TREE-RING GROWTH AND SUPPRESSION DYNAMICS FOR *Acer saccharum* IN THE PRESENCE OF INTER- AND INTRA-SPECIFIC COMPETITION

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Abstract

Northern Wisconsin and the Upper Peninsula of Michigan have been greatly impacted by a history of large-scale logging, resulting in a loss of old-growth forests. Human interaction and deer browsing are changing areas formally dominated by the shade tolerant eastern hemlock (*Tsuga canadensis*), into sugar maples (*Acer saccharum*) stands. We analyzed secondary forests' growth rates and forest dynamics for *Acer saccharum* trees in monotypic and heterogeneous stands. Sampling consisted of stand mapping and inventorying, and increment core extraction within three 0.05-ha plots located at the University of Notre Dame's Environmental Research Center within the Ottawa National Forest in Michigan's U.P. Stands were chosen to sample across a compositional and age gradient including an *Acer saccharum* monoculture and two compositionally heterogeneous and uneven-aged plots. Our hypothesis was correct in that *A. saccharum* in competition with other tree species had higher growth rates, but not for homogeneous competition. Understanding *A. saccharum* growth rates can help to explain current species assemblages and predict the future trajectory of forest tree species richness, dominance and competition within the Northwoods.

Introduction

The impact of both natural and human disturbances that effect forest ecology can significantly change overall composition and productivity over time. Since European settlement, the North American landscape has changed drastically and knowing how these changes are caused is vital in predicting significant changes in the future (Rhemtulla 2009). Land use and increased deer browsing have changed forest dynamics such that previously logged areas once dominated by hemlock are now being dominated by *Acer saccharum* (Rhemtulla 2009). Initially, logging companies preferred durability of white pine but in the late nineteenth century when high amounts of logging created a very scarce abundance, hemlock was the next best alternative for mass logging (Whitney 1990). Also, logging, deer browsing and fires devastate seedling regeneration and sampling growth for hemlock (Rogers 1978). *Acer saccharum* is a species known to be quite shade and brose tolerant, and may out-compete hemlock sapling growth. Old growth stands once contained high species richness as opposed to a second growth forests with distinct dominant species (Dyer 2006). The clear cut of many shade tolerant hemlocks gave the opportunity for *Acer saccharum* to increasingly grow. *Acer saccharum* and *Acer rubrum* (red maple) had shown a significant increase within many disturbed plots throughout the northeastern United States (Whitney 1990).

The Ottawa National Forest in the Michigan's U.P. is a region greatly impacted by human influence. Our study site is located in the University of Notre Dame's Environmental Research Center (UNDERC) is located within the Ottawa National Forest. The original purchase the land was from the Bonifas Lumber Company (UNDERC 1999). UNDERC has been impacted by mass logging, just as most of the northwoods. By conducting forest surveys of composition combined with dendrochronology, we can analyze species competition of *Acer saccharum* and various deciduous and conifers to predict changes and future impacts for the Northwoods.

There are two projected outcomes which many competition studies are analyzing; plant survival with density and spatial distribution of vegetation (Duncan 1991). We are testing a similar idea to survival and density, the effects of total basal area within inter- and intra-specific plots on mean growth rate. If there is a significant importance of distances and spatial patterns of competing neighbors, they should have an effect on size and overall performance of a tree (Weiner 1985). Sugar maple dynamics are important to understand in competition with other species, these factors are important in maintaining species diversity and abundance in a second-growth forest.

Sugar maple is a shade-tolerant species and better adapted to disturbances than hemlock, and this allows *Acer saccharum* abundance to increase due to less competition and their less-intense regeneration requirements, and are not as affected by consumers (Rogers 1978). Sugar maples also contain deep root structures allowing them to retrieve nutrients from further distances (Rogers 1978). Many factors are influencing the high rate of growth of *Acer saccharum* after disturbances and out-competing many other species.

