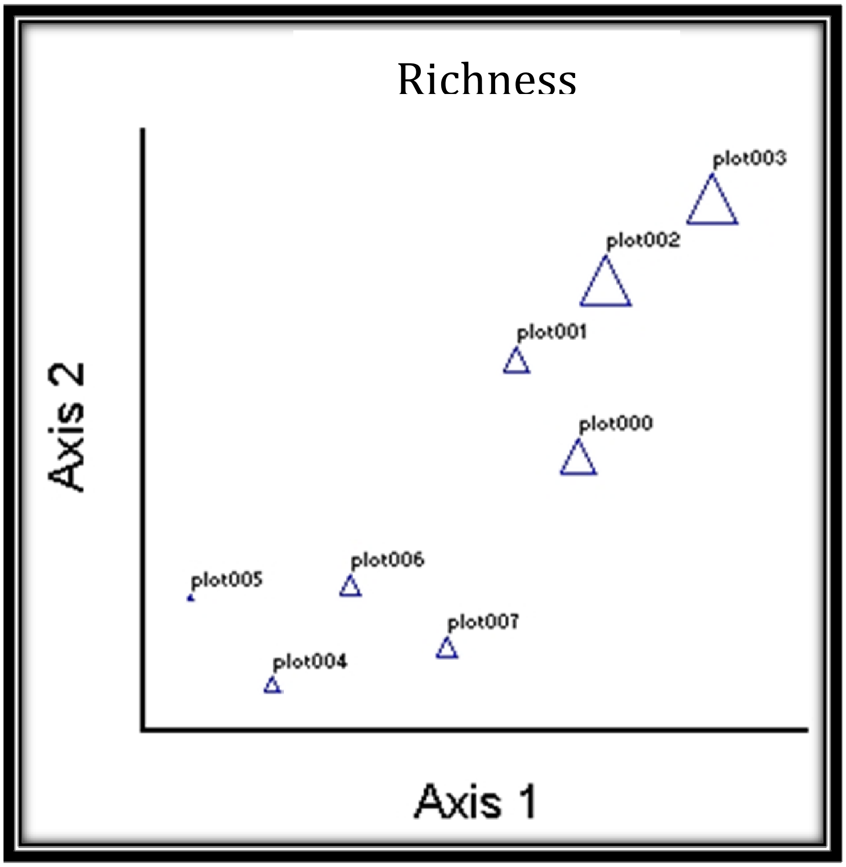
Table 1 Aboveground, Belowground and Total Carbon Stocks by Plot

Plot	Mean of Carbon Stock (t C/ha)	Mean of Carbon Stock - 95% C.I.	Mean of Carbon Stock + 95 % C.I.
1	3.95	2.67	5.23
2	4.62	3.00	6.24
3	3.83	2.24	5.42
4	2.56	1.48	3.64
5	5.86	4.00	7.71
6	9.24	7.17	11.32
7	4.86	2.51	7.21
8	3.04	1.47	4.60

Table 2 Mean Carbon Stocks by Plot

Species	Axis 1	Axis 2
American Beech	0.909	0.837
Black Cherry	-0.367	-0.577
Black Oak	0.071	0.357
Box Elder	-0.356	-0.356
Flowering Dogwood	0.357	0.214
Ironwood	0.472	0.367
Mulberry	-0.500	-0.357
Norway Maple	0.519	0.519
Red Oak	0.806	0.886
Shagbark Hickory	0.483	0.645
Tulip Poplar	-0.929	-0.786
White Ash	-0.265	-0.340
	p = 0.12	

Table 3 NMS Importance Values by species



Plot	Land Use	Richness
1	1	7
2	1	6
3	1	9
4	1	9
5	2	4
6	2	3
7	2	5
8	2	5

Table 4 Land Use and Richness. Land use is qualified where 1 = Old Wood Lot and 2 = Former Apple Orchard

Fig. 5 Richness NMS test (McCune)

