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Forest composition of a recently restored hardwood, deciduous forest in Southeastern Minnesota

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Abstract

The purpose of this study was to determine the progress made in the reforestation and restoration of an old agricultural field in the St. Olaf Natural Lands in Northfield, Minnesota. The field was reforested in 2017 with eight different native Minnesotan hardwood, deciduous trees through direct hand-seeding. A survey of the field was conducted by splitting the field into four quadrats and laying two transects in each quadrat. Three plots were laid on each transect for a total of twenty-four plots. Each tree species in the plot was counted, measured, and identified. Four out of the eight planted species were found in the survey. The survey found that the most abundant tree species in the field was Siberian elm, an invasive species. The next most common species was red oak, which was planted in the reforestation effort. The south side of the field had a greater density of seedlings and saplings compared to the north side. The field had a significant number of native species growing, but was dominated by the invasive Siberian elm which could threaten the progress of the reforestation. The Siberian elm may need to be managed in order for the native trees to survive and thrive. More surveys could be conducted to further investigate the species composition of the reforested field and to further study the extent of the presence of Siberian elm. Even with the prominence of Siberian elm, red oak, bur oak, and swamp white oak all had a strong presence in the restored forest, leading to the beginning of a successful restoration project

Key Words

deciduous, direct-seed, forest, hardwoods, reforestation, restoration, Southeastern Minnesota, *Quercus rubra, Ulmus pumila*

Introduction

Urban and agricultural development have led to the loss of many ecosystems, but efforts to restore ecosystems mitigate some of the damage done. Restoration is the act of restoring or reestablishing something as it once was. A large part of conservation biology now includes restoring habitats or ecosystems. Reforesting is the act of restoring forest ecosystems, and often focuses on returning a place to its “natural state” or restoring ecosystem functions (Stanturf et al. 2014). Ecosystems cannot be returned to exactly how they once were, but restoration provides benefits through increasing ecosystem productivity, improving food web interactions, and balancing the hydrological cycle (Stanturf et al. 2014). Greater tree diversity leads to an increase of ecosystem production within reforestation projects (Aerts and Honnay 2011)**.** It is important to focus on the restoration of species richness and community structure as they lead to an increase in ecosystem complexity and function (Aerts and Honnay 2011). Although restoration and reforestation improve the ecosystem, the land will not reach the composition and structure of what it once was, and different species, interactions, and functions may occur (Aerts and Honnay 2011).

The Maple-Basswood forest, also known as the Big Woods, was once a prominent deciduous forest ecosystem in southern and central Minnesota. Of the original Big Woods, less than 10% remains standing today (Shea 1993). The dominant tree species of this forest type are *Acer saccharum* (sugar maple), *Tilia americana* (basswood), and *Ulmus americana* (American elm). Southern and central Minnesota used to mainly consist of prairie until it was invaded by an oak woodland forest. Around 300 years ago the Maple-Basswood forest took over the oak woodland forest (Shea 1993). The Maple-Basswood forest and other hardwood trees were once prominent in this area, but much of these forests were clear cut in order to convert the forests to fields for agricultural purposes and for urban development (Berland et al. 2011). Now the Big Woods and hardwood ecosystems are a fragmented version of what they once were.

The presence of agricultural fields and the absence of forests proves detrimental to the local ecosystems. Forests provide many ecosystem services and play an important role in earth systems and ecosystem functions. Forests play a vital role in the hydrological cycle as they mitigate floods, droughts, and erosion through wind and rain (Lorey 2002). They also play a large part in the carbon cycle, through carbon sequestration, while also providing habitat for animals, maintaining biodiversity, and functioning as climate regulators (Aznar-Sánchez et al. 2018).

Fragmentation or "landscape level" disturbance has been tightly linked to the spread of invasive species (With 2002). The high levels of land use change from natural habitat to agricultural fields in southeastern Minnesota put the land at risk for invasive species. One invasive tree species in Minnesota is the Siberian elm (*Ulmus pumila*). Siberian elm was introduced to the United States in the 1860's from East Asia. Siberian elm spread through wind-dispersal of their samara, or winged seed. Siberian elm thrive in disturbed landscapes and the seeds dominate sparsely vegetated landscapes and germinate quickly. The seeds thrive in open and sunny areas. Additionally, Siberian elm are able to invade and dominate a disturbed prairie or landscape in just a few years ("Siberian elm (*Ulmus pumila*)" n.d.).

The Natural Lands at St. Olaf College in Northfield, Minnesota mainly consists of restored ecosystems, as this area was once clear cut for agriculture. Not all of the restored habitats look like they once did. A variety of ecosystem types have been implemented for education and research. An additional section of the Natural Lands, once a field used for agriculture, was recently direct-seeded with trees native to Minnesota in order to restore this field to a hardwood forest ecosystem. Benefits of direct seeding include lower cost, flexibility in timing of planting, and avoids transplanting shock (Farlee 2013) The restoration of the field took place in 2017 and native Minnesota hardwood trees were planted. Red oak (*Quercus rubra)*, bur oak (*Q. macrocarpa)*, swamp white oak *(Q. bicolor)*, Kentucky coffee tree (*Gymnocladus dioicus)*, bitternut hickory (*Carya cordiformis*), black walnut *(Juglans nigra*), black cherry (*Prunus serotina)*, and wild plum (*Prunus americana*) were planted in the field.

