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An Economic and Ecological Analysis of: Northern Hardwood Single-Tree Selection Order of Removal Procedures and Evaluation of Red Pine Plantation and Aspen Forest Type Rotation Ages

(SLS 4700)

Client:
National Council for Air and Stream Improvement, Inc.

Prepared for:
Great Lakes Timber Professionals Association

Wisconsin County Forests Association

Prepared by:
Steigerwaldt Land Services, Inc.
Tomahawk, Wisconsin

Effective Date:
February 4, 2016

Wisconsin Forest Practices Study
Factors Influencing Wisconsin's Forest-Based Manufacturing Competitiveness

Summary of Facts and Conclusions	
Project	An Economic and Ecological Analysis of: Northern Hardwood Single-Tree Selection Order of Removal Procedures/Evaluation of Red Pine Plantation and Aspen Forest Type Rotation Ages
Prepared for	Great Lakes Timber Professionals Association Wisconsin County Forests Association
Client	National Council for Air and Stream Improvement, Inc. P.O. Box 13318 Research Triangle Park, North Carolina 27709-3318
Submitted by	Steigerwaldt Land Services, Inc. 856 North Fourth Street Tomahawk, Wisconsin 54487 T: (715) 453-3274 F: (715) 453-8325
Effective Date	February 4, 2016
Project Objectives	We investigated forest conditions created on Native Community designated state lands, as well as public and private forestlands by strictly following the Wisconsin Department of Natural Resources (WDNR) Order-of-Removal (OOR). We used alternative marking scenarios to evaluate the economic and ecological consequences of the OOR guidelines. In a second study, we evaluated the WDNR rotation age guidelines for red pine and aspen using discounted cash flow principles to identify financial optimum rotation lengths.

Results	For the OOR studies, the alternative marking scenarios prioritized the removal of high-risk trees (low Growing Stock [GS] classification) and often increased the economic value of "cut" timber. This result was significant on the Native Community timber sale analysis and most pronounced in the Scenario 1 model results. In a sample of northern hardwood stands marked statewide, harvest value increased by an average of 46 percent for all owners (state, county, and private MFL) using an alternate marking scenario. In comparison, harvest value on the Native Community timber sale increased by over 100 percent for Scenario 1. The current rotation length regulation reduced financial returns from aspen harvests on only the best quality sites, while the red pine rotation regulation of 60 years reduced timberland financial returns on all sites. We estimated total impact to statewide timberland value to be $5.2 million for both red pine and aspen.
Conclusions	Our results suggest that simplifying the decision criteria for northern hardwoods, and allowing flexibility when using a marking guide could increase financial returns. Removal of medium to large sawtimber, 14 inches DBH and greater, would increase by applying a marking approach that more strictly follows maximum tree size management at sizes smaller than typically applied (24 inches DBH). Financial returns for aspen could be increased by using a minimum age of approximately 33 years for better sites, while 40 years is adequate for lower quality sites. Financial returns for red pine could be increased on better quality sites by allowing harvest at 45 years of age, while poor sites would be better suited for harvest at 55 years.

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1. Project Overview

1.1 Investigators

This research investigation is a collaborative effort including team members from Steigerwaldt Land Services Inc. (Steigerwaldt) and James W. Sewall Company. The primary investigator for the project is Forrest M. Gibeault (Steigerwaldt), along with the project partner from James W. Sewall Company, Gary Mullaney. Contact information for the investigators is below.

Primary Investigator:

Forrest M. Gibeault, ACF
Analysis and Investments Operations Director
Steigerwaldt Land Services, Inc.
856 N. 4th Street
Tomahawk, Wisconsin 54487
T: 715-453-3274
C: 715-966-5975
Email: forrest.gibeault@steigerwaldt.com

Partner:

Gary Mullaney
Forest Economist and Senior GIS Consultant
James W. Sewall Company
2317 Salt Wind Way
Mount Pleasant, South Carolina 29466
T: 843-606-1022
C: 843-834-1710
Email: mulga@sewall.com

Contributors:

Tim Mack
Senior Consultant and Biometrician
James W. Sewall Company
International Falls, Minnesota 56649
T: 218-331-2568
Email: macti@sewall.com

Kevin Burns
Vallier Treehaven Forest Ecologist
University of Wisconsin Stevens Point
College of Natural Resources
W2540 Pickerel Creek Road
Tomahawk, Wisconsin 54487-9112
T: 715-346-2461
Email: Kevin.Burns@uwsp.edu

Terry Strong
5061 Crystal Lake Rd.
Rhinelander, Wisconsin 54501
T: 715-362-2224
C: 715-401-3884

Volker Radeloff
Professor, Department of Forest and Wildlife Ecology
University of Wisconsin
Russel Labs
1630 Linden Drive
Madison, Wisconsin 53706

1.2 Wisconsin Forest Practices Study Overview

The Wisconsin Forest Practices Study (WFPS), pursuant to s.26.105(1), Wis. Stats., was made possible by means of a grant awarded by the WDNR to the Great Lakes Timber Professionals Association (GLTPA) and the Wisconsin County Forests Association (WCFA). The broad objective of the WFPS is to obtain research results that will help guide decisions and policy development for investment in forest-based manufacturing industries in Wisconsin, while ensuring that social and ecological benefits provided by Wisconsin's forests remain viable for future generations.

