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Abstract
Forest composition is an important first step in understanding how or if a forest should undergo any land management practices. This study focused on two maple-basswood forests on St. Olaf College's campus, Heath Creek and Norway Valley. Heath Creek has had no known land management practices for the last 30-40 years while Norway Valley is actively managed by the college. Maple-basswood forests most commonly contain species like elms, sugar maple, ironwood and basswood among others, although it was expected that there would be variance in species diversity between both sites. Tree diversity was based on samplings of saplings, seedlings and mature trees in both forests while soil was collected to analyze organic matter content, soil moisture and nitrate levels. Overall, Heath Creek had a higher diversity than Norway Valley. The soil composition was similar between sites. Hopefully this study will provide more information to St. Olaf College concerning forest management and the composition of Heath Creek forest since there is currently little known about this plot of land.

Introduction:

Studying the Big Woods of southern Minnesota allows us to establish how these forests are composed, what they may look like in the future and how land management may be used to keep them healthy (Shea 1993). Big Woods or maple-basswood forests are a native Minnesotan habitat that include species such as elms (*Ulmus*), sugar maple (*Acer saccharum*), ironwood (*Ostrya virginiana*) and basswood (*Tilia americana*). Surveying maple-basswood forests and deciphering present species composition allows us to decide what styles or types of land management are best, if any. This is especially important as fragmentation caused by human activities becomes an increasing problem. Fragmented forests isolate, reduce and remove natural vegetation that may be vital to an ecosystem's composition (Marzluff 2001). Thus conserving these areas has become a large concern for the future of both managed and unmanaged forests (Lindenmayer, et al. 2000). No matter what the method may be, conservation is a highly discussed topic that requires detailed observation in order to monitor an ecosystem. Studying the vegetation species composition of a forest is an important preliminary step towards conserving that area.

Studies that focus on how forests are composed and how they have been composed in the past are valuable for possible future ecological changes (Berland, et al. 2011). Since forest composition may change due to many factors such as disturbances like weather, wind fire or anything resulting in canopy openings and will shape how a forest will exist for years to come, tree species composition is important to establish in forests.

In a study of a maple-basswood forest near Minneapolis, Bray found that sugar maples are the most important trees to these Big Woods. Their prominence is due mostly to their high seedling rates, shade tolerance and quick growth which allows them to overcome oaks, elms and hickories (1956). Yet other species in maple-basswood forests are more sensitive to certain growth conditions such as the amount of shade they can tolerate which affects what species may exist in the future composition of these areas (Bray 1956).

In addition to competition, other factors may affect the number of a species found in a maple-basswood forest. Diseases may change a forest's composition for example. Oaks and elms are at a particular disadvantage due to fungal diseases such as oak wilt and dutch elm disease. Even within a genus there may be differences in survival rates. Red oaks tend to die quickly of oak wilt while white oaks may survive for a few years (Shea 1993). Thus growth, reproduction, shade tolerance, disease and disturbance will all have an impact on a forest's composition. This means that studying what species are present in a forested area helps determine how they react to disturbances and therefore what a forest may look like both in the present and future.

Soil influences organisms in an area as well. Maple-basswood forests tend to be in areas with intermediate water-holding soil which means a change in soil composition will affect the tree species growing from it. Soil texture also affects nutrient retention and how accessible they may be to certain species. Soil changes over time due to physical, weather, chemical interactions, seasonal changes and organisms living in soil (Shea 1993). This indicates that soil surveys of forests are just as important in determining forest composition as any species composition studies.