In this study I returned to the reforested field and conducted a survey to determine which species are present. This study focuses on determining the species composition of the restored field, identifying which seedlings and saplings germinated, and what that means for the future of the field. The survey was conducted five years after the trees were planted, allowing the seedlings time to grow. This survey indicated which tree species survived and if more planting or managing needs to be done for the restoration to be successful. I hypothesized that the restoration would be successful, as evidenced by the presence of seedlings and saplings. The specific objectives of this study were 1) to determine if the seeds planted were present in the form of seedlings and saplings in the field, 2) to compare the seedlings and saplings present in the survey of the field to the seeds planted, and 3) to determine what future actions must be done to facilitate the success of the restoration project.

Methods

Site Description

Data were collected on October 4th, 8th, and 10th of 2021. The survey site sits on the southernmost point of the St. Olaf Natural Lands in Northfield, Minnesota (Figure 1). The replanted field sits adjacent to Heath Creek and a Maple-Basswood forest that surrounds the field on three sides. One side of the field sits adjacent to an industrial site with few trees separating the two locations. The field receives ample sunlight. Recreational trails are present in the woods surrounding the field. The field is approximately 10 acres in size. The field was once used for agricultural purposes before it was reforested in 2017. The field was reforested using direct tree seeding and then was planted with a cover crop to prevent soil erosion (Lands n.d.). Deer activity was found at the site, through the observation of deer beds and trails throughout the field.

Data Collection

The field was cut into four approximately equal quadrats. Two 50 m transects were laid in each quadrat running parallel to one another. All transects were placed at least 10 meters away from each forest edge to avoid edge effects, and about 10 meters away from each other. Plots were placed in 3 locations along the transect, at 15 m, 30 m, and 45 m. A total of six plots were surveyed per quadrat. The plot was set up using surveyor pins, flagging, and quadrat frames for the rectangular meter (squared) plot, as suggested by Brower, Zar, & VanEnde (1998). I counted and identified all seedlings and saplings within each plot. Seedlings were defined as less than 50 cm in height. Saplings were categorized as taller than 50 cm, with a diameter less than 13 cm. The process was repeated for every plot in each quadrat, for a total of twenty-four plots.

Data Analysis

Analysis of variance was conducted using R Commander (Version 3.3.1) to determine 1) the difference in density of seedlings found in each quadrat, 2) the difference in density of saplings found in each quadrat, 3) the difference in density of seedlings of each species found in each quadrat, and 4) the difference in density of saplings of each species found in each quadrat. Contingency tables were created using R commander to determine 1) what percentage of each seedling species was found in each quadrat and 2) what percentage of each sapling species was found in each quadrat. Stand densities are reported by hectare. The percent of trees planted was calculated by taking the bushels planted of one species divided by the total number of bushels planted and multiplying by 100. The percent of trees found was calculated by taking the number of trees found of one species and dividing by the total number of trees found that were planted and multiplying by 100. The difference between trees planted and found was calculated by taking the percent of planted trees found and subtracting the percent of trees planted. The percent of seeds planted per species was calculated by first multiplying the number of bushels per species planted by the average pounds of seed per bushel for each species. Then the number was multiplied by the average number of seeds per pound. The number of seeds planted per species was then divided by the total number of seeds planted to calculate the percent of each species in the seed mix.

Results

Seedlings

In total, five seedling tree species were found in my survey of the reforested field (Table 2). Siberian elm was the most prominent seedling species found (n=79) (Table 2, Figure 2). Red oak was the second most common species found (n=15) (Table 2, Figure 2). Bur oak and slippery elm were tied for the third most common species (n=2) (Table 2, Figure 2). Swamp white oak was the least common seedling species found (n=1) (Table 2, Figure 2).

Siberian elm (32,916.67) had the highest stand density value, followed by red oak (6,250.00) (Table 3). Swamp white oak (416.67), bur oak (833.33), and slippery elm (833.33) had the lowest stand density value for seedlings (Table 3). Siberian elm had the greatest average density of seedlings (3.17) per plot ($p<0.001$, n=23) (Table 8). Red oak had the second highest average density of seedlings (0.88) per plot ($p<0.001$, n=17) (Table 8). Bur oak had the lowest average density of seedlings (0.25) per plot (pp<0.001, n= 8) (Table 8).

50.6% of the Siberian elm seedlings were found in quadrat four ($p=0.05711$, $\chi^2= 12.226$, n=40) (Table 4). 24.1% of the Siberian elm seedlings were found in quadrat three ($p= 0.05711$, $\chi^2= 12.226$ n=19) (Table 4). 40% of the red oak seedlings were found in quadrat two ($p=0.05711$, $\chi^2= 12.226$, n= 6) (Table 4). 26.7% of red oak seedlings were found in quadrats three and four ($p=0.05711$, $\chi^2= 12.226$, n=4) (Table 4). Quadrats one and two each contained 50% of bur oak seedlings found ($p=0.05711$, $\chi^2= 12.226$, n=1) (Table 4).There was a significant difference in the number of seedlings found per plot in each quadrat ($p= 0.00167$) (Table 6). Quadrat four had the greatest average density of seedlings (7.33) per plot (n=6) (Table 6, Figure 3). Quadrat three had the second highest density of seedlings per plot (4.33), while quadrats one and two had around an average of 2 seedlings per plot (n=6) (Table 6, Figure 3).

