Characterizing an Oak Savanna at Fermi National Accelerator Laboratory

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Table of Contents

ABSTRACT

Characterizing an Oak Savanna at Fermi National Accelerator Laboratory. ASHLEY WENTLAND (University of Illinois at Chicago, Chicago, IL 60607) ROD WALTON (Fermi National Accelerator Laboratory, Batavia, IL 60510)

The oak savanna, a mixture of prairie grasses, forbs and scattered tress, mainly oaks, was one of the major natural communities of the Midwest. Today, they are a top concern for restoration. Our objective was to document and characterize the tree population and age structure of the oak savanna by examining relative density, relative frequency, and relative cover for most common species. We conducted tree research in the remnant savanna on Fermi National Accelerator Laboratory's property using the point-centered quarter method. We also prepared soil samples for analyses by First Environmental Laboratories, Inc. in Naperville, Illinois. Ca^{++} and Mg^{++} concentrations were identified for each soil sample. The north side of the savanna has a high tree and vegetation density compared to the south side where there is an abundance of open space and prairie grass. Bur Oak (*Q. macrocarpa*) is by far the most important species in the savanna. However, the basswood (*T. Americana*), white ash (*F. Americana*), and black cherry (*P. serotina*) are slowly dominating the oak savanna at Fermilab, which poses a problem. The data suggest that the north side of the savanna is degraded compared to the description of the healthier side of the savanna. The savanna is being invaded by trees and vegetation and may convert into a woodland if nothing is done. Some possible strategies indicated by our results that may help aid restoration are: removing the invasive tree species, planting more oak species and prairie grasses, and carrying out fires to control the density of vegetation.

INTRODUCTION

Oak savannas were once a dominant community in Illinois, but now are among the most endangered. They are unstable ecosystems that have developed along the prairie and consist of scattered trees, shrubs and a ground layer rich in grasses and forbs. Oak trees are the dominant species that make up a "healthy" savanna. The dominant oaks are usually 80 to 250 years old [1]. Oak savannas, in the Midwest, are unusually diverse and are dominated by forbs [2]. They once covered millions of acres in the Midwest. Around the 19th century, it was completely imbalanced and mostly destroyed. Oak savannas are now among the most threatened plant communities in the Midwest and the world. "Intact examples of oak savanna vegetation are now so rare that less than 500 acres are listed in the Natural Heritage Inventory as having a plant assemblage similar to the original oak savanna. This is less than 0.01% of the original 5.5 million acres" [4].

There are several factors causing concern about the oak savanna including: loss of recovery opportunities, general neglect and lack of knowledge about oak savannas, resistance to burning, invasion by other trees and grasses and increase in human population [4]. In the Midwest, research has not yet solidified solutions to successfully restore oak savannas [4]. In 1992, the University of Wisconsin-Madison Arboretum recognized oak savanna as being a main concern for new restoration projects [2].

The savanna located at Fermi National Accelerator Laboratory was the site used for this study. It is filled with prairie grasses, forbs and scattered trees. However, in the absence of controlled fires, native and exotic trees, shrubs and herbs invaded the oak savanna. The tree species that should be present in an oak savanna are primarily bur oak (*Quercus macrocarpa),* white oak *(Quercus alba),* and swamp white oak (*Quercus bicolor* Willd). The savanna has an area of about 8.2 ha. Destructive tree species such as box elder (*Acer negundo)* and cottonwoods (*Populus deltoides),* weedy brush, and other species such as blackberry *(Rubus occidentalis)* and reed canarygrass *(Phalaris arundinacea)* are common invasive species in this savanna. Fermilab land managers have been, and will continue to control these species by herbiciding, prescribed burning, and mowing. Depending on the extent of woody plant invasion, the savanna is burned every two to three years. It was last burned in the spring of 2003 [5].

In 2005, Fermilab land managers mowed around oak seedlings to protect them from the fires, performed two vegetation surveys listing the native plants, and enhanced the savanna species. The plans for 2006 were to develop a restoration plan depending upon a grant, to burn in 2007, thin non-native trees, and continue to enrich the savanna with native species [5].

Our objective was to document and characterize the tree population and age structure of the oak savanna by examining species density, frequency, and cover for most common species. In this way, the relative importance for the species was used to characterize the savanna and provide a baseline for comparison in the future. We hope this study will provide the land managers at Fermilab with the necessary information to devise a suitable management and restoration plan.

MATERIALS AND METHODS

We conducted research in the remnant savanna on Fermi National Accelerator Laboratory property using the point-centered quarter method [6]. For this study five parallel transects, 36 meters apart, were measured along a 95-degree bearing, approximately parallel to Holter Road. A series of random points were generated along each of the five transects. At each random point, the area was divided into four quadrants by bisecting the transect with an imaginary line perpendicular to the transect line.