Thus determining what the species and soil composition in modern Big Woods not only helps determine what current conditions are like but also how management can be beneficial to these forests and how they maybe react to changes in climate or disturbances. In this study we compared two different maple-basswood forests sites in Northfield, Minnesota, USA. We studied Heath Creek forest and Norway Valley which are both part of St. Olaf College's natural lands. What is interesting about this two sites is that Norway Valley (NV) is a restored forest that has undergone land management practices for one hundred years while Heath Creek (HC) is a mystery. There has been no known restoration efforts or land management practices at Heath Creek Forest for at least the past 30-40 years. Our goals in this study were to compare species composition, including the population structure of trees in these two nearby forests using data from plot and plotless sampling, and to consider soil conditions to determine how restoration and management practices (or lack thereof) have affected each site and what further steps we might consider for these forests. We aimed to (1) compare tree species diversity, density, frequency, coverage and size of mature trees in an unmanaged maple-basswood forest (HC) with a restored and actively managed forest (NV), (2) determine if mature trees, saplings and seedlings are of the same species and occur at the same proportions within sites, and (3) compare soil nitrate levels, bulk density, percent moisture and organic matter between the two sites.

Methods:

Study sites were Heath Creek Forest (44° 27'22.538" N x 93° 11'22.221" W) and Norway Valley (44° 27'29.679" N x 93° 11'3.199" W), two maple-basswood forests on St. Olaf College's natural lands in southeastern Minnesota, USA. Norway Valley (NV) is an 18 acre plot of restored maple-basswood forest located on the southern part of St Olaf's campus. Heath Creek (HC) is also a maple-basswood forest located south of St Olaf College. Not much is known about its history and whether or not it has undergone any restoration or land management practices. Both sites are similar in location and climate.

Trees

We sampled vegetation using a combination of plots and line transects. For shrubs, woody plants and tree seedlings, we used 1 m^2 plots (0.71 x 1.41 m). For tree saplings and small trees, which we defined as >0.5 m tall (approximately knee height) and >13 cm diameter at breast height (DBH), we used 10 m^2 rectangular plots (2 x 5 m). For mature trees (<13 cm DBH) we used point-quarter sampling (Cottam and Curtis 1956). The sampling point we used for the point-quarter sampling was also used as a corner for the seedling and sapling plots. We noted species and number of individuals per species for seedlings and saplings. When sampling mature trees, we measured the distance from the sample point to the nearest individual tree in each of four quadrants. We also recorded species and DBH of each individual (Shea unpublished work). We sampled 9 plots at HC and used class data from Kathy Shea's fall 2016 Field Ecology 371 course at St. Olaf College for NV.

Soil

We used a 15 cm soil corer to core each of our samples. Twelve samples were taken, two from the first six plots at HC. One sample from each plot was used to determine soil density, organic content and soil moisture while the other was used for KCl extracted NO_3 concentrations. Soil data from Field Ecology fall 2016 was used for NV.

Data Analyses

Tree sample data were analyzed in Rcmdr version 2.1-7 model of R, and Excel. We created a contingency table using Rcmdr and determined density, frequency, coverage and species diversity using Excel according to Brower et al (1998). Soil data were analyzed through one-way ANOVA tests using Rcmdr.

Results:

HC was significantly more diverse with a higher species evenness than NV, although NV had a higher species richness (Table 1). There were few common species between sites, especially within seedlings and saplings. All classifications (mature trees, saplings and seedlings) were combined to compare species proportions within sites. The contingency table revealed that HC had significantly different species proportions than NV with a more even split between basswood, hackberry and sugar maples while NV was predominantly composed of sugar maples.

In NV, sugar maples had an importance value of 1.4682, higher than any other species between both sites (Table 2 and 3). The tree species with the highest importance value in HC was basswood (0.8913, Table 3). White ash had the second highest importance value (0.6195) in HC, followed by sugar maple (0.5014) and hackberry (0.4575, Table 3). Sugar maple was followed by basswood (0.4814) and white ash (0.4667) in NV (Table 3).

In terms of density, buckthorn was the highest in HC with saplings at 303.4169 trees/ha and seedlings at 150.6993 trees/ha. In NV, buckthorn was present only within saplings at a density of 2.3153 trees/ha (Table 4). The density of mature white ash in HC was eight times that of white ash in NV (80.5823 trees/ha compared to 10.6591) while mature basswood was about ten times denser in HC than NV (Table 4).