Saplings

Overall, six species of saplings were found in the survey (Table 2). Siberian elm was the most common sapling species found (n=118) (Table 2, Figure 2). Red oak was the second most common species found (n=30) (Table 2, Figure 2). Bur oak was the third most common sapling found (n=7) (Table 2, Figure 2). A single black walnut sapling was found and was located in quadrat 4 (n=1) (Table 2, Figure 2).

Siberian elm had the highest stand density (49,166.67) followed by red oak (12,500.00) (Table 3). Black walnut (416.67) and slippery elm (833.33) had the smallest stand densities values (Table 3). Siberian elm (5.83) had the highest average density of saplings per plot ($p<0.001$, n=23) (Table 9). Red oak (1.73) had the second highest average density of saplings per plot ($p<0.001$, n=17) (Table 9). Swamp white oak (1.00) had the third highest average density of saplings per plot ($p<0.001$, n=4) (Table 9). Bur oak (0.875) had the second lowest average density of saplings per plot ($p<0.001$ n=8) (Table 9). Slippery elm (0.667) had the lowest average density of saplings per plot ($p<0.001$, n=3) (Table 9).

There was not a significant difference between the number of saplings found per plot in each quadrat (p= 0.0744) (Table 7). Quadrats three and four had the highest average of sapling density with 9 saplings found per plot (n=6) (Table 7, Figure 4). Quadrats one and two had average densities of saplings found per plot at 4 and 6, respectively (n=6) (Table 7, Figure 4).

The greatest number of Siberian elm saplings was found in quadrat four, at 35% (p=0.05659, χ^2= 12.251, n=48) (Table 5). 29.9% of the Siberian elm were found in quadrat three (p=0.05659, χ^2= 12.251, n=41) (Table 5). 22.6% of the Siberian elm were found in quadrat two

($p=0.05659$, $\chi^2= 12.251$, $n=31$) (Table 5). The least number (12.4%) of Siberian elm seedlings was found in quadrat one ($p=0.05659$, $\chi^2= 12.251$, $n=17$) (Table 5). Half of the red oak saplings were found in quadrat three ($p=0.05659$, $\chi^2= 12.251$, $n=15$) (Table 5). 23.3% of the red oak saplings were found in quadrat two ($p=0.05659$, $\chi^2= 12.251$, $n=7$) (Table 5). 20.0% of the red oak saplings were found in quadrat four ($p=0.05659$, $\chi^2= 12.251$, $n=6$) (Table 5). The lowest number (6.7%) of red oak saplings was found in quadrat one ($p=0.05659$, $\chi^2= 12.251$, $n= 2$) (Table 5). 42.9% of bur oak were found in quadrat one ($p=0.05659$, $\chi^2= 12.251$, $n=3$) (Table 5). 28.6% of the bur oak saplings were found in quadrat two ($p=0.05659$, $\chi^2= 12.251$, $n=2$) (Table 5). The lowest number (14.3%) of bur oak saplings was found in quadrats three and four ($p=0.05659$, $\chi^2= 12.251$, $n=1$) (Table 5).

Planted vs. Found

Calculations based on bushels put black walnut with the greatest percentage of seeds planted with 50%, while it only made up 1.66% of the species found (n=1) (Table 10). Bitternut hickory, black cherry, Kentucky coffee tree, and wild plum all were not found in the survey, although together they made up only 10% of the seeds planted (Table 10). Bur oak seeds made up 20% of the total seeds planted, while bur oak seedlings and saplings represented 15% of the total trees found of the species that were planted (n=9) (Table 10). Red oak only represented 20% of the seed mix planted, but made up 75% of the trees found that were planted (n=45) (Table 10). Swamp white oak made up 2% of the seed mix planted, while it was represented in planted trees found at 8.33% (n=5) (Table 10). Black walnut had the greatest negative difference between seeds planted and trees found at -48.34% (Table 10). Red oak had the greatest positive difference between seeds planted and trees found at an increase of 55% (Table 10). Calculations based on seeds planted put red oak (37.7%) as the majority of the seed mix (Table 11). Red oak

(75% of trees planted trees found) was also the most found species in the survey and had the greatest positive difference (+37.2%) between percent planted and found (Table 11). Black walnut (24.1%) was the second most common species in the seed mix, but only made up a small portion of trees found in the survey (1.66%) and had the greatest negative difference (-22.5%) between seeds planted and trees found (Table 11). Bur oak made up about a fifth (18.1%) of the seed mix and was found at a similar rate (15%) (Table 11). Swamp white oak made up a small portion (3.62%) of the seed mix and was found at a higher percentage (8.33%) (Table 11). Together wild plum, bitternut hickory, and black cherry made up less than a fifth (16.34%) of the seed mix and were not found at all in the survey (Table 11).

