Forest Management Plan

Easterseals Society of Wisconsin
Camp Wawbeek

University of Wisconsin-Madison Forest Science Capstone: Fall 2022

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Contents

Executive Summary

Objective: We wanted to evaluate and characterize the ecological community of the Camp Wawbeek woodlands, which span an area of roughly 400 acres. With the data collected, we are looking to create detailed management plans that account for variations in forest structure, composition, and land-use history throughout the property. We also predicted the future forest structure and composition that would result if our proposed management plan was implemented. Management plans which conserve the tract's aesthetic and recreational values were given the highest priority.

Tract description: At the tract level, the overstory is primarily dominated by white pine as well as red and black oak. Averages for live tree density, basal area and snag density are 716 trees/acre, 110 ft^2/acre, and 39 snags/acre. As for a general description of the understory, we noted an alarmingly high presence of invasive shrub species throughout the entirety of the property. Invasive species encountered include common buckthorn, showy bush honeysuckle, and Japanese barberry. For the most part, invasive species occur the least within the most southern sections of the pine plantations, while the highest concentration is present in the transitional area between the central hardwoods, pine plantations, and savanna. In terms of distinct species assemblages throughout the tract, both the northern and westernmost areas of the property are dominated by oaks and other hardwoods with scattered white pines. Unique to the northern area is a relatively high occurrence of red maple. Plantations of red and white pine occupy much of the southern tract boundary. Although white pine captures a disproportionate percentage of the tree density in these plantations, red pine makes up a greater percentage of the total basal area. Finally, the east and northeastern areas of the tract are composed of hardwood and conifer mixes often dominated by white pine. Notably, tree regeneration in these areas comprises a diverse collection of hardwood species, including white, red and black oaks, black cherry, and both red maple and sugar maple. Across the tract, black and red oak regeneration are present in nearly all the plots we sampled, with varying degrees of frequency. Based on these data, we expect oaks and other hardwoods to emerge as the dominant overstory within the next fifty years in the absence of competition with invasive shrubs.

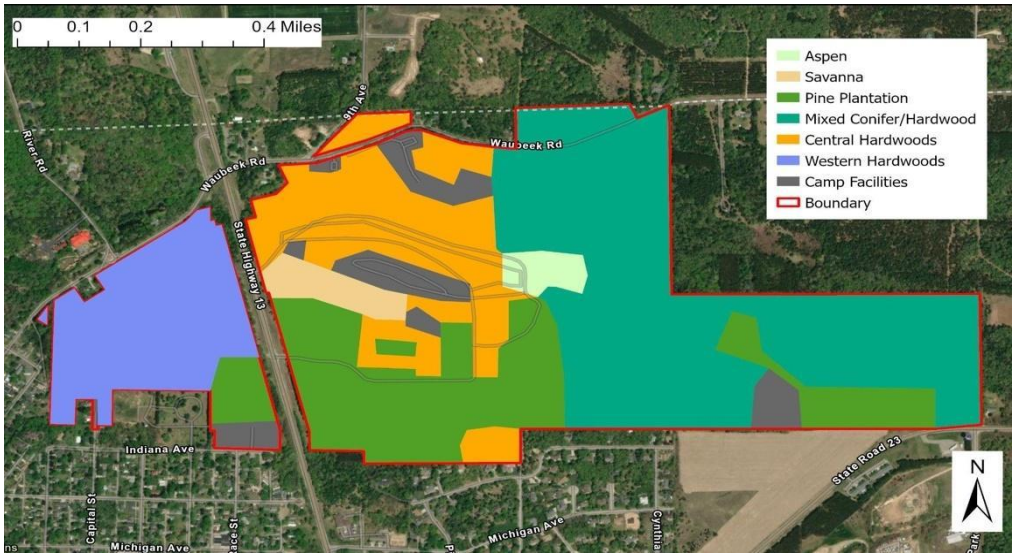


Figure 1: Overstory community assemblages.

Proposed management plan: As a framework for our proposed management plan, the entirety of the tract was delineated into six areas of distinct overstory community assemblages: hardwoods (further delineated into western and central stands), savanna, aspen stands, pine plantations, and northeast mixed conifers and hardwoods (Fig. 1). Bordering the southern edge of the main campus is the proposed savanna, currently composed of scattered white, red, and

black oaks as well as white pine. The aspen 'stand,' located just to the east of the main campus, contains the highest density of aspen trees anywhere on the property.

Management recommendations: Taking into account these current landscape characteristics in conjunction with the landowner's goals of maintaining aesthetics and recreational potential, we have devised six recommended management strategies:

Hardwoods (Western Tract): A focus should be placed on preventing the spread of invasives into new areas and removing invasives with flowers and fruits. There is a diverse mix of hardwoods in this area that we recommend letting grow uninhibited. Removal of hazardous trees could be important due to the use of this area by people not affiliated with Camp Wawbeek. Finally, we recommend hiring a forest pathologist to professionally diagnose what we believe to be oak wilt within this tract.

Hardwoods (Central Tract): We believe that the best management goal for the central hardwoods would be to place a concerted effort on controlling and eliminating invasive shrubs (the majority of which are buckthorn and barberry in this area). Another target for removal in this section are Norway maples due to their allelopathic characteristics. Although managing this section for hardwoods, we suggest leaving the large white pines that are currently present for aesthetic reasons.

Pine Plantations: In all pine plantations, we recommend conducting a thinning of conifers to a basal area of 70 ft^2/acre. This should be accomplished by a Grade C thinning from below. Doing so will allow the (currently stunted) white pine regeneration in the understory to grow and mature at a faster rate, while maintaining the large dominant and codominant trees in the overstory. We predict that this will result in a less 'messy' looking understory, thus improving the aesthetics and general health of the pine plantations on the property.

Savanna: In order to influence the establishment of an oak savanna, we recommend heavily thinning the conifers in this area in order to allow for increased light penetration to the understory. Due to the presence of mature oak species in this section, oak tree planting is not necessary. Upon completion of thinning, the tree density should not exceed 20 trees/acre, or a total canopy cover of 50%. Continued maintenance in the form of prescribed burns is necessary in sustaining savanna ecosystems.

Aspen Stand: We suggest creating multiple well-designed, one-acre openings within the tract that contains a high concentration of aspens. Like all other management areas, invasive species will need to be continuously managed. Both actions will facilitate the continued regeneration of aspen trees in this area, owing to their high light requirements as an early-successional species. Due to this management area's close proximity to camp, we must emphasize the importance of designing clearings in organic shapes rather than a simple square openings. This mimics natural disturbances in appearance and is far less descript than those that have clearly defined edges, thereby maintaining the aesthetic value of the forest stand.

Northeast Mixed Conifer/Hardwood Stands: This management area comprises the largest continuous parcel on the property and therefore will require management over large scales. We recommend placing an emphasis on regenerating underrepresented species, mainly white oaks. Multiple actions are necessary in order to accomplish this goal: Firstly, removal of invasive shrubs and Norway maple trees will increase the ability of white oaks to regenerate (see 'Considerations', p.24). Removal of invasives should be followed by a prescribed burn

to remove the high concentrations of rubus in the northeast section, thus increasing the chances of successful recruitment of white oak saplings.

Introduction

As forestry majors, we hope to improve forestland through proper management, acting as stewards of the land by implementing the best management practices. We aim to use science to ensure a healthy forest ecosystem for this generation and future generations.

We are senior students at the University of Wisconsin-Madison. This forest inventory and management plan for the Easterseal's Camp Wawbeek is a final capstone project intended to assess our skills as forestry students by incorporating knowledge we've gained from our courses. This type of work is something that we could be doing on a daily basis in our careers, so we need to show that we are capable of these duties. In this forest ecosystem assessment, we were tasked with measuring various attributes in both the forest overstory and understory in 93 variable-radius plots distributed across the entire tract. These data helped us develop an informed management plan with the landowner's goals in mind.

We were not provided explicit direction regarding how the tract should be managed, other than background knowledge of how it's currently used. This gives our group more flexibility to decide how we think the forests of this camp should be managed. This camp is currently used as a nature retreat for disabled children, adults, and their families to provide them with a fun camp experience in a safe space. With this information in mind, we aimed to create a management plan that maintains good trail access and semi-flat open spaces for camp activities and outings, while also enhancing the natural spaces across the camp.

Overview of Data Collected

In this project, we collected data at 93 plots over roughly 400 acres (Fig. 2). At each plot we collected data on the overstory, midstory, and understory. For all trees present in each plot, we recorded species and measured tree diameter at breast height (DBH) as well as volume of merchantable timber. Recorded trees included all those greater than one inch in DBH. The midstory and understory comprise all other data that we collected, including shrub cover and height, tree regeneration frequency and height, and volume of coarse woody debris. Below is a brief description of what information was collected at each plot. Greater detail on all measurement methods can be found in Appendix A (p. 46).

Photo of team at a sampling plot

Plot locations

Plots were located equidistantly across the entire study area and represented about 4 acres each. A total of 99 plots were placed and 6 were dropped (shown in red below) for various reasons such as location on a building, baseball field, or other spots that were not representative of the forested area.

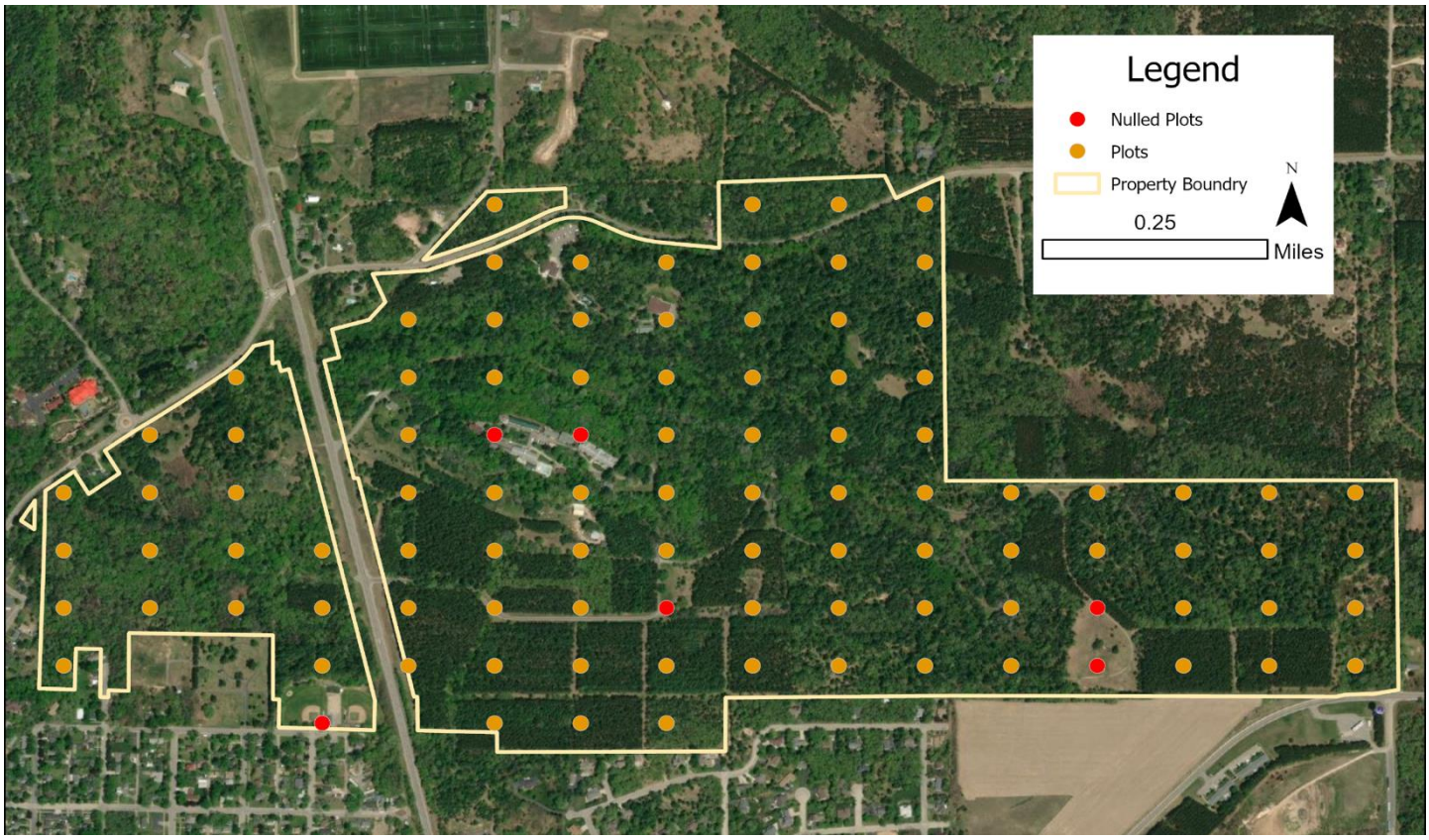


Figure 2. Location of 99 sample plots. The 93 orange plots were included, the 6 red plots were dropped.

Overstory Data Collected

The following is a brief description of the overstory data we chose to collect and how we collected it. A more detailed version can be found in Appendix A on page 46. Basal area (BA) was measured for all trees and snags that fell into the plots. It is the cross-sectional area of a tree, measured at 4.5 feet above the ground, using variable area plots and out 10 factor prism, any tree or snag that fell in counted for 10 square feet/acre of basal area. Merchantable height is the height at which the tree will no longer be able to be sold, for our purposes the cutoff were where conifers narrowed down to 7 inches in diameter (inside bark) and where hardwoods narrowed down to 8 inches. This was measured using a Merritt hypsometer which indicates how many logs (16-foot sections of a tree) can fit between the cutoff and where the stump would be cut, measured to the half log. Log grade denotes the value of the log based on straightness and defect; each hardwood log was given a grade. Diameter at breast height (DBH) is the diameter of the tree measured at 4.5 feet (breast height) above the ground. This was taken for every tree and snag that fell into a plot. Species was indicated for all living trees. Tree health refers to a distinction made between healthy and declining trees; every living tree was assessed. Snag decay stage refers to the degree of decay in dead trees, based on a standardized scale. Canopy cover is the percentage of the sky blocked out by the canopy as seen from the ground, it's a metric that refers to how much light can get to the ground. This was measured by taking pictures directly upwards from the plot center and using a program to determine how much of the picture was sky versus canopy.

Midstory/Understory Data Collected

The following is a brief description of the Midstory and Understory data we collected and how we collected it. Tree regeneration frequency by height class is the amount of trees smaller than 1 inch DBH growing within a milacre plot (1/1000th of an acre). This was measured between 5 different subplots at each plot. Shrub cover by height class is the percentage of an area covered with non-tree woody plants, measured along two 25 foot transects. Coarse Woody Debris is the volume of fallen woody debris greater than 3 inches at its narrowest point, by decay class.

Tract Description

Presettlement landscape

According to the 1840 Wisconsin Public Land Survey records, the property contains two vertical survey lines were collected on the Western and Eastern sides of the property (see Appendix C, p.52). These notes can be generalized and applied to the site level. Survey notes mentioned the property contained mostly black and bur oak trees, with some white oaks that were all substantially far apart. In addition, there was a small amount of pine species present. The survey also mentioned gently rolling topography and poor, sandy soils, which suggests the site resembled somewhat of an oak savanna at that point in time. On a larger scale, Fig. 3 shows the four pre-settlement vegetation types that were contained in Wawbeek and the surrounding areas. These include oak savannah, lowland hardwood, sedge meadow, and pine barrens.

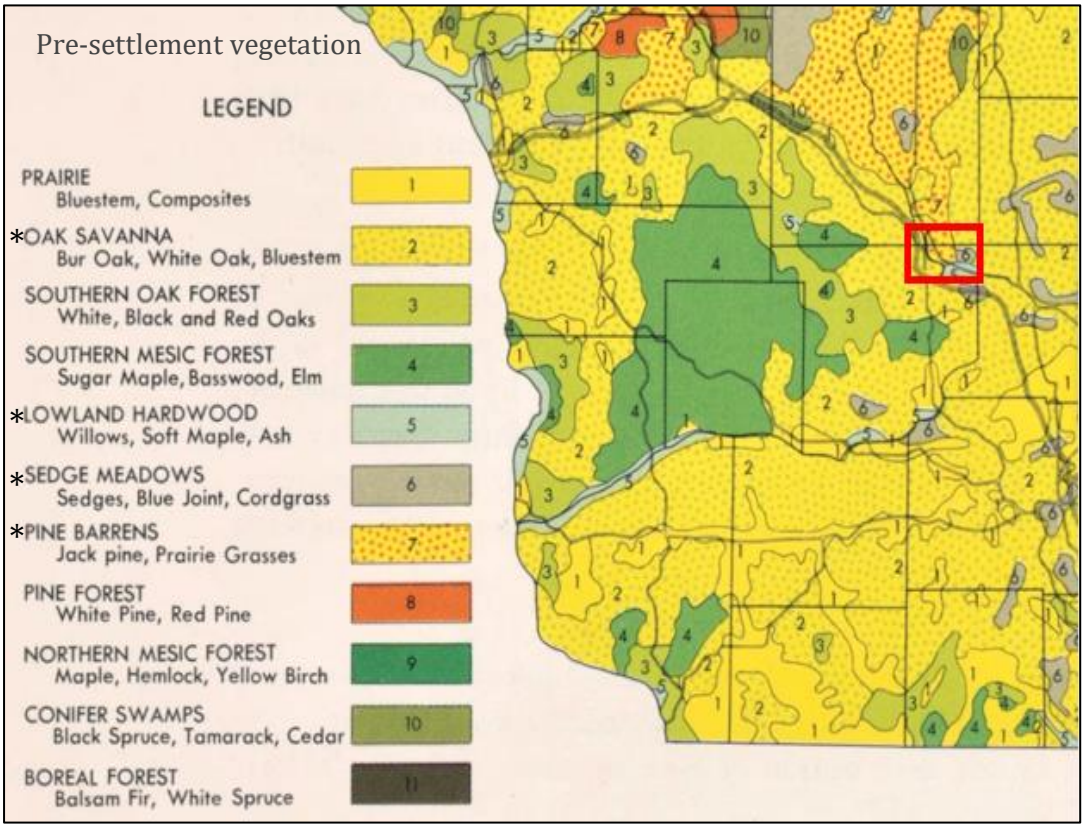


Figure 3: Map of the vegetation of Wisconsin from the Geological and Natural History Survey (1965). The red rectangle shows the location of Camp Wawbeek; Vegetation types that occur within the camp are denoted by asterisks on the left side.

The presettlement observations contrast with what the 1938 aerial photograph (Fig. 4) looks like, indicating that agricultural disturbance had an impact on the landscape. Heavy clearing for this purpose is present all along the bottom half of the tract. This photo, taken in April, indicates a concentration of conifers in the northern portion of the property surrounding what looks to be a tributary of the Wisconsin River. The remainder of the tract looks to be mainly agricultural fields with a few interspersed trees, mainly near roads. There is a dense concentration of trees on the easternmost portion of the tract as well.

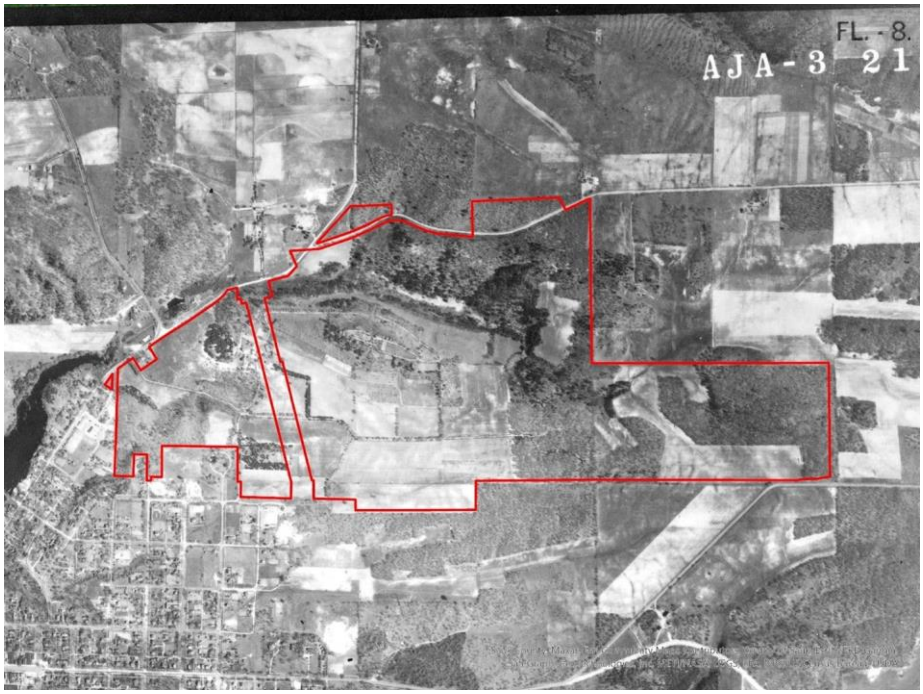


Figure 4: Historical aerial photo of Camp Wawbeek land, outlined in red (1938)

According to the 1958 Wisconsin Land Inventory conducted in Columbia County (Fig. 5), tract conditions were a bit different. This survey was completed by foresters who physically walked the area, so it should be seen as ground truthing, complimenting the aerial photo. These data show a good portion of the center of the property, around what we assume to be the buildings, being mostly cleared and denoted by "C". Other old homesteads are denoted by the black filled in squares. The other portions of the survey include the deep rocky gorge, permanent pasture (PP), southern oak-hickory forest (D1, 6-12" DBH), and some mixed upland hardwoods (A1, 12-18" DBH). This indicates an increase in forested area and change in composition in the two decades between when the aerial was taken and this survey.

Recent land use

Overall, the tract is almost entirely forested at this point in time. Apart from the historical agricultural use, pine plantations had been planted in the former agricultural fields around 1960-1970. These currently reside in the southern portion of the property and a bit to the southwest, across Wawbeek road. The remainder of the tract has been used for either camp buildings, as campgrounds, or recreation through the trail system, and much of the cleared land in 1958 has reverted to forest.

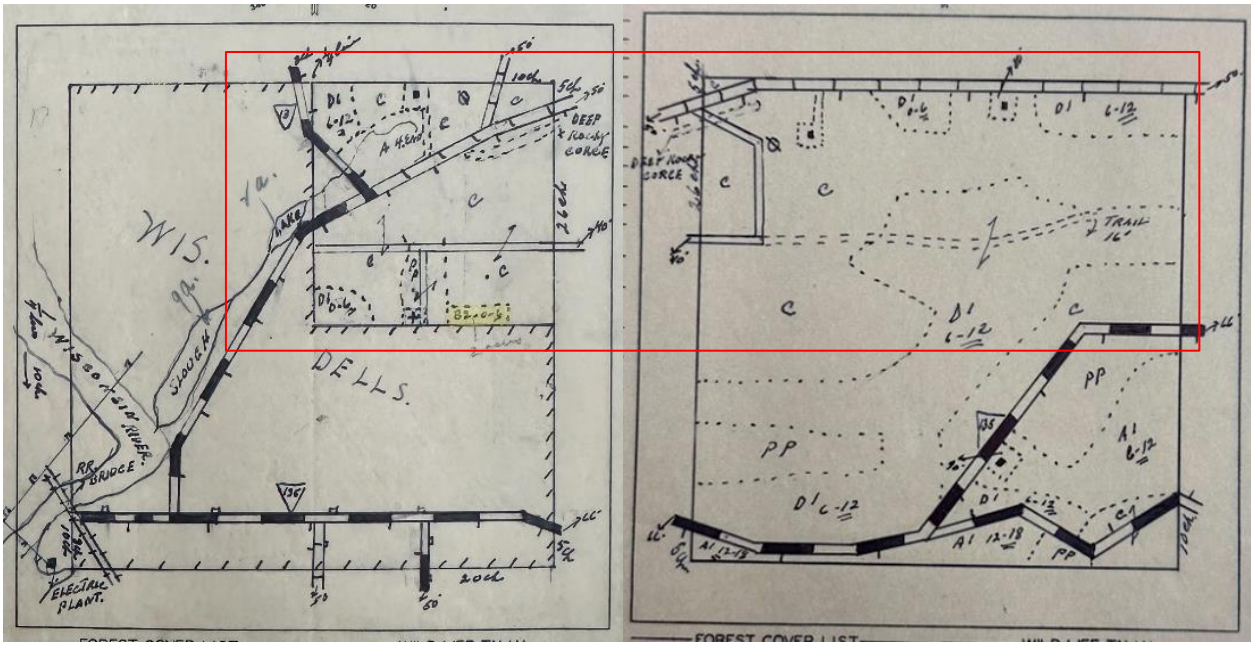


Figure 5: 1958 Land Survey; Camp Wawbeek is within the red rectangle; 'C' = Cleared land;

'PP' = Permanent Pasture; 'D1' = Southern oak hickory forest; 'A1' = Mixed upland hardwood forest types

Topography and Soils

The site is comprised of mostly Plainfield Loamy Fine Sand, and other sandy soil types. The sand results in higher nutrient leaching and well-drained soils that can be seen (Fig. 6) throughout most of the tract. Trees that tend to do well in these sandy soil types are red oak, white cedar, aspen, and white and red pine. Around the gorge, exists alluvial deposits and consequently, more wet and fertile soils. Trees that tend to thrive in these environments include sugar maple, river birch, ash, cottonwood, hemlock, and white oaks.

