Forest stumps as indicators of past logging activity at UNDERC

BIOS 35502: Practicum in Environmental Field Biology

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Abstract:

During the early 1900's, major logging companies harvested a number of tree species including white pine (*Pinus strobus*) and cedar (*Thuja occidentalis*) in the Ottawa National Forest, and what later came to be known as the UNDERC property. Half a century later, the UNDERC property experienced another logging event where quaking aspen (*Populus tremuloides*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*) became the chosen tree species. Maps of the logging areas were generated for use, however in 2006 these maps are considered to be incomplete. I proposed to survey the UNDERC property and determine the density and distribution of the sawn stumps found across the property, and compare this with the logging maps. After completing the surveys and calculating the density of sawn stumps per hectare I generate a new map based on the old archive-logging maps with markers on the stands that had been found to have a high density of sawn stumps. My results showed that the there indeed has been logging in areas not depicted by the archive maps and that a more complete survey should be done to observe the full level of logging upon the UNDERC property.

Introduction:

Extensive logging started in the 1870's in the Great Lakes region (Whitney 1987). When the white pine (*Pinus strobus*) and northern white cedar (*Thuja occidentalis*) in the area had all been removed, logging companies turned towards other sources of wood. The more commonly chosen species removed by the loggers include quaking aspen (*Populus tremuloides*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*) and others. At the University of Notre Dame Environmental Research Center (UNDERC) in Land O' Lakes, Wisconsin, logging took place ca. 1880-1910 (Archive papers). As found in archive maps and spreadsheets, the more common tree taken during the 1950s and 60s from the UNDERC property was the aspen tree species. The next most taken species from the property was the maples.

Common forest management practices in the 1880's included partial, selective and clear cutting. During the early years of logging in the Great Lakes region, the most prevalent method for taking white pine and later hemlock (*Tsuga canadensis*) was a selective clear-cutting (Whitney 1987). As the availability of white pine and hemlock decreased, the remaining trees were harvested by completely clear-cutting the areas (Whitney 1987). These cuts are used for different purposes depending on the needs of the logging company. Partial cuts allow for higher levels of productivity from logging expenditures by leaving small and medium size trees to grow into larger trees for future logging (Helphinstine 2005). In the later years selective cuts and partial cuts were used when specific species became of interest to the logging companies, such as when demand is high for hard woods, or soft woods (Helphinstine 2005). The last most common logging practice is the clear-cut, which is used when preservation of the forest stand is not the major concern (Helphinstine 2005). It is also used in the regeneration of aspen stands (Shepperd 2001).

Early successional species such as quaking aspen and paper birch (*Betula papyrifera*) help indicate past disturbances in forest stands such as clear-cutting because, as a pioneer species, they quickly establish in areas with high levels of sunlight (Martin and Gower 1996a). At UNDERC, selective cutting that minimized damage to reproduction was probably the dominant logging practice during the decades of 1950 and

1960, as stated by Wendel (1968) in an archive letter. However, several pure and even-sized aspen stands found at UNDERC suggest that clear-cutting was also employed.

Aspen decomposes more quickly than the pine species (*Pinus* spp.) that in turn decompose faster than the maple species (Martin and Gower 1996b). The particle density of aspen trees could be the reason for the quicker decomposition. As Redding et al. (2005) found that aspens have a lower particle density than pines and maples, which may allow for relatively faster decomposition. This lower particle density could be a result of aspens allotting proportionally more time and energy into its rapid growth vertically rather than placing the time and energy into the density of its composition. Although there are many aspen stands on the UNDERC property, aspen stumps aging > 75 y will be rare. This is due to the short lifespan of aspens, 50-60 y, and their relatively quick decomposition in over-mature stands (Martin and Lorimer 1997). Godman et al. (1981) state that the sugar maple stands can live anywhere from 300 to 400 y. However, under the uneven-aged management plans these same stands may only live to be 250 y (Godman et al. 1981). Because the lifespan and decomposition of aspens, maples, and other species are known, a stand can theoretically be aged based on the decomposition level of the stumps found. As part of my project, this index was developed in the Ottawa National Forest (ONF) by correlating the decay rate of wan and natural stumps of various species indifferent stand types to the known age of the stand. This decay index was then applied to stumps found in similar forest stands at UNDERC to estimate their age.

In this study, I investigated the past logging activity of UNDERC based on a survey of stump origin, distribution and decay rate in several randomly chosen forest stands including pure maple, mixed late-successional and mixed early-successional upland forests. Additionally, for each stand surveyed, I add to the information currently found on the map layer of the forest stands of UNDERC in ArcView 3.3 such as stump origin and density as well as an average diameter and percent cover of the canopy species.