Study Site and Field Methods

Three plots were selected within the University of Notre Dame's Environmental Research Center. Our three plots (Figure 1.) consisted of: two compositionally heterogeneous and un-even aged tree stands with *Acer saccharum* and; *Populus tremuloides*, *Abies balsamea*, *Acer rubrum*, *Populus grandidentata*, *Fraxinus americana*, *Tilia americana*, and one monotypic stand of *Acer saccharum*. Plot 1 was our homogeneous sugar maple stand, and plots 2 and 3 were our compositionally heterogeneous stands and were selected by a habitat map of UNDERC on ArcGIS®. The plots were 0.05-ha plots (23.36 m x 23.36 m). For each plots setup on a slope, we used a clinometer to account for the difference in plot size. We set up the plots based on the program Interpoint, which uses triangulation to create an aerial stand map of each individual tree within a plot. Interpoint can accurately map to 0.1 m by using both DBH and tree-to-tree distance measurements. From each tree with a DBH of ≥5cm.in our plot we recorded; tree species, canopy class, and DBH, and extracted two cores from all living trees. Increment core extraction involved removing 2 cores from each tree at 180 degrees from each other with increment borers in order to calculate tree-level average mean growth rate (MGR). Cores were all taken ≈1.5 m from the ground. Extracted cores were dried, before mounting. Each measured tree was tagged with metal number tags on the same direction of each tree.

Lab Methods

When all tree-to-tree distance and DBH measurements are correct, Interpoint gives each tree an x and y-coordinate, which was used to create the aerial plot map in ArcGIS®. We used the Excel stand map to select particular *A. saccharum* within each plot that were sufficiently surrounded by mapped trees for proper analysis. Radial growth in trees varies with; temperature, precipitation, species response to disturbance and competitive interactions (Frayer et al. 2005). We selected areas close enough to each other so climate was not an issue, our main concert only being species, we did our best at selecting similar areas to avoid outside influences on mean growth rates of *Acer saccharum*.

Cores were used to measure growth rates for *Acer saccharum* when surrounded by different species providing different competition. To analyze the cores, we took a sub-sample of *Acer saccharum* from each plot selected to represent both types of stands. We chose our tree cores from the heterogeneous plot that were relatively surrounded by conspecifics and not near the edge of the plot. Because the homogeneous plot was even-aged and evenly distributed, we selected tree cores more towards the center of the plot.

Once we had our cores dried, they were mounted on wooden molding with Elmer's glue and held down with either string or rubber bands. Once dried, we removed the bands and sanded the cores beginning with increasingly finer grit sand papers (up to 320) and then coated them with clear nail polish to get a more visible view of the rings. From our second and third plots, the heterogeneous stands, we analyzed 22 *Acer saccharum* trees. The 37 trees selected (74 total cores) were measured by using a Velmex (Velmex Inc. Rochester, NY), a linear measurement system that is accurate to 1 μm resolution. Linear measurements were digitally recorded starting at the innermost portion of the bark to the center of the core. Curved center rings were measured radially to get a more accurate reading to calculate mean growth rate.

Mean growth rate was calculated by taking the sum of each measured distance between two rings and divided by the total number of rings for each core. Since the two cores are simply two replicates of the same rings, they gave a replicate of rings to take the mean. Then, the two means where then averaged and divided by two to get mean growth rate of each target tree.

A GIS map of each plot was used for tree selection. Tree health, growth and productivity are directly influenced by neighboring individual trees within a fixed 10 m radius due to shading levels and resource competition (Busing 1991).

We modeled our tree buffering region on the method of Busing (1990), which selects all trees surrounding the target tree in a 10 m radius. Having a 23.36m x 23.36m plot limited our buffering area, and we ultimately decided to only select trees within a 5 m radius of the target tree for replication considerations. From our first plot, the monoculture of *Acer saccharum*, we took a sub-sample of 15 trees.

Data Analysis and Results

A multiple linear regression test was run for the homogeneous plot on 15 *A. saccharum* trees, to determine whether total basal area of surrounding trees within the 5m radius influences mean growth rate for *A. saccharum*. Our results show no significant relationship between total basal area of conspecific trees and mean growth rate for this homogeneous plot. (P-value = 0.165555, $F_{1, 13}$ = 2.158590). Another multiple linear regression test was run on summed basal area of non-sugar maples within the heterogeneous plot and their effects on mean growth rate; P = 0.014, $F_{1, 20}$ = 7.292717, R^2 = 0.267205 (Figure 3.). Total basal area around a target tree also P = 0.047, $F_{1, 20}$ = 4.485058, R^2 = 0.183175 (Table 1.)(Figure4.).