Quadrants were numbered one through four clockwise from the northwest. The tree closest to the point in each quadrant was identified and the species, its distance from the point (m), and circumference at a height of 130 cm were recorded. Circumference was used to calculate the cross-sectional, or the basal area of each tree sampled. The point to the tree distance was measured to the center of the trunk. When there were multiple trunks, the closest trunk was used for the distance measurement. When multiple trunks were encountered, the circumference was recorded and the basal area was calculated for each trunk. The sum of the areas (A_{total}) was used to calculate a circumference equivalent to the total area of the multiple trunks according to the equation $C = 2\sqrt{(A_{total}\pi)}$ [6].

Savanna Indices

After the data were collected, we computed relative density, relative frequency, relative cover and overall importance of each tree species. Relative density is the absolute density in trees per area of one tree species in the entire savanna compared to the absolute density of all the tree species in the savanna. Relative frequency is the percentage of points at which each tree species is found to be the closest to a point on the transect. Relative cover is the total basal area of one species compared to the basal area of all the species. The importance value for each species is the sum of relative density, frequency and cover [6].

We prepared soil samples for analyses by First Environmental Laboratories, Inc. in Naperville, Illinois. The soil cores were taken at about 15 cm deep and the ground vegetation was removed. Ten samples were taken; two from each transect. The samples were evenly distributed along each transect to ensure maximum coverage. Ca^{++} and Mg^{++} concentrations were identified for each soil sample.

RESULTS

The savanna changes dramatically as you walk from south to north. The north side of the savanna has a high tree and vegetation density compared to the south side where there is an abundance of open space and prairie grass. The trees represented in our data include basswood *(Tilia americana),* black cherry *(Prunus serotina),* bur oak *(Quercus macrocarpa),* pin oak *(Quercus palustris),* white ash *(Fraxinus americana),* white oak *(Quercus alba),* slippery elm *(Ulmus rubra Muhl),* hackberry *(Celtis occidentalis),* swamp white oak *(Quercus bicolor)* and shagbark hickory *(Carya ovata)* [7 & 8)].

Relative Density

According to Figure 1, *Q. macrocarpa* has the highest relative density in transect 1 and slowly decreases from south to north. *P. serotina's* relative density is low in transect 1 but continues to rise from transect 1 to 5. In transect 5, *P. serotina* has the highest relative density and the *Q. macrocarpa* has the lowest relative density. The south side of the savanna is filled with prairie grass and has a lot more open space than the north side of the savanna. Black raspberry bushes, poison ivy and thick shrubs cover the north side of the savanna leaving little room for open space or prairie grass. In Figure 1, *T. americana's* relative density has little fluctuation throughout the savanna, but disappears by transect 5. In transects 1 and 5, *Q. bicolor* and *Q. alba* have low relative densities, but in the middle of the savanna they have a high relative density.

Relative Frequency

According to Figure 2, *Q. macrocarpa* has the highest relative frequency in transects 1 through 3. By transect 3, *Q. macrocarpa's* relative frequency starts to decrease and the relative frequency of *P. serotina* and *Q. bicolor* starts to increase. In transect 1, there is a huge difference between the *Q. macrocarpa's* relative frequency and the relative frequency of the other species. *P. serotina's* relative frequency remains steady throughout the savanna and then skyrockets by transect 5. *F. americana* starts off with a rather low relative frequency, but by transect 5 is one of the species with the highest relative frequency. *T. americana's* and *Q. alba's* relative density remains steady throughout the savanna, but then disappears by transect 5.

Relative Cover

Indicated by Figure 3, *Q. macrocarpa* has the highest relative cover, thus it is the largest tree species in the savanna. *Q. macrocarpa's* relative cover decreases from south to north. *P. serotina* starts off with a low relative cover, therefore is one of the smaller trees in the savanna. *P. serotina's* relative cover slowly shifts to the highest relative cover by transect 5. *Q. bicolor* and *Q. alba* have high relative cover in the middle of the savanna, but on the ends of the savanna have low relative cover. *F.americana* has an extremely low relative cover throughout the savanna but by transect 5, it becomes one of the species with high relative cover.

Importance Value

According to Figure 4, *Q. macrocarpa* is by far the most important species in the savanna. However, the *T. americana, F. americana,* and *P. serotina* are slowly dominating the oak savanna at Fermilab, which poses a problem. Nonetheless, *Q. bicolor* and *Q. macrocarpa* still remain the most important species in the savanna. *Q. palustris, U. rubra Muhl, C. occidentalis* and *C. ovata* were also found in the savanna, however have a minimum importance value.