I hypothesized that stumps of human origin would not be evenly distributed across UNDERC's forest stands. Their distribution should corroborate information available on archived logging maps for the last known proposed cuts (1954-1967). I also hypothesized that stump abundance will vary across stand types. Based on varying decay rates for different species, I expected to find a lower density of stumps of human origin in early-successional aspen stands than in stands composed of late-successional species. I also expected to find a higher density of natural stumps in aspen stands than in other stand types because it is approaching its lifespan in forests that originated in the 1950s.

Methods:

I randomly placed north-to-south transect lines spaced a kilometer apart using the software ArcView 3.3 (Environmental Systems Research Institute, Redlands, CA). I visited a total of 32 stands in upland areas, and categorized the different stands into three groups; pure sugar maple, mixed late successional, and mixed early successional dominated by aspens.

I surveyed all the stumps encountered along the transect lines in each forest stand and recorded all stumps less than 1.37m tall and greater than 20cm in diameter, within a 10m distance to either side of the transect line. I recorded stump origin in the following categories: sawn stumps (flat, little to no jagged edges); possibly sawn stumps (old, suspected of being sawn but is not obvious); and natural (microburst, beavers, etc.). I used the Geographic Information System (GIS) (ArcView 3.3) to measure the distance that was surveyed in each stand to calculate the density of stumps. Across 32 stands, I surveyed an area of 18.94 ha, just shy of 19 ha. Each stump was assigned to one of five decay classes developed by Whitman (2004). Refer to Table 1 to view the five decay classes.

In each stand surveyed for stumps, I also identified the dominant and co-dominant canopy species and estimated their relative abundance and average height in five categories: less than 2m, 2-6m, 7-12m, 12-19m, and greater than 19m. I also randomly chose three locations within each stand to visually estimate the percent cover using four different canopy closure categories: greater than 75%, 50-75%, 25-50%, and less than 25%. After taking the visual estimate, I also took a measurement of the diameter at breast height (DBH; 1.37m) of 12 randomly selected canopy trees, selecting the first three trees encountered along the four cardinal points to obtain the average tree size in each stand. These data were also added to the associate .dbf table of a currently existing forest stands layer in ArcView 3.3.

I used a Kruskal-Wallis non-parametric test to investigate differences in sawn stump decay classes among stand ages for each of the three stand types surveyed at ONF. I also used a Kruskal-Wallis test to determine if there is a difference between both sawn and natural stump density among UNDERC stands types surveyed. I used a Mann-Whitney test to determine which stand types differed from one another. Outliers were removed in the analysis. Stumps that were obviously sawn and those that were possibly sawn were pooled together for the analysis based on the assumption that the stumps designated as possibly sawn was most likely sawn.

In addition, I created a map showing sawn stump distribution for the sawn stump distribution hypothesis of the UNDERC property based on the sawn stump distribution that I found for comparison to the archived logging maps. This will give a clear indication of distribution throughout the UNDERC property and corroborate the known logging data as well as possibly add new data to the logging history of the property.

Results:

I used a Kruskal-Wallis nonparametric test to investigate the relationship between the decay class of sawn stumps and the age of stands at ONF. There was no significant relationship between the two variables for aspen stands (χ^2 (3) =4.449, p = 0.217). In all aspen stands sampled at ONF, most stumps recorded were extremely decayed (Figure 1a). However, there was a statistically significant relationship between sawn stumps decay class and stand age for both the maple (χ^2 (4) = 29.6, p < 0.01) and the mixed stands (χ^2 (3) = 13.87, p < 0.01). Since there is no trend to the relationship for neither the mixed stands or the maple stands, I could not use this model to assign an age to UNDERC stands based on sawn stump decay class (Figures 1b and 1c).

To test the hypothesis that the sawn stump distribution across UNDERC was not evenly distributed I calculated the density of sawn stumps in each stand visited. I did this by using Global Positioning System (GPS) coordinates for my start and finish length, and calculated the area of each stand based on a 20m wide transect. I then calculated the number of sawn stumps per hectare (ha). After the density of each stand had been calculated I compared the areas with high density of sawn stumps to archive maps of the areas that are known to have been logged (Figures 2 and 3). My results after comparing my density map and the archive-logging map shows that areas outside of the known logging areas have been logged. The distribution was also even throughout the UNDERC property.