Discussion

We predicted that when *A. saccharum* is in competition with non-sugar maple species, they will have lower growth rates, which may increase mortality, create canopy gaps, and allow other species to take root. No significant relationship occurred between total biomass of competitors and MGR for the homogeneous plot of *A. saccharum*. For our heterogeneous plot, we analyzed both basal area for selected trees and separated these values into; *A. saccharum*, conspecific (non-sugar maple trees), and total basal area. Our p-value for influence of *A. saccharum* basal area on mean growth rate of selected trees was insignificant, but there was a correlation between conspecific basal area and mean growth rate. When analyzing both the *A. saccharum* homogeneous stand and *A. saccharum* basal area within the heterogeneous stand, they showed no direct correlation on mean growth rate, which could mean they are better suited as co-existing stands. For the test to support our hypothesis, basal area of non-sugar maples had an influence on mean growth rate of *A. saccharum,* as did total basal area. This means that as basal area of non-sugar maple increases, mean growth rate also increases. Interspecific competition is not of high concern for *A. saccharum* within our plots, and the location is more suitable for radial growth of *A. saccharum*.

Although replications of plots were not abundant, this gives a proposed idea for further research on how *A. saccharum* interacts with other tree species. Also, one direction of plant neighboring influence that can occur is the distance between plant and neighbor will have a positive influence on size, or growth rate (Pielou 1962). As stated before, understanding *A. saccharum* growth rates can help explain current species assemblages. Although there are many factors influencing tree abundance and diversity, Vanclay (2006) states that when developing a mixed-species experiment in forestry, there are many factors and complex designs which can be achieved and numerous considerations to account for in a forest ecosystem setting, not just a few simple variables. Our stand maps and tree surveys were quite simplistic, and we tested for only one dependent variable of mean growth rate and effects of inter and intra-specific competition between three plots – and tested numerous replicates of subplots within the three. For future tests, it would be best to have several more plot replicates and larger plots size to be able to use Busing's method of a 10m radius for the tree buffer zone. Understanding specific interactions of suppression and growth rates between the abundant *A. saccharum* and other tree species within Northern Wisconsin and Michigan's U.P. can allow us to predict species dominance and competition for future trajectories of the northwoods. Pielou (1962) states that if intra-specific competition is occurring, competitors will be limited in growth and productivity, which can ultimately influence long-term forest composition within a forest. The spatial patterns and interactions greatly affect forest structure and dynamics (Busing 1991).This is an especially vulnerable truth within a second-growth forest, where changes are still occurring since massive clear cutting of the Northwoods.

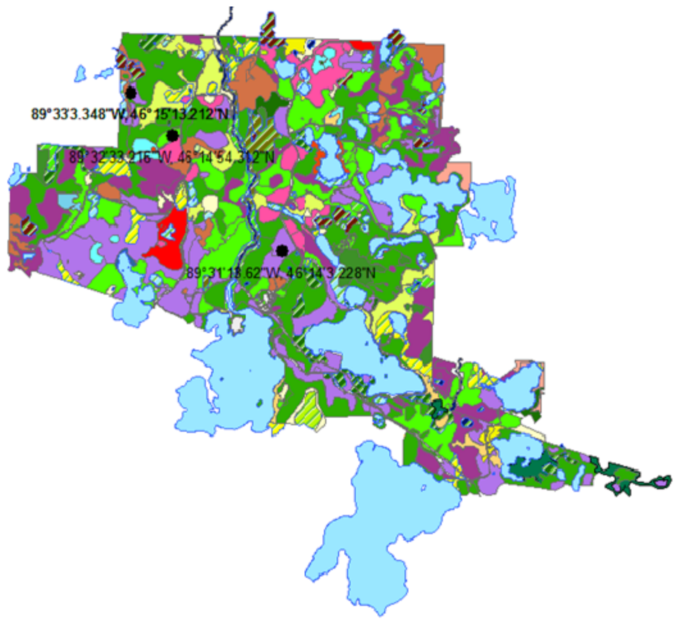

Figure 1: Map and GPS coordinates of 3 selected plots within UNDERC property from ArcGIS®.