Overall, mean tree diameter was lower at HC than NV. Despite the number and importance of white ash and basswood in HC, the average diameter for both species was much lower than those in NV. Red oak had the largest diameter in HC while white oak was the largest in NV (Fig.1 and Table 5).

Soil analysis revealed no significant difference in percent moisture, percent organic matter or nitrate concentrations between sites (Tables 6, 7, 9 and 10). Soil density however was significantly higher at HC (4.553 g/cm^3) than at NV (1.0947 g/cm^3, Table 6 and 8).

Discussion:

Composition and Mature Trees:

Our analysis revealed that HC has higher species diversity within mature trees than NV as well as higher species evenness. Prominent species found in HC also differed from those found in NV, although the five species found within both sites (white ash, basswood, boxelder, hackberry and sugar maple) are common core species that make up maple-basswood forests, which is reassuring. What is concerning though, is the huge discrepancy between sugar maple presence in NV and any other species throughout mature tree, sapling and seedling density.

Soil

There was not much difference between the two sites in terms of soil composition. Nitrate levels at NV were higher than HC although it was insignificant. In contrast, HC had a very high soil density (>1.6 g/cm^3) which could potentially restrict plant growth and may be a factor in the mean diameter of mature trees at HC which were found to be lower than those at NV.

Future of the Forests

What we found to be most interesting is the tree diversity at HC compared to NV. Lack of management and restoration efforts doesn't seem to have hurt the forest too much in terms of diversity and species evenness, while NV seems to have a more concerning future. The large amount of sugar maples present at NV throughout mature trees, saplings and seedlings indicates that the forest is losing tree species diversity. We can probably expect to see more sugar maple growth in the future of NV while HC will most likely continue to express higher tree species diversity.

While the lack of diversity at NV is frustrating, especially considering that the site has undergone restoration efforts along with continuous land management practices, the number of sapling and seedling buckthorn present at HC could also be cause for alarm. Although this study focused almost entirely on tree species, one can observe an alarming lack of undergrowth in HC upon entering the forest. In contrast, NV has a healthy and actively maintained undergrowth. We believe that he lack of undergrowth in HC is most likely due to the buckthorn overgrowth, considering that leaf and fruit exudes have been found to reduce seed germination of other species and it is likely that buckthorn is detrimental to native species. Although not observed in this study, buckthorn is also known to increase nitrogen levels in soil and alter decomposition rates within forests (Knight et al. 2007). This suggests that the forest's composition could potentially change depending on how buckthorn interacts with seedling and sapling growth and soil composition at HC.

Conclusions

In terms of restoration efforts, our results suggest that tree diversity at HC has not suffered from neglect. In fact, HC has maintained a satisfactory level of evenness between species while NV has suffered a decrease in diversity with sugar maples crowding out other species commonly found in maple-basswood forests. Additionally, HC has smaller mean mature trees diameters than NV which may be linked to its high soil density and large numbers of buckthorn growing in dense thickets that may be affecting the undergrowth and soil composition of the forest.

Buckthorn management may be a first step in considering restoration efforts at HC. Cutting and herbicide are efficient techniques that the college already employs. Some of the trees are small enough that hand-pulling buckthorn could also be a useful tactic. Unfortunately, there are legacy effects of buckthorn which may leave the soil and forest recovering for years after removal. If we manage to remove the buckthorn, a long process of soil management and introducing native plants to help recreate a healthy understory awaits us in HC. This may mean recreating plant succession in order to reestablish chemical and physical soil characteristics (Heneghan et al. 2006).

Although management may be needed, and discussing possible restoration efforts is a good conversation to start, this study was primarily focused on tree species composition and had a limited scope concerning soil composition. Therefore, rather than proposing steps in land management within NV or HC, it would probably be wiser to continue studies that compare both sites to further investigate how HC may be affected by buckthorn. A sensible next step would most likely be studying forest undergrowth and soil composition more closely within these two study sites.