To test the relationship between sawn stump densities and stand type, I also used a Kruskal-Wallis nonparametric test. I found a statistically significant relationship between sawn stump densities and stand type (χ^2 (2) = 7.761, p = 0.021). However, there was no significant relationship between natural stump density and stand type (χ^2 (2) = 2.806, p = 0.246). Figure 4 shows the density of the natural stumps and the sawn stumps over all the sites for aspen, maple, and mixed stand types.

Discussion:

The methods used in the Ottawa National Forest (ONF) contained a number of inherent problems. The most influential problem to be addressed is the issue that the variability in decay rates among species is drastically different from each other. Because stumps were not identified to species analysis was problematic. Without the ability to group the different stumps by species, the decay to age index became unreliable. One suggestion to would be to add another method of aging, such as coring or recording the average DBH. Another issue that arose with the ONF work was replication. Only one stand of each age group of each stand type was surveyed. This also made the decay to age index unreliable because no set of deviation between locales could be determined. The only way to fix this problem would be to visit more stands of the same age.

In the aspen stand the analysis showed no significant relationship between the decay class of sawn stumps and the stand age (Figure 1a). The reason for this can be attributed to the aspens' faster decay rate and the refinement of the decay classes. One way to work with the aspens' fast decay rate is to gather data from younger stands. As for the refinement of the decay classes, the best suggestion is to actually set different requirements based on the species that is being classified. This however entails a refinement in the identification of stump species, which might include collecting wood samples and looking at the cell structure to identify the stump; a similar technique was used by a professor and research associate from the University of Tennessee (Bond and Hamner).

Although the mixed and maple stands showed clear trends when comparing decay class and stand age, I did not find the trend that I had predicted (Figures 1b and 1c). I had expected a linear relationship, in which older stands would have to have a higher concentration of upper level decay classification with the younger stands following a linear decay rate.

This did not happen however so we cannot apply this model to the UNDERC forest for aging. It follows no mathematical curvature, and resists modification to the point of being useless.

In the comparison of my density map, I see that there are a number of stands that have been logged. When compared to the archive-logging map, there are some stands that are inside the known logging areas, and some stands that are outside of the map. The distributions of areas that are logged appear to be evenly distributed throughout the UNDERC property (Figures 2 and 3). My conclusion to this result is that the archive-logging maps are incomplete and that the UNDERC property has an even sawn stump distribution.

My results indicated that on the UNDERC property, maple had a higher abundance of sawn stumps (Figure 4). This can be a result of that maple's slower decomposition rate, as compared to aspen stumps. The natural stump abundance of all forest types did not turn out a significant result. The result, although not significant, is a useful piece of information to show that the data are not skewed one way or another. One thing that I noted during my surveys in the aspen stands is that a high number of aspen snags that had not yet fallen over from gusts of wind. It is clear to me that although the aspen stands are dying; they are leaving behind snags for some years before actually falling down and creating stumps.

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Table 1. Decay Class Categories.

Decay Class 1	Decay Class 2	Decay Class 3	Decay Class 4	Decay Class 5
Bark firmly attached. Wood has fresh color still.	Bark is flaking and is not firmly attached. Can see the start of decay.	Bark is mostly gone. Wood is bare and flakes or shreds off when kicked.	No longer solid, mostly soft powder but still has strong points.	Powdered wood, very soft and can be easily broken with hand.

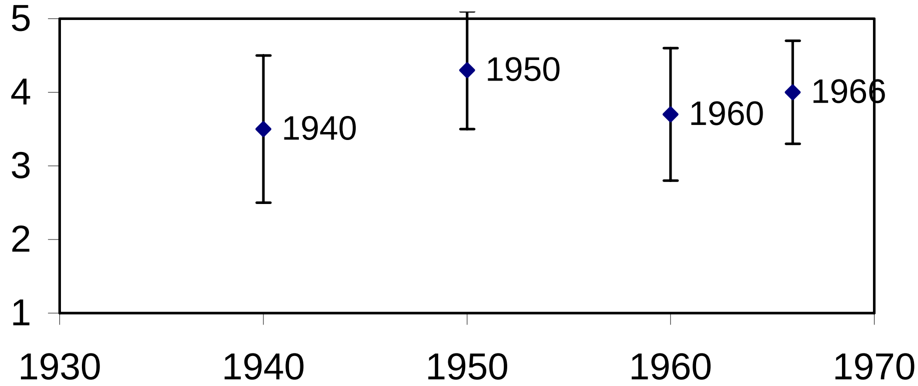

Figure 1a. Aspen Stand.