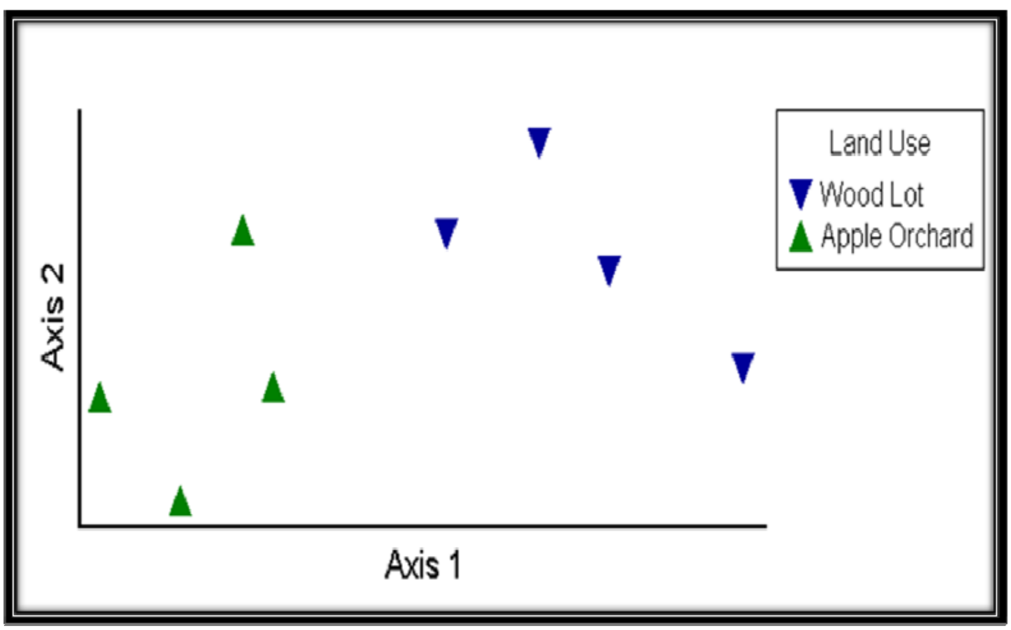


Fig. 6 Land Use Ordination

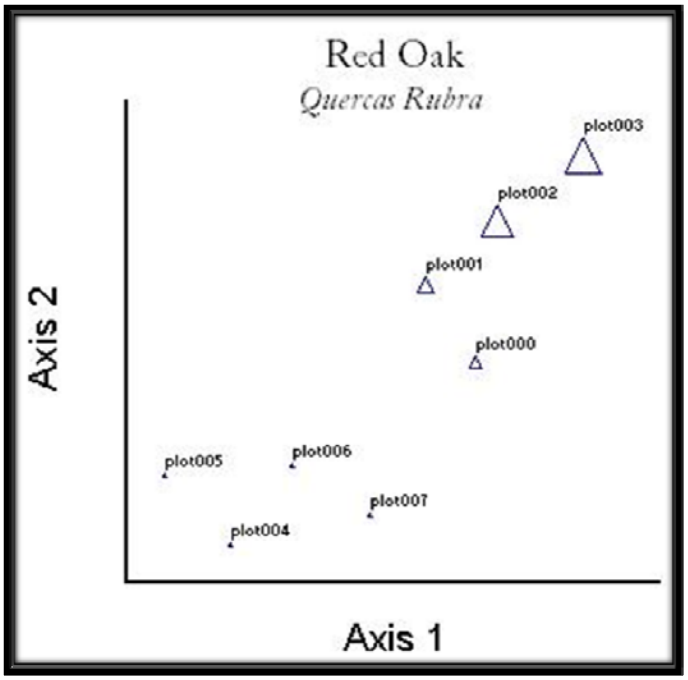


Fig. 7 NMS test results for Red Oak , p = 0.12 (McCune

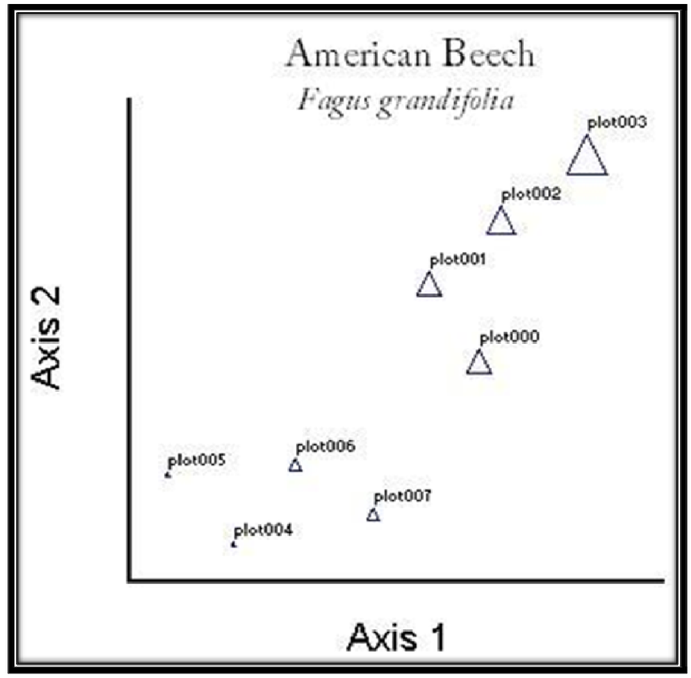


Fig. 8 NMS test results for American Beech, p = 0.12 (McCune)

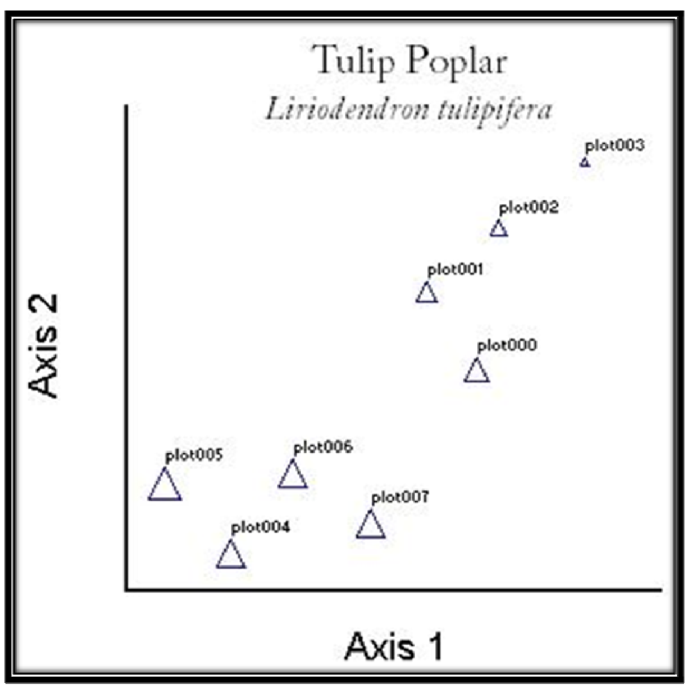


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Fig. 9 NMS test results for Tulip Poplar, p =0.12 (McCune)

Discussion

Deforestation in the 18th century led to various, different past land uses in the Gordon Natural Area. Two of those were used as the main determinants in this study; commercial logging in the woodlot and farming in the apple orchard. This study suggests possible correlations between these two different past land uses and the present day forest structure as well as composition of the GNA (Foster 1992).

The woodlot which had been used for logging differs from the orchard in its structure and composition. The former has an overstory that is dominated by Tulip Poplar (*Leriodendron tulipfera),* American Beech (*Fagus grandifolia*), Red Oak (*Quercas rubra*) and Norway Maple (*Acer platanoides*).

The orchard's overstory was mainly comprised of *Leriodendron tulipfera,* White Ash (*Fraxinus americana*) and Box Elder (*Acer negundo*). Both overstories show deforestation successional patterns as they are composed of species that are shade tolerant (Monk 1961).

The woodlots understory also follows this pattern as *Fagus grandifoli*a and *Acer platanoides* are this story's most common trees. The orchard's understory was made up of only two tree species: *Leriodendron tulipfera* and *Acer negundo*. Invasive shrubs were the most common form of understory vegetation in the orchard (*Lonicera sp.* and *Celastrus orbiculatus*). Thus, the study also found a correlation between the two different past land uses and richness (Foster 1992), as plots in the woodlot had a higher richness than those in the orchard.

Furthermore, *Leriodendron tulipfera* was missing in the understory of the woodlot, suggesting that this tree is less competitive than *Acer platanoides* or *Fagus grandifolia*. Interestingly, *Fagus grandifolia* was almost absent in the apple orchard, suggesting that this species might be less competitive than the invasive shrubs taking over the understory of the woodlot.

In addition to this, the woodlot has a far larger number of trees with a DBH < 20cm, indicating that the woodlot forest has a larger number of trees that will make up its canopy in the future (Fig. 10 Size Class

Diagram). Whereas the orchard has almost no trees that could make up its canopy cover in the future.