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Tables and Figures

Vegetation

Table 1. Species diversity at NV and HC.

	NV	*HC*
Total # of Individuals	106	36
Richness	19	11
Shannon (H')	0.43	0.70
Simpson (Ds)	0.32	0.75
Variance of Ds	0.000580	0.001077

P-value: <0.05

Table 2. Species proportion (includes mature trees, saplings and seedlings) within NV and HC.

Species (all)	*NV*	*HC*
Ash- White	1.1%	5.0%
Basswood	1.8%	32.5%
Boxelder	4.4%	7.5%
Hackberry	1.1%	20.0%
Maple- Sugar	91.8%	35.0%
Count	571	40

X-squared = 171.3997, df = 4, p-value < 2.2e-16

Table 3. Importance Values from Norway Valley (NV) and Heath Creek (HC).

Species	**Relative Density (RD)**		**Relative Frequency (Rf)**		**Relative Coverage (RC)**		**Importance Value (IV)**	
	NV	*HC*	*NV*	*HC*	*NV*	*HC*	*NV*	*HC*
Ash-White	0.0377	0.1944	0.0816	0.2500	0.3473	0.1751	0.4667	0.6195
Basswood	0.0849	0.3333	0.1633	0.2917	0.2332	0.2663	0.4814	0.8913
Boxelder	0.0377	0.0833	0.0612	0.0833	0.0046	0.0798	0.1036	0.2465
Elm	0.0189	0.0278	0	0.0417	0.0146	0.0205	0.0334	0.0899
Hackberry	0.0094	0.1389	0.0204	0.0833	0.0019	0.2353	0.0318	0.4575
Hickory-Shagbark	0	0.0278	0	0.0417	0	0.0081	0	0.0775

Ironwood	0.0189	0	0.0408	0	0.0051	0	0.0648	0
Maple-Sugar	0.7358	0.1667	0.5306	0.1667	0.2018	0.1681	1.4682	0.5014
Oak- Red	0	0.0278	0	0.0417	0	0.0469	0	0.1163
Oak- White	0.0377	0	0.0816	0	0.1252	0	0.2446	0
Spruce-Norwegian	0.0189	0	0.0204	0	0.0663	0	0.1056	0

Table 4. Density (trees/ha) of mature trees, saplings and seedlings at NV and HC.

Species	**Mature**		**Saplings**		**Seedlings**	
	NV	*HC*	*NV*	*HC*	*NV*	*HC*
Alternate Leaf Dogwood	0	0	0	0	0	37.6748
Amur Cork Tree	0	0	2.3153	0	0	0
Ash-Mountain	0	0	0	0	4.8462	0
Ash-White	10.6591	80.5823	2.3153	0	0.6923	0
Basswood	23.9830	138.1410	2.3153	22.2012	0	0
Boxelder	10.6591	34.5353	2.3153	7.4004	13.8464	0
Buckthorn	0	0	2.3153	303.4169	0	150.6993
Cherry-Choke	0	0	20.8377	0	5.5385	0
Cherry-Black	0	0	13.8918	0	0	0
Elderberry	5.3295	0	6.9459	0	0	0
Elm	2.6648	11.5118	2.3153	0	0.6923	0
Hackberry	0	57.5588	6.9459	7.4004	2.0770	37.6748
Hawthorne	0	0	4.6306	0	0	0
Hickory-Bitternut	0	0	4.6306	0	4.1539	0
Hickory-Shagbark	5.3295	11.5118	0	0	0	0
Ironwood	207.8523	0	2.3153	0	0	0
Maple-	0	69.0705	208.3765	74.0041	246.4654	150.6993

Sugar						
Oak- Red	10.6591	11.5118	0	0	0	0
Oak- White	5.3295	0	0	0	0.6923	37.6748
Spruce- Norwegian	0	0	0	0	0	0
Virginia Creeper	0	0	0	0	2.0770	0
Unknown leaf	0	0	0	0	1.3846	0