Essentially, the question posed is: How does Wisconsin continue to provide sustainably-grown wood fiber to support competitive wood-using industries in the future? The WFPS study included three general topic areas of research. This research addresses the topic of: What forestry-related factors are expected to enhance or reduce the competitiveness of forest-based manufacturing in Wisconsin?

The specific objective for this topic is to provide research that investigates the consequences of policies, regulations, and guidelines that impact the implementation of forest management and harvesting, including those that may become economically burdensome.

1.3 Analysis Subject Areas – Objectives and Outcomes

This study includes three analyses. The analyses are related due to the similar direct impact they have on timber production through the implementation of guidelines inherent in the Managed Forest Law (MFL) program and practiced routinely on state, county, and private forestlands.

We conducted the following analyses:

1. *Single Tree Selection Order-of-Removal (OOR) Approach in Northern Hardwood Forests*
    a. *Evaluation of OOR in Native Community designated forest on State of Wisconsin forestlands, which are described as areas of the state forests with the management objective as defined in Wisconsin Administrative Code NR44.06, "…is to represent, restore and perpetuate native plant and animal communities, whether upland, wetland or aquatic, and other aspects of native biological diversity." (**Native Community Analysis**)*
    b. *OOR comparative analysis on state, county, and private forest lands enrolled in tax incentive programs (**OOR Analysis**)*
2. *Rotation Lengths in Red Pine Plantations and Aspen Forests*

Additional detail is provided in the following overview sections.

1.3.1 Northern Hardwood Order of Removal Analysis Summary

This first component of the study evaluated marking of trees using the OOR established by the WDNR for application in single-tree selection harvest methods in northern hardwood forests. We evaluated potential economic effects through the supply chain, as well as potential ecological considerations, of strictly following the WDNR OOR and the application of two alternative marking approaches. We compared OOR marking approaches on 1) Native Community acreage on State of Wisconsin lands managed by the WDNR and 2) a sample of stands marked for harvest under the OOR guidelines on state, county, and private forest lands enrolled in tax incentive programs. These two studies differ in design and application of results, as the Native Community Analysis is considered a case study on State forest lands focused on evaluating strict ecological considerations, while the OOR Analysis considers a large range of stands across various owners, representing much of the geographic region that supports the northern hardwood forest type in Wisconsin.

The current marking guidelines outlined in the WDNR Silvicultural and Forest Aesthetics Handbook (SFAH, HB2431.5) have brought much discussion and debate in recent years. Many in the forest industry have expressed concern over the results of strictly following the current northern hardwood OOR in single-tree selection. In some cases, it has been expressed that the guidelines only allow for thinning from below, the removal of only co-dominant stems, or result in the development of even-aged forest structure dominated by mature and over-mature timber. It has also been noted that use of the OOR may not be appropriate in all regions of the state or uniformly across all hardwood-dominated forest types. Therefore, one may conclude that a one-size-fits-all approach to every stand may not benefit all objectives in a harvest situation. Every marking system will have such consequences, as it is a challenging feat to develop a system that optimizes stand structure, ecological considerations, economics, etc., on any given site. This study will not analyze all stand components that may be impacted by single-tree selection, but rather focus more on near-term economic consequences and ecological considerations.

1.3.2 Red Pine and Aspen Rotation Age Analysis Summary

Topic 2 of the WFPS investigates the consequences of policies, regulations, and guidelines that impact forest management and harvesting, including those that may be economically burdensome. This portion of the study specifically evaluates guidelines that set rotation ages for two economically vital tree species – aspen (*Populus* spp.) and red pine (*Pinus resinosa*).

For even-aged forest management, the regulatory guidelines of most interest are the minimum rotation ages: 40 years for aspen and 60 years for red pine. These were studied using two methods. A regional wood supply optimization model (Woodstock) was used to simulate the impact of the presence or absence of mandatory minimum rotation lengths. The second approach included individual stand simulation defined by Land Expectation Value (LEV).

2. Northern Hardwood Order of Removal Procedures

2.1 Methods

This analysis was supported by a forest inventory implemented on the various ownerships studied in the two-part OOR analysis. The pre- and post-harvest forest structure, cut and leave tree characteristics, and ecological and economic consequences of tree selection were evaluated following the methods outlined in the following sections.