Discussion

Forest Composition

First and foremost, seeds planted in the restoration project were found in the form of seedlings and saplings. Red oak, bur oak, swamp white oak, and black walnut were all planted in the fall of 2017 and were found to have a presence in the form of seedlings or saplings in the field in the fall of 2021 (Table 2). Bitternut hickory, black cherry, Kentucky coffee tree, and wild plum were the rest of the species planted in the restoration, but were not found in the survey (Table 10, Table 11).Two additional species were found in the survey: slippery elm and Siberian elm (Table 2). These two species were not planted but established themselves in the field through wind-dispersal of seeds from mature trees ((“*Ulmus rubra* (Grey Elm, Red Elm, Slippery Elm, Soft Elm)” n.d.) and (“Siberian elm (Ulmus pumila)” n.d.)). The presence of slippery elm was an exciting find, as it is a native tree and wind-dispersed seeds were specifically not planted in the restoration as they could establish themselves through wind on their own. On the other hand, Siberian elm is an invasive species to southeastern Minnesota, and its presence signified the possible takeover of Siberian elm in the field. Siberian elm was the most commonly found species in the survey of the restored forest. The high levels of Siberian elm found are concerning for the future of the restored field. In a survey of the field in 2018, only a year after the planting, only four species were found in total: bur oak, red oak, boxelder, and Siberian elm, while only two of the species, red oak and bur oak, had been planted in the restoration effort (Koerth 2018). This indicates that Siberian elm has had a presence in the field approximately immediately following the restoration.

Red oak made up about 40% of the seed mix planted in the restoration, based on the number of seeds planted, and therefore was the majority of the seed mix (Table 11). Red oak was found to comprise 75% of the planted trees found and thus was the majority of planted trees found (Table 10). As a result, red oak had the greatest positive difference between seeds planted and seeds found. This suggests that red oak had extremely high germination rates. Bur oak seeds consisted of a fifth of the seed mix planted and was found barely at a rate lower than the amount planted. This is not surprising as not all seeds germinate and survive to become seedlings or saplings. Swamp white oak made up a small portion of the seed mix, but was found at relatively high rates, also suggesting a high germination rate (Table 10, Table 11). One study found that red oak could have higher germination rates than bur oak because red oak germinates in the spring and bur oak germinates in the fall which makes it susceptible to winter frost (Laliberte et al. 2008).

Previous research has found that acorns in restoration projects are often predated by small rodents, but when the size of the clear cut is larger than one hectare without vegetation, the rodent habitat is minimized and predation decreases following restoration (Villalobos et al. 2020). As the size of the restored field was approximately 10 acres, the red oak seeds must have escaped high levels of predation. Additionally, research has found that direct seeding leads to a better developed root structure that allows for the seeds to overcome stressors, such as drought (Villalobos et al. 2020). Oaks often invest more energy into the establishment and expansion of their root system in early development (Haas and Heske 2005). The root development in red oaks must have aided their high presence found in the restored field.

Black walnut was the second most common species in the seed mix, comprising 25% (Table 11). The survey found only one black walnut sapling in 24 square meters (Table 2). Black walnut had the greatest negative difference between seeds planted and found (Table 11). As black walnut was a quarter of the total seeds planted, there should have been more found in the survey of the field, suggesting something went extremely wrong with germination. Direct seeding can fail when the seed is not viable, seed predation occurs, or the seed type does not match the ecosystem (Farlee 2013). Previous studies have found that when black walnut is planted within 300 feet of a forested habitat where small rodents may be present, there is a large loss of seeds due to predation (Farlee 2013). As other species have been found in the survey, it's possible black walnut seeds were predated or their seeds were not viable, leading to a lack of black walnut in the field. Small rodents may have had a preference for black walnut over red oak, which led to the high levels of red oak germination and the low levels of black walnut.

Bitternut hickory, black cherry, Kentucky coffee tree, and wild plum were the species not found at all in the survey, but altogether only comprised about 15% of the seed mix (Table 10, Table 11). As each of these species was planted at low densities it's possible they did successfully germinate, but were just not found in the survey of the field. Although, it has been found that black cherry struggles to establish itself within the presence of deer and direct seeding for black cherry only succeeds if the seeds are protected from deer populations (Farlee 2013).

During the survey of the field deer beds and trails were found throughout the field, suggesting a high presence of deer, which could contribute to the lack of black cherry seedlings or saplings found.

Density

Overall, Siberian elm was the species found at the highest densities and was found in 23 out of 24 survey plots (Table 2, Figure 2, Table 8, Table 9). Siberian elms grow quickly in disturbed, sunny, open, and sparsely vegetated areas ("Siberian elm (*Ulmus pumila*)" n.d.). Thus, the restored field, immediately following restoration, was a great location for Siberian elm to invade and dominate. Red oak was found at the highest density out of all the species planted in the restoration and was found in 17 out of 24 plots (Table 2, Figure 2, Table 8, Table 9). As red oak comprised the majority of the seed mix, it makes sense that it was found at the highest density of all the planted species.