Soil

According to Figure 5, there is higher Ca^{++} and Mg^{++} concentration along the north side of the savanna. The Ca^{++} and Mg^{++} concentration rise steadily from transect 1 to transect 5. In all five transects there is a higher Ca^{++} concentration than Mg^{++} concentration.

Tree Age

According to Figure 6, most of the *Q. macrocarpas* are around the same age. In relation to Figure 7, *P. serotina* are also all around the same age and are relatively young.

DISCUSSION AND CONCLUSION

As indicated by our data, the *Q. macrocarpa* population remains quite important, but restoration should be of utmost importance considering the overall decrease in the oak population from the south side to the north side of the savanna. The south side is filled with *Q. macrocarpas,* which has a high relative cover, relative density and relative frequency. The north side of the savanna is filled with mainly *P. serotina,* which is a rare species on the south side. As mentioned earlier, the vegetation throughout the savanna changes tremendously from south to north. This poses many questions such as: Does the invasive vegetation on the north side of the savanna have a negative effect on oak species or, how will the distribution of trees and invasive vegetation affect the land management plan?

The soil samples helped broaden our research on the oak savanna. Calcium is the dominant cation in most forest soil solutions [9]. Our research shows that Ca^{++} concentration is always higher than Mg^{++} concentration. Magnesium concentrations are commonly 20 to 50 percent higher than calcium concentration [9]. There is also a Ca^{++} and Mg^{++} concentration rise from transect 1 to transect 5. Why is there so much more Ca^{++} and Mg^{++} along the north side of the savanna? Could it be that the soil with higher Ca^{++} and Mg^{++} concentration may have tree species that use less Ca^{++} and Mg^{++}? The correlation between tree species and specific soil chemical properties implies that change in abundance and distribution of tree species varies the cation concentrations [10]. So, in the oak savanna at Fermilab, *Q. macrocarpas* may require more Ca^{++} and Mg^{++} than *P. serotina.* What kind of correlation does the soil have with the tree population?

Tree age is also another concern for the oak savanna at Fermilab. According to Figure 6, most of the *Q. macrocarpas* are around the same age. In relation to Figure 7, *P. serotinas* are also all around the same age. According to Curtis, many of our existing oak savannas consist of trees with trunks all the same age because of uncontrolled fire that was sufficiently hot to top-kill most oaks [11]. The savanna at Fermi National Accelerator Laboratory is in need of restoration because sooner or later the older tree species, namely *Q, macrocarpa, Q. bicolor* and *Q. alba*, will be gone because of the lack of young trees and the invasion by *P. serotina*. Why are there hardly any young *Q. macrocarpa* species in the savanna? A possible answer may be that the *Q. macrocarpa* species prefer a less dense vegetation.

Generally, the south side of the savanna is exceedingly different from the north side. As shown earlier, they differ in soil, vegetation and tree species population. *P. serotina,* an invasive tree species is taking over the north side of the savanna; thus poses several questions. Do oak species prefer soil with less Ca^{++} and Mg^{++} or do they prefer less dense vegetation? The data suggests that the north side of the savanna is degraded compared to the description of the "healthy" savanna. This savanna is in danger and some possible strategies to help aid restoration indicated by our results consist of: cutting down the invasive tree species, planting more oak species and prairie grasses, and carrying out fires to control the density of vegetation.

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REFERENCES

[1] S. Apfelbaum, A. Haney. (1987). Structure and Dynamics of Midwest Oak Savannas. *Unpublished Report to Illinois Non-game Fund* [Online], pp. 1-6. Available: http://www.appliedeco.com/Projects/StructureDynamicsSavannas.pdf

[2] Bader, Brian. (2001). Developing a Species List for Oak Savanna/Oak Woodland Restoration at the University of Wisconsin-Madison Arboretum. *Ecological Restoration,* 19(4), pp. 242-251.

[3] R. Henderson. (1995). Oak Savanna Communities. *Wisconsin's Biodiversity as a Management Issue* [Online]. Available: http://dnr.wi.gov/org/land/er/biodiversity/06_Oak_Savanna.pdf

[4] S. Apfelbaum, A. Haney. (1987). Management of Degraded Oak Savanna Remnants in the Upper Midwest Preliminary Results from Three Years of Study. *Proceedings of the Oak Woods Management Workshop* [Online], pp. 1-8. Available: http://www.appliedeco.com/Projects/MgmtDegradedOakSav.pdf

[5] Land Management at Fermi National Accelerator Laboratory (2006). http://www.fnal.gov/cgibin/ecology/frame?TYPE=TRACT&YEAR=NOW

[6] K. Mitchell. (2007, May 16). Quantitative Analysis by the Point-Centered Quarter Method. *Department of Mathematics and Computer Science* [Online], pp. 1-32. Available: http://people.hws.edu/mitchell/PCQM.pdf

[7] Mohlenbrock, Robert. *Forest Trees in Illinois.* Springfield, IL: Department of Conservation Division of Forestry, 1995, pp. 90-91, 104-105, and 136-137.