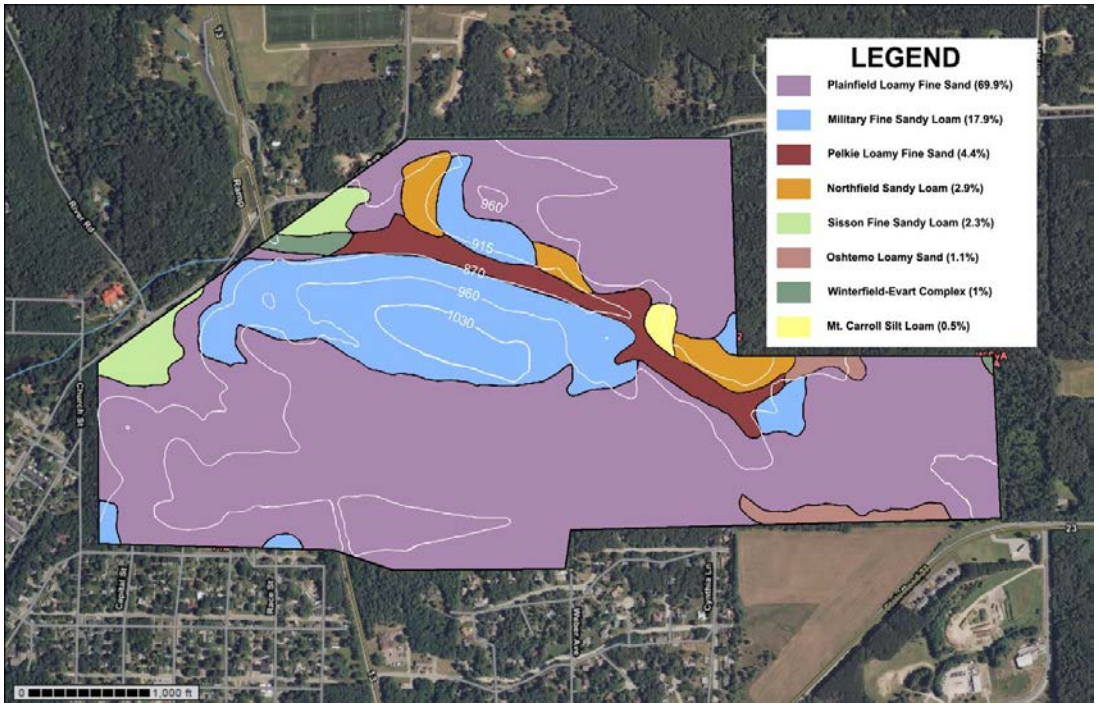


Figure 6: A map of the soil types of the project area as determined by WebSoilSurvey with topographic lines. The site is dominated by sandy soils.

Forest Composition and Structure

Overstory:

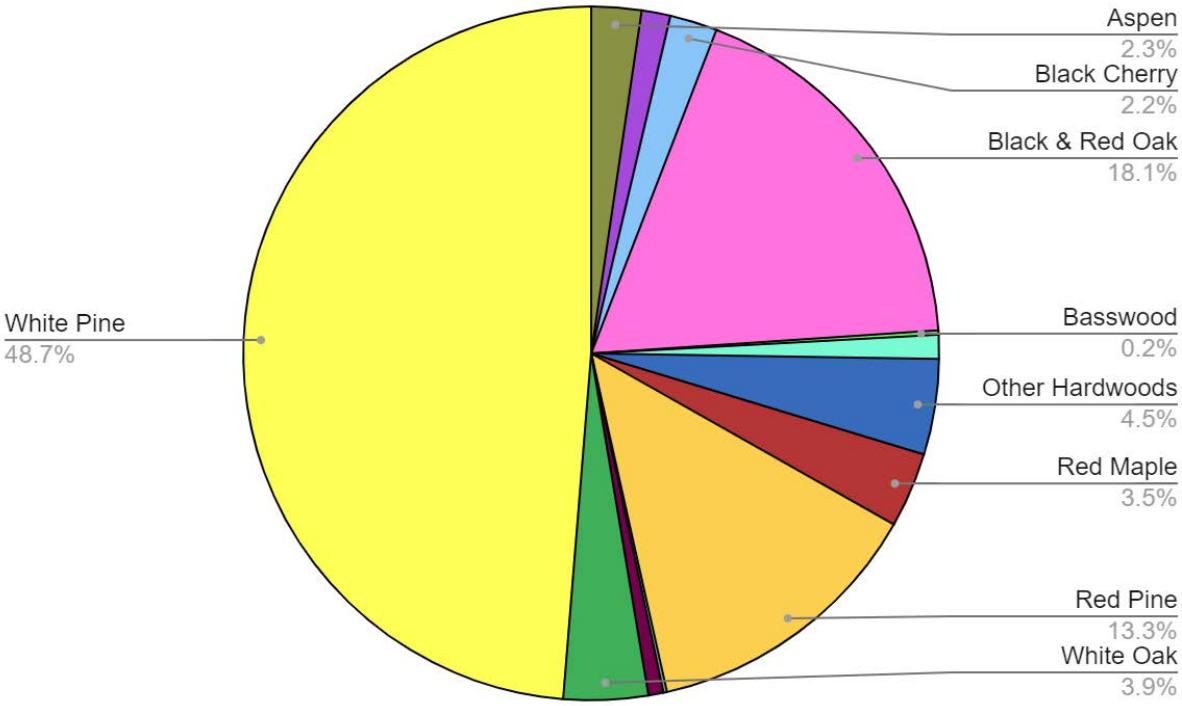


Figure 7: Percentage of the total basal area by species

Figure 7 shows the percentage of the total basal area for the tract that each species comprises. At the stand level, white pine dominates the total proportion of land area by trees. The next two most abundant species are red pine and the black oak group.

In figure 8 the pie size is based on the total basal area of each plot. The sections of the pie are based on the percent of the total basal area by species. The average basal area per plot is 109.8. Pines are the dominant species in many areas. White pine is quite dominant in the northeastern portion of the tract. Red Pine is present throughout, especially in the southern part within the pine plantations. Black oak and red oak is also dominant throughout the tract.

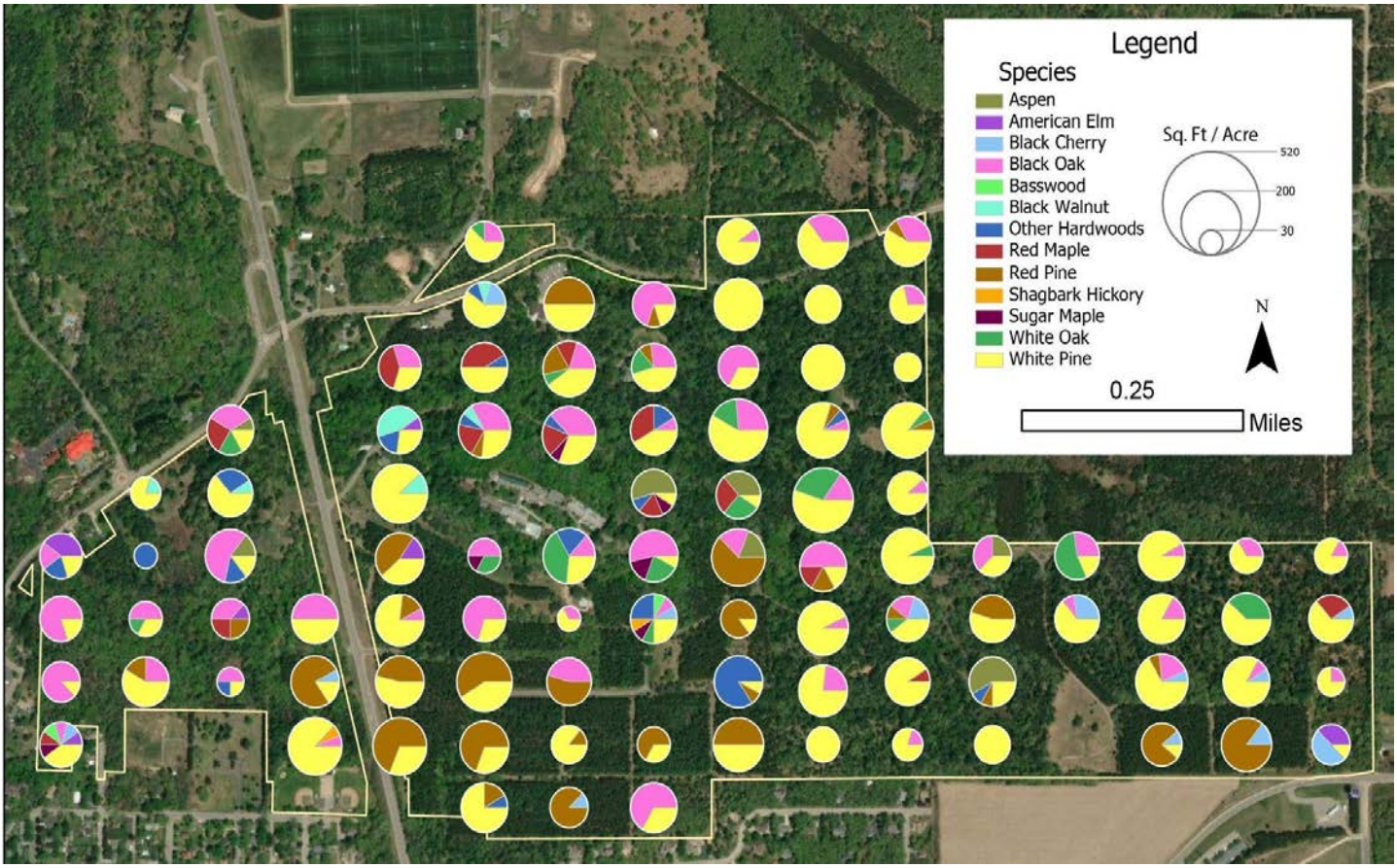


Figure 8: Basal area per acre by species.

Figure 9 shows the species percentage of the number of trees that could be expected on each acre of the tract. Red pine, white pine, and the black oak groups have the highest makeup of the number of trees on an acre, and close behind them are both maple species and black cherry. All other stems of species are pretty evenly dispersed in any given acre.

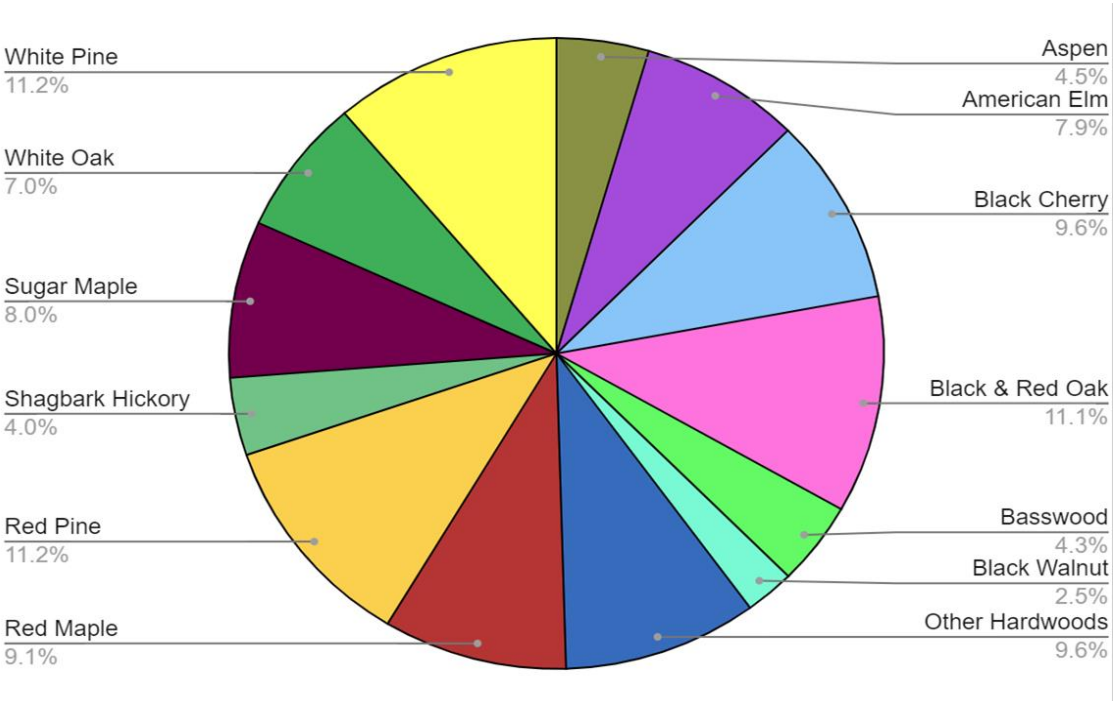


Figure 9: Tree density per acre on the tract.

In the map below (Fig. 10), you can see that areas with

a heterogeneous mixture of species have a smaller total of stems per acre. Areas with the highest percentage of white pine tend to have a larger grand total of stems per acre. The average tree density is 715.7 ± 189.2 trees/acre (95% confidence).

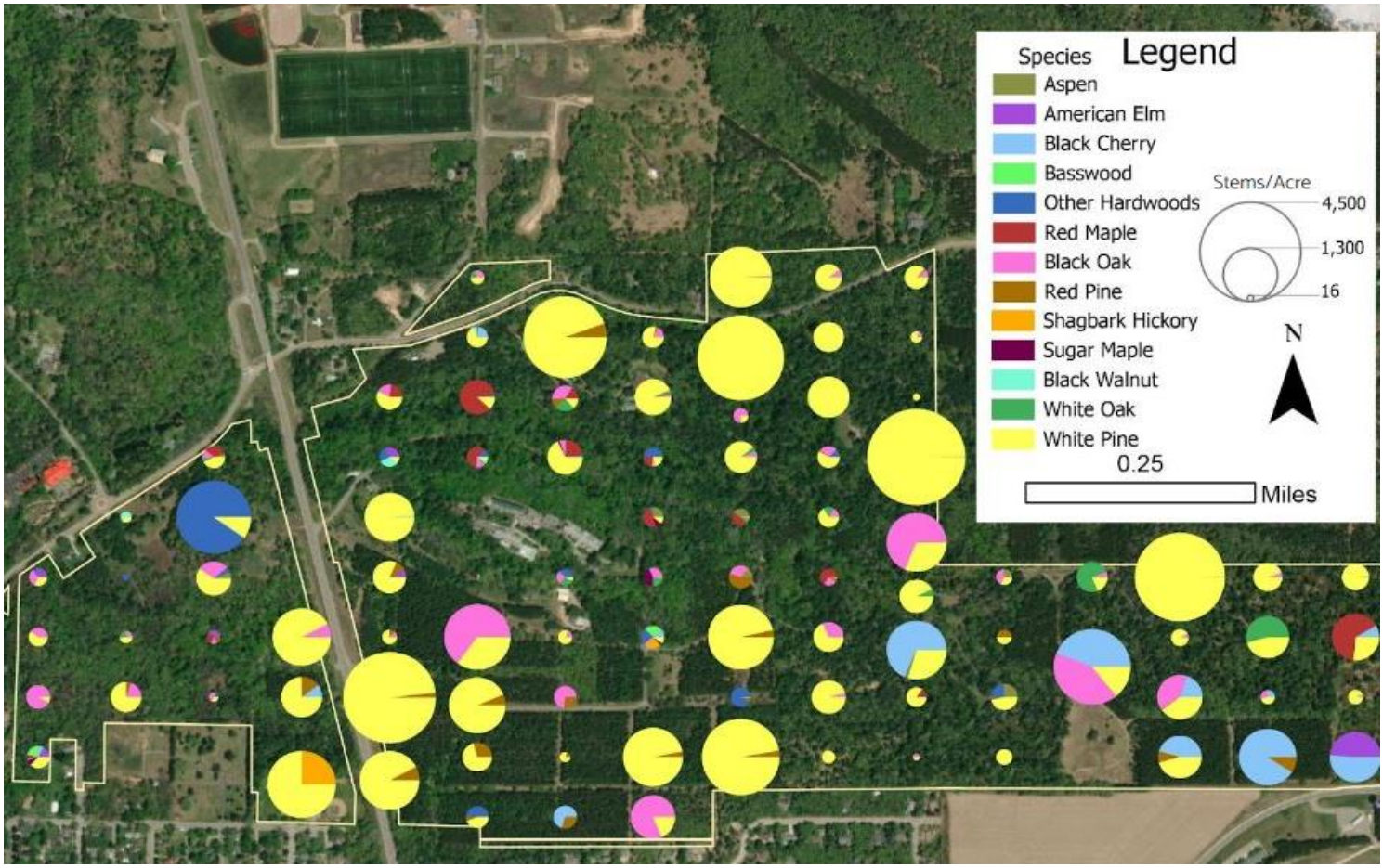


Figure 10: Tree density per plot; The size of the pie is based on total trees per acre of the plot. Sections of the pie are based on the percent of total trees per acre by species.

Figure 11 shows the estimated average number of trees per acre by species, grouped into two-inch size classes. White pine makes up most of the trees per acre for nearly all size classes. The extremely large amount of white pine trees in the 1-3 inch size class indicates that there exists a disproportionate amount of suppressed white pine regeneration on the property. Even with white pine excluded, the reverse J-curve remains, indicating that the property is an uneven age stand. Note that size classes 17 through 41 are grouped, indicating that there are very few trees per acre of 17+ inch DBH.

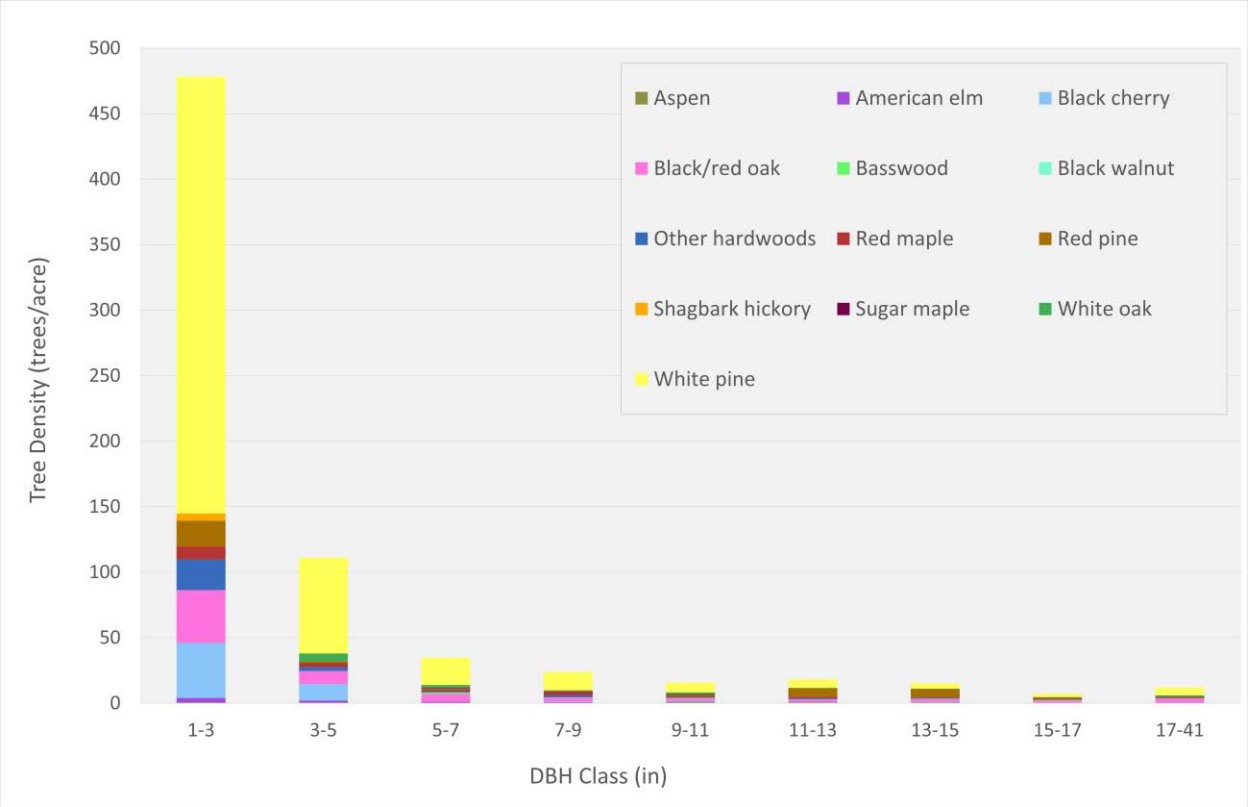


Figure 11: Diameter distribution by species

The map below (Fig. 12) shows the percentage of canopy cover by plot. The average canopy cover per plot is 79%. The southern pine plantation has more open canopy cover

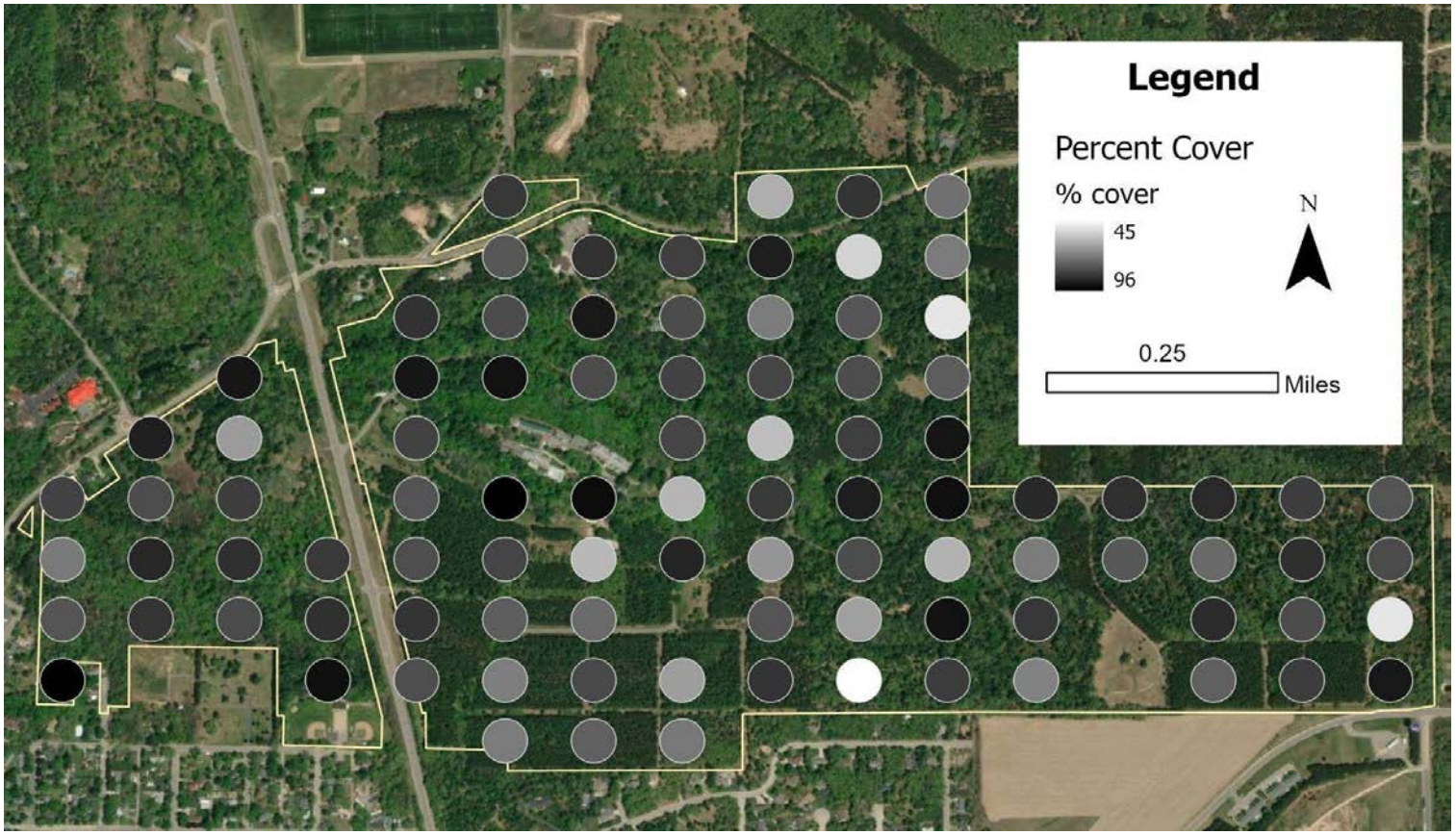


Figure 12: Percent canopy cover by plot; Shows the percent of canopy cover per plot. A continuous color scheme is used to represent canopy cover - Darker colors represent a higher percentage of canopy cover.

Figure 13 shows the average number of snags per acre, grouped into two-inch size classes and levels of decay. The stages of decomposition most consistently present through all size classes are stages 3 (orange) and 4 (gray), meaning a majority of standing dead trees on the property have died relatively recently. The snags/acre for snags with a DBH of 23 inches and above was very low, so snags between 23 and 35 inches in diameter were grouped.

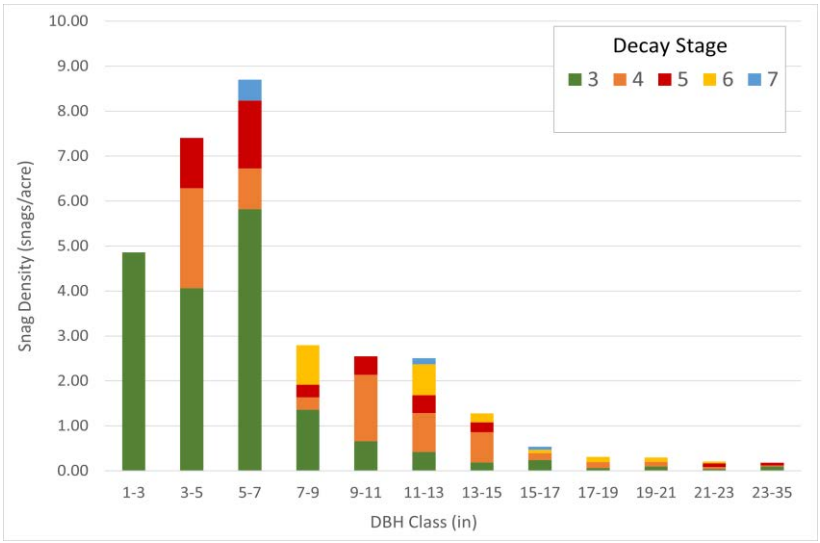


Figure 13: Snag density by size class and decay stage

Figure 14 shows that the Western area has a high number of snags which can mean more

falling trees, widowmakers, and greater potential for being liable in an accident. Average snag density is 32.2 snags/acre.