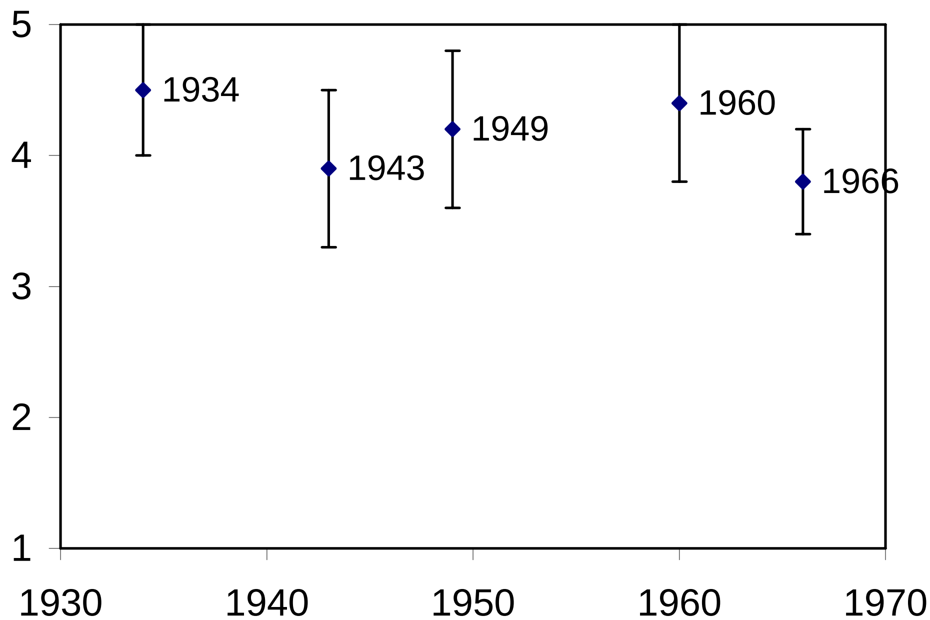

Figure 1b. Mixed Stand.

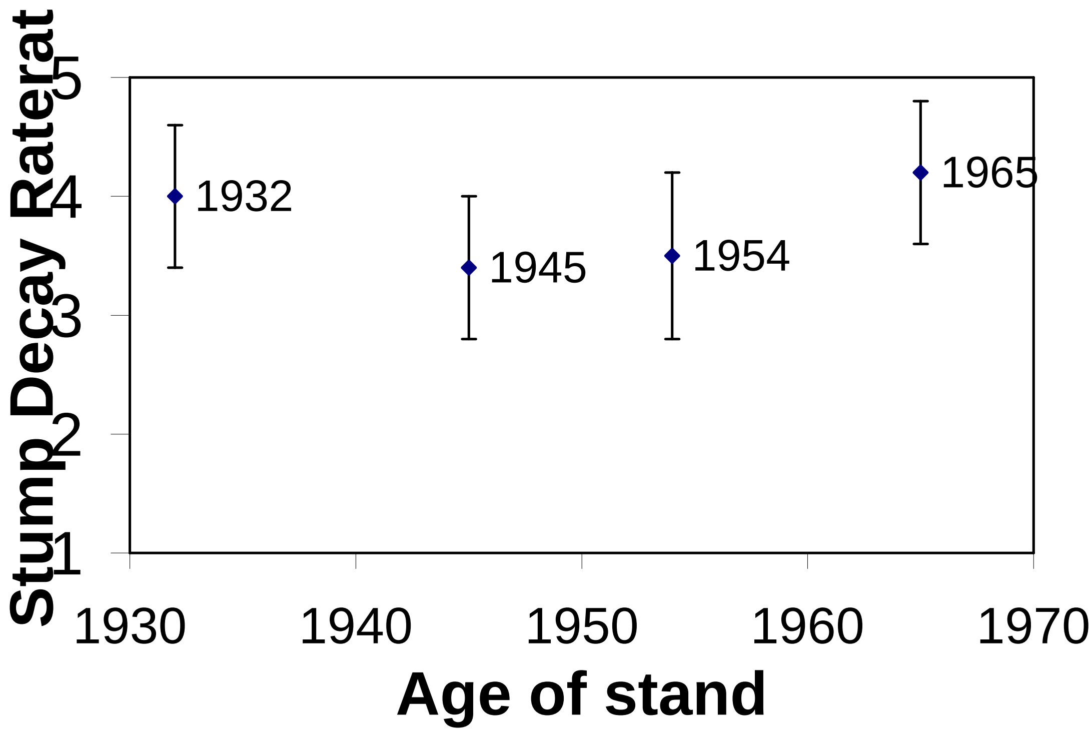

Figure 1c. Maple Stand. Mean ± SD decay rate for sawn stumps in relation to stand age at aspen, mixed and maple stands at Ottawa National Forest.