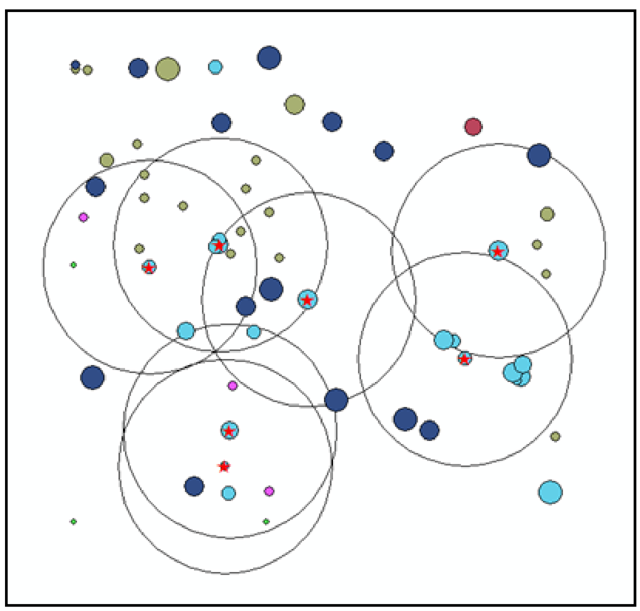

Figure 2: Plot 2 on GIS – All trees with the heterogeneous plot. Size of colored circles indicates DBH, and colors determine species. Red stars indicate analyzed trees, and larger circles are the 5m radius buffers to define the direct influencing trees.

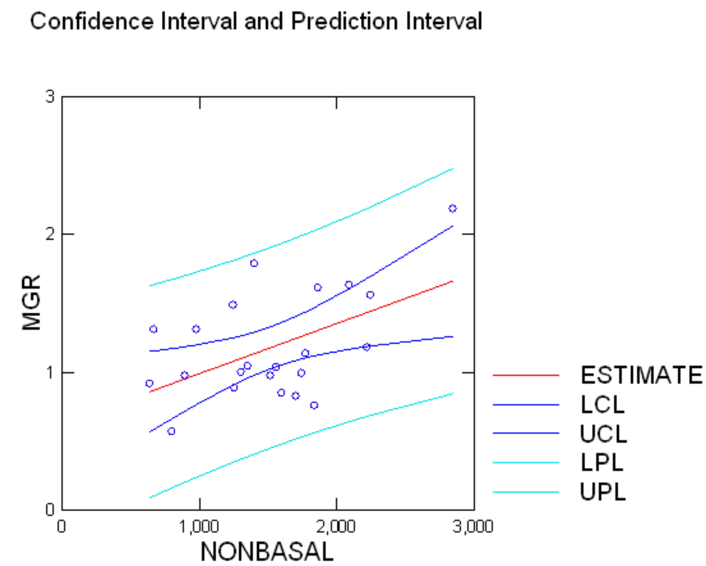

Figure 3: Non-sugar maple basal area per tree buffer zone and mean growth rate correlation graph.

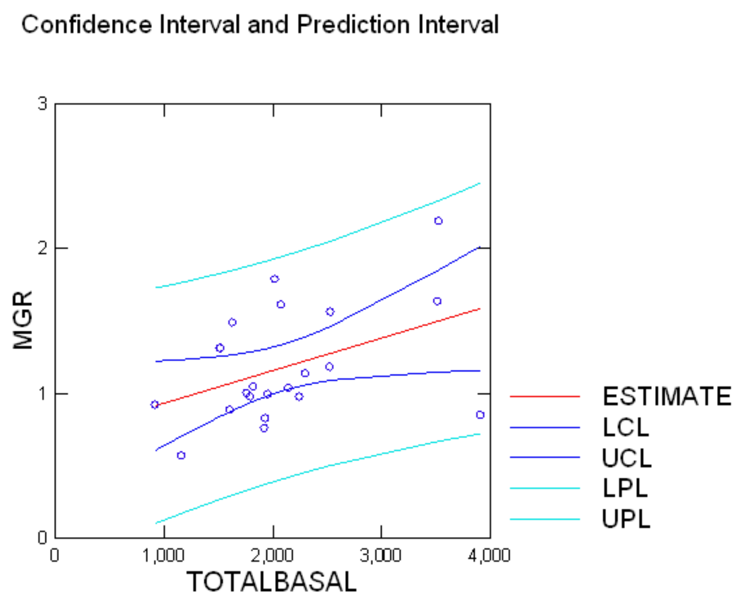

Figure 4: Total basal area per tree buffer zone and mean growth rate.

Table 1: Significant p-values and associated tests quantified with SYSTAT.

Test	**P-Value**
Total basal area of *A.saccharum* on MGR in homogeneous plot	0.165555
Total basal area of conspecifics on MGR in heterogeneous plot	0.013763
Total basal area on MGR in heterogeneous plot	0.046915

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