Location

Quadrats three and four were found on the south side of the field, while quadrats one and two were on the north side. Quadrats three and four were surrounded by thick forest on two sides adjacent to the field, while quadrats one and two each had one forested side while the other bordered urban development. There was a significant difference in the densities of seedlings in each quadrat (Table 6). Overall, quadrats three and four had higher densities of seedlings and saplings compared to quadrats one and two. The higher densities in quadrats three and four are most likely due to the fact that the majority of Siberian elm were found in quadrats three and four (Table 4, Table 5). Additionally, the majority of the red oak saplings were found in quadrat three which could contribute to the high densities found in the south side of the field. The high prevalence of Siberian elm in quadrats three and four is most likely due to the close proximity of the mature forest. Siberian elm seeds must have blown into the restored forest from the mature forest on the south side. The survey in 2018 also found that density was higher nearer to the forest edge (Koerth 2018), with quadrats three and four being closer to the forest edge. Research has found that mature forests near restoration sites influence species composition in the restored areas and diversity tends to be higher closer to the original forest (Matlack 1994).

Quadrats one and two had much lower densities of seedlings and saplings compared to quadrats three and four (Table 6, Table 7). This is most likely due to the low presence of Siberian elm in quadrats one and two compared to three and four (Table 4, Table 5). The wind would have to carry the Siberian elm samaras much farther in order to establish a presence in quadrats one and two. The majority of bur oak seedlings and saplings were found in quadrats one and two (Table 4, Table 5). This could be because there was less competition with Siberian elm in quadrats one and two. An alternative reason for the difference in densities is due to differences in microclimate or soil factors throughout the field. One study found that the emergence and early growth of bur oak is more dependent on microhabitat variations than red oak (Laliberte et al. 2008). Although, this seems improbable as studies of the soil throughout the field were conducted in 2018 and there were no significant differences between soil types in the field (Koerth 2018). A future study could conduct further research into soil characteristics throughout the field.

Future of the field

The reforestation efforts in this plot of land is promising. A large number of planted trees were found. Four out of the eight species planted were found in the plots, comprising, only 24 meters squared out of a 10 acre field. The red oak seedlings and saplings seemed to be abundant and growing well. There was a significant presence of bur oak and swamp white oak as well, compared to the number of seeds planted of each species. In the future more red oak, bur oak, and swamp white oak could be planted as they have proved to successfully germinate in the field. Other species may need to be planted in order to increase the diversity of the field and increase ecosystem function (Aerts and Honnay 2011). If black walnut and black cherry are planted again, steps may need to be taken to protect them from predation. The presence of deer may play a large role in the lack of germination and may prove detrimental to the continued growth of the seedlings and saplings, as they may be predated. It may be beneficial to implement deer exclosures in parts of the field to prevent predation and selective pressures. Bitternut hickory, Kentucky coffee tree, and wild plum could be planted at higher densities to increase species diversity.

One concern for the progress and success of the restoration is the abundance of the invasive Siberian elm that was found. If the Siberian elm grows more quickly than the native planted trees or faster than the native wind-dispersed trees, then it could quickly outcompete the native species and dominate the field. Some actions might need to be taken to control the invasive species. Although the Siberian elm has quickly spread across the entire field in five years, it would most likely reinvade the field even if the Siberian elm present in the field now were removed.

Conclusions

Seedlings and saplings of the species planted in the restoration were found in the survey, proving the restoration is under way. Some planted species, black cherry, Kentucky coffee tree, wild plum, bitternut hickory, were not found in the survey. A single black walnut was found even though it comprised a large amount of the seed mix, suggesting predation or some other factor led to low levels of germination. Red oak, bur oak, and swamp white oak all had a strong presence in the restored forest, leading to the beginning of a successful restoration project. The restored forest had high levels of Siberian elm which could threaten the success if management is not initiated. While the presence of Siberian elm is concerning, the success of germination and presence of red oak, bur oak, and swamp white oak show the restoration is underway and will require periodic monitoring to develop management plans.