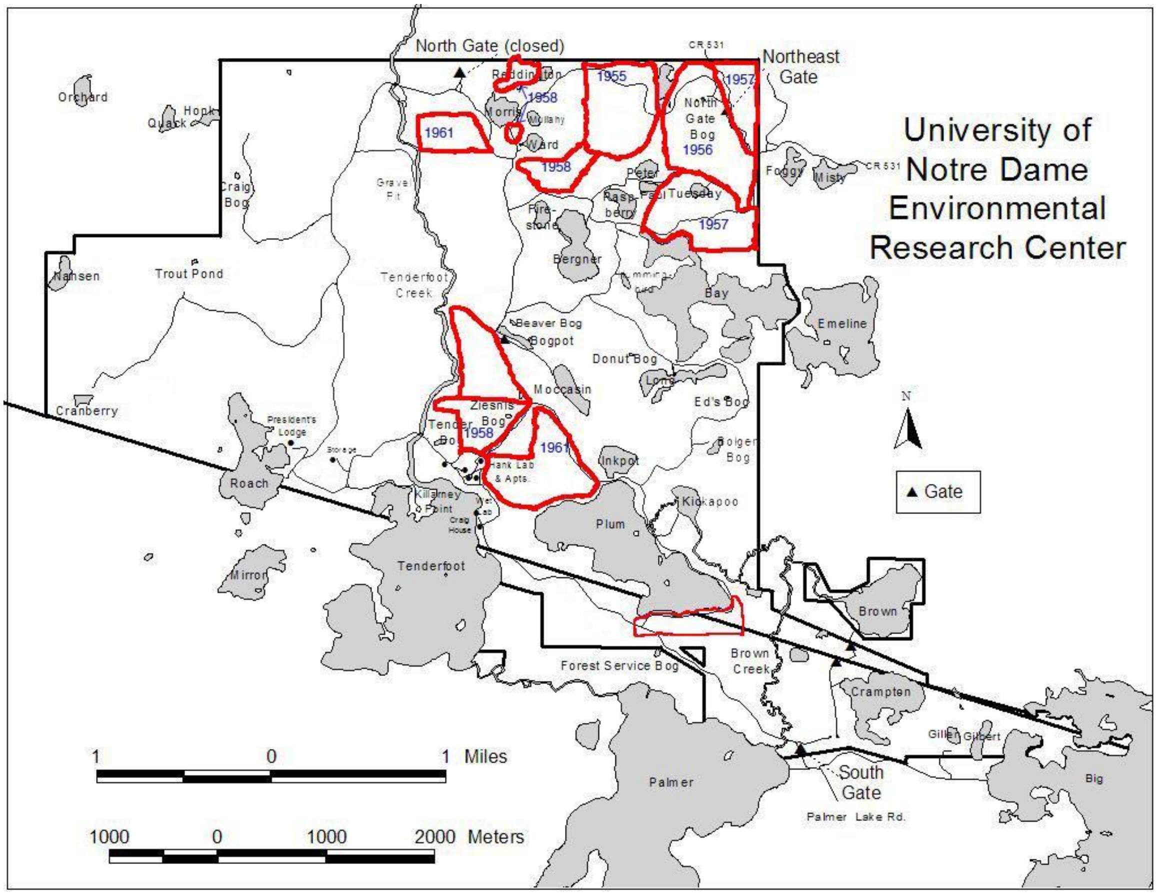

Figure 2. Map of UNDERC property with areas highlighted based on the Archive-logging maps.