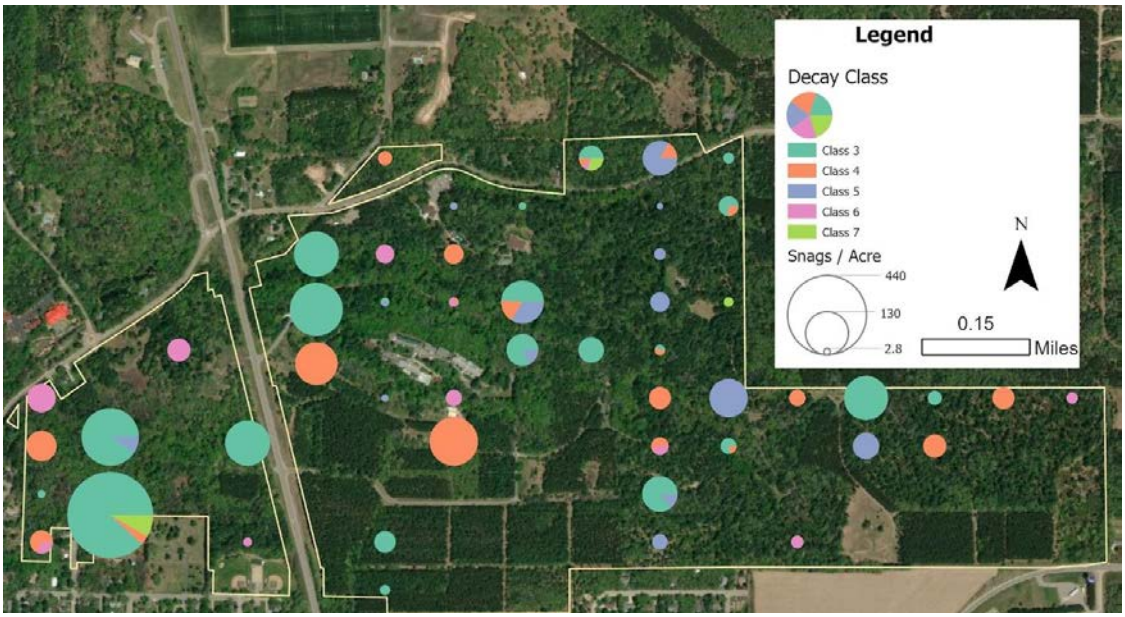


Figure 14: Snag density per plot; Shows the number of snags per acre by plot. The size of the pie is based on total snags per acre of the plot. Sections of the pie are based on the percent of total snags/acre by species.

In figure 15, the most consistently present shrub species through all height classes is buckthorn (gray), which occurs in each of the five height classes. In terms of total land cover percentage however, buckthorn is second to Rubus species (navy blue) by around one tenth of one percent. Besides Rubus, the three most frequent shrub species are all invasive (buckthorn, barberry, and honeysuckle).

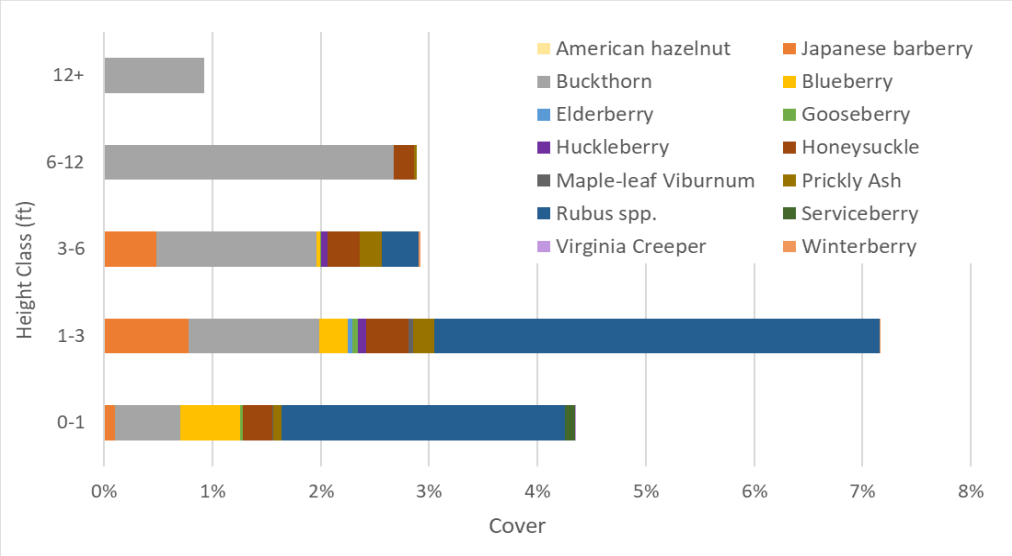


Figure 15: Average land cover percentage of each shrub species by height class

In figure 16, you can see that the shrub cover is more dominant in the eastern part of the property. Rubus and Buckthorn are the most frequent shrubs.

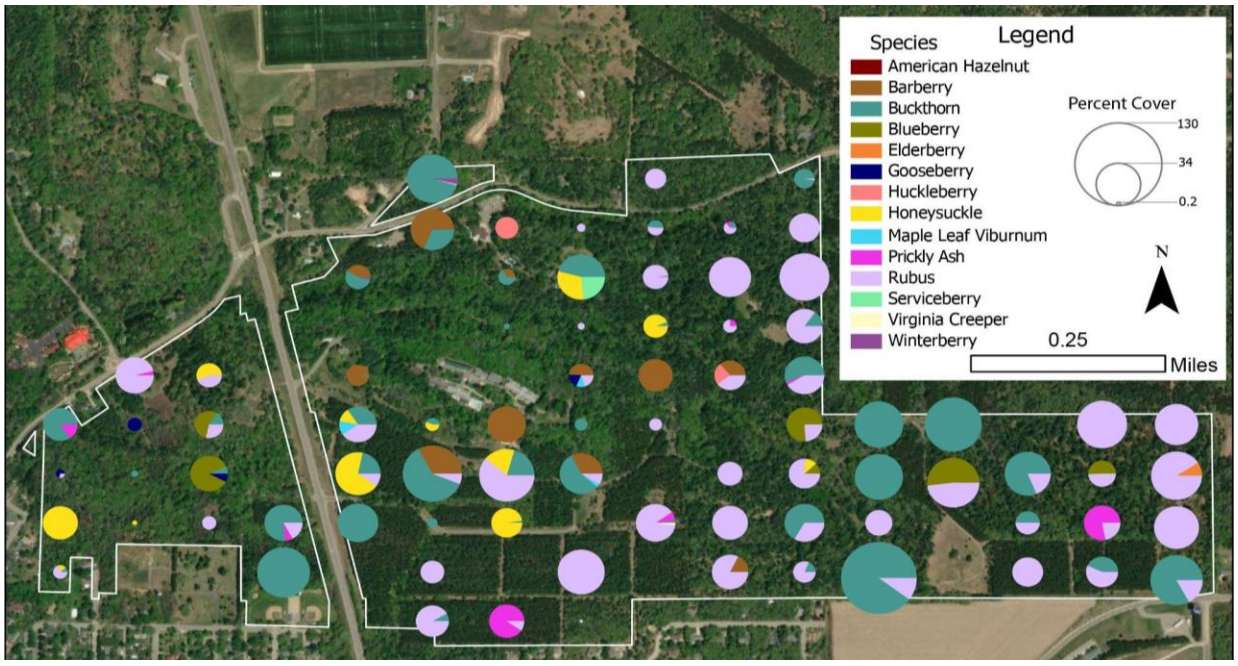


Figure 16: Shrub cover by species per plot; The section of pie is based on the frequency of each species. The size of pie is based on total percent cover.

The map below (Fig. 17) shows that there is not much shrub cover. Where buckthorn is dominant, there are higher height classes; above six feet. Where rubus is dominant, there are lower height classes; below three feet. In the pine plantation area, most of the shrubs are less than six feet tall, meaning that there is easier tree regeneration if the area is thinned.

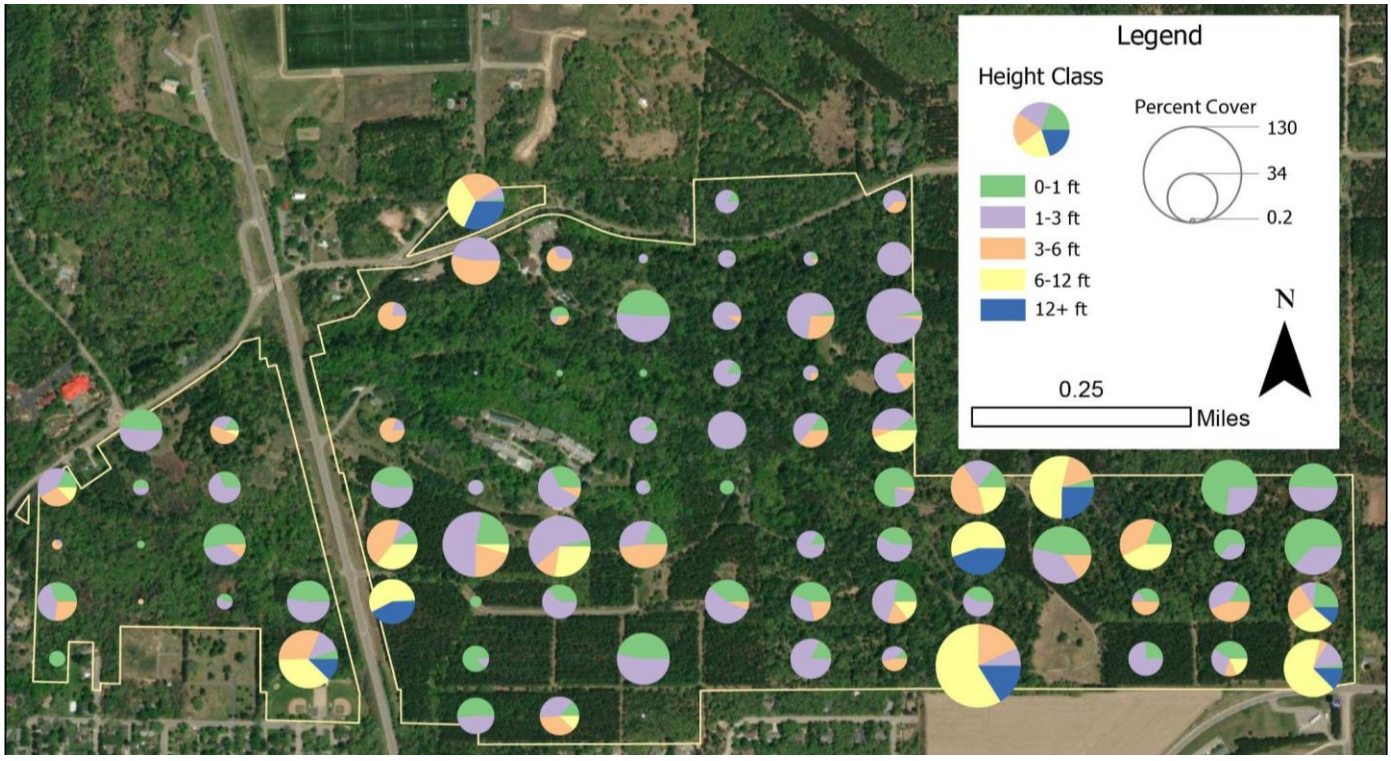


Figure 17: Shrub cover by height class per plot; The section of the pie is based on the frequency of the height class. The size of the pie is based on the percent cover of the shrubs.

By looking at figure 18, on any given acre one could estimate that most downed logs on the property belong to decay classes three or four. It should be noted that the relative volume of slash found in these plots is substantial (Green, 33% of total CWD), but existed only within two plots.

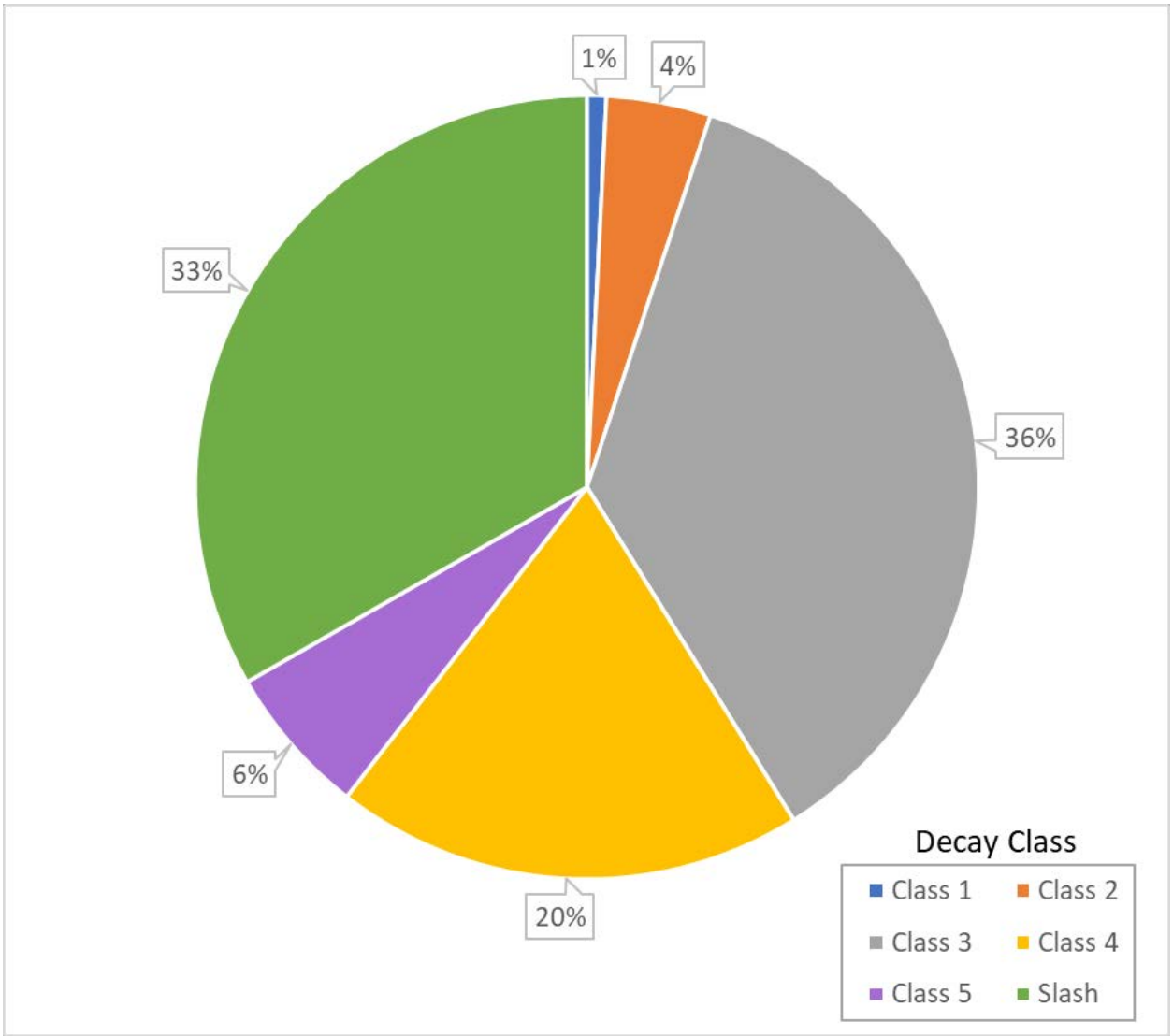


Figure 18: Average volume of CWD per acre by stage of decay

The map below (Fig. 19) is CWD per plot. For mapping purposes, plot 28 was left out due to CWD volume being too large (15,930.10 ft^3 / acre) as this was a slash pile. The average CWD per plot, not including the slash pile, is 463.4 ft^3/acre.

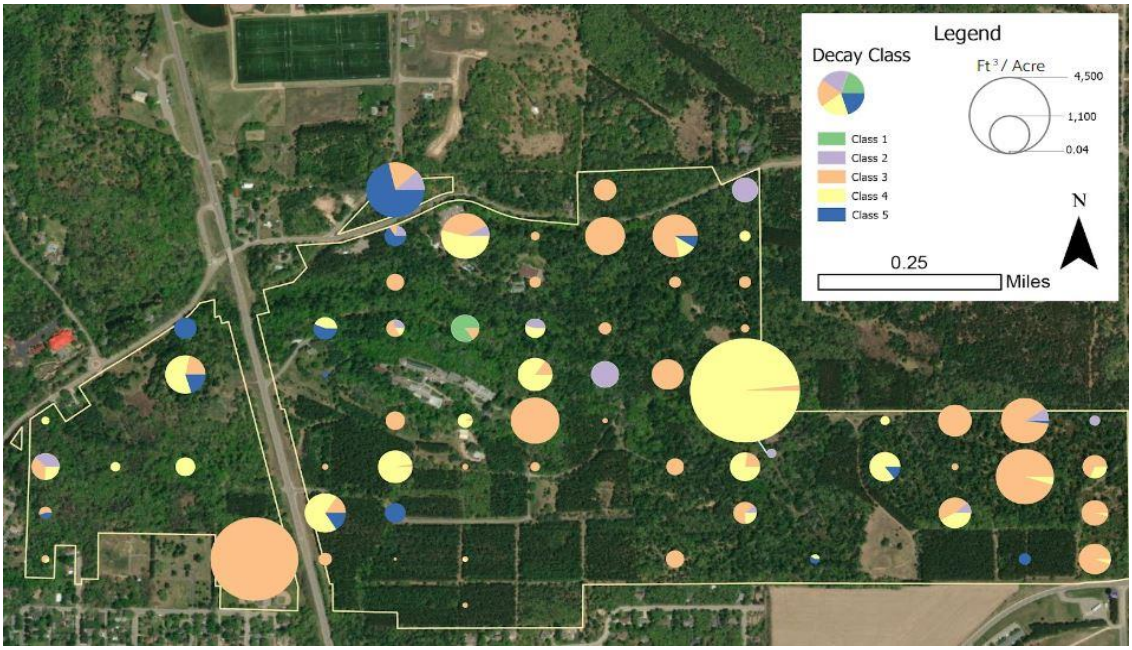


Figure 19: CWD per plot by decay class; The size of the pie is based on the total volume of CWD (ft^3/acre) per plot. The pie sections are based on the percent of the total CWD volume by decay

Figure 20 shows most of the volume of CWD per acre belongs to decay class three, of which we can expect around 230 ft^3 per acre.

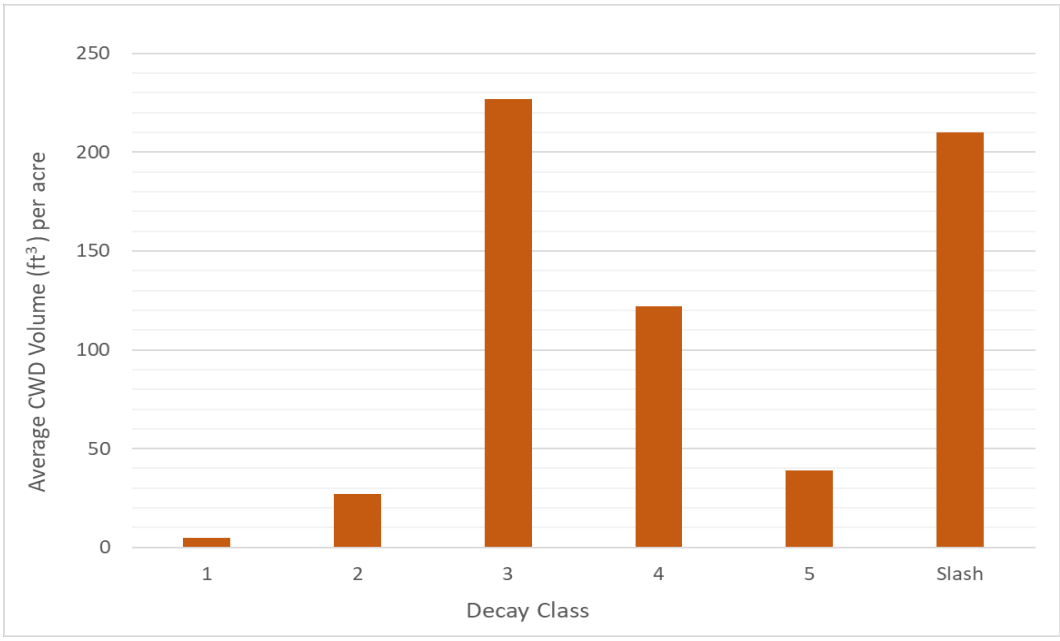


Figure 20: Average volume of coarse woody debris per acre by decay class

Figure 21 shows how frequently each tree species seedling/sapling is present across all plots and is categorized by height classes. Overall, most of the regeneration can be seen in the first two height classes. The most frequently occurring tree species include the black oak group [BRO], white pine [WP], red maple [RM], and black cherry [BC] consecutively. To be clear, this chart shows the percentage of plots that a given species in each height class was found. For example, across all plots measured, 38% contained a BRO species in the 0-1 height class, 20% contained a BRO species in the 1-3 foot height class, etc.

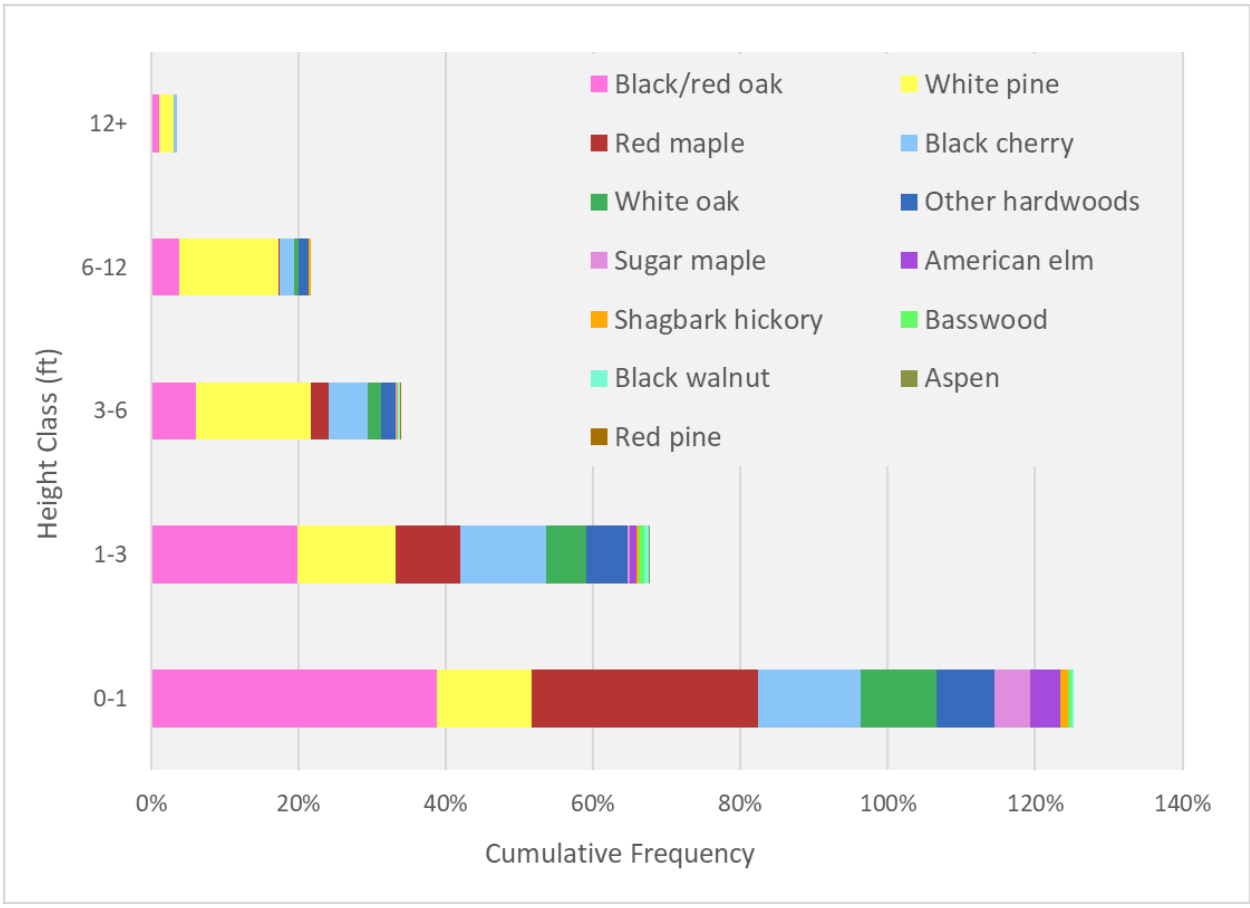


Figure 21: Frequency of tree regeneration per species by height class

In the map below (Fig. 22), you can see that there is good white pine and red/black oak regen in the pine plantation areas. In the northeastern region of the map there is white oak regen. You can also see that there is more diversity in the west wide.

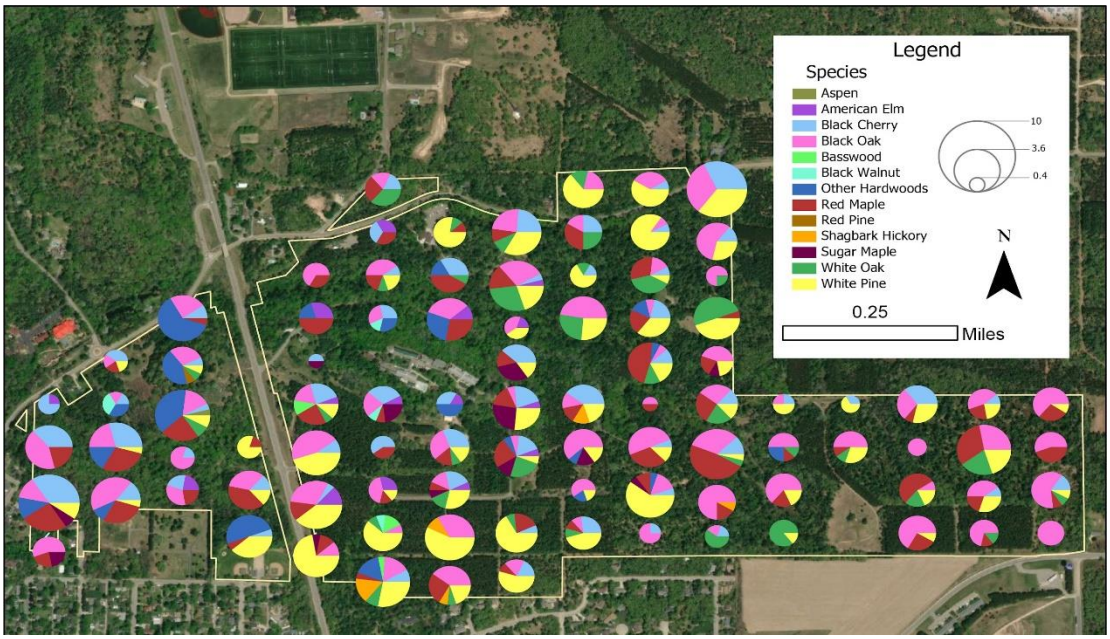


Figure 22: Tree regeneration per plot by species

The map below (Fig. 23) shows that height class 0-1 feet is clearly dominant. However, this can not be banked into developing into the overstory. There is not much 6+ feet regeneration. Where we are seeing class 12ft+ regeneration is in the pine plantations.