[8] Fuller, George. *Forest Trees of Illinois.* Springfield, IL: Department of Conservation Division of Forestry, 1995, pp. 24, 25, 30 36, 60, 50.

[9] Fisher, Richard F. *Ecology and Management of Forest Soils.* New York, NY: John Wiley and Sons, Inc., 2000, pp. 88-89.

[10] Finzl, Adrien. (1998). Canopy Tree-Soil Interactions within Temperate Forests: Species Effects on pH and Cations. *Ecological Applications,* 8(2), pp. 447-454.

[11] Packard, Stephen. (1991). Rediscovering the Tallgrass Savanna of Illinois*.* *Proceedings of the Oak Woods Management Workshop,* pp. 55-65.

FIGURES

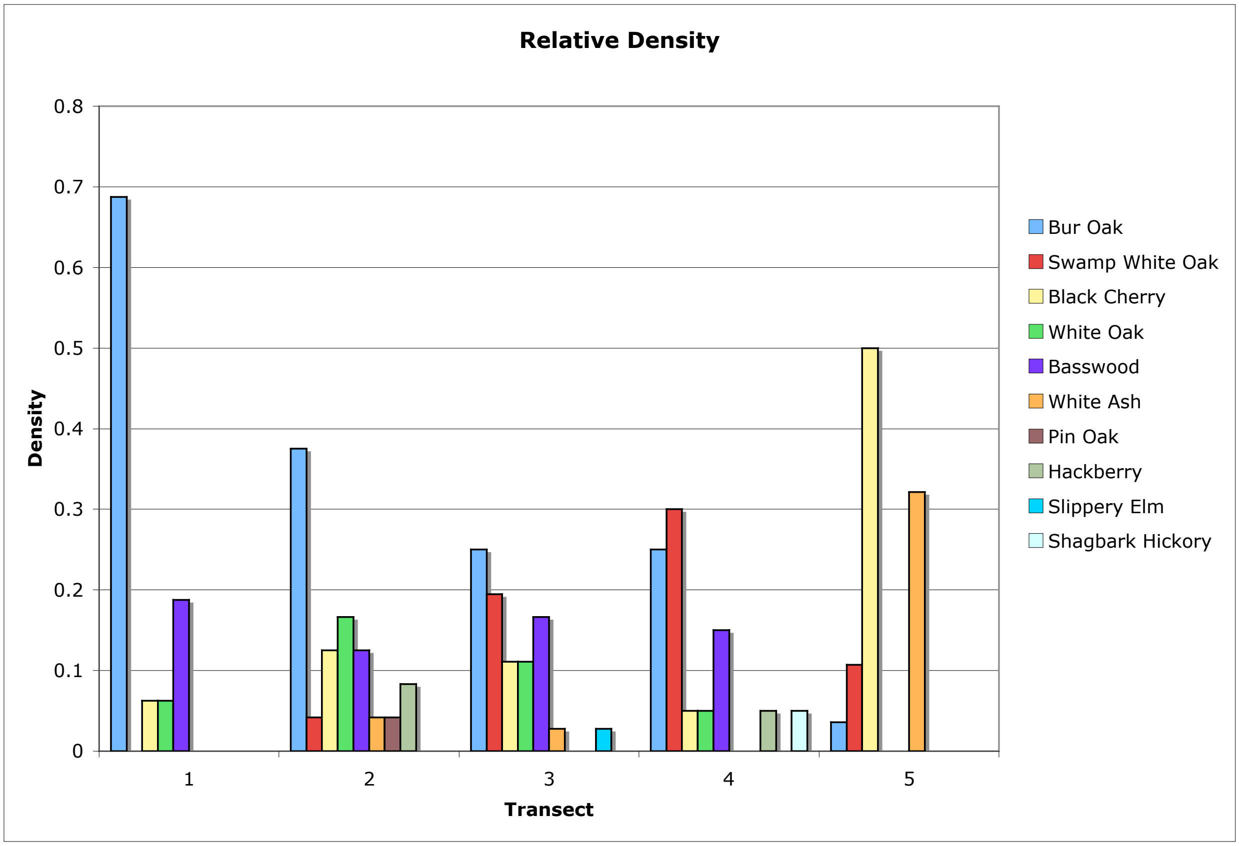

Figure 1. Relative Density