This study also suggests possibly that the abundance of invasive species is correlated with different past land uses (Lundgren 2004). Although, we did not account for invasive shrubs in our study and did not use their DBH for analysis, we noted the presence of the two major invasive species in the eight sampled plots of the Gordon Natural Area: Honeysuckle (*Lonicera sp.*) and Oriental Bittersweet (*Celastrus orbiculatus*). These two species were dominantly present in the part of the forest that had been previously used for farming (apple orchard) and were not as abundant in the woodlot. Also, these two invasive shrubs almost entirely account for the orchard's understory. Thus, this study suggests the possibility that different past land uses have an influence on the abundance of invasive species.

The study found a small correlation between mean carbon stock and the two different past land uses. Since only one plot in the apple orchard is statistically different from the woodlot plots, no real correlation between land use and mean carbon stocks can be drawn from the data. Although, in general total carbon stocks were lower in the apple orchard because there were twice as many trees in the woodlot, also an affect of the missing understory trees in the apple orchard due to the high abundance of the invasive *Lonicera sp.* and *Celastrus orbiculatus.*

Tests run in PC-Ord made it evident that there was a clustering of the woodlot and apple orchard plots. The clustering is possibly influenced by richness (axis 1), due to the fact that plots with a higher richness are located in a cluster further on the right of axis 1 in perfect ascending order. Axis2 could consist of unaccounted variables such as slope, shade tolerance or presence (or lack thereof) of invasive shrubs. A statistically significant correlation is evident among the dominant trees through these tests and through further, more intensive analysis, the exact variables influencing these differing clusters may be found.

With *Fagus grandifolia* and *Acer platanoides* representing the greatest abundance, and the missing *Leriodendron tulipfera* in the woodlot's understory, it is likely that the woodlot's overstory composition is going to change in the future. The woodlot's overstory then might be dominated by the deer-browse immune *Fagus grandifolia* and the invasive *Acer platanoides*. Thus, the importance value of *Leriodendron tulipfera* is likely to decrease in the future.

The orchard's overstory also is going to change more dramatically in the future than the woodlot, as its understory is almost entirely composed of invasive shrubs, suggesting that one day this area might become a forest only consisting of invasive undergrowth.

With the goal to preserve the GNA and its richness of species, it is important to consider the results of this study as they clearly show that parts of the forest (apple orchard) might be lost to invasive shrubbery or lose their richness without proper management and preservation strategies.