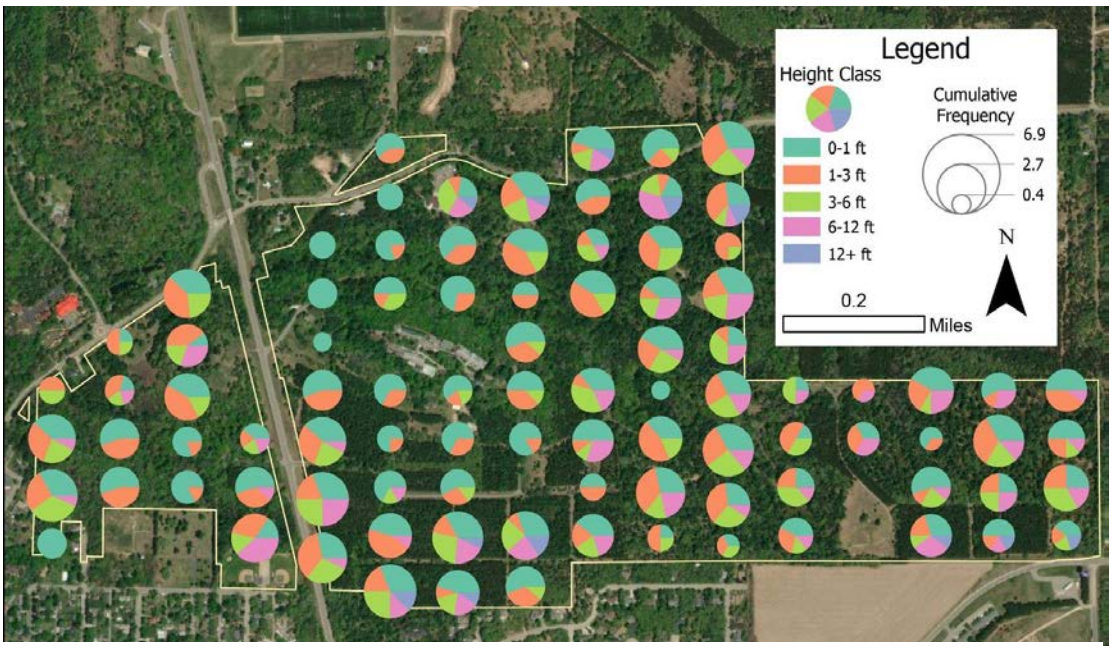


Figure 23: Regeneration per plot by height class.

Figure 24 shows that the vast majority of invasive species land cover is captured by buckthorn throughout all height classes. Barberry accounts for more land cover than honeysuckle by less than one percent, though honeysuckle is present in larger height classes.

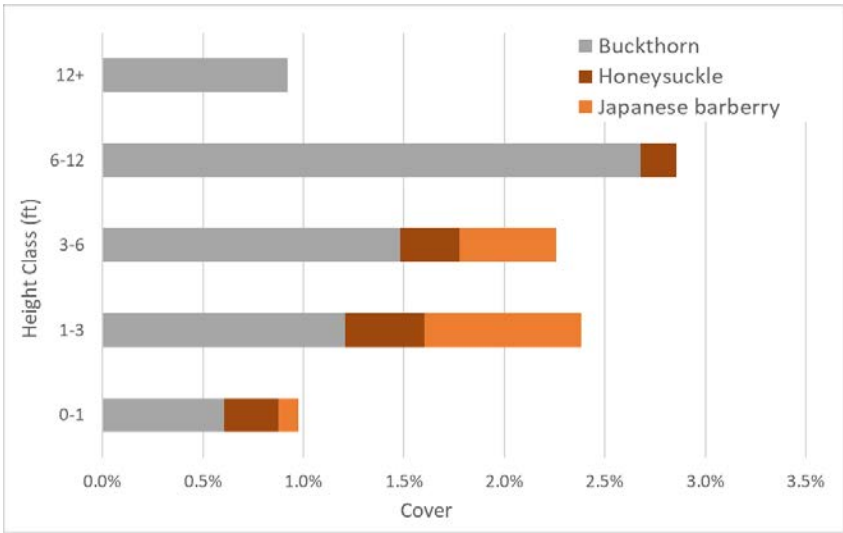


Figure 24: Total percent of land cover of invasive shrub species by height class

As seen in the map below (Fig. 25), the invasive shrub species found were buckthorn, honeysuckle, and japanese barberry. Buckthorn is the most present invasive. In the pine plantation, there are areas with no invasives to compete with tree regen.

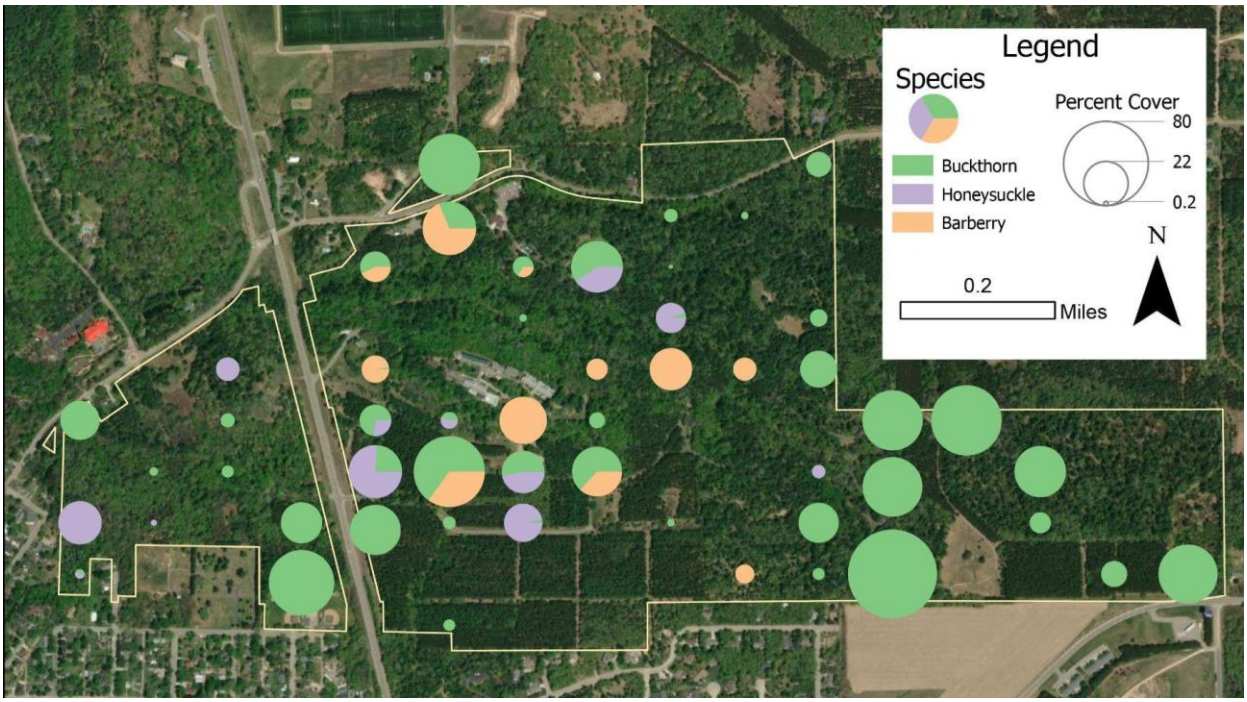


Figure 25: Invasive shrub cover per plot by species; The section of pie is based on the frequency by species. The pie is based on total percent cover.

Figure 26 shows the frequency of browse per species. Aspen has 100% deer browse. However, there was only one aspen seedling, and it happened to be browsed. Black walnut and black cherry had a high percentage of deer browse compared to other species. There was little rabbit browse spotted on the tree regeneration.

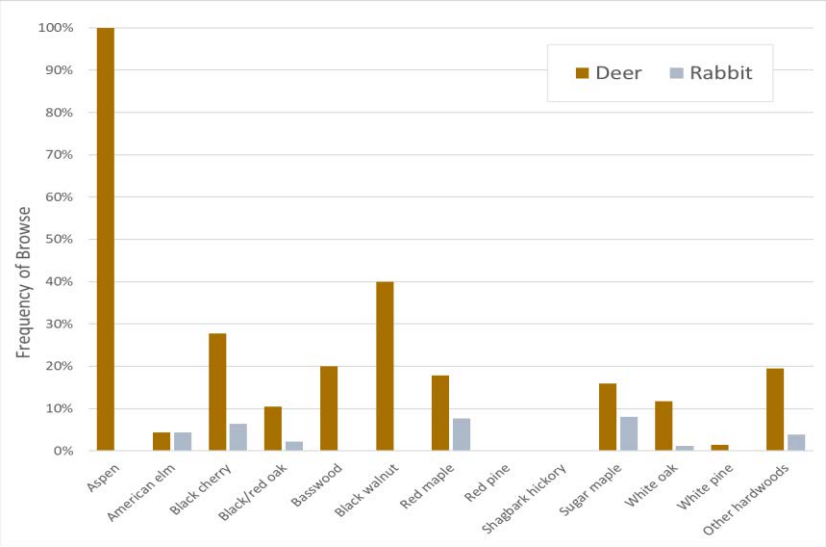


Figure 26: Frequency of deer and rabbit browse by regeneration species

The map below (Fig. 27) shows the percentage of browse frequency per species. There is a high percentage of browse frequency per species in the western part of the tract. Black cherry, and black/red are the most frequently browsed species.

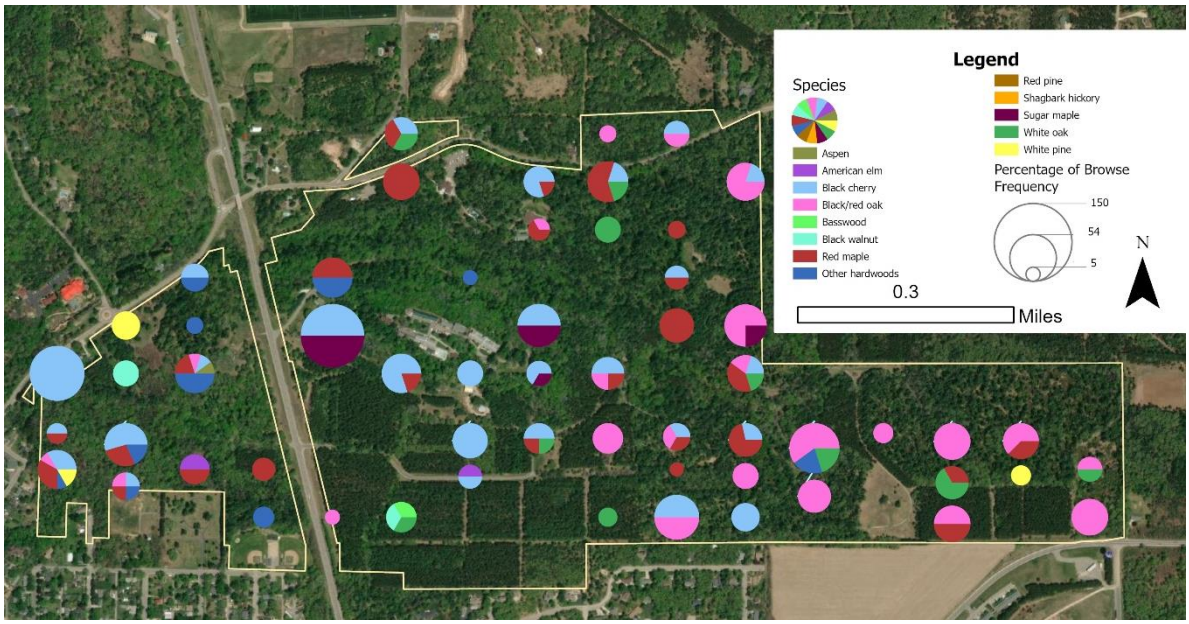


Figure 27: Percentage of browse frequency by species

Considerations

Invasive Species

Invasive plant species are of large ecological and economic concern. They have the potential to grow and spread rapidly, completely replacing and excluding native species from their natural ranges. In doing so, invasive species can create potentially irreplaceable cascading effects that echo throughout ecosystems. Within the Camp Wawbeek property, we found three invasive shrub species of concern:

Buckthorn (*Rhamnus cathartica*): Buckthorn (Fig. 28) is by far the most frequently encountered invasive shrub on the property. It thrives on well-drained soils, and is known to invade oak forests, riparian forests, savannas, prairies, old fields, and roadsides, making it particularly well suited for this property. It typically leafs out very

Figure 28: Common buckthorn (*Rhamnus cathartica*) leaves and berries

early in the season and retains its leaves longer than native plants. Additionally, it has a relatively dense leaf cover, meaning it shades out and kills any potential competition from native plants or regenerating trees. Moreover, buckthorn further inhibits growth by way of allelopathy (producing toxic root exudates that poison the surrounding soil for other plants). Buckthorn removal is critical in maintaining the health of the forest as well as in accomplishing the management recommendations discussed later.

Figure 29: Invasive showy-bush honeysuckle (*Lonicera x bella*, left side) compared to native honeysuckle (*Diervilla lonicera*, right side)

Honeysuckle (*Lonicera x bella*): Showy-bush honeysuckle (Fig. 29) is the second most common invasive species on the property. It is very similar in appearance to the native honeysuckle *Diervilla lonicera*, making it more challenging to effectively target for removal. It can invade many habitat types, including forest edges, open woods, old fields, and roadsides. It often grows in large clusters of stems and suckers, especially after decapitation. Like buckthorn, it creates dense shade that limits the success of native species and regenerating trees. Although not proven, it is thought to also produce allelopathic chemicals from its roots.

Japanese Barberry (*Berberis thunbergii*): Although it's the least common invasive on the property, Japanese barberry (Fig. 30) can withstand the widest range of ecological and environmental conditions: It is shade

Figure 30: Japanese Barberry (*Berberis thunbergii*) in summer (left) and fall (right)

tolerant, drought resistant, and adapts readily to a variety of wooded habitats. Like honeysuckle and buckthorn, Japanese barberry shades out competing native vegetation and dominates the landscape. By doing this, it alters the foraging habits of wildlife, of which deer are the most notable. Unlike the other two invasive species, Japanese barberry can indirectly impact human health by acting as a prime habitat of wood and deer ticks, which can carry Lyme disease.

Promoting Underrepresented Species:

As the figures and maps above (*See:* 'Tract Description', page 7) make clear, white pine is wildly overabundant in terms of its proportion of the total basal area per acre. Within our management alternatives and recommended strategies section below, we hope to influence the ecological conditions of the landscape in such a way to promote the growth of underrepresented species. By limiting the disproportional dominance of a few species on the landscape, the biodiversity of the property will be greater. Diverse ecosystems provide a myriad of benefits, including but not limited to: Increased efficiency in nutrient cycling, increased erosion control, decreased vulnerability to pest and disease outbreaks, increased water filtration/amelioration, and increased diversity of wildlife species. For these reasons, the general goals of our recommended management strategies are to promote the growth of mixed hardwood species (most notably white oak) while simultaneously limiting the ability of white and red pine to regenerate. In facilitating the creation of multiple distinct ecosystems within areas surrounding campus, not only will the biodiversity of the landscape be increased, but so too will the aesthetic potential.

Oak Wilt:

Although not confirmed, we noticed localized pockets of oak mortality that are characteristic of oak wilt, a majority of which occurred in the hardwood section to the west of Highway 13. Oak wilt (Fig. 67) is a fungal disease caused by the pathogen *Ceratocystis fagacearum* (also referred to as *Bretziella fagacearum*) that disrupts the vascular system of trees, causing wilted leaves and eventually leading to death. Red oak species (meaning black, red, and northern pin oaks) are particularly vulnerable. This is concerning since most oak species on the property - both in the overstory and understory regeneration - are black and red oaks.

Liability for Public Use in the Western Tract

Property owners are not generally liable for injuries to trespassers on their property. However, it still may be beneficial to install additional signage around the land to the west of Highway 13 because the area is used so extensively by the public. It should be noted that the western stand contains the largest density of snags per acre of anywhere on the property, and therefore poses a higher risk of danger. During our time taking measurements for Camp Wawbeek, we witnessed many people walking and biking on the trails. Without proper signage, it may be unclear to residents that the area they are hiking in is private property, which in our opinion contributes to the area being more of a liability than it is worth.

Maintaining Aesthetics

We were given the task of managing the area to maintain aesthetics and promote recreation, so it is important that the property looks healthy and attractive to visitors and passersby alike. To comply with this consideration, we have steered away from major harvests near the campus and roads. The only management alternative that we would recommend with any clearing would be for the aspen stand. However, this would only be done in organically shaped ~1-acre sections and is recommended purely to benefit the growth of new aspen. Aspen grows and spreads quickly, so the cleared areas should not stay clear long, and the long-term benefits to biodiversity are worth the short-term disturbance.

Economics

Management is expensive and is often limited by its cost. While considering our management recommendations we were careful to keep economics in mind. Working with what we had we tried to find ways to generate funds to cover our management costs, thinning in the pine plantations for example. We also tried to minimize management costs where possible, like comparing costs of herbicides and suggesting bundling the thinning sale with management in the savanna and aspens. With a tract of this size, there are always going to be further management options, but we were careful to keep our recommendations economically feasible while satisfying our goals for the property.

Management Alternatives and Implications

Management Option 1: No active management

If the decision is to make no changes to the current forest, we can make predictions about what the forest will look like in the future. Based on the regeneration data, white pine could continue to be a prevalent species, especially in the northeast corner and the southern part of the property. Black/red oak and red maple regeneration is abundant throughout the tract (Fig. 22). For the next 20-50 years the canopy will likely continue to be dominated by white pine with a mix of hardwoods such as red oak, black oak, black cherry, shagbark hickory, and red maple. Our predictions show that the black/red oaks, red pine, and white pine will increase the most, at 82%, 34%, and 41%, respectively (Fig. 31). This means that in 20 years there will be greater stocking and more value in the stand.

The abundance of red maple regeneration indicates a potential "maple-ization" of the forest in the future as more red maples grow into the canopy and shade out oak and other hardwood regeneration. The presence of Norway maple will also contribute to this "maple-ization," as this species is non-native and can spread rapidly, resulting in a dense canopy that will shade out the regeneration of potentially desirable tree species. In the red pine plantations, there is very little red pine regeneration due to the lack of sunlight, but young white pines are abundant. As the red pines age and canopy gaps open, white pine will grow into the canopy and eventually replace red pine. There is also oak regeneration in the red pine plantation, but these conditions might be too shady for successful recruitment into higher canopy levels. For many decades, the plantation will likely be a mixed conifer forest of white and red pine, with some possible scattered oak trees if large enough gaps open.

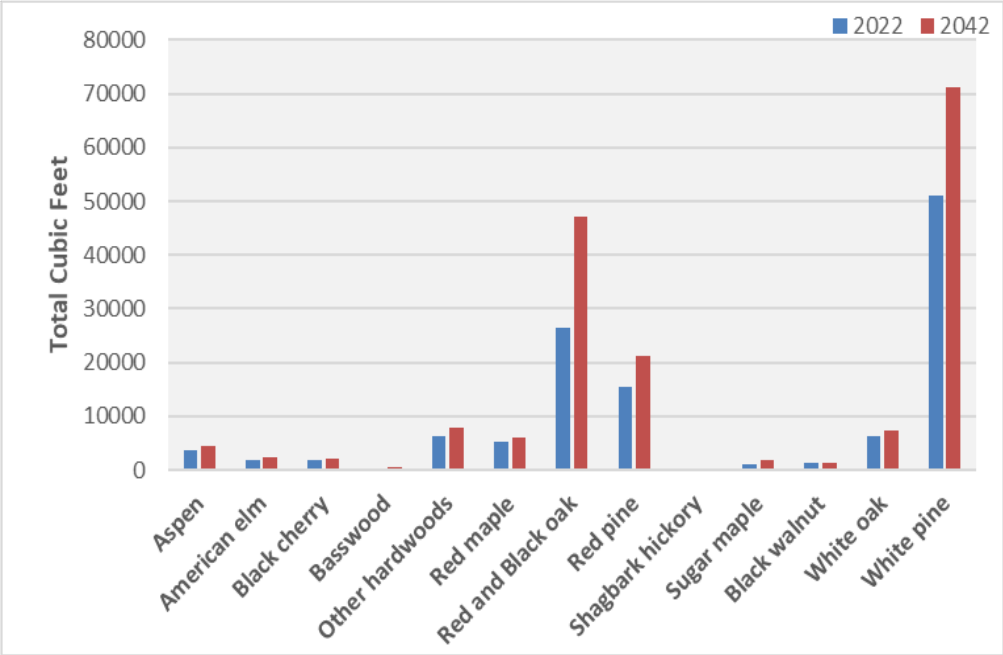


Figure 31: Volume Changes from 2022 - 2042 under no management; This figure represents the increase of total volume of the entire tract, broken down by species. For all species, the total volume stayed about the same or increased.

If invasive species like Japanese barberry and buckthorn are not managed, these shrubs will spread quickly, and the problems that they can produce will be worsened. These invasives are a problem in many Wisconsin forests because they outcompete many native shrub and tree species, monopolizing space, light, and nutrients. Both common buckthorn and Japanese barberry have thorns on their stems and can be nuisances in recreation areas. Unfortunately, much of the barberry we found within the property was centered around the campus buildings and surrounded outdoor activity areas. Buckthorn was found to a lesser extent in these areas

but was more prevalent throughout the rest of the tract. Barberry is also associated with ticks and creates a greater risk of exposure to Lyme disease. The longer these species are allowed to proliferate, the more devastating their impact will be on the Camp Wawbeek ecosystem. Therefore, if they are dealt with soon, it will be easier to control them in the future, and they will not be able to have as much of an effect on the landscape.

Honeysuckle, although not thorny like barberry and buckthorn, is also an invasive that spreads very quickly and can be found near the Camp Wawbeek campus. It has similar effects to barberry and buckthorn on our forest ecosystems and grows very wide and tall to form walls of shrubs that make areas hard to traverse.

Management Alternatives

We have divided the Camp Wawbeek property into six management areas (Fig. 32) based on the data we collected on forest composition and structure. We also took camp facilities into account. We have created multiple options and strategies for implementation for each of the management areas.

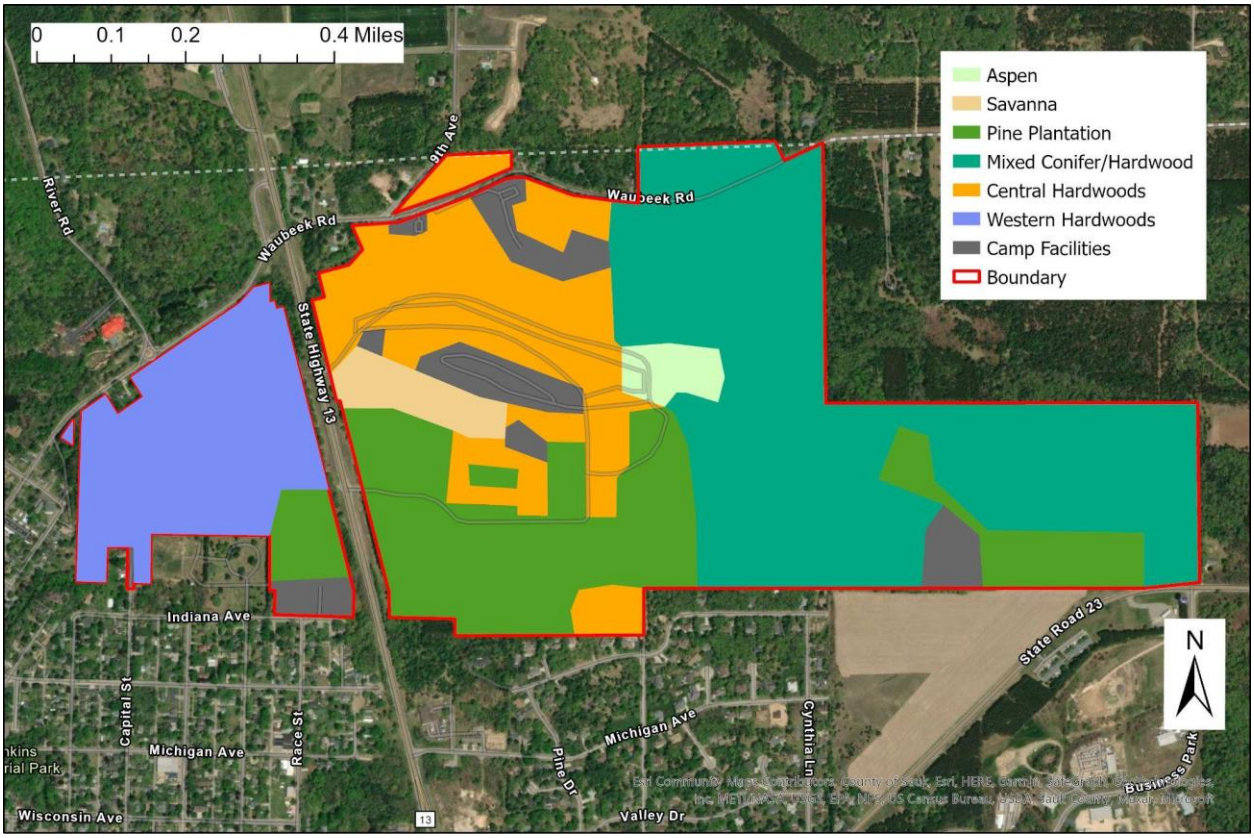


Figure 32: Map of Camp Wawbeek property divided into management areas.

Western hardwood area

This area is about 51.5 acres. One goal could be to have a mixed hardwood stand with a diverse group of tree species, with an understory of mostly native shrubs. There are invasive species (buckthorn and honeysuckle) present on the site. The first step would be to remove these invasives, which will take multiple years and require diligent monitoring. This can be done by cutting the invasives with brush saws, chainsaws, and loppers (depending on the diameter) and treating the stumps with an herbicide containing triclopyr or glyphosate. If plants are small (less than ~⅜ in) these can be pulled out by hand, with care to remove the root system. Removal

should be conducted in late summer and throughout fall. Removal should be conducted in sections, targeting areas with small amounts of invasives first to prevent further invasion (Fig. 68). This will be a more manageable goal than trying to remove all invasives at once. It is also important to target berry-producing plants first to reduce the amount of seed reaching the ground. Once these sections are free of invasives, work can be focused on the large patches of invasives.

When considering the overstory, there seems to be a good mix of hardwoods and white pine (Fig. 34). The regeneration data shows a wide range of hardwood species regenerating which is promising for the goal of having a diverse hardwood overstory (Fig. 35). One concern for the future would be preventing maple from dominating the area if the goal is to sustain a diverse overstory. Although a maple-dominated forest could also be desirable and is not necessarily a bad thing, care should be taken to not allow Norway maple to become dominant. Hazardous trees near trails should be removed as these could be a liability due to public use of the area.