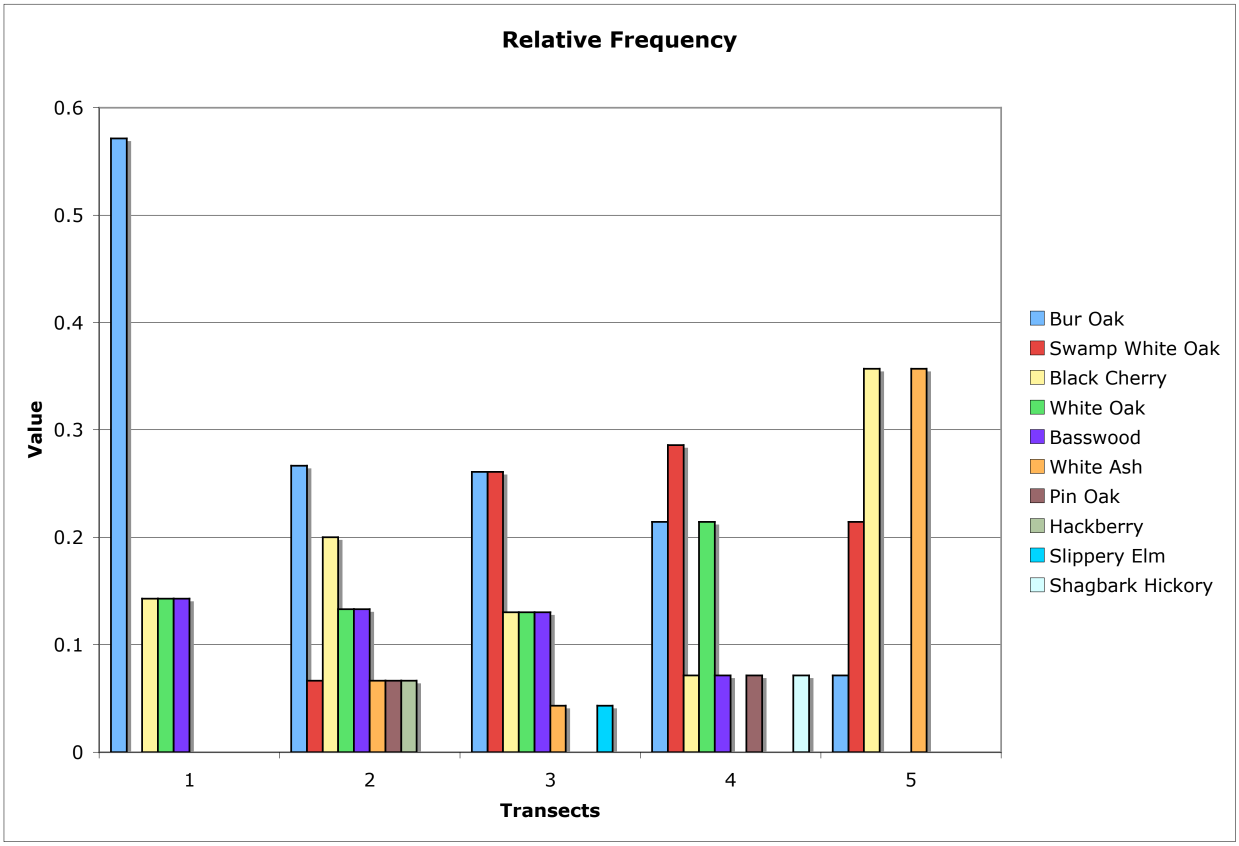

Figure 2. Relative Frequency

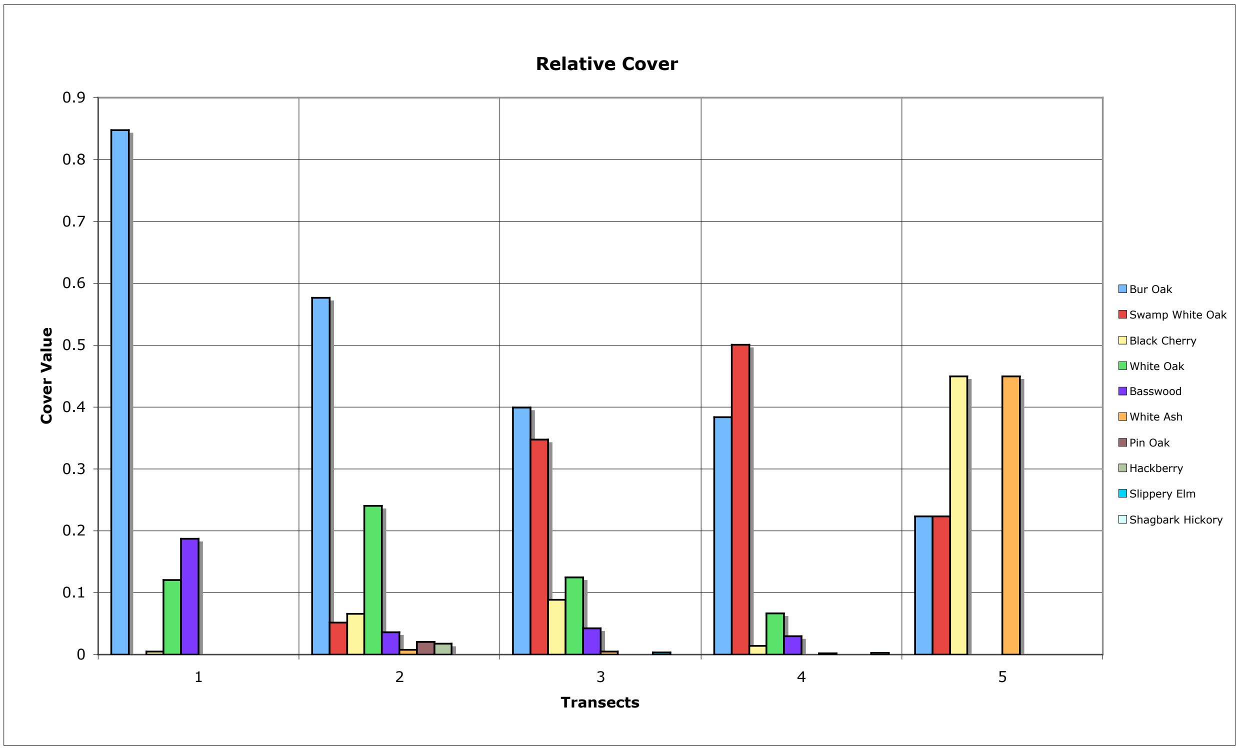

Figure 3. Relative Cover

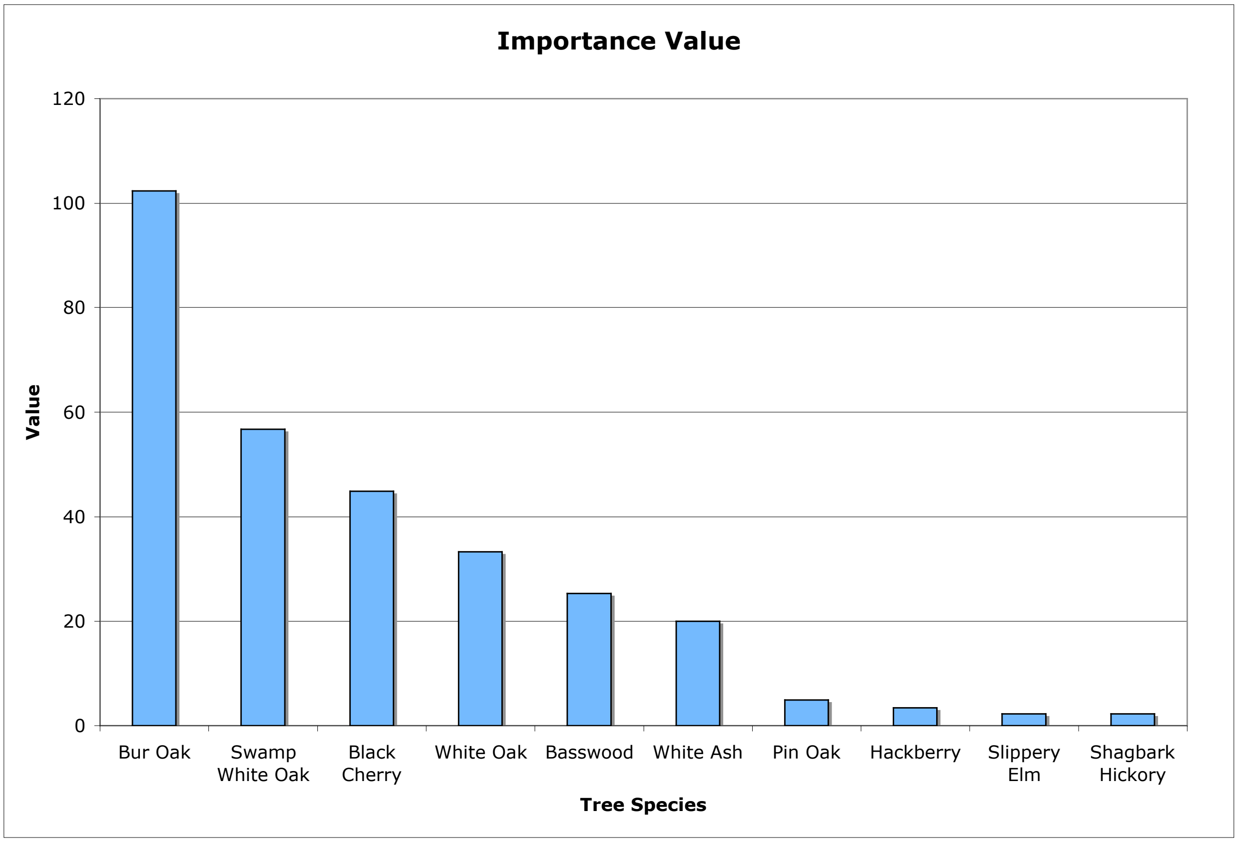

Figure 4. Importance Value