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Tables and Figures

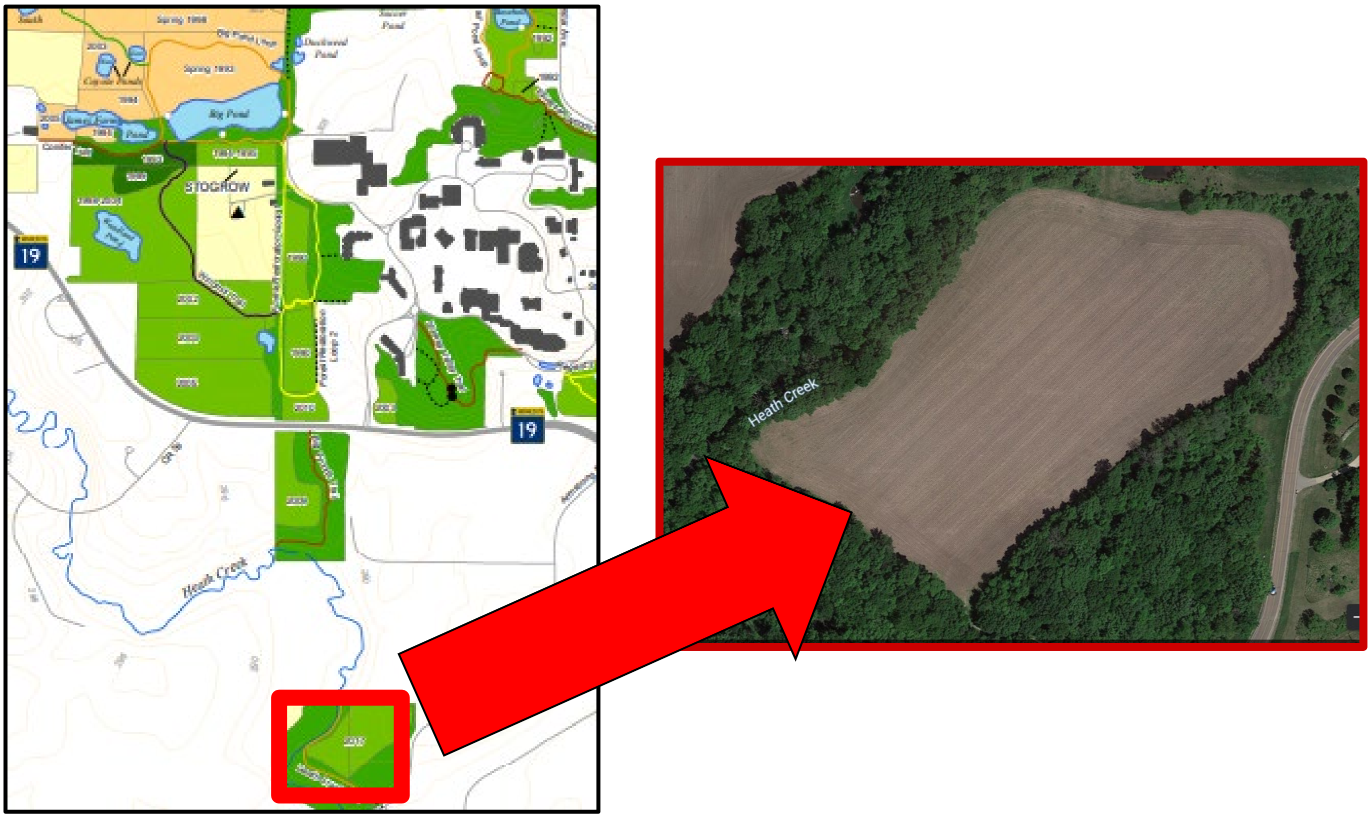

Figure 1. The survey site sits on the southernmost point of the St. Olaf Natural Lands in Northfield, Minnesota. The replanted field sits adjacent to Heath Creek and a Maple-Basswood forest that surrounds the field on three sides. The field was once used for agriculture before it was reforested in 2017. The field is approximately 10 acres in size.

Table 1. The tree species that were planted in the reforestation. The amount of seeds hand planted for each tree species in bushels or pounds. The seed mix was spread onto a 10 acre field.

Tree Species	Seeds Planted	Seeds Planted/Acre
bitternut hickory	5.0 bu	0.5 bu/acre
black cherry	2.5 lbs	0.25 lbs/acre
black walnut	50 bu	5.0 bu/acre
bur oak	20 bu	2.0 bu/acre
Kentucky coffee tree	2.0 bu	0.2 bu/acre
red oak	20 bu	2.0 bu/acre
swamp white oak	2.0 bu	0.2 bu/acre
wild plum	2.0 lbs	0.2 lbs/acre

Table 2. The total number of seedlings and saplings found for each tree species in the survey and the total number of each species found in the reforested field.

Tree Species	Seedling	Sapling	Total
slippery elm	2	2	4
bur oak	2	7	9
black walnut	0	1	1
red oak	15	30	45
Siberian elm	79	118	197
swamp white oak	1	4	5