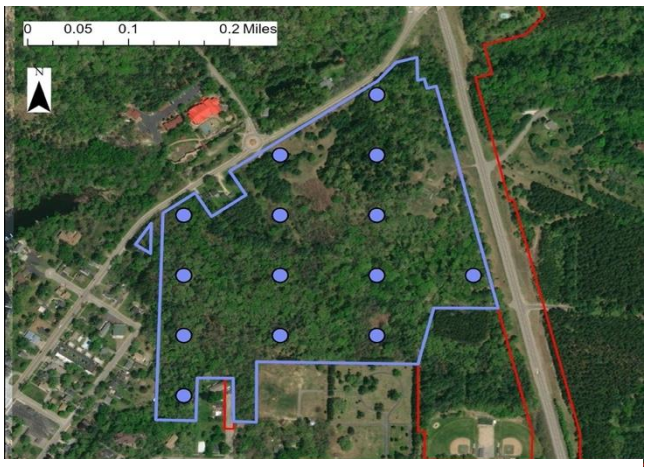


Figure 33: Map showing the 14 plots in the 51.5-acre western hardwood area.

It would be helpful to plant native shrub and herbaceous species to improve the condition of the site and reduce the amount of bare ground available for buckthorn or honeysuckle resprouting. In areas of dry-mesic hardwood forest, we could consider planting highbush or lowbush blueberries, various dogwood species, witch hazel, serviceberry, winterberry, doll's eyes, jack-in-the-pulpit, hog peanut, enchanter's nightshade, and a variety of other species. In dry forested areas, *Rubus* species, gray dogwood, American hazelnut, wild geranium, false Solomon's-seal, hog-peanut, and rough-leaved sunflower are suitable. This process could be fairly expensive, and it may be more cost-effective to purchase and spread the native seed instead of grown shrubs. Prairie Future Seed Company sells annual cover crops at a rate of $6.50 per pound of seed.

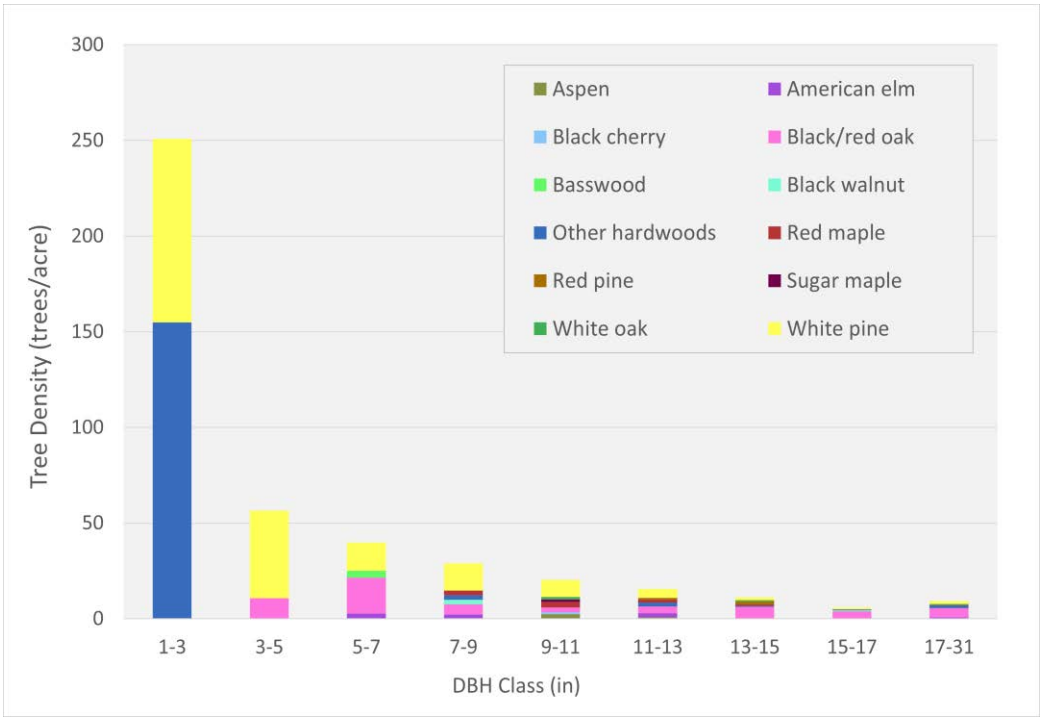


Figure 34: This graph shows the diameter distribution of trees found in the western hardwood area by species, broken into 2-inch size classes.

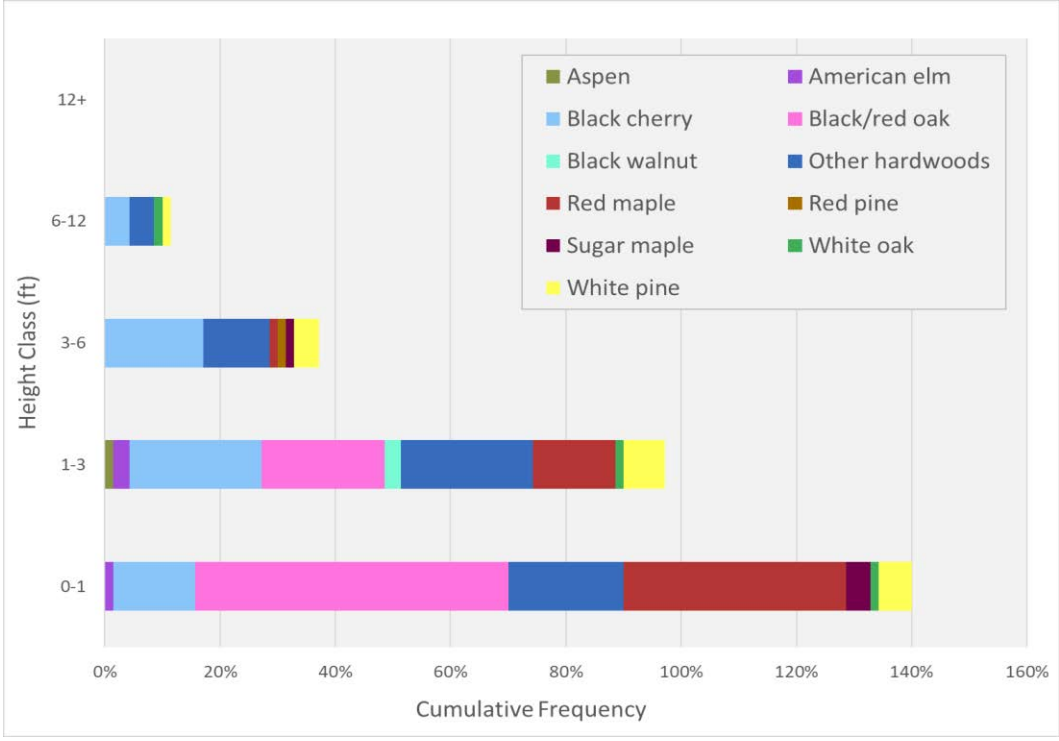


Figure 35: This graph shows the cumulative frequency of tree regeneration by species and height class in the western hardwood area.

When mentioning how many oaks were in this western stand in 1997, Fred Clark left a note regarding the presence of oak wilt. A concern for the future of the oak species in this stand would be the uncontrolled spread and death of many of the oaks due to this pathogen. Although we did not see much while cruising these woods, a professional forest pathologist will be necessary to accurately assess the severity of oak wilt in this stand. This would ensure it does not get out of control and can be dealt with accordingly.

Central hardwood area

Similarly, to the western hardwoods, this 67-acre area (Fig. 36) can be managed for mixed hardwoods. This area also has a good number of old and very sizable white pines that would be left for their aesthetic qualities (Fig. 37). Underneath the dominant white pines are large red and black oaks as well as sizable sugar maples. Steps to improve this area are in line with those presented in the management of the western hardwood area: Invasive shrub removal, Norway maple removal, and planting of desired native species.

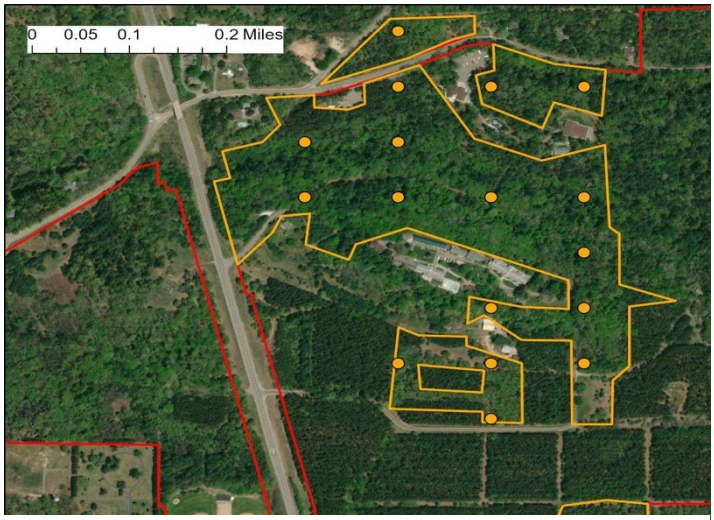


Figure 36: Map showing the 18 plots in the 67-acre central hardwood area.

A second option would be to remove the red maples from this section of the stand to open the canopy and prevent maple-ization for some time. This would be an aesthetic choice for many years into the future, preventing the current red maple from shading out all other regeneration (Fig. 39) and creating areas where only it can regenerate. Cutting down these maples might lead to another generation of oak and white pine before maples take over in the absence of serious disturbance. An alternative approach to stopping red maple regeneration

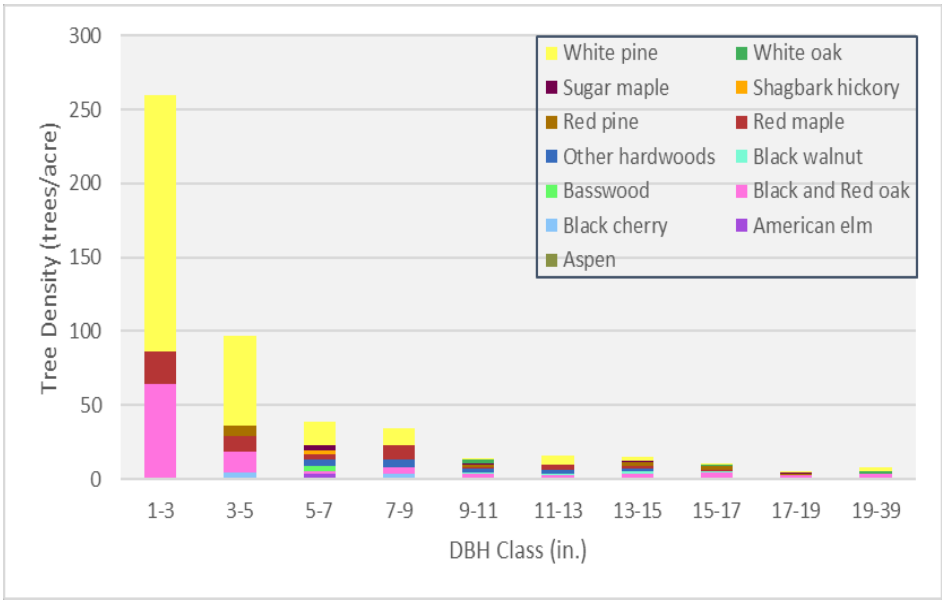


Figure 37: Diameter distribution of trees in the hardwood central tract by species. This graph indicates an uneven-aged stand.

could utilize a method such as girdling so that the trees would be killed but allowed to stand. The addition of standing dead trees (snags) would provide excellent habitat for mammals, woodpeckers, and other bird species.

To add to the aesthetic value and natural beauty of the gorge in the northern region of Camp Wawbeek's land, eastern hemlock (*Tsuga canadensis*) could be planted along the ridge (Fig. 38). These trees grow well on rocky outcroppings, so they would be well adapted to the gorge's slopes. Hemlocks are shade tolerant, so they would have no problems growing under the established overstory in the area. Planting hemlocks here would benefit the biodiversity of the ecosystem and could help resist erosion in the streambed. Over 15 species of birds in Wisconsin are drawn to hemlock trees and the roots of the hemlocks could solidify the sandy slopes for a long time, as eastern hemlocks can live up to 800 years. It is important to note that hemlocks are vulnerable to deer browse. Although we didn't notice intense browse in the gorge (browse Fig #), it may still be beneficial to provide fencing for the young trees until they reach a height of six feet. This would ensure that they survive and become established without being eaten.

Figure 38: Image of an eastern hemlock (*Tsuga canadensis).*

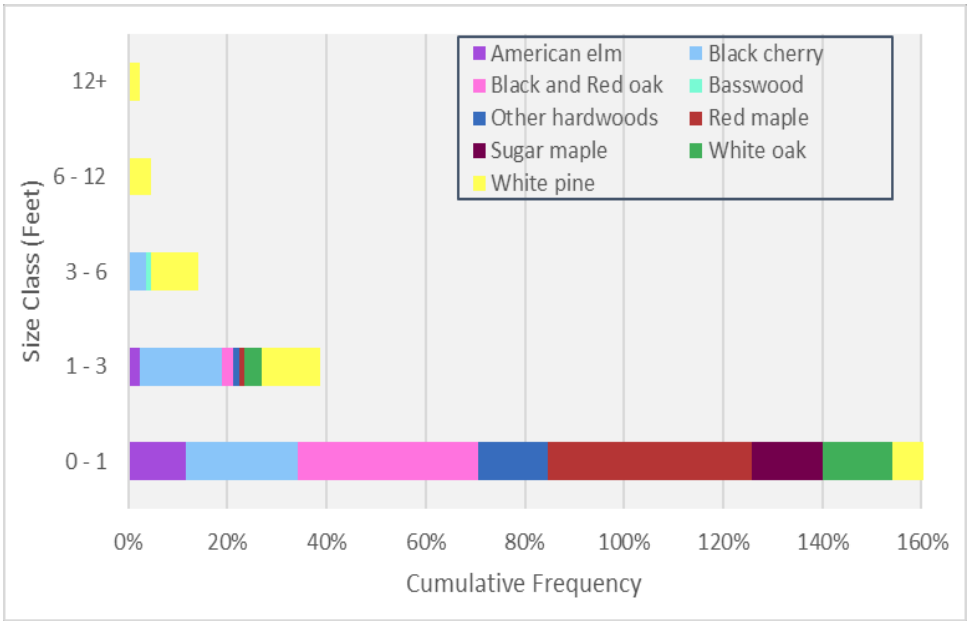


Figure 39: Cumulative frequency of tree regeneration by species and height class for trees in the central hardwood area.

Pine Plantations

One option would be to let the plantations continue to grow for 20 years. Presently, the plantations are sitting between the "A" and "B" lines in their respective stocking charts (Fig. 44, Fig. 46). This means that they are fully stocked but still have room to grow before they start impeding each other's growth through competition for light. The tree density has a bimodal distribution, indicating an even-aged overstory (bell curve shape centered around the 11-inch to 13-inch size classes) along with the recruitment of young trees (mostly white pine) in the understory, seen in the 1-inch and 3-inch size classes (Fig. 41). The tree seedling/sapling numbers indicate potential for strong regeneration of a variety of species, especially red/black oak and white pine (Fig. 42), but based on our volume projections the plantations will not be suitably overstocked for some time. The volume of red pine is expected to increase by 41% and white pine is expected to increase by 37% (Fig. 42). In 20 years, when stands are nearly overstocked, they could be thinned to release the dominant and ideally formed crop trees. This could promote the growth of white pine and red oak in the understory because they will have enough open canopy to grow under the large overstory pines. The total value of the stand now is around $37,500, and in 20 years (assuming the stumpage prices stay the same as the value in today's dollars) it will be worth around $56,300 based on the increased volume of the stand. If we assume that stumpage prices keep up with inflation this would mean a 50% increase in revenue. The revenue from the timber harvest can be used for further invasive species management and other management projects.

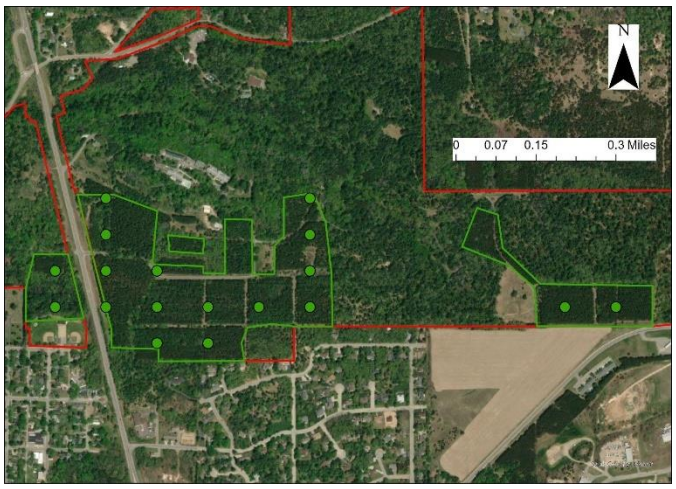


Figure 40: This map shows the 18 plots found in the 81 acres of pine plantation.

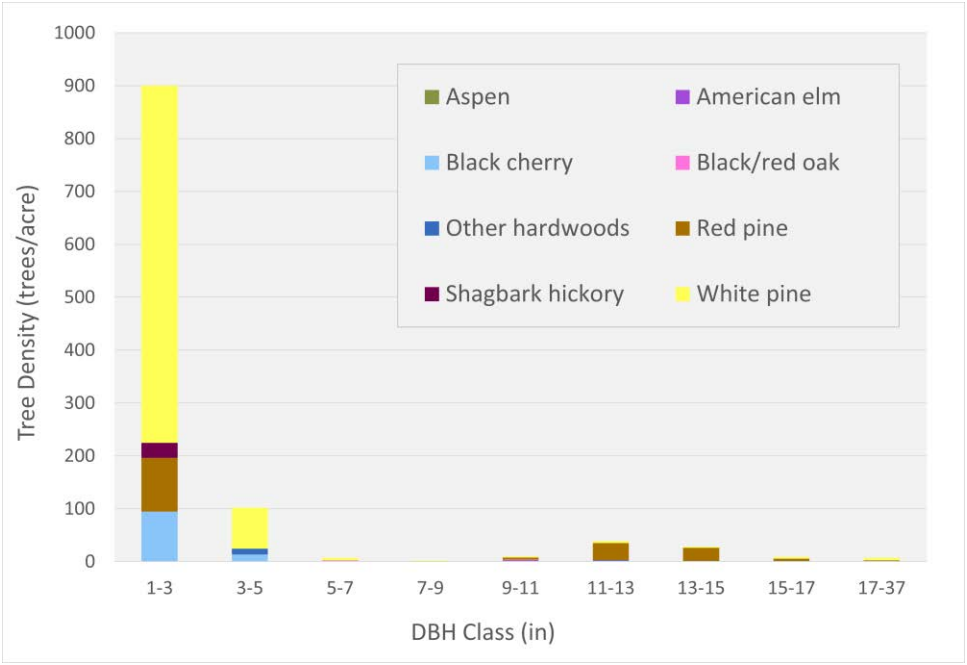


Figure 41: Diameter distribution of trees in the pine plantation management area.

A second option would be to thin the plantations now. We want this thinning to leave us with a basal area of 70 sq ft/acre, where the large trees make up almost all of the remaining basal area. We suggest a Grade C thinning from below (Fig. 45) so that most of the overtopped and intermediate trees are removed as well as some codominant trees to open up some of the canopy. In this

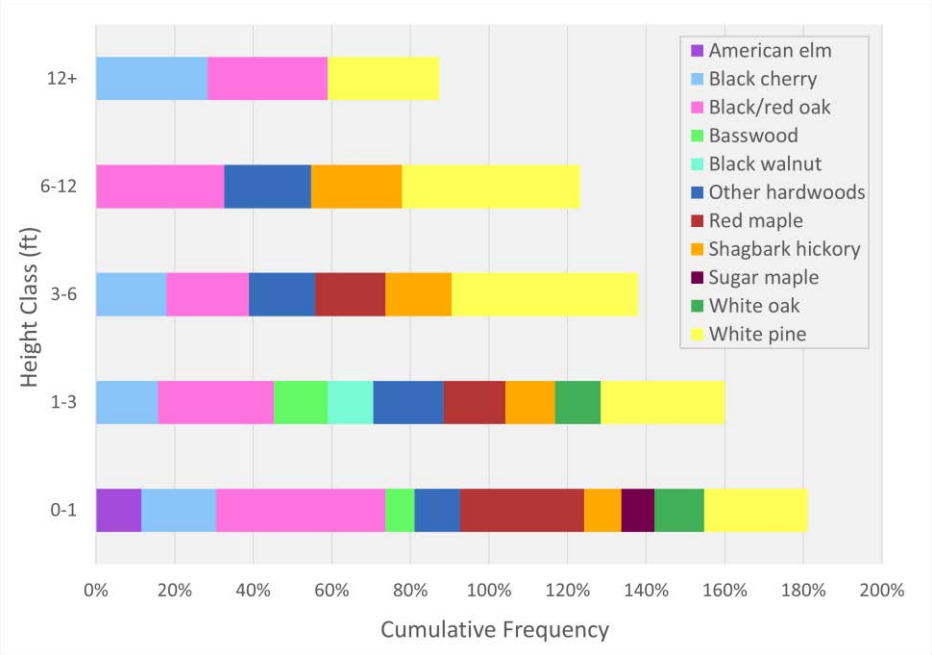


Figure 42: Cumulative frequency of tree regeneration by species and height class for trees in the pine plantation management area.

case, we would expect to see our abundant and sizable white pine and red/black oak regeneration to grow and fill the canopy gaps. It would be beneficial for the logger to remove deformed and declining trees to increase the health and future productivity of the stand.

We have to consider the proximity to a pulp mill when assessing the possibility of a harvest in the pine plantation. Domtar Paper Mill is located 1 hour (53.1 miles) north of the camp in Nekoosa, WI, which is a reasonable distance. We are basing our estimated timber sale value for Camp Wawbeek on the 2022 Wisconsin State Land Stumpage rates for Central Sands. The DNR set the value at $19/ton for red pine and $15/ton for white pine. We are estimating the weight of green lumber at 3.5 lbs/bdft for both pine species based on information found in the ANSI Z133-2017 handbook and on the Global Wood website.

In the timber sale setup, the forester should mark trees with the average DBH calculated from the nearest plot to maintain the assumption that removing a certain percentage of the basal area will also be removing the same percentage of volume. There should be an emphasis on removing deformed/forked trees first before marking trees with good form. Despite the red pine plantations currently being fully stocked, we could thin to 70-80 sq. ft of basal area per acre to enhance the growth of the remaining pines. This could create a more open pine forest with large, aesthetically pleasing pines. This could also enhance the growth of the oak and pine regeneration in the understory. Since this area is not primarily managed for economic purposes, it is okay to have an understocked stand because of the aesthetic benefits, such as having larger overstory trees, and greater structural and species diversity. If the plantations were thinned to <u>70 sq ft/acre</u>, we estimate the value to be around **$18,320** for Camp Wawbeek, meaning the logger would pay this amount to Camp Wawbeek for stumpage. If the plantations

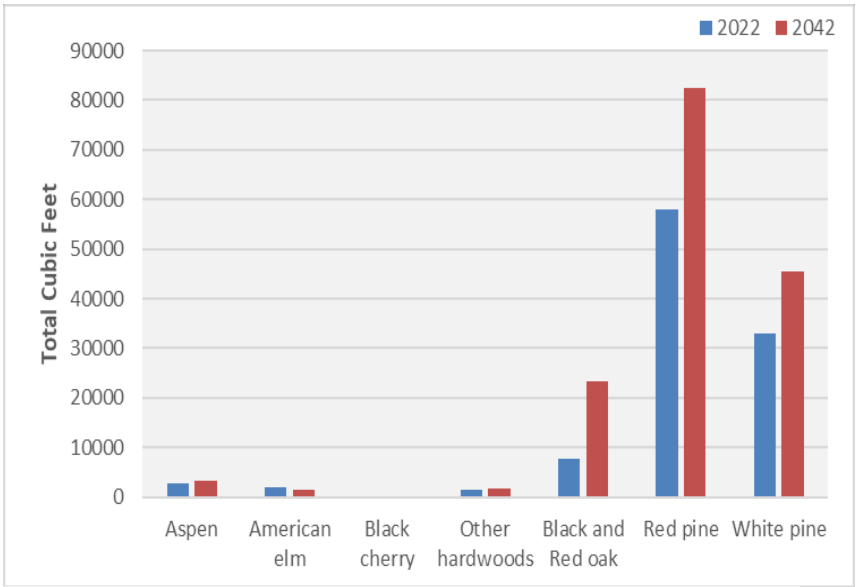


Figure 43: This figure shows the total cubic feet in the pine plantation today (2022) as compared to the expected values in 20 years (2042) under no thinning.

were thinned to 80 sq. ft/acre, we estimate the value to be around **$15,030** for Camp Wawbeek (See Appendix B, pg. 69, for greater detail on timber value calculations).

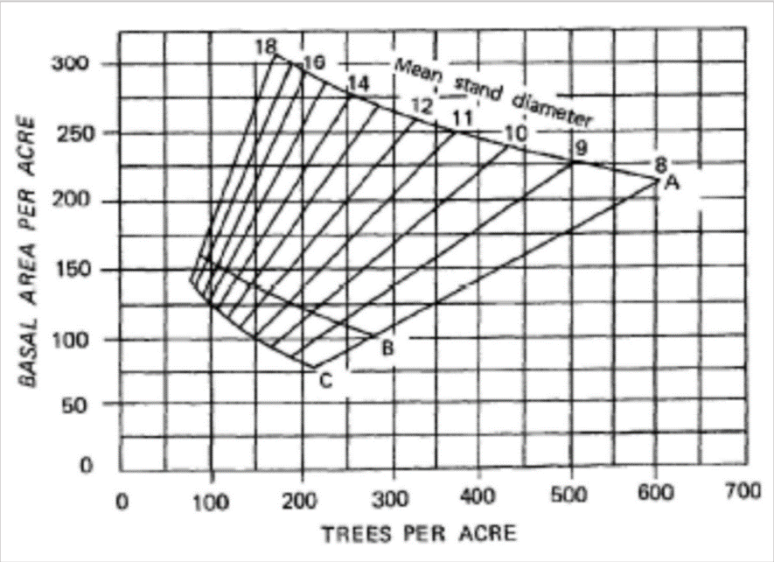


Figure 44: White pine stocking chart.