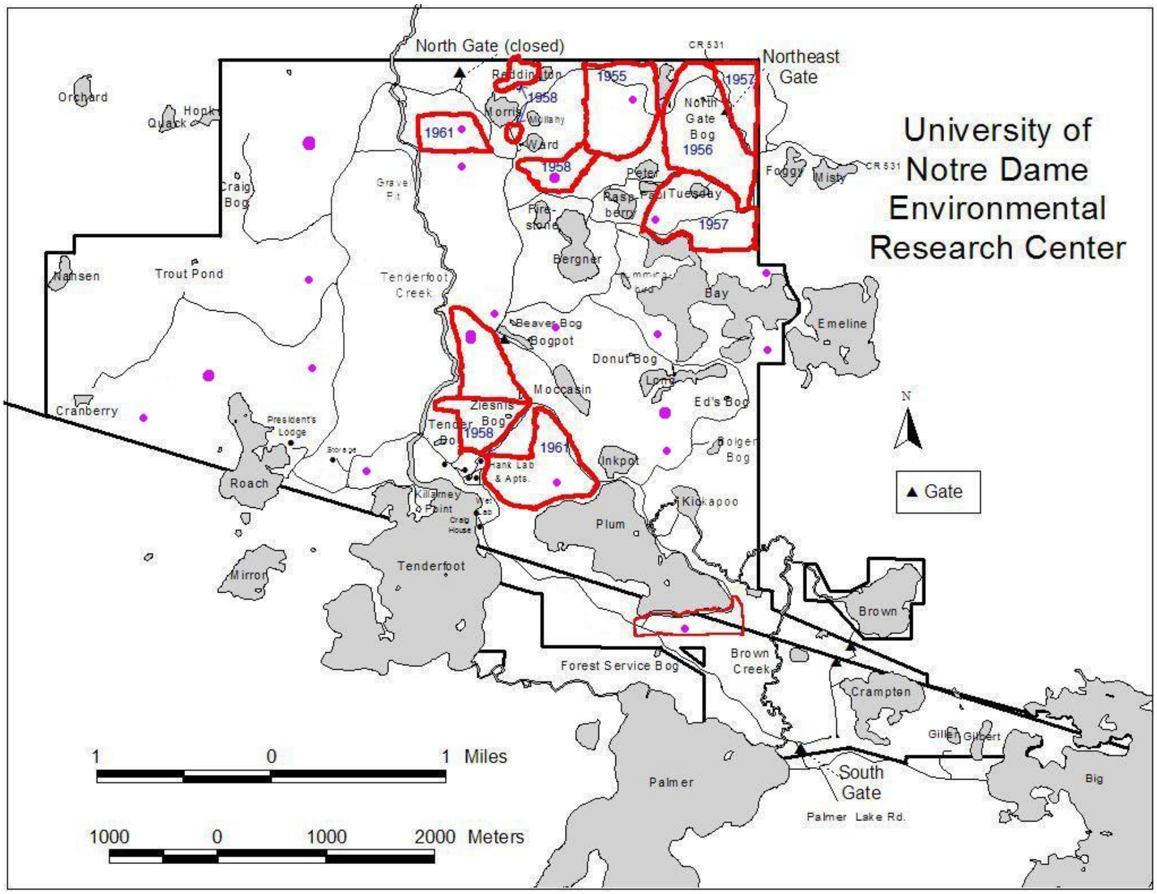

Figure 3. Map of UNDERC property with 'density dots' and known logging areas highlighted.

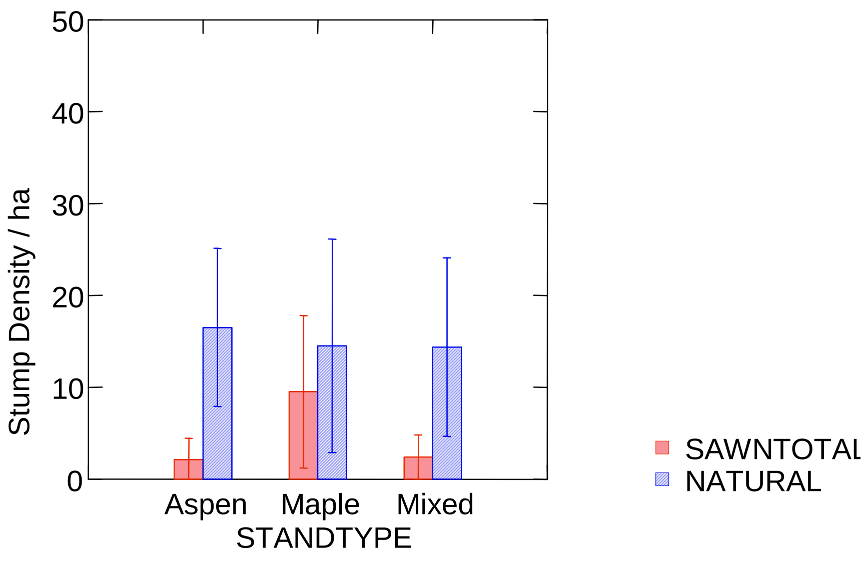

Figure 4. Sawn and natural stump abundance across UNDERC property.