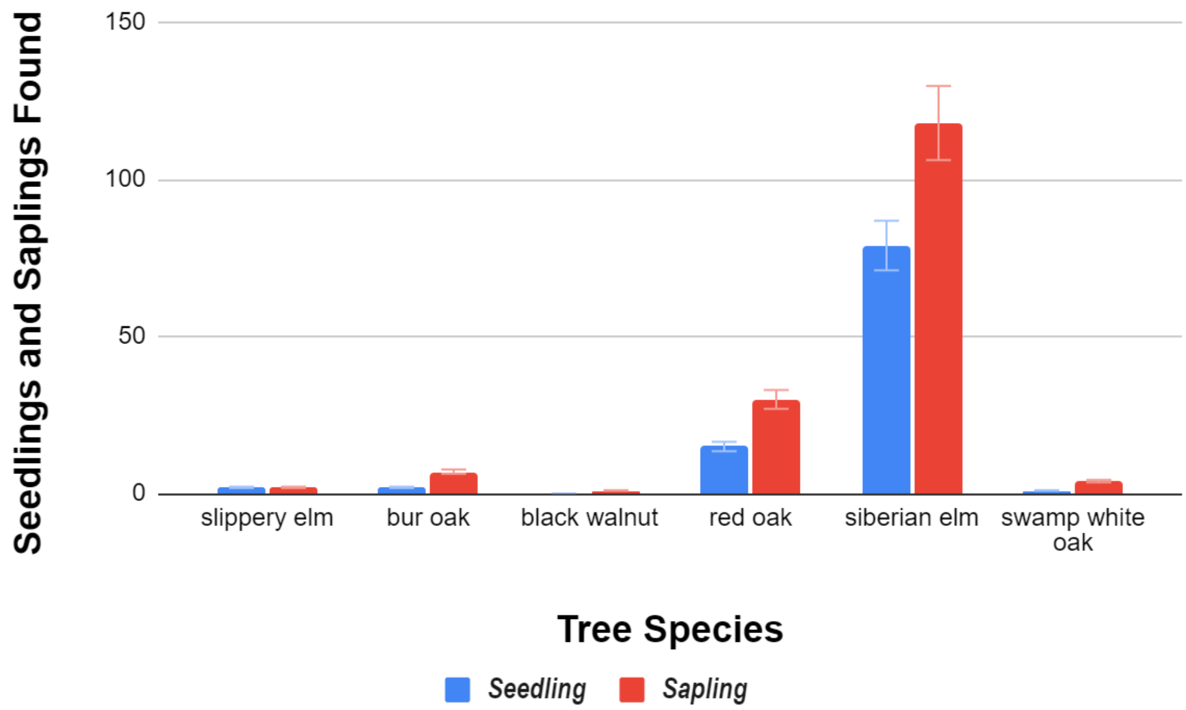

Figure 2. The density of seedlings and saplings of each tree species found in the survey of the reforested field.

Table 3. Stand densities for each species of seedlings and saplings found. The stand densities predicted for an area of a hectare. Total number of each species found was multiplied by 10,000 meters squared, which is equal to a hectare, divided by the total area surveyed which was 24 meters squared.

Tree Species	Seedling	Sapling	Total
slippery elm	833.33	833.33	1666.67
bur oak	833.33	2916.67	3750.00
black walnut	0.00	416.67	416.67
red oak	6250.00	12500.00	18750.00
Siberian elm	32916.67	49166.67	82083.33
swamp white oak	416.67	1666.67	2083.33

Table 4. Contingency table showing the species diversity for seedlings of the top 3 most

commonly found species in all four quadrats. The percentage of each seedling species found in each quadrat out of the total number of seedlings found for that species.

Tree Species	Quadrat One	Quadrat Two	Quadrat Three	Quadrat Four	Count
bur oak	1 (50%)	1 (50%)	0 (0.0%)	0 (0.0)%	2
red oak	1 (6.7%)	6 (40%)	4 (26.7%)	4 (26.7%)	15
Siberian elm	10 (12.7%)	10 (12.7%)	19 (24.1%)	40 (50.6%)	79
Chi-Squared	12.226	-	-	-	-
P-Value	0.05711	-	-	-	-

Table 5. Contingency table showing species diversity in saplings for the top three most common species in all four quadrats. The percentage of each sapling species found in each quadrat out of the total number of saplings found for that species.

Tree Species	Quadrat One	Quadrat Two	Quadrat Three	Quadrat Four	Count
bur oak	3 (42.9%)	2 (28.6%)	1 (14.3%)	1 (14.3%)	7
red oak	2 (6.7%)	7 (23.3%)	15 (50%)	6 (20%)	30
Siberian elm	17 (12.4%)	31 (22.6%)	41 (29.9%)	48 (35%)	137
Chi-Squared	12.251	-	-	-	-
P-Value	0.05659	-	-	-	-

Table 6. A comparison of the density (trees/meter squared) of seedlings found per plot in each quadrat.

	Mean	Standard Deviation	Number of Measurements
Quadrat One	2.166667	1.1690452	6
Quadrat Two	2.833333	0.7527727	6
Quadrat Three	4.333333	3.1411251	6
Quadrat Four	7.333333	2.3380904	6
P-Value	0.00167	-	-

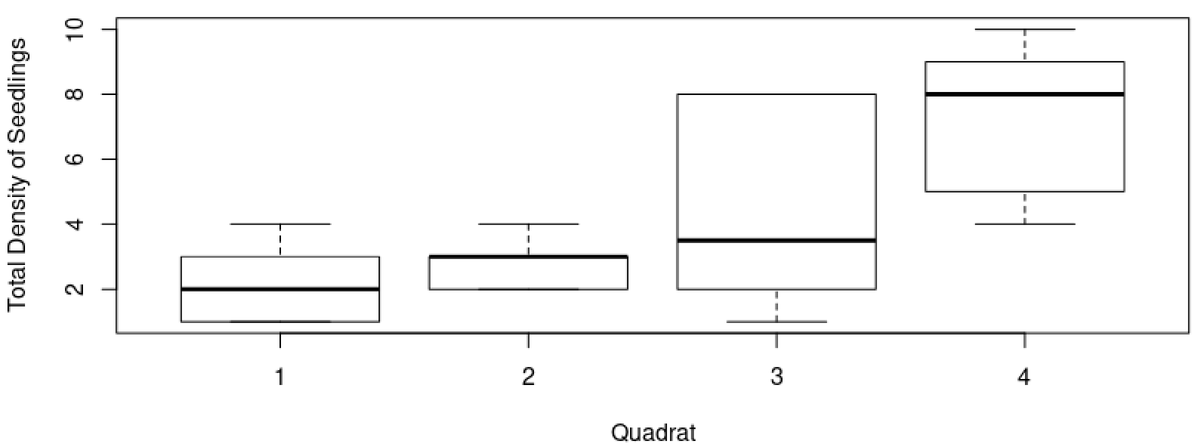

Figure 3. Boxplot showing the density(trees/meter squared) of seedlings found in each quadrat.