Figure 45: Illustration showing how a Grade C thin-from-below will change the canopy structure. Trees with diagonal lines would be removed.

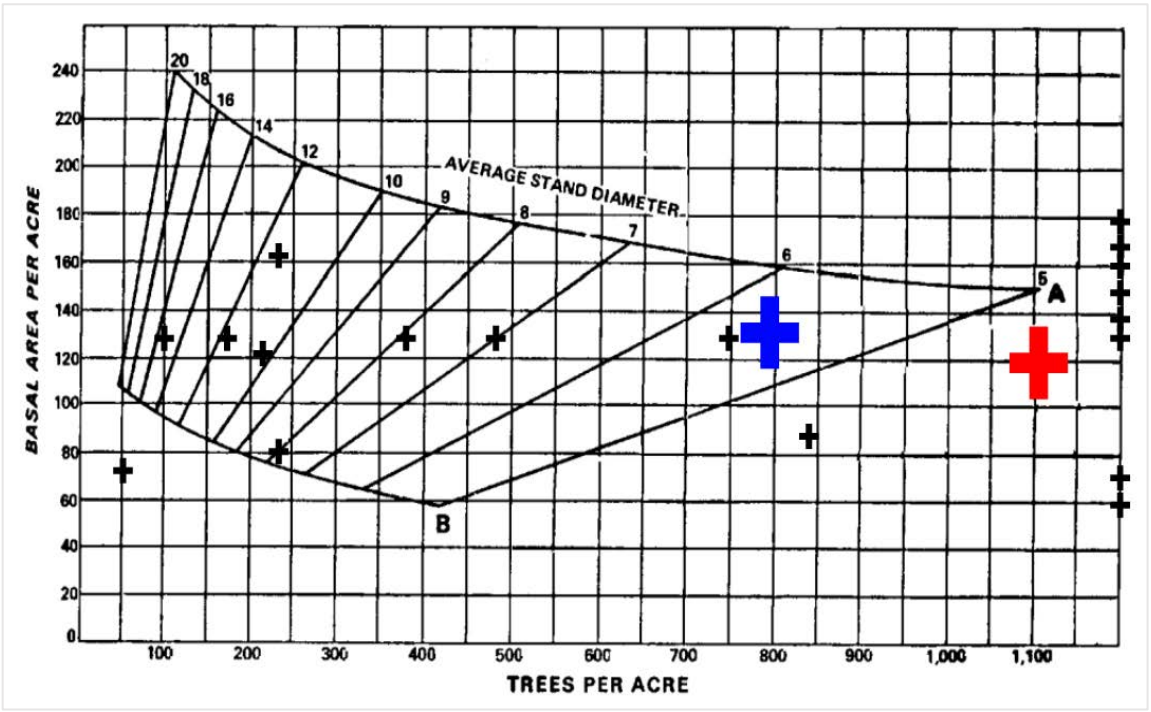


Figure 46: Red pine stocking chart; black crosses = measured plot values; red cross = average of all plots; blue cross = median of all plots.

Savanna (Near Main Campus):

Figure 47: Map showing boundary of the savanna management area. There were two plots in the 9.4-acre area.

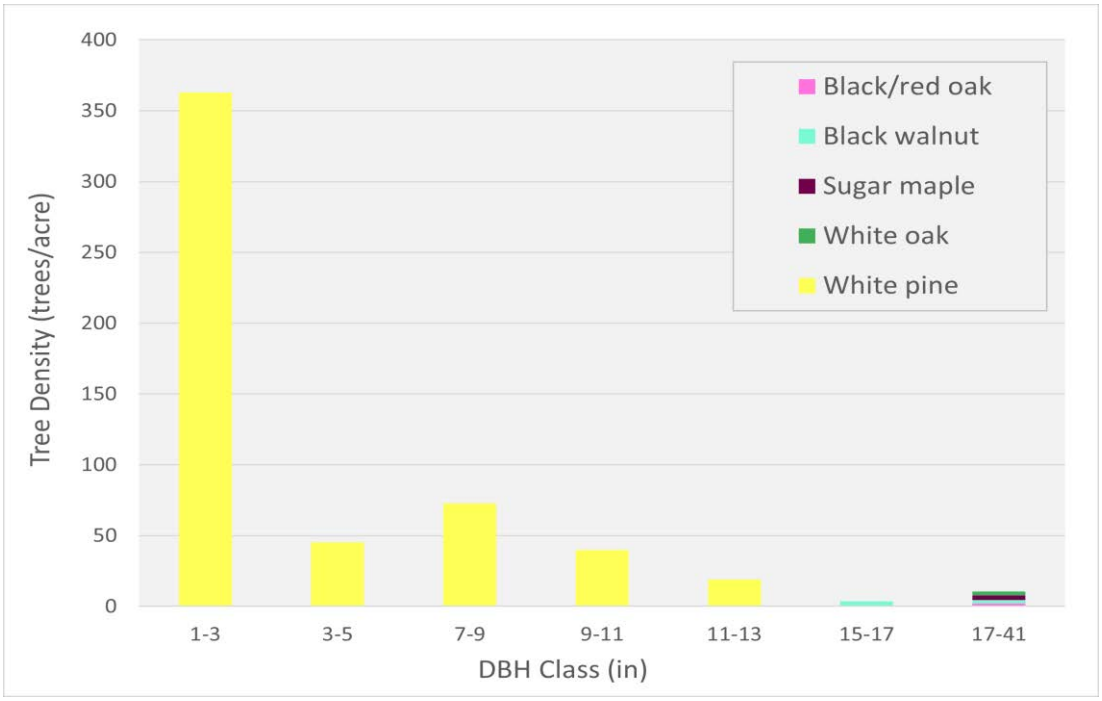


Figure 48: This graph shows the diameter distribution of trees in savanna by species. The area is currently dominated by white pine.

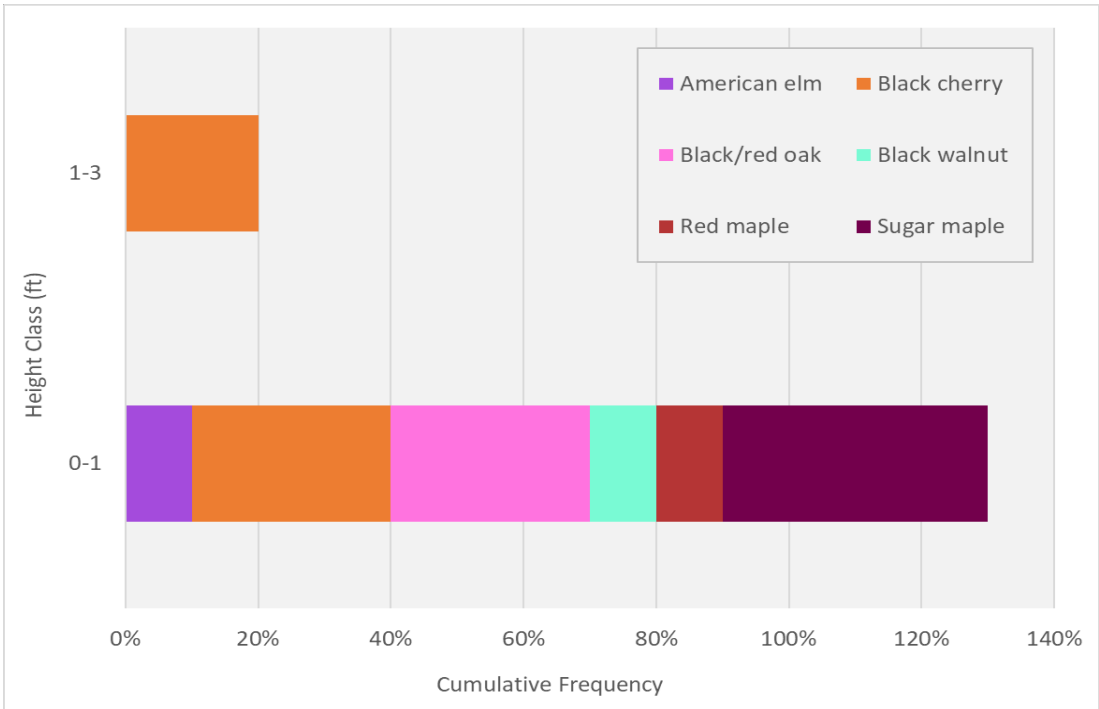


Figure 49: This graph shows the cumulative frequency of tree regeneration by species and height class. Regeneration was scarce, besides some small seedlings in the 0-1 ft height class.

1. This area should be thinned to a basal area of 20 and have a fire regime implemented. We recommend contracting the logger who is doing the pine thinning to also thin this area, leaving white, red, and black oaks. After that, a prescribed burn should be implemented in the fall to catch all of the most recent years growth. This should be repeated every two to three years until the savanna has established and invasives are no longer present on the site. After the initial two burns a

Figure 50: An example of what an oak savanna could look like.

group should go through the area to cut and treat any standing invasives that may have survived the burn.

Extending the savanna and removing its invasives will increase the biodiversity of the camp, as wildlife species who prefer savanna will move in, as well as because savanna species will be more widely represented on the site. It will also serve as a learning opportunity for campers to see this ecosystem (Fig. 50) that's not represented anywhere else in the camp.

2. This area can be left as is and combined with the mixed management area or hardwood management. There is natural hardwood regeneration of species such as oak, black cherry, black walnut, and red maple. There is not much white pine regeneration. There is an overstory with white pine and mixed hardwoods that would persist for decades, but could potentially shift to a hardwood dominated forest lacking white pine.

Aspens

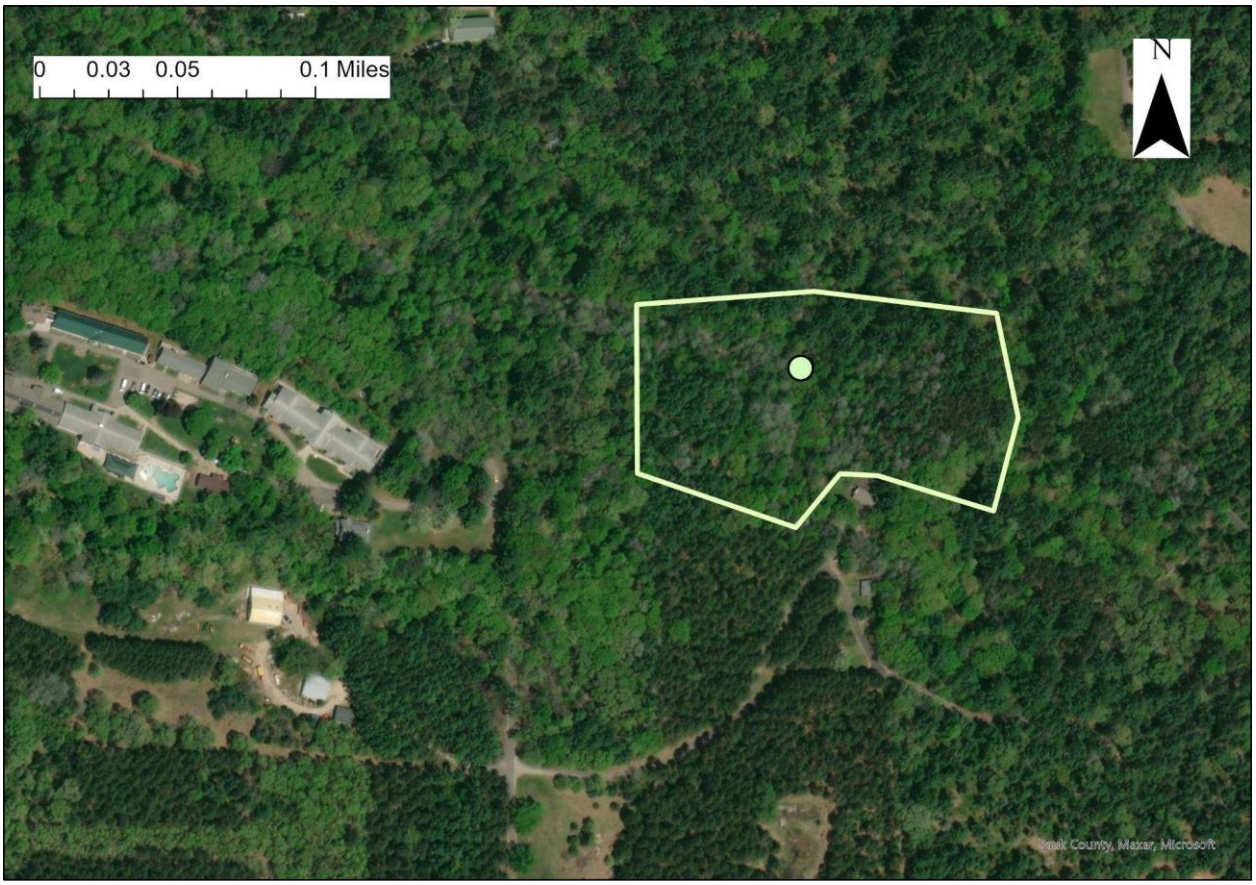


Figure 51: This map shows the boundary of the aspen management area. This area had one plot located in the 6.1 acre area.

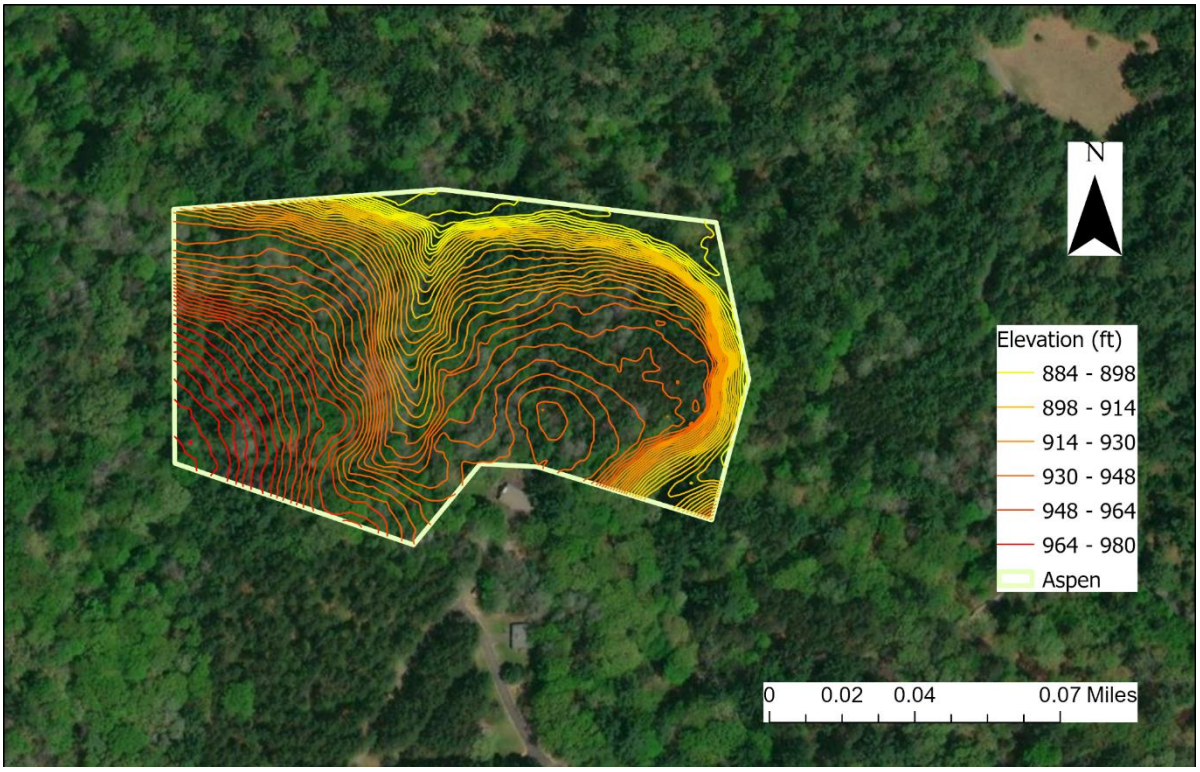


Figure 52: This map shows the aspen management boundary with topographic lines. Steep slopes will affect the feasibility of harvest and susceptibility to erosion.

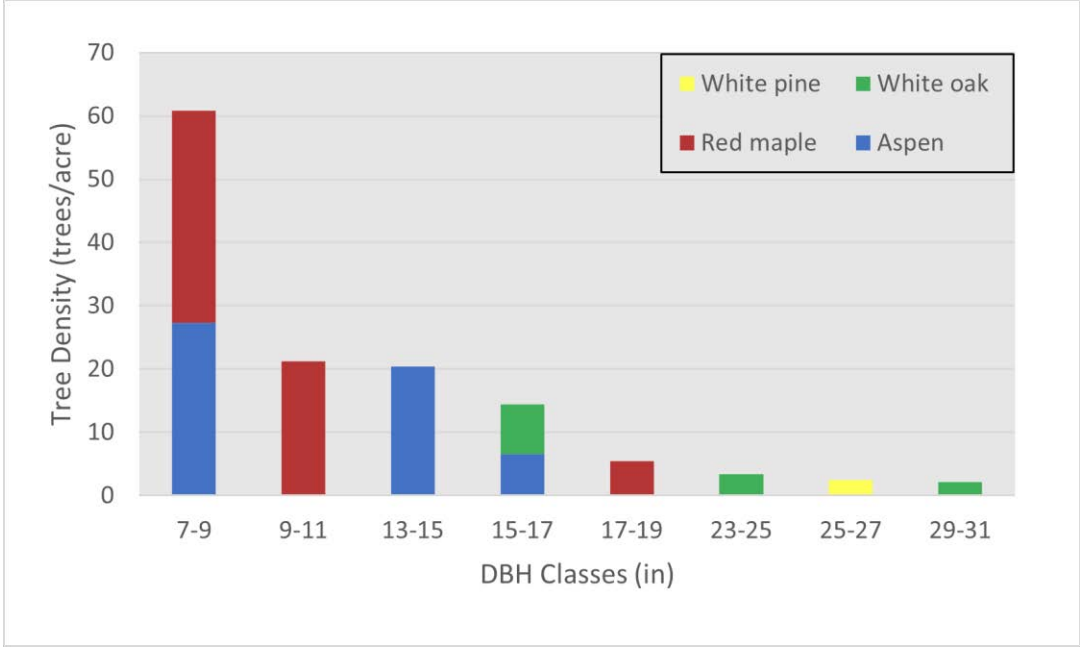


Figure 53: This graph shows the diameter distribution of trees in the aspen plot by species. This data is only from one plot. There was no tree regeneration found.

1. This location has the most aspen of any area on the property (Fig. 53) and sits on a slope which must be accounted for (Fig. 52). Within this area, two single-acre openings should be cleared in a way that leaves them with irregular shapes and edges to maintain aesthetics. There should be at least a 25 foot buffer zone between the cleared areas, with no clearing between them if either is up slope of the other. The slash should be left on the ground to slow water flow and intercept rain in this newly opened area for the following few years. Over time, this debris will decompose, allowing the new aspens to emerge and protect the soil and slow water cycling. This newly created aspen stand would add to the biodiversity of Camp Wawbeek by increasing the species evenness of the entire property. Additionally, it could also increase wildlife diversity as species who prefer open areas and edges would make this location their home. We suggest combining this management process with the pine thinning contract.
2. Combine with the Northern and Western Hardwood management plans for natural hardwood growth. This would be in the case that the erosion or sloping of the area was too difficult to take management of aspens into account.

Northeast Mixed Conifer/Hardwood Stands

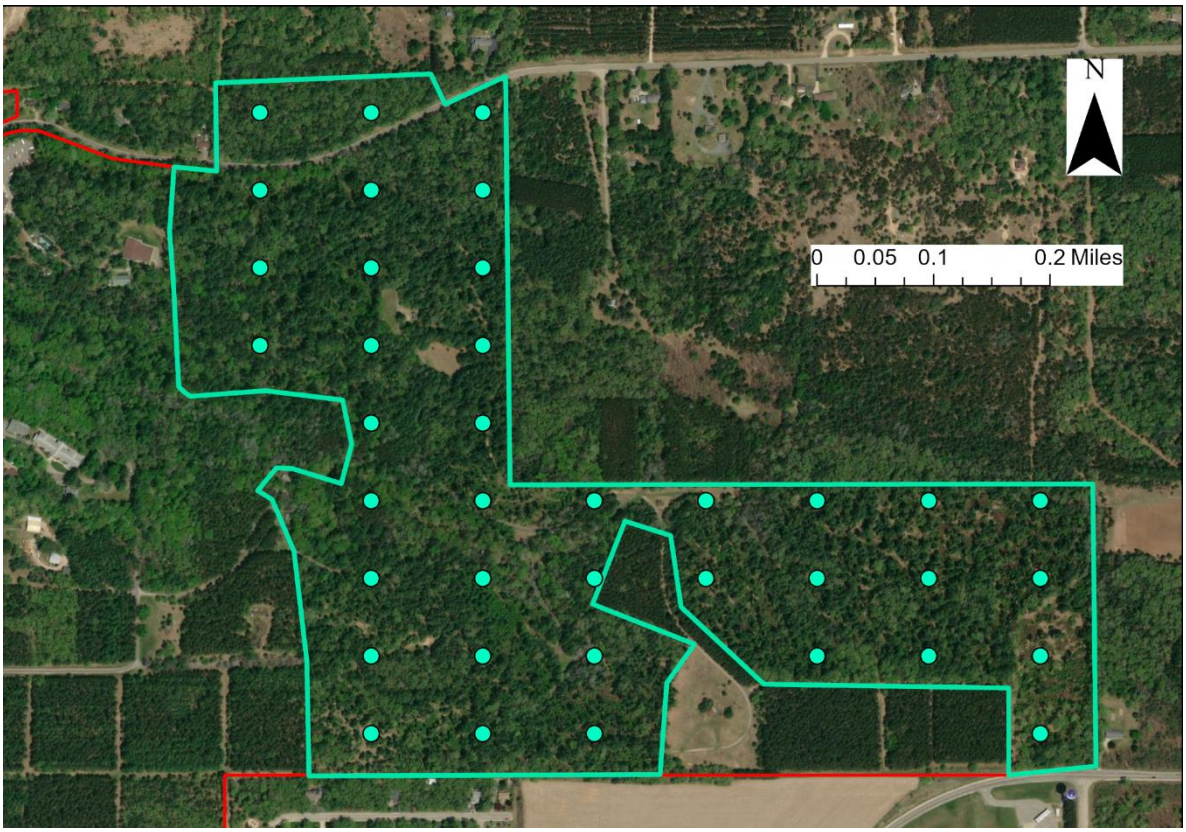


Figure 54: This map shows the boundary of the Northeast Mixed Conifer/Hardwood management area. This area contained 38 plots within around 143 acres.

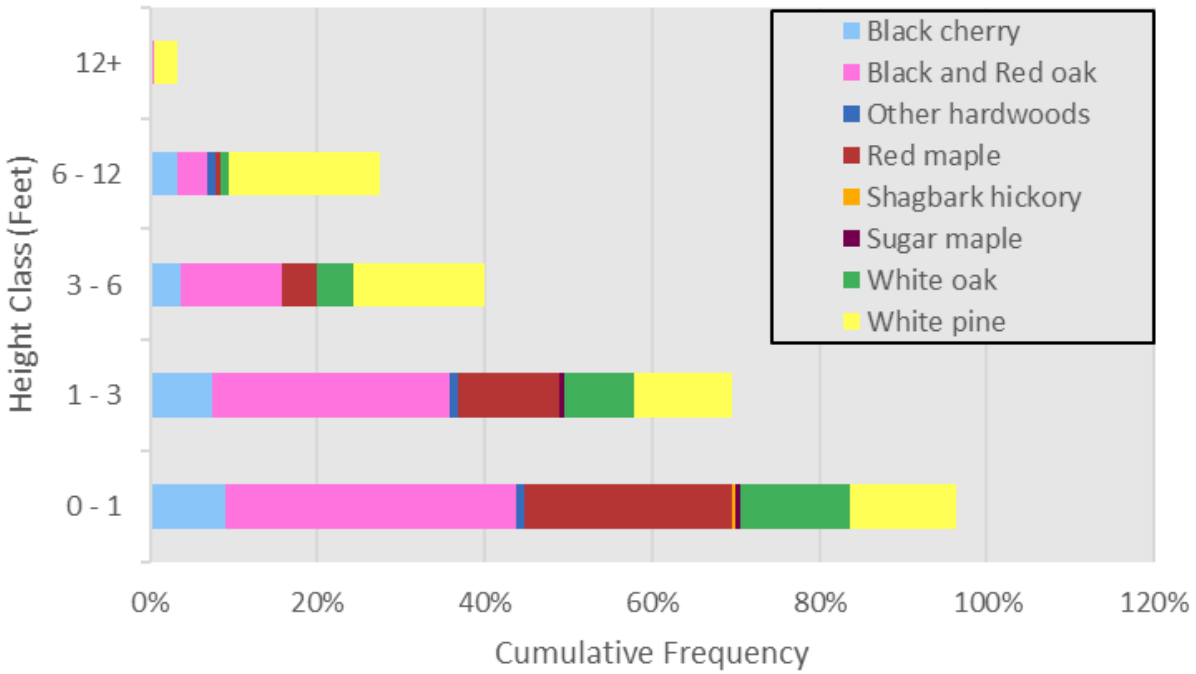


Figure 55: This graph shows the cumulative frequency of tree regeneration in the Northeastern Mixed Conifer/Hardwood management area. The most sizable regeneration is white pine, indicating a future white pine forest.