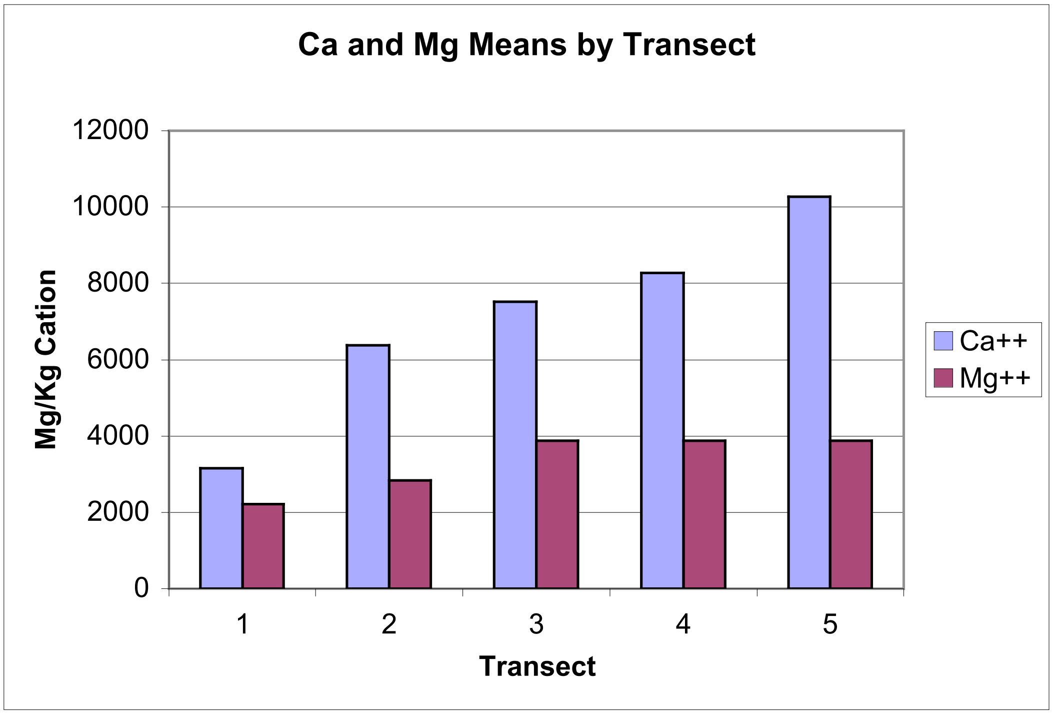

Figure 5. Soil Sample Results

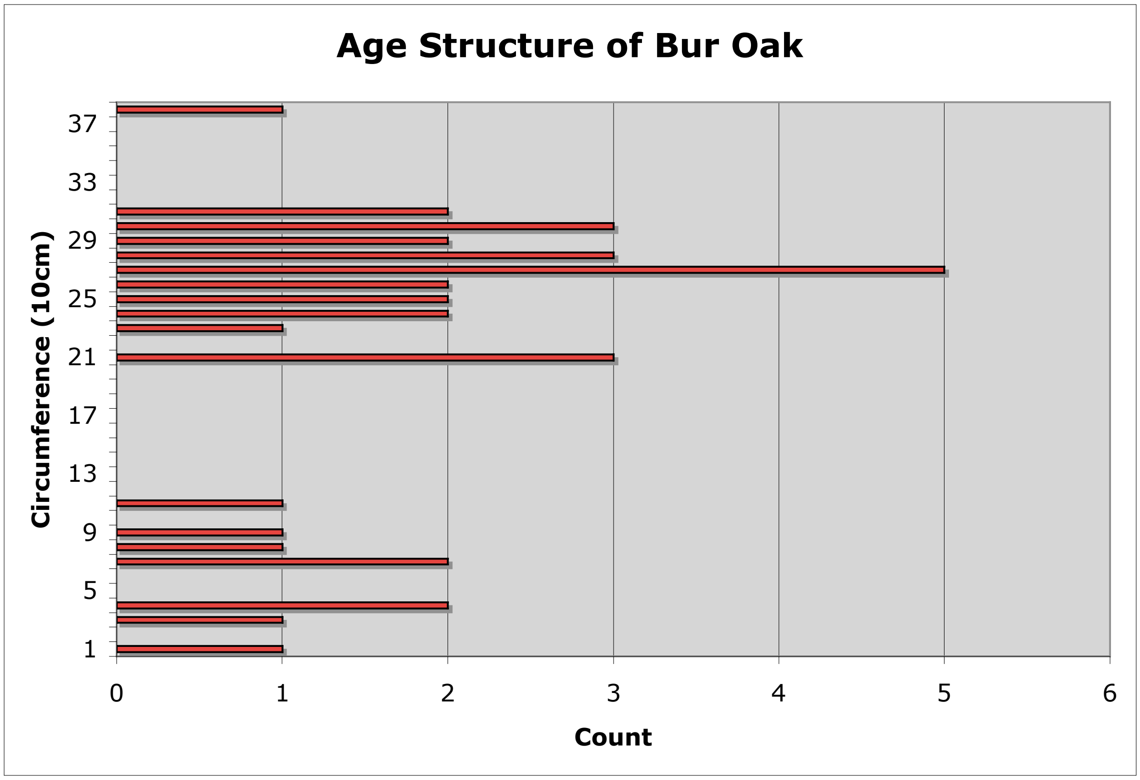

Figure 6. Age Structure of Bur Oak

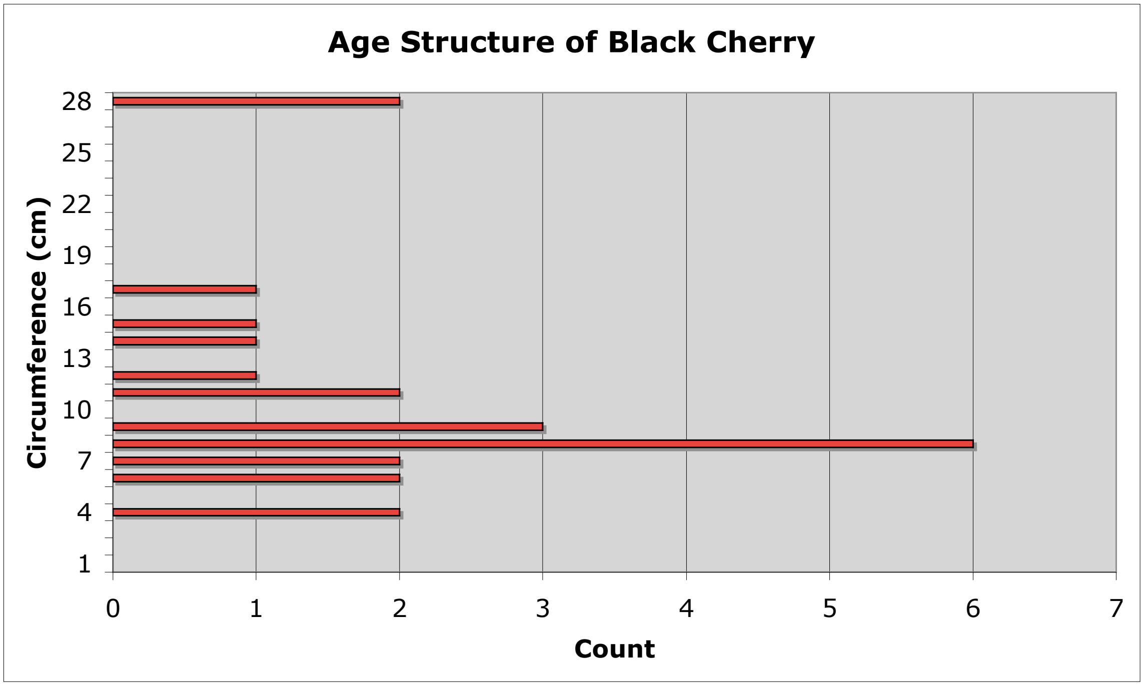

Figure 7. Age Structure of Black Cherry