Table 7. A comparison of the density (trees/meter squared) of saplings found per plot in each quadrat.

	Mean	Standard Deviation	Number of Measurements
Quadrat One	4.333333	4.082483	6
Quadrat Two	6.666667	3.881580	6
Quadrat Three	9.666667	2.875181	6

Quadrat Four	9.500000	4.230839	6
P-Value	0.0744	-	-

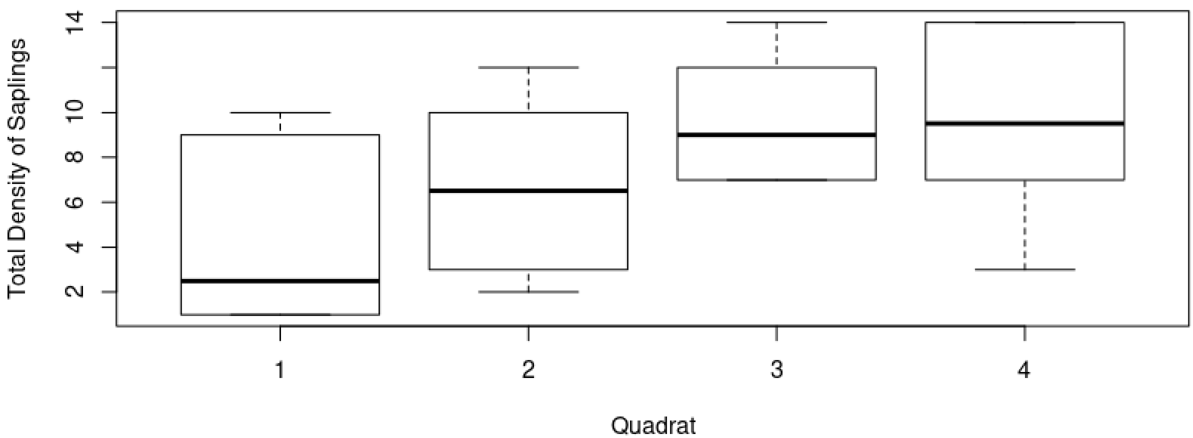

Figure 4. Boxplot showing the density (trees/meter squared) of saplings found in each quadrat.

Table 8. A comparison of the densities of each seedling species found in the survey by average density of each seedling species per square meter. The number of measurements is the number of plots that each species was found in.

Tree Species	Mean	Standard Deviation	Number of Measurements
bur oak	0.2500000	0.4629100	8
red oak	0.8823529	1.1663165	17
Siberian elm	3.1739130	2.6224932	23
slippery elm	0.6666667	1.1547005	3
swamp white oak	0.5000000	0.5773503	4
P-Value	0.00044	-	-

Table 9. A comparison of the densities (trees/meter squared) of each sapling species found in the survey by average density of each sapling species per plot. The number of measurements is the number of plots that each species was found in.

Tree Species	Mean	Standard Deviation	Number of Measurements
bur oak	0.8750000	0.6408699	8
red oak	1.7647059	1.6781467	17
Siberian elm	5.8260870	3.8216152	23
slippery elm	0.6666667	0.5773503	3
swamp white oak	1.0000000	1.4142136	4
P-Value	1.24e-05	-	-

Table 10. The percent of tree species planted, based on the number of bushels planted, out of the total amount of trees planted. The percent of each tree species found out of the total number of trees found that were planted. Tthe difference of percent of tree species that were planted and found.

Tree Species	Percent Seeds Planted	Percent Trees found	Difference Between Percent Planted and Found
bitternut hickory	5%	0%	-5.0%
black cherry	0.55%	0%	-0.55%
black walnut	50%	1.66%	-48.34%
bur oak	20%	15%	-5.0%
Kentucky coffee tree	2%	0%	-2.0%
red oak	20%	75%	+55.%
swamp white oak	2%	8.33%	+6.33%
wild plum	0.45%	0%	-0.45%

Table 11. The number of seeds planted, based on an average number of seeds per pound and an average of pounds of seed per bushel. The percent of seed in the seed mix was based on the number of seeds planted per species divided by the total number of seeds planted. The percent of

trees found was based on the number of planted trees found per species divided by the total number of planted trees found. Kentucky coffee tree was omitted from this table due to a lack of seed data.

Tree Species	**Number of Seeds Planted**	**Percent of seed in total seed mix**	**Percent of Trees found**	**Difference Between Percent Planted and Found**
bitternut hickory	39000	11.78%	0%	-11.78%
black cherry	13425	4.05%	0%	-4.05%
black walnut	80000	24.1%	1.66%	-22.5%
bur oak	60000	18.1%	15%	-3.12
red oak	125000	37.7%	75%	+37.2
swamp white oak	12000	3.62%	8.33%	+4.71
wild plum	1740	0.525%	0%	-0.525