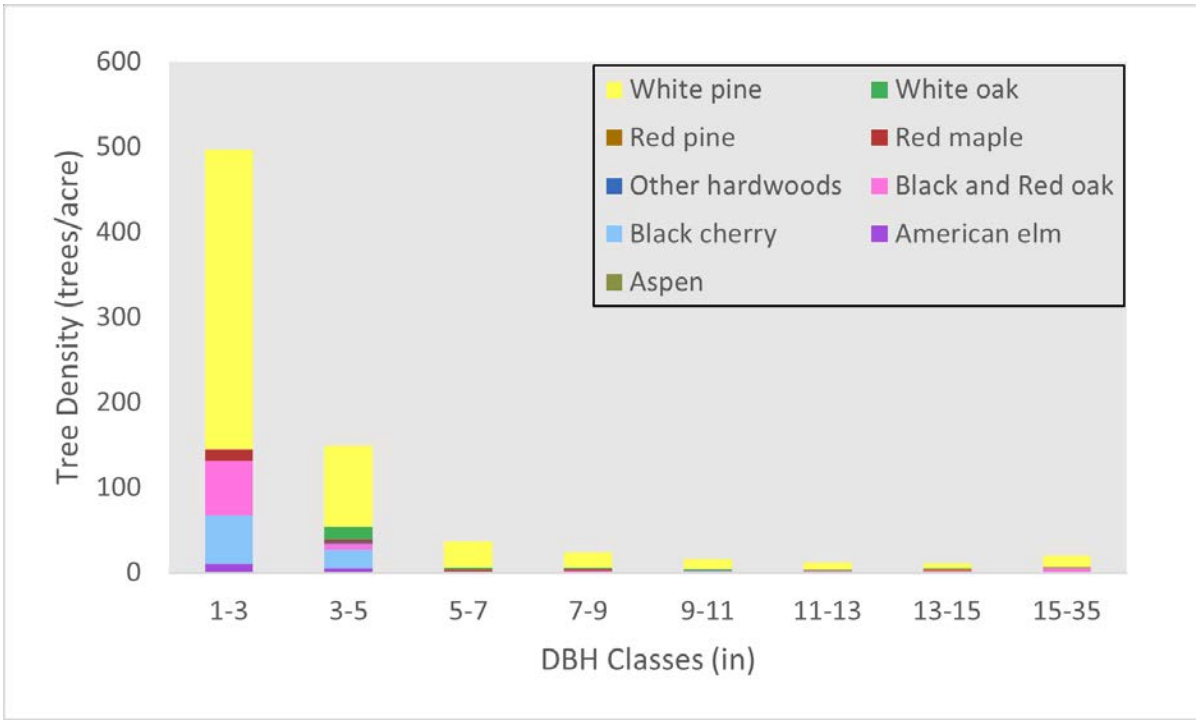


Figure 56: This graph shows the reverse-J curve diameter distribution of trees in the Northeastern Mixed Conifer/Hardwood management area, which is indicative of an uneven age stand.

1. Clear out invasive species, including buckthorn (in both the over- and understory) Japanese barberry, honeysuckle and Norway maple. We recommend using a cut stump treatment and applying glyphosate to the outer edge of the stump, where it will be sucked up through the stump and roots. The cuttings can be piled and burned the following winter. This would be a good place to begin large-scale management of Japanese barberry, honeysuckle, and buckthorn because all are just beginning to enter the area.
2. Burn to promote white oak regeneration. White oak can be found regenerating substantially in the northeast portion of the Camp Wawbeek property. This is encouraging because white oak regeneration is relatively rare. Seventeen of our plots in the northeast contained white oak in the understory, so managing to promote their growth holds importance for the biodiversity of the forest. White oak grows slowly, so removal of invasive species that could shade the white oaks out could be an integral part of how the northeast section is managed.

   One spatially limited burn where white oak regen is present would be the recommended method of management here, namely in the northwestern and south central part of this management area. Oaks are a fire adapted species that have the ability to quickly resprout from their root collar before other species can recover. We recommend doing one dormant season burn in the spring, ideally right as early leaf out species begin to flush. This should harm the survival chances of these competing species and favor oak regeneration.

3. As for browse management, we found that only about 10% of white oak seedlings were browsed. This leaves 90% of the regeneration free to grow, and because of this we do not feel that it is necessary to protect white oak regeneration with fencing. If, however, browse is observed during the regeneration stage of white oaks - so much so that the regeneration is not overcoming the deer browse - then it would be at this stage that we'd recommend the use of fencing. This fencing would be around undamaged white oak seedlings and saplings until they grow to a height of 6ft, where we feel they won't be susceptible to deer browse. This means that, depending on site nutrients and resources, fencing would remain for a minimum of 6 years.

Recommended Strategies

Western hardwoods: We would recommend hiring a plant pathologist to assess the western tract for the presence of oak wilt. Regarding the rest of the western hardwood tract, the strategy we recommend is similar to the central hardwood tract, with a focus on removal of invasive species. We would want to select the areas of highest concentrations of invasives to be cleared first in order to prevent their dominance and reduction of tree regeneration. This would be accomplished with a cut stump treatment in the late fall or winter season with chemical glyphosate or triclopyr at 25% concentration and burning all brush piles. Application of a foliar herbicide spray would be necessary to control invasive species in the summer time following a cut stump treatment. Native shrub seedlings could be planted to establish a native and biodiverse ecosystem, but we recognize the cost of this over a large acreage is not feasible. The seeding of herbaceous native sedges could also be considered to create a more open understory.

Central hardwoods: The strategy we recommend for the central hardwoods tract is to control the invasive species located within that section. This would include the strategies mentioned in the Hardwood Stand (West of Hwy 13) management alternatives above. Along with clearing the invasive shrub species, Norway maple trees should be removed because of their allelopathic qualities. The rest of the hardwoods would be allowed to grow and we would not recommend any further management at this time. Over time we expect this area to transition from a white pine/red and black oak dominated overstory to mixed hardwoods that are abundant in the regeneration. Red maple will likely become the dominant cover type in the next 50-75 years, and will then begin to shade out competing regeneration. At that point, new management decisions can be made to prevent a red maple takeover by introducing artificial disturbance or letting this section of the stand become dominated.

Pine Plantations: The recommended strategy for the pine stand locations throughout the campsite would be to thin them down to 70 BAF. The specific thinning, we prescribe is a Grade C thinning from below so that most of the remaining basal area is left in dominant and codominant trees with spacing in between. Evidence to thin the stand can be seen in the management strategies where we stated that the current stand is in between the A and B levels on its stocking chart. This means the stand is not yet overcrowded, but it is decently stocked. The stumpage price that a logger would pay the Easter Seals to log the pine plantations would be $18,320. Normally this would be less due to the creation of access roads and harvest land management that a logger would have to do. In the case of Camp Wawbeek, there are many access roads that a logger can easily maneuver through, and they should have no issue with a clean thinning of trees.

Having a logger come to the site and clear this land will not only help the trees grow and be healthy, but it also provides income to the camp. In addition, fostering a good relationship with the logger will make it easier to contract him for the other management procedures, as stated in the aspen and savanna recommended strategies. A healthy pine plantation leads to large, older-growth pine trees that will be awe to both campers and staff alike for years to come. In addition to thinning, we also recommend an invasive species removal in the same way as the other management areas to allow for a healthier forest understory.

Savanna (Near Main Campus): We recommend thinning conifer trees and opening the canopy to create an oak savanna. This is recommended due to its low maintenance and ease to accomplish. A more open prairie and oak landscape is inviting to families and doesn't have dense scrub with a forest that is hard to see and walk through. This management alternative would require the removal of conifer overstory and a decrease in tree density to 20 trees/acre, or a canopy cover of less than 50%. This thinning would be accomplished by a logger that was hired for the thinning of the pine plantations if that recommendation is chosen. The value of the downed trees did not significantly add to the stumpage calculated. Therefore, the negotiations would allow the logger to take logs of value to be included in the pine sale. The future maintenance of this stand would be a recommended prescribed burning regimen that follows a 2–4-year cycle in late fall or early spring when the camp is no longer in use. There is a small existing savanna/prairie located near the front entrance of the property that would be included in the 9.4-acre area outlined in the savanna management area boundary. This savanna includes a variable buffer surrounding the main campsite and other man-made structures in order to preserve the aesthetic "feeling" of camping, i.e., being surrounded by trees. This buffer should be located both around the main campgrounds as well as any man-made building for which it's not desirable to be surrounded by an open savanna environment. In addition, this variable buffer will also serve as a safety zone to prevent unwanted fire encroachment toward buildings.

Aspens: The recommended strategy for the aspens is to open this section with large 1-acre canopy gaps to encourage the growth of Aspens. Aspen stands are beautiful to have and serve valuable ecosystem processes. Clearcutting this portion of the forest would be a massive undertaking for this type of management, and the cleared stand would be an eyesore for numerous years before emerging as an aspen stand. During this time, it's necessary to continue managing invasive species in the area to keep the stand in a healthy condition. It is best that we open the canopy in a strategic way that allows enough light to stimulate aspen growth while also keeping the forest intact. Again, invasive species would need to be cleared simultaneously to allow for less intense competition when the aspen suckers start to sprout. Considerations to protect from erosion will need to be taken, including leaving enough slash to protect exposed soil and avoiding areas with the greatest slope in the area.

This recommendation comes with the addition that Camp Wawbeek would need to hire labor to conduct this type of tree felling. The stipulation comes in the Pine Plantation management area recommendations, where we mention thinning and bringing a logger to the site for that job. With a certified logger on-site, it would be easier to ask him to cut a few one-acre openings in the aspen stand (only after prior planning and proper steps were taken to make this cut). This would save both time and money because the logger will already be in contact with the camp and could easily add work, rather than outsourcing to other labor if the pine plantation is not thinned.

Northeast Mixed Conifer/Hardwood Stands: This location is a mix of hardwoods and pines with a much larger presence of red and white pines than the rest of the property in both the overstory and understory. The recommended strategy is to clear out invasive species, mostly buckthorn in the over- and understory, Japanese barberry, honeysuckle, and Norway maple. This will clear the forest floor and allow for the regeneration of the white oak that we see in this location. After clearing up the large invasive shrub layer, we recommend a prescribed burning like the savanna sections in the campgrounds. This will clear the high concentrations of *Rubus* for proper seed dispersal from white oaks and help seed germination with the cleared openings we are suggesting. The aforementioned small openings will work well for the regeneration of white oaks. They are not as a representative of the forest composition right now as red oak, but we would like to see them proliferate. Small canopy clearings and a cleared ground layer will allow white and red oak to grow properly.

Regarding deer and rabbit browse, we recognize the need for protection. We didn't observe much browse, but if it becomes an issue, we recommend the protection of the white oak seedlings and saplings with 6 ft tall protective fencing. We recognize the cost of this endeavor, and therefore recommend allowing for natural regeneration with no fencing before installing fences. These management strategies will create a more open canopy

Appendix A

Collection Details

Plots:

At each plot overstory, midstory, and understory data was collected. The overstory portion of measurements started with variable area plots, where a 10 BAF prism from the plot center was used to select which trees were "In" vs "Out" (Fig. 57) Trees determined to be in were then measured for all relevant overstory characteristics. "Borderline" trees that were not clearly "in" or "out" were measured on every other tree basis.

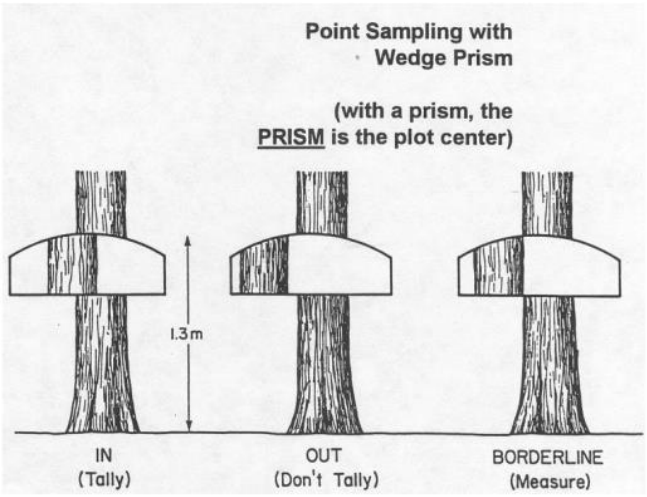


Figure 57: Shows how an observer would see a tree in the case that the tree is "in," "out," or "borderline."

The midstory/understory was measured based on a transect system. Two 25-foot transects were imagined through the plot center, one North to South and the other West to East. At the end of each transect was a mil-acre subplot as well as one on the plot center (Fig. 58). Coarse Woody Debris (CWD) and shrubs were recorded along the transects and regeneration plots were taken in each of the mil-acre subplots.

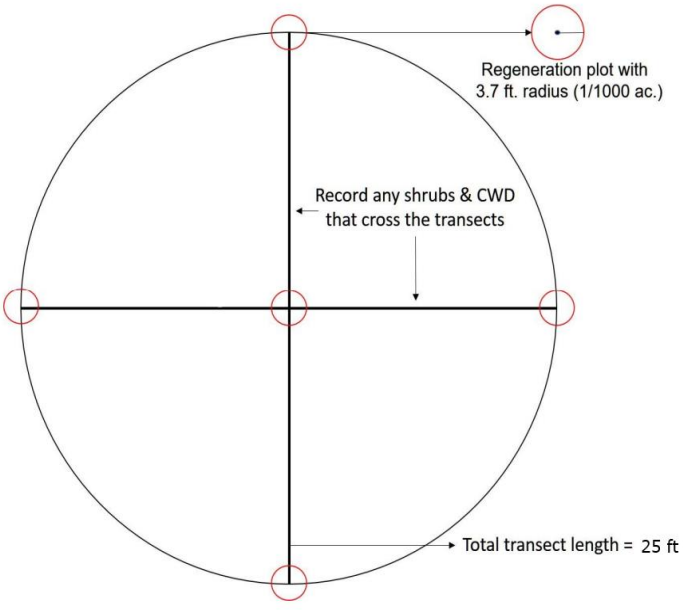


Figure 58: A representation of how the transects and regen subplots are laid out at each plot.

Overstory Measurements

a. *Basal Area (Trees and Snags)*: Measured using a 10 BAF Prism. Sighted while standing directly over the plot center, the measurer looked around in a circle. All trees that look "in" at breast height will be counted for 10 Feet of Basal Area (Figure 57).

b. *Merchantable Height*: Using a Biltmore stick (specifically the Merritt Hypsometer side) and standing 66 feet away while holding the stick vertically 25" from your eye, trees were assessed for how many logs they had. Hardwood logs had to be at least 10 inches at breast height and 8 inches at the smallest end. Softwood had to be a minimum of 9 inches at breast height and 7 inches at the smallest end (Fig. 59).

c. *Log Grade (Hardwoods only)*: Hardwood logs were assessed based on a grading scale with veneer and grades 1, 2, and 3. Each butt log of a suitably sized

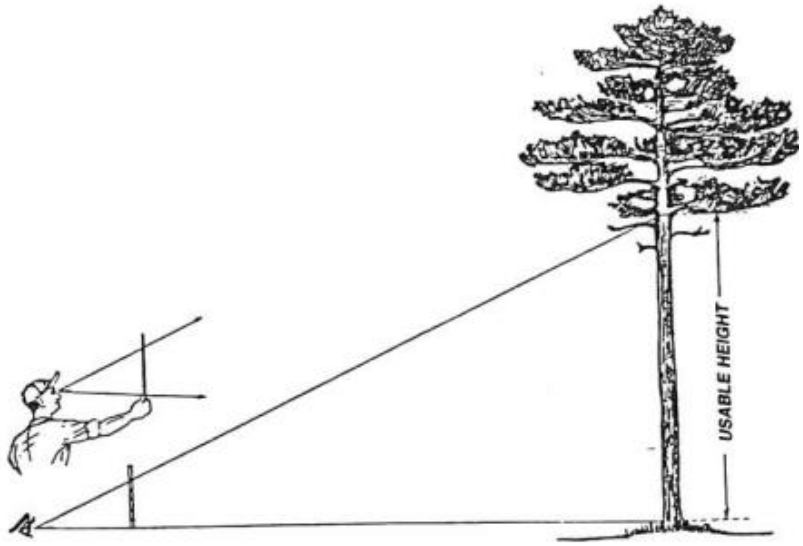


Figure 59: How to use a biltmore stick

hardwood is assessed. To begin the assessment, we found the second worst side of the log - with the second largest amount of defect - and looked exclusively at that. If at least 50% of the log is clear of defects, then it is considered a grade 3. At least 75% clear would be a grade 2, and at least 90% clear would be a grade 1. For veneer, the log must be nearly perfect with no defect, little taper, and no branches or sizable knots. The value of the wood corresponds with these grades: Trees with less defect will be more valuable than similar trees with greater amounts of the defect. Any trees that had more than 50% defects were considered cull and lacking commercial value.

d. *Diameter at Breast Height (DBH)*: Every "in" tree was for its diameter at 4.5 feet above the ground. Certain notable exceptions apply to this rule. For example, trees that fork below 4.5 feet are considered two trees and measure separately. Trees that are on a slope will be measured standing on the highest side of the slope. Trees that are leaning will be measured parallel to their lean (Figure 60).

e. *Species*: For every “in” tree, its species was determined and recorded.

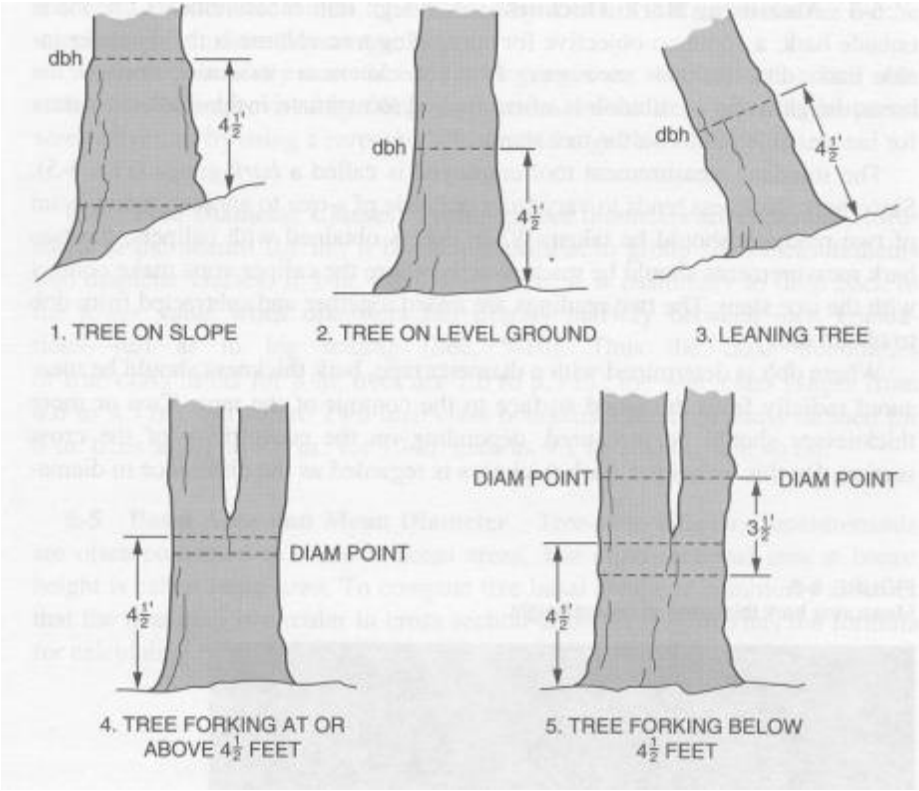


Figure 60: How to take a DBH measurement under different conditions

f. *Tree Health*: Every tree that was “in” was evaluated for its health. Trees were either determined to be healthy or declining. Declining trees were those that were still alive but had canopy dieback, large dead scaffolded limbs, and/or significant defects throughout the tree, among other indicators of poor health (Figure 61). Healthy trees are simply trees that are alive and not significantly impacted by poor health.

Figure 61: An example of a declining tree with significant dieback

g. *Snag Decay Stage*: Snags were also graded for their degree of decay, which can be important for wildlife who have preferences for certain decay stages as a habitat. It also gives an idea of the recency of disturbance. Snags were graded using an image scale (Figure 62). Recent snags that are still standing and holding onto their fine woody material were graded as a 3. Snags that have begun to lose bark and parts of their branches, grade 4. Grade 5 consists of snags that have become "buck skinned", meaning they lack any bark but are still mostly standing. Grade 6 are broken snags whose heartwood structural integrity has been lost. Stage 7 is any snag that is beyond that, e.g., one that is significantly decomposed and hardly standing.

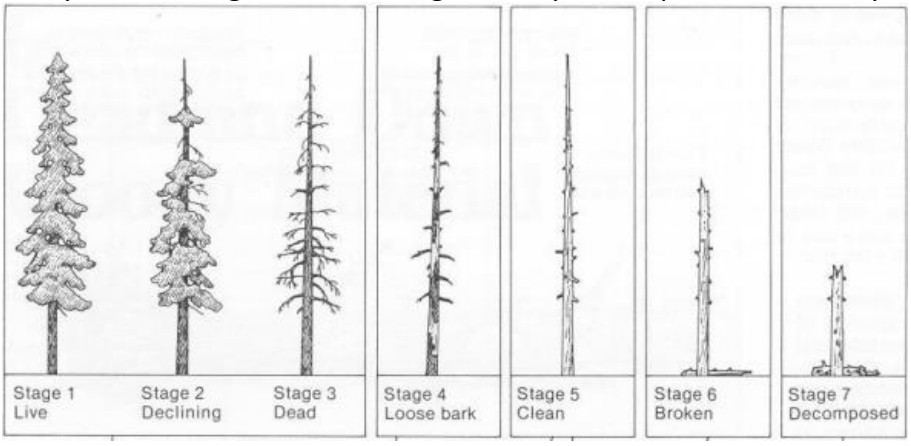


Figure 62: Shows the physical look of a tree at different health stages

h. *Canopy Cover*: At the center of every plot, a picture was taken of the canopy (Figure 63). The picture was directed straight up and taken from the plot center at breast height. Using the ImageJ program, all pictures were converted to a binary form so that the open sky pixels were white, and all canopy pixels were black. The percentage of all pixels that were black (canopy) was recorded. This is a way of measuring how much light is allowed to reach the forest floor at each plot.

Midstory/Understory Measurements (Figure 57)

a. *Tree Regeneration*: At the end of each transect as well as at the plot center, 5 milacre regeneration subplots were located. In each subplot, a mil-acre stick was used to sweep for tree regeneration, or any tree < 1-inch DBH. If a tree was present, it was recorded and documented what height class it belonged to. The 5 height classes are: Class 1 = 0 - 1 foot, Class 2 = 1 - 3 feet, Class 3 = 3 - 6 feet, Class 4 = 6 - 12 feet, and Class 5 = 12+ feet. Trees were recorded for presence or absence within a height class within a subplot. For example, if a size class 1 red maple was found in the Northern subplot, it gets recorded, if another second size class 1 red maple

Figure 63: Open canopy (left) and closed canopy (right)

was found in the same subplot, it would not be recorded again. If a size class 1 red maple was found in a different subplot it would be recorded. If a size class 2 red maple was found in the Northern subplot (the first subplot), then it would be recorded. All trees in their respective size classes are recorded for presence or absence in each of the 5 subplots for every plot.

b. *Shrub Cover*: Recorded along each of the 25-foot-long transects. The transects are lines that acted like sheets of glass that extended up from the line into the sky. Any shrubbery would be recorded if the transect passed through it. The species of the shrub, the distance it intersected with the transect, and the height class (same as above) of the shrub were all recorded. This gave us an idea in each of the cardinal directions what shrubs existed, how much, and how big they were.

c. *Coarse Woody Debris (CWD)*: Recorded along the transects that were used to center a one-meter-long measuring stick. This stick was used to "sweep" along each of the transects. Any part of CWD with a diameter >3 inches that fell in was measured for its small and large side diameters, as well as the length that fell into the sweep. Any CWD that fell near the plot center where the two transects crossed and the sweep overlapped was only measured once.

d. *Soil Type*: This was collected using WebSoilSurvey data. We took 3 soil cores and hand-identified the soil type in one area of the project area where the soil type changed from a sandy loam to a silty loam. Otherwise, the entirety of the area was assumed to be sandy loam or loamy sand as shown by WebSoilSurvey.

Appendix B

Timber Value Calculations

To calculate the timber values, we used a 2022 Recommended Base Stumpage Rates table put out by the Wisconsin Department of Natural Resources. The table indicated that in the local area stumpage was $19/ton for red pines and $15/ton for white pines. Because our pine plantations are mixed with the two, we assumed that the value would be $17 per ton.

We then split the pine plantation area up into our plots so that each plot would represent a proportional amount of the area and determined the volume of material in their immediate proximity. For each plot within the plantation area, we used our calculated value of board feet per acre and multiplied it by a conversion factor (1 board foot = 3.5 lbs) to get the weight in pounds. Dividing that value by 2000 gave us the value of how many tons of material each plot was worth.

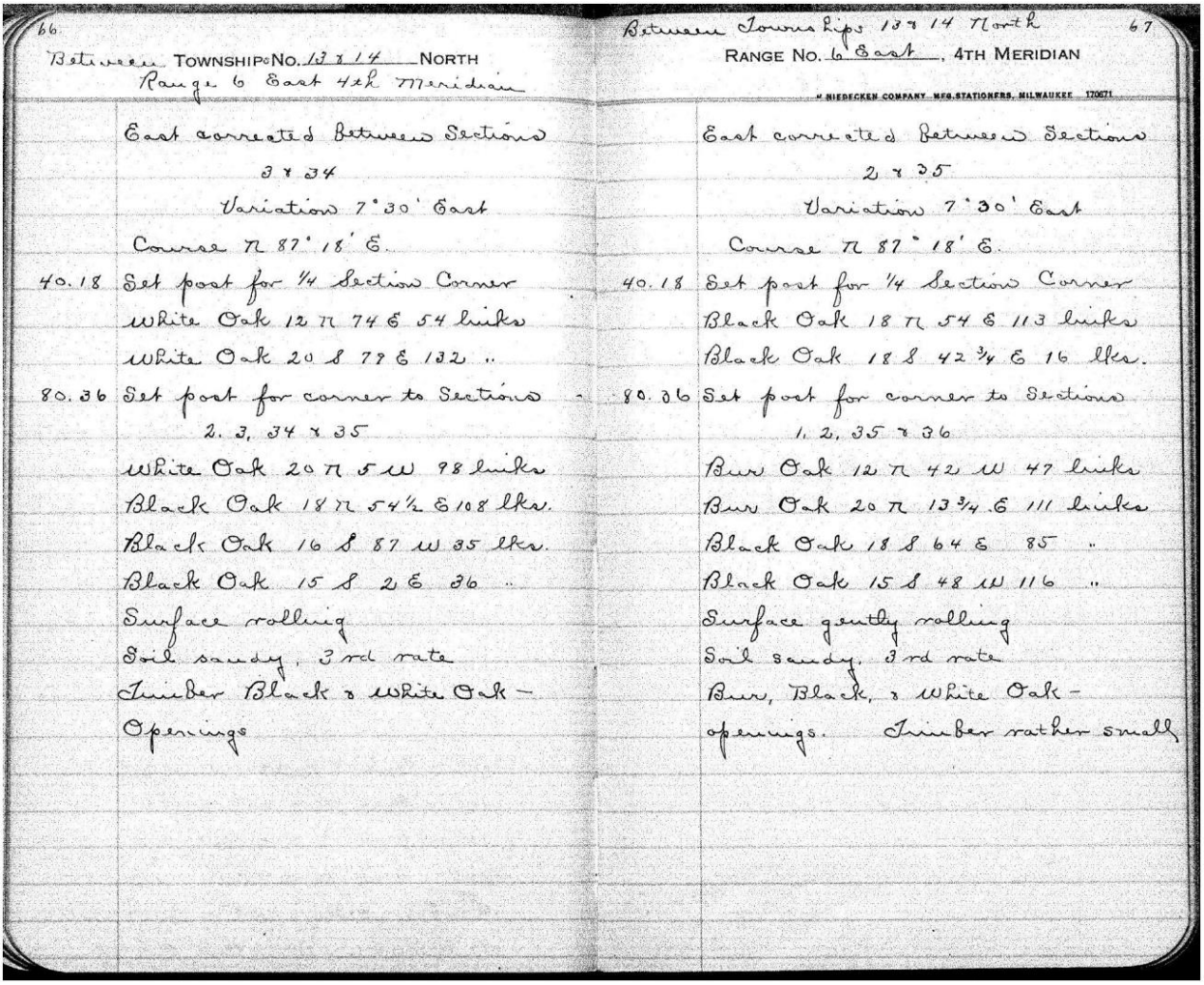
Then, with the value of 70 Basal Area (BA) for the residual stand in mind, we took the intended BA of 70 and divided it by the current BA at each plot to get a percentage of allowable BA to be removed. We then applied this to the 'percentage of allowable removal' to get the total tonnage calculated for each plot area. Ending up with a value of tons that can be removed from each plot area and get us to our desired basal area. Our assumption is that trees will need to be marked with the average tree in mind so that more volume is not being removed than intended.