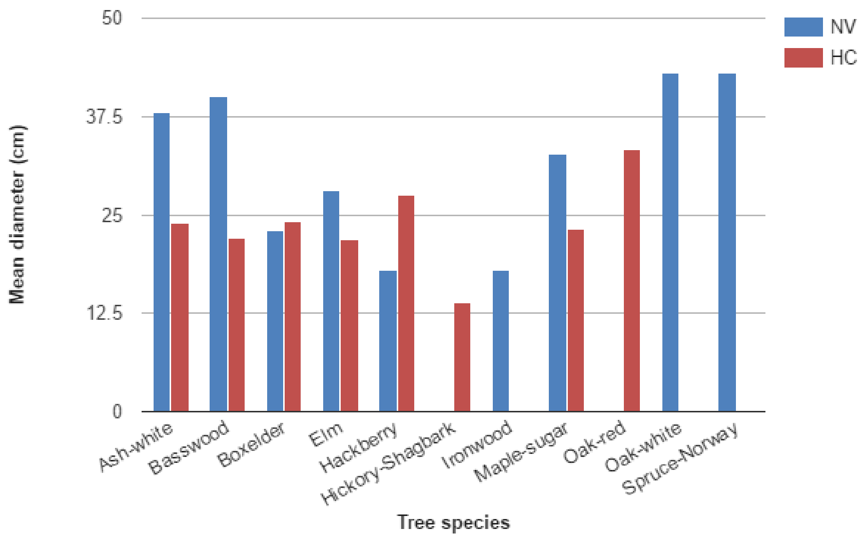

Fig 1. Mean diameter of mature trees within NV and HC.

Table 5. Diameter classes of mature trees at NV and HC.

Diameter Classes								
Diameter (cm)	13.0-22.9		23.0-32.9		33.0-42.9		>43	
Species								
	NV	*HC*	*NV*	*HC*	*NV*	*HC*	*NV*	HC
Ash-white	0	4	0	3	4	0	0	0
Basswood	1	7	0	5	2	0	9	0
Boxelder	2	2	2	1	0	0	0	0
Elm	0	1	2	0	0	0	0	0
Hackberry	1	4	0	0	0	0	0	1
Hickory-	0	1	0	0	0	0	0	0

Shagbark								
Ironwood	2	0	0	0	0	0	0	0
Maple-sugar	19	4	15	1	19	0	25	1
Oak-red	0	0	0	0	0	1	0	0
Oak-white	0	0	0	0	0	0	4	0
Spruce-Norway	0	0	0	0	0	0	2	0

Soil

Table 6. Mean physical and nutrient properties of soil samples from HC and NV class data.

	NV	*HC*
% moisture	32.4015	30.2641
bulk density (g/cm^3)	1.0947	4.5530*
% organic matter	6.4472	6.8718
NO3-N (mg/kg soil)	5.6340	4.3933

Table 7. One-way ANOVA of soil moisture between HC and NV.

	Df	Sum of Squares	Mean Square	F-Value	P-Value
Plot	1	6.85	6.853	0.283	0.614
Residuals	6	145.5	24.192		

Table 8. One-way ANOVA of soil density between HC and NV.

	Df	Sum of Squares	Mean Square	F-Value	P-Value
Plot	1	17.939	17.939	173.1	1.19E-05*
Residuals	6	0.622	0.104		

Table 9. One-way ANOVA of organic matter present in soil between HC and NV.

	Df	Sum of Squares	Mean Square	F-Value	P-Value
Plot	1	0.27	0.27	0.058	0.818
Residuals	6	28.07	4.679		

Table 10. One-way ANOVA of nitrate soil concentration between HC and NV.

	Df	Sum of Squares	Mean Square	F-Value	P-Value
Plot	1	2.309	2.309	1.495	2.67
Residuals	6	9.266	1.544		