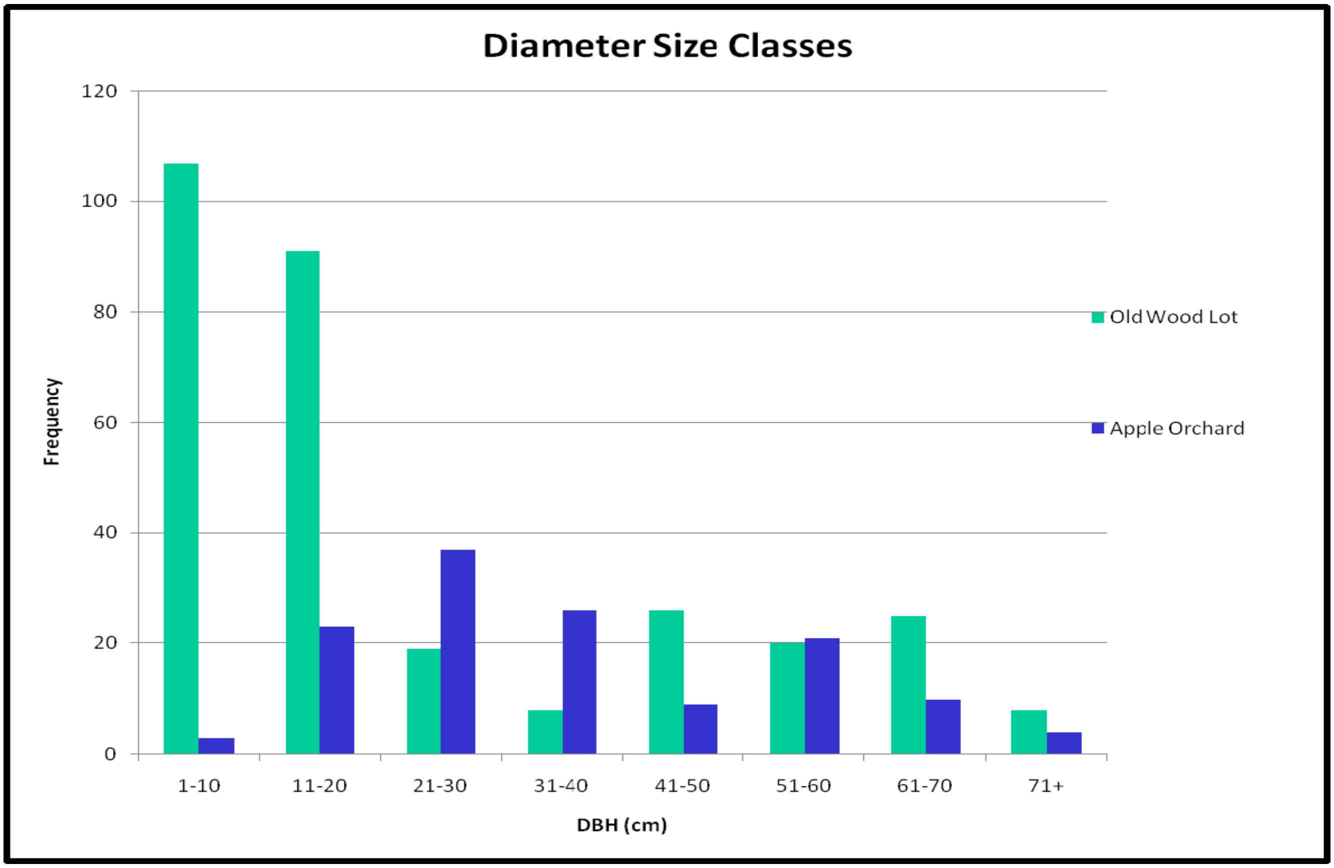

Fig. 10 Size Class Diagrams for overstory and understory for all eight plots

Conclusion

This study supports the idea that past land uses readily effect present day forest composition, structure and richness. Also it found a correlation between the abundance of invasive species and different past land uses. However, it is not possible to suggest this definitively. Although differences statistically exist, this simply serves as a pilot study. Several more variables (slope, deer-browse, soil type/structure) must be included as well as additional plots for ample data collection and representation. Continued research in this field is of great importance so we may begin to realize and quantify the long term effects of human development on our natural world and thus ultimately implement steps aimed at conserving these landscapes for future generations.

Works Cited

Board on Agriculture. *Managing Global Genetic Resources: Forest Trees*. Washington D.C.: National Academy Press, 1991.

Brandywine Conservancy. 2004. *Upper East Branch, Brandywine Creek Watershed Conservation Plan*.

Department of Biology: West Chester. 2003. "Robert B. Gordon Natural Area for Environmental Studies Annexation Proposal." Map Document.

Foster, D.R. 1992. "Land-use history (1730 – 1990) and vegetation dynamics of central New England, USA." *Journal of Ecology 80*: 753-772.

Hertel, Dr., Personal Interview. 11 November 2010.

Lundgren, M.R. Small, C.J., and Dreyer, G.D. 2004. "Influence of land use and site characteristics on invasive plant abundance in the Quinebaugh Highlands of southern New England." *Northeastern Naturalist* 11(3): 313.

Matlack, R.G., 1997. "Four centuries of forest clearance and regeneration in the hinterland of a large city." *Journal of Biogeography*, Vol. 24, p. 281-295.

McCune B, Mefford MJ. 1999. PC-ORD, Multivariate analysis of ecological data, version 5.0. MjM Software, Gleneden Beach, Oregon.

Monk, Carl D. 1961. "Past and present influences on reproduction in the William L. Hutcheson Memorial Forest, New Jersey." *Bulletin of the Torrey Botanical Club* Vol. 88, No. 3, p. 167 – 175.

Niering, W.A., 1998. "Forces that shaped the forests of the northeastern United States." *Northeastern Naturalist* 5:99-100.

Pennsylvania Department of Conservation and Natural Resources. 2005. *A Gap in Understanding*.

Pennsylvania Department of Conservation and Natural Resources. 2005. *Pennsylvania: Our Place and It's Past.*

West Chester University GIS Data. "Strategic Plan Map: 1937."