Next, to find the total value of the stand, we took the number of plots within the project area (16 plots) and divided the total project area (81.22 acres) by this number to get the acreage each plot represents, which is 5.08 acres. We were then able to determine the value per acre of each plot area by multiplying the tons to be removed at each plot by our value per ton, $17. Finally, knowing what each plot was worth per acre, we just had to multiply them by how many acres they represented (5.08ac) to get a final value. Summing all of this up, with a cut down to 70 BA, there should be just over $18,000 within the 81.22-acre project area.

For example, the calculation of the value of an area surrounding a plot with 120 BA and 10,000 board feet/acre will be demonstrated: First, you must find the tons per acre by multiplying by 3.5 (the conversion factor from board feet to lbs) and then dividing by 2000 lbs to get tons. This results in 17.5 tons per acre. Then, if harvesting those areas to 70 BA, you must find the percentage of basal area that can be removed: 1 - (70/120) = 42%. Multiplying 42% by the 17.5 tons per acre leaves 7.29 tons to be removed from each acre. Multiplying this by the price per ton, $17, means that each acre in this plot's vicinity will be worth $123. Since each plot represents 5.08 acres, $629.70 is the value for this part of the management area. Add all these up and parts of the management area up and there is the total value.

Appendix C

Presettlement Landscape Description



66

Between TOWNSHIP No. 13 & 14 NORTH
Range 6 East 4th Meridian

	East corrected Between Sections 3 & 34
	Variation 7°30' East
	Course N 87° 18' E.
40.18	Set post for 1/4 Section Corner
	White Oak 12 N 74 E 54 links
	White Oak 20 S 77 E 132 "
80.36	Set post for corner to Sections 2, 3, 34 & 35
	White Oak 20 N 5 W 98 links
	Black Oak 18 N 54½ E 108 lks.
	Black Oak 16 S 87 W 35 lks.
	Black Oak 15 S 2 E 36 "
	Surface rolling
	Soil sandy, 3rd rate
	Timber Black & White Oak —
	Openings

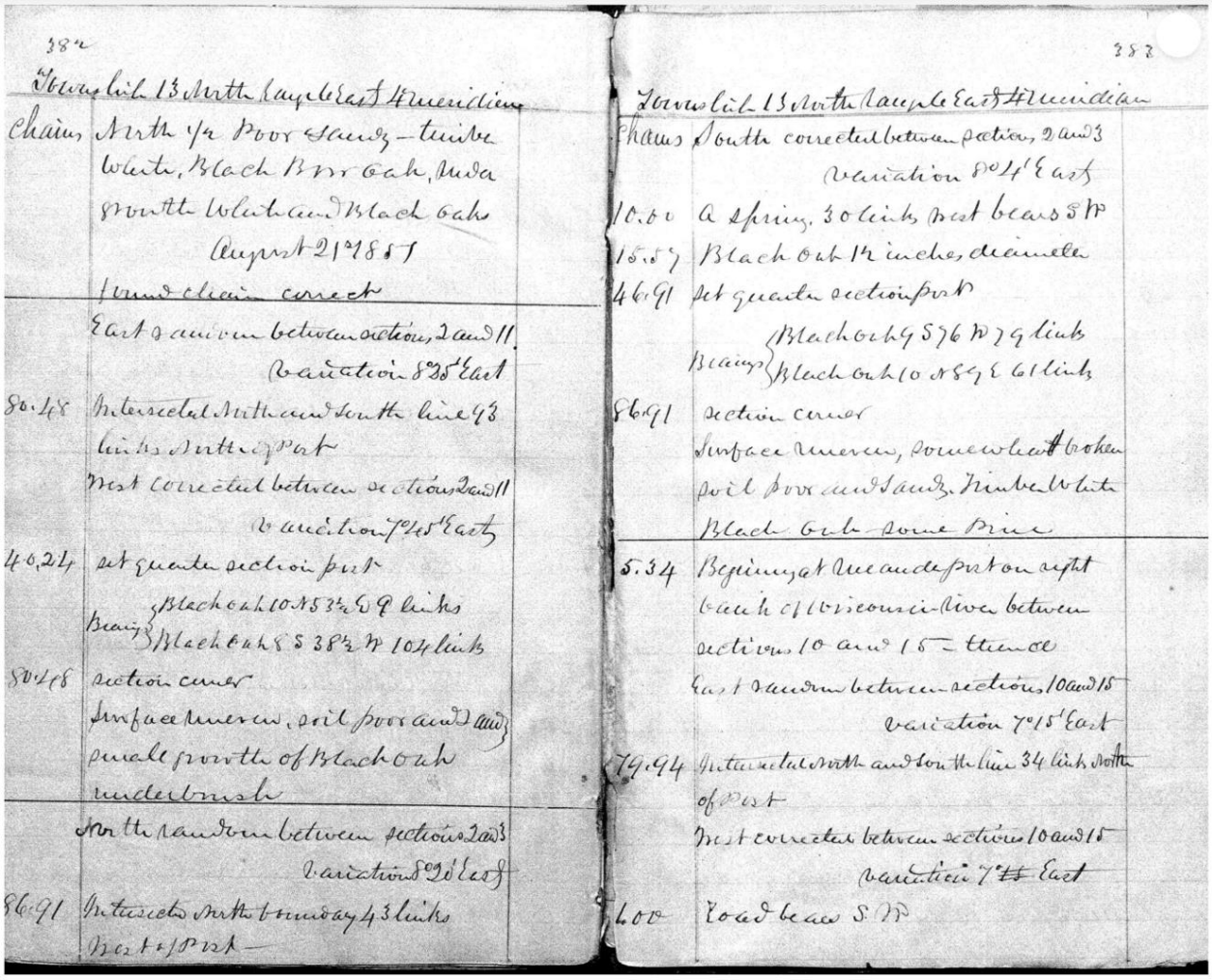
Between Townships 13 & 14 North 67

RANGE No. 6 East, 4TH MERIDIAN

" NIEDECKEN COMPANY MFG. STATIONERS, MILWAUKEE 170671

	East corrected Between Sections 2 & 35
	Variation 7°30' East
	Course N 87° 18' E.
40.18	Set post for 1/4 Section Corner
	Black Oak 18 N 54 E 113 links
	Black Oak 18 S 42¾ E 16 lks.
80.36	Set post for corner to Sections 1, 2, 35 & 36
	Bur Oak 12 N 42 W 47 links
	Bur Oak 20 N 13¾ E 111 links
	Black Oak 18 S 64 E 85 "
	Black Oak 15 S 48 W 116 "
	Surface gently rolling
	Soil sandy, 3rd rate
	Bur, Black, & White Oak — openings. Timber rather small

Figure 64: Notebook from the Land Survey conducted from the 1830s to 1860s



382

Township 13 North Range 6 East 4th meridian

Chains	
	North ½ Poor Sandy – timber White, Black Burr Oak, Linda mouth White and Black Oaks August 21st 1857 found chain correct
	East random between sections 2 and 11 Variation 8°35' East
80.48	Intersected North and South line 43 links North of Post West corrected between sections 2 and 11 Variation 7°45' East
40.24	set quarter section post Bears {Black Oak 10 N 53½ E 9 links / Black Oak 8 S 38½ W 104 links}
80.48	section corner Surface uneven, soil poor and Sandy small growth of Black Oak underbrush
	North random between sections 2 and 3 Variation 8°30' East
86.91	Intersects North boundary 43 links West of Post

383

Township 13 North Range 6 East 4th meridian

Chains	
	South corrected between sections 2 and 3 Variation 8°14' East
10.00	A spring, 30 links West bears S W
15.57	Black Oak 14 inches diameter
46.91	set quarter section post Bears {Black Oak 4 S 76 W 7 9 links / Black Oak 10 N 84 E 61 links}
86.91	section corner Surface uneven, somewhat broken soil poor and Sandy. Timber White Black Oak Some Pine
5.34	Beginning at meander post on right bank of Wisconsin River between sections 10 and 15 – thence East random between sections 10 and 15 Variation 7°15' East
79.94	Intersected North and South line 34 links North of Post West corrected between sections 10 and 15 Variation 7°15' East
4.00	Road bears S W

Figure 65: Notebook from the Land Survey conducted from the 1830s to 1860s

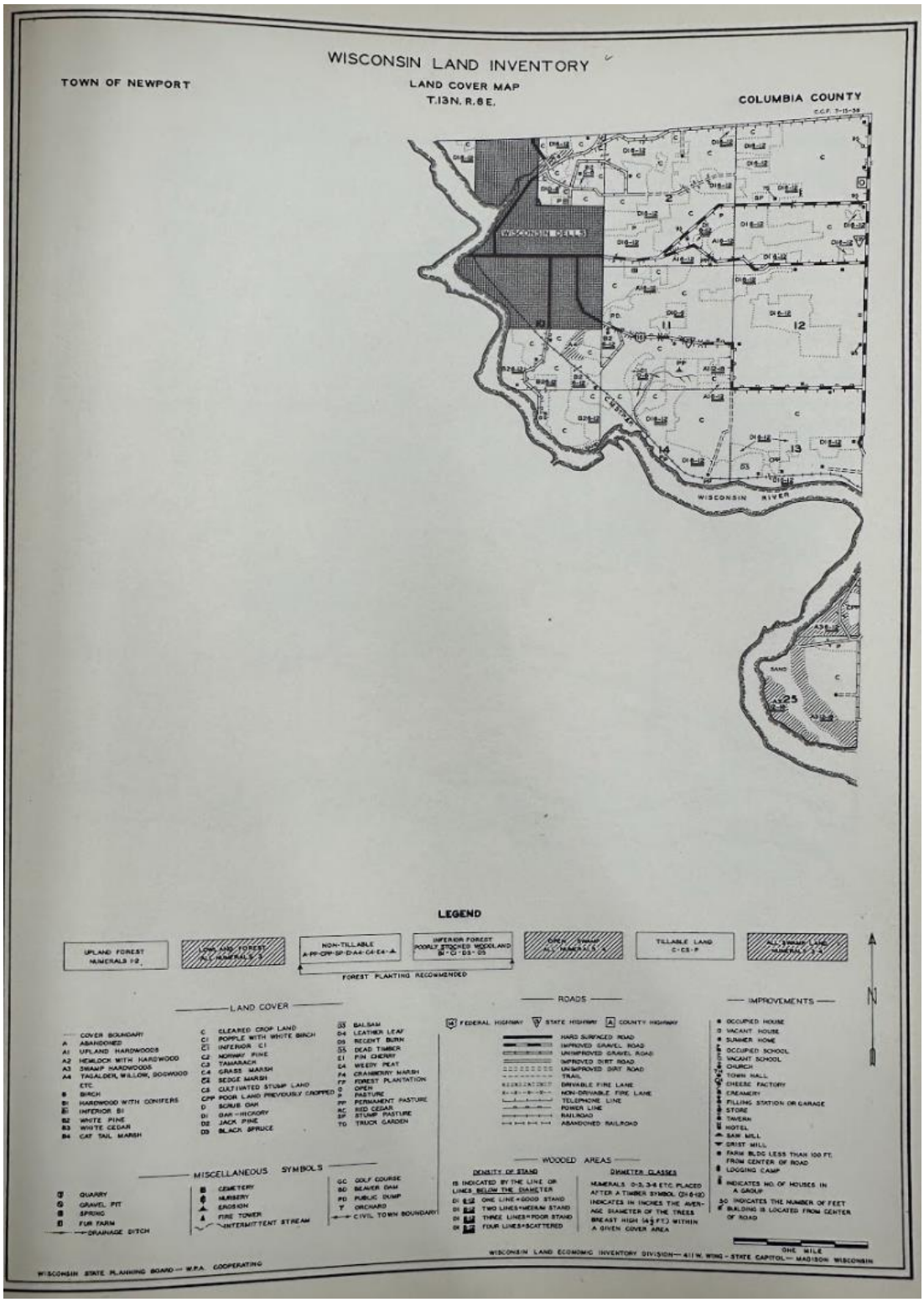


Figure 66: Map of a section of the 1958 Wisconsin Land Inventory of Columbia County that includes Camp Wawbeek.

Appendix D

Soil Descriptions:

These soil types affect the plant communities by way of drainage and their ability to hold organic nutrients that many plants rely on to germinate and grow. Many of these soil types listed below are sandy or some variety of sand combination. This means they are quick draining soils and do not hold soil moisture for very long after rainfall. This can affect a plant's ability to obtain water because it will not be plant available for long. A low organic nutrient layer is also not ideal for many plant communities. These sandy soils don't normally maintain high nutrient capacity and often leech out due to the larger size of the sand particles accompanied by quick drainage. This leaves only well-adapted plant communities that are present already such as oak, pines, aspens, and some other hardwood species to pioneer these sites and maintain them.

Plainfield Loamy Fine Sand: The most abundant soil type on the property (69.9% of total). It is characterized as a very deep, excessively drained entisol, meaning it has a low nutrient holding capacity due to rapid nutrient leaching. Trees that do well on well-drained, sandy soils include jack pine, white and red pine, and northern pin oak.

Military Fine Sandy Loam: Mainly present in the areas surrounding campus, it is the second most abundant soil type on the property (17.9%). Military fine sandy loams are described as well-drained, moderately deep soils underlain by sandstone bedrock. The most common native tree species to appear on this soil include but are not limited to northern red oak; white oak; black cherry; and shagbark hickory.

Pelkie Loamy Fine Sand: Present as a thin strip following the northern and eastern edges of campus, Pelkie loamy fine sand makes up only 4.4% of the total soil area. It consists of very deep, moderately well-drained soils formed in sandy alluvium. Generally forested with mixed hardwoods and some conifers.

Northfield Sandy Loam: Present in a patchy distribution that follows the Pelkie loamy fine sand, Northfield sandy loam composes 2.9% of total soil types. Generally shallow, well-drained soils that are in contact with sandstone bedrock. The native vegetation of Northfield sandy loam includes mixed hardwoods with a predominance of oak species.

Sisson Fine Sandy Loam: Restricted to the west and northwest boundaries of the property, Sisson fine sandy loam is negligible in its proportion to total soil at 2.3%. It is a well-drained soil formed by the stratification of loam and silt in outwash plains. Native vegetation on this soil is typically only hardwood tree species - specifically maple; elm; oaks; beech; and hickory species.

Oshtemo Loamy Sand: Only present in the southeastern tract of the property, composing 1.1% of the total soil makeup. Typically, very deep, well-drained soils with usual native vegetation comprising oak, hickory, basswood, and sugar maple. Current species compositions are mostly pine species, owing to the history of red pine plantations in the areas underlain by Ostemo loamy sand.

Winterfield-Evart Complex: Present in negligible amounts within the southeast and northwest sides of the property, it makes up only 1% of the total soil composition. Winterfield-Evart complex soils are described as very deep, somewhat poorly drained soils that are nearly always naturally hardwood forests. Typical forest composition on this soil includes elm; red maple; swamp white oak; and quaking aspen.

Mt. Carroll Silt Loam: The least common soil within the measurement area (0.5%), Mt. Carroll silt loam is present near the center of the property. It is characterized as a very deep, well-drained soil that is typically host to prairie vegetation and scattered hardwood trees.

Appendix E

Herbicide Application

Methods of control for the invasive species listed above are fairly uniform. One method is mechanical removal, which includes pulling plants out by the roots or digging them out of the soil. We don't recommend performing mechanical methods of control on the property due to variations in topography and general accessibility issues. The most efficient method of invasive removal would include prescribed burns and/or herbicide application, of which we are focusing on the latter for this section. We are aware that the landowner would prefer Element 4 (triclopyr) as the main herbicide, but it is not effective on honeysuckle or Japanese barberry. For this reason, we suggest using glyphosate to control honeysuckle and barberry, and triclopyr for all buckthorn control. A section regarding the details of the triclopyr application is included after this one.

In terms of glyphosate, the cost may present a barrier to the feasibility of its use. Although it depends on the specific shrub being targeted, a general estimate of the total glyphosate necessary per acre is anywhere from 3 to 30 gallons. Using a conservative estimate of around 15 gallons per acre, and including the acreage covered by buckthorn, the price is as follows: 15 gallons/acre (37 total acres shrub cover) ($50/gallon) = ***Around $24,975*** to control all three invasive species with glyphosate (30 Gallons of 41% Glyphosate - $1,350). If the landowner chooses to treat buckthorn with triclopyr, the total price of glyphosate required to treat only honeysuckle and Japanese barberry is as follows: 15 gallons/acre (9.4 acres total shrub cover) ($50/gallon) = ***Around $7,050.*** Keep in mind this number may be higher or lower depending on specific methods used for each invasive species.

- Buckthorn Control: Buckthorn control is a multi-year process, as seeds can remain in the soil for years. Buckthorn can be killed by first cutting the plant at the stump, followed by an application of a 25% glyphosate mix diluted with water. This operation should be carried out in August or September, and monitoring for new growth should occur each growing season.

- Honeysuckle Control: It should be made clear that simply cutting honeysuckle will not be effective for complete removal. A combination of mechanical cutting removal and herbicide application is required. Although foliar sprays of glyphosate are effective against honeysuckle, this method will most likely induce negative results upon non-target plants. For this reason, we recommend an initial stump cutting of honeysuckle (as close to the soil as possible) followed immediately by an application of 25% glyphosate diluted in water. If glyphosate is not applied directly following cutting, it will not work as intended. This process should be conducted from August to September.
- Japanese Barberry Control: Similar to buckthorn and honeysuckle, Japanese barberry can be effectively controlled with a stump cut followed by the application of a 25% glyphosate dilution in water. This can be done at any point in the year.

Triclopyr Application - Element 4 Label (Directions, Precautions)

Use Element 4 at rates of 1 to 8 quarts per acre to control broadleaf weeds and woody plants. It is suggested that rates higher in this rate range be used to control woody plants. It should not be applied on ditches currently being used to transport irrigation water, or where runoff or irrigation water may flow onto agricultural land as injury to crops may result.

- Oil Mixture Sprays for Basal Treatment: Prepare oil-based spray mixtures using either diesel fuel, No. 1 or No. 2 fuel oil, kerosene, or commercially available basal oil. Substitute other oils or diluents only as recommended by the oil or diluent's manufacturer. Note that triclopyr *should not be stored in polypropylene containers*, as they will be degraded.
- Basal Bark Treatment of Buckthorn: To control susceptible woody plants with stems ***less than 6 inches in basal diameter***, mix 1 to 5 gallons of Element 4 in enough oil to make 100 gallons of spray mixture. Apply with a backpack sprayer or power spraying equipment using low pressure (20 to 40 psi). Spray the basal parts of brush and tree trunks to a height of 12 to 15 inches from the ground, thoroughly wetting the indicated area. Spray until runoff at the ground line is noticeable. Old or rough bark requires more spray than smooth young bark. Apply anytime, including the winter months, except when snow or water prevents spraying to the ground line.
- Cut-stump Treatment of Buckthorn (Recommended): To control resprouting, mix 20 to 30 gallons of Element 4 in enough oil to make 100 gallons of spray mixture. Apply with a backpack or knapsack sprayer using low pressure and a solid cone or flat fan nozzle. Spray the root collar area, sides of the stump, and the outer portion of the cut surface, including the cambium, until thoroughly wet, but not to the point of runoff. Apply anytime, including in winter months, except when snow or water prevents spraying to the ground line. ***Mixing with oil requires vigorous agitation to form an oil solution***. Once a solution is formed it will stay stable.

Estimation of Triclopyr Cost

Based on our measurements, buckthorn accounts for roughly 27.6 acres of land cover on the property. At the highest allowable limit (2 gallons of triclopyr per acre treated), with a cost of $235 per 2.5 gallons the total cost of treating buckthorn with triclopyr is estimated to be: 2 gallons/acre(27.6 acres total buckthorn cover)($94/gallon) = ***Around $5,188***. Compare this to the price of treating buckthorn alone with glyphosate: 15 gallons/acre (27.6 acres total buckthorn cover) ($50/gallon) = ***Around $20,700***. In terms of price, it's clearly

preferred to use triclopyr for buckthorn control. With regard to ease of operation, however, it may be more efficient to use glyphosate for all invasive shrubs.

Environmental Concerns of Glyphosate and Triclopyr Application

Glyphosate is a non-selective herbicide, meaning that it'll kill any vegetation it encounters. Even minute amounts that are windblown (during foliar spray application) can cause severe damage to plants. Overapplication of glyphosate may result in bare soil, increasing the erosion potential of the site. A critically important aspect of glyphosate and triclopyr is their behavior in soil and water: Both can leach through the soil all the way to the water table, resulting in polluted drainage water. In addition, it can mobilize in overland surface flows. Both processes result in the transportation of these herbicides downstream from their site of application. Such effects can be substantially lessened and/or completely avoided by careful application of glyphosate and/or triclopyr directly onto cut stumps.

Appendix F

Oak Wilt:

Dispersal of Disease: Sap-sucking beetles are a major vector of oak wilt, as they transport fungal spores from infected trees to healthy ones. Additionally, once present in a tree, the fungus can spread below ground by way of interconnected root systems. This method of dispersal leads to spatially localized incidences of mortality like the ones we witnessed.

Symptoms of Disease and Identification: Symptoms occur most commonly through July and August. The most characteristic symptom of oak wilt is the premature dropping of leaves while they are still somewhat green, as pictured below. In identifying the disease, it's important to remember that these symptoms are common for other biotic and abiotic stresses as well. The only way to be certain the problem is indeed oak wilt is to have it tested in a lab.

Preventing Disease: The Wisconsin DNR has developed oak harvesting guidelines to prevent the risk of spreading the disease. Such guidelines include restricted harvest periods (in the southern part of the state; April 1 - July 15) if you are in a county, or within 6 miles of a county, that has reported oak wilt.

Managing Stands with Disease: Managing a stand with oak wilt is typically very costly, as the major route of dispersal occurs mostly belowground. This requires disrupting the spread between trees by way of severing grafted roots or removing healthy trees that border pockets of disease. While these methods are a sure way to control the disease, there also exist several less costly (but less effective) control procedures. This compendium of oak wilt management provides alternative methods of control.

Figure 67: Oak leaves showing symptoms of oak wilt

Appendix G

Large-Scale Invasive Species Control Methods

The best time to deal with invasive species is early when the invasion is small. When invasions become unmanageable or resources are not enough to eradicate the invasives all at once, the ideal method is to control the invasives from the outside-in. The first step is to eradicate the outliers to prevent their spread to new areas in the future, as well as to make a barrier around the current infestation. Second, the advancing front can be attacked. This would reduce the spread from the core infestation and set a perimeter around it. Lastly, attacking the core and attempting to suppress the remaining infestation is the final step.

This strategy can be employed for one invasive at a time. For this property, first steps may include eliminating Japanese barberry to reduce tick habitat. Starting in July and up to mid-September barberry can be cut at 1 inch above the ground, have glyphosate applied to it working farther from the camp towards the center. After controlling the barberry, steps can then be taken to begin controlling the more widespread buckthorn and honeysuckle.

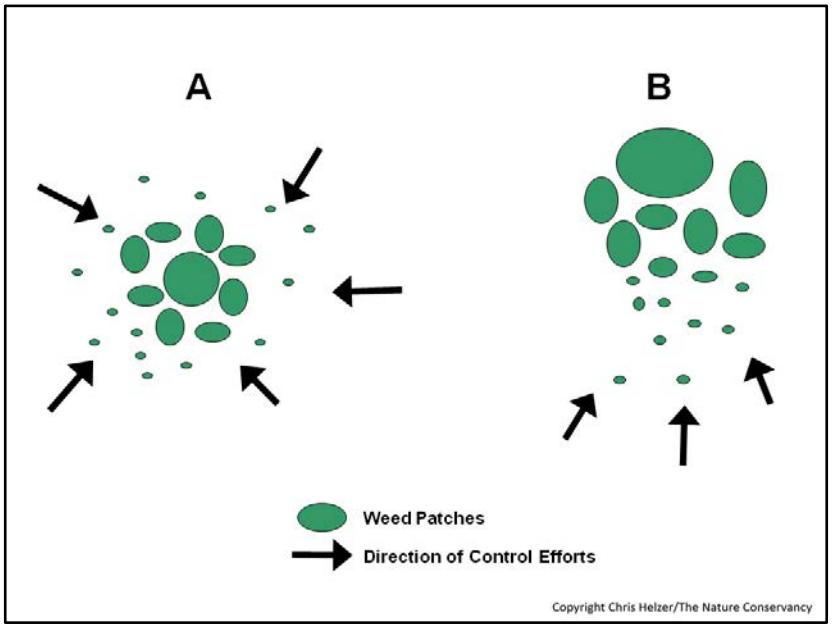


Figure 68: Invasive control method of working from edges of invasion.; It's more feasible to first prevent further spread of the invasives into new areas before trying to eradicate the main invasion.