2.1.1 Literature Review

We compared marking guideline outcomes on lands required to explicitly following the WDNR SFAH northern hardwood chapter with outcomes of alternative marking criteria. WDNR SFAH marking guidelines are enforced on all tax law forestlands, and similar marking guidelines are followed on state and county forestlands. The WDNR has adapted the SFAH guidelines from Arbogast (1957) and USDA Forest Service (2005) research. The guideline instructions as paraphrased in the SFAH read as follows: *"in overstocked size classes, cut the poorest trees to obtain the recommended density and to release timber crop trees."* The works of Arbogast may have promoted the concept of an idealized stand structure in northern hardwood forests, but these structures were first studied by Eyre and Zillgitt (1953). These concepts have been well accepted in the Lake States region, and the prominence of their adoption in mainstream forest management is well documented (Pond, Froese, Nagel, 2012). Over time, certain aspects of these historical guidelines were applied in forest management applications, such as tree selection based on quality or the order in which to remove trees. Other concepts such as maintaining an idealized stand structure or diameter distribution took a backseat, as these concepts were likely more difficult to implement during a marking exercise and are difficult to enforce. Pond, Froese, and Nagel (2012) found that only 23 percent of stands sampled followed the Arbogast post-harvest stand structure, providing evidence of the difficulty for land managers to develop an idealized stand structure. Although northern hardwood stand structure has been well studied, many researchers have noted that idealized structures may not be all that common or successfully implemented. Today, enforcement of the WDNR SFAH northern hardwood management is centered on tree selection criteria (OOR guidelines defined in HB24315.40), with potential bias towards retaining trees in the sawtimber-size classes of 12-inch diameter at breast height (DBH) and larger).

Moreover, research is needed to evaluate marking guides developed in the 1950s, as we are just now beginning to understand how these guides have affected the structure of managed northern hardwood stands in the Lake States. Undoubtedly, significant social and economic changes have occurred since development of the historical science quoted in this section. Well-respected Lake States foresters, such as Bill Cook, have noted how forest professionals are being confronted with many new challenges. Northern hardwood forests now face failing regeneration due to deer browse, invasive insects that have the potential to significantly change tree species composition, and invasive plants and animals that change the forest floor and soils. In a recent article, Bill Cook noted how, “Single tree selection was researched and designed in a time when many of these new social and ecological factors either did not exist or were uncommon” (Michigan State University Extension, 2014).

The forest products community also has an interest in the economic assumptions used to develop the guidelines in the 1950s, as this science was based on the financial markets at that time. These assumptions were the basis for establishing the maximum tree size criteria in Arbogast’s desired stand stocking. Current roundwood log markets allow smaller diameter trees to reach economic maturity much earlier. For example, recent research suggests that hard maple trees in the 14- to 16-inch DBH range should be considered for harvest on lower quality sites, while the maximum tree size criteria on sites with average quality may range from only 16 to 18 inches DBH and increase to 18 to 20 inches DBH on only the best sites. From a purely financial standpoint, retaining trees over 20 inches DBH is cautioned and may only apply to high quality sites for trees that could meet superprime veneer grade, which is quite rare. This compares to Arbogast’s maximum tree size recommendations of 20 to 24 inches DBH. Webster, Reed, Orr, Schmierer, and Pickens (2007) report that annual growth rates are greatest for 14-inch DBH stems and smallest for 18-inch DBH stems (when evaluating trees in the 14-, 16-, and 18-inch DBH classes), but increased as site quality improved. This study suggests that tree grade is also key to assessing the ability of an individual stem to increase in value by jumping grade classes. In most cases, trees in the 14-inch DBH and greater size classes have low present value (PV) if grade jump is unlikely. Trees that could increase in grade or occur on high-quality sites should be retained, and those that have reached their highest grade or may not increase in value should be considered for removal (Webster, Reed, Orr, Schmierer, and Pickens, 2007). Keeping these concepts in mind when marking timber is fine in theory; however, these concepts can be difficult to execute in practice. Therefore, it is not surprising that marking northern hardwood timber is often referred to as an art, not just science.

As stated earlier, residual stand stocking in northern hardwood stands was first recommended by Eyre and Zillgitt (1953). The stocking guidelines published by Arbogast suggest that 84 $ft.^2$ per acre of basal area (BA) be retained in trees 5 inches DBH and larger, with 19 percent of the stocking in the 5- to 9-inch DBH classes, 26 percent in the 10- to 14-inch DBH classes, 31 percent in the 15- to 19-inch DBH classes, and 24 percent in the 20- to 24-inch DBH classes (1957). Research by Crow et al. (1981) found that a residual BA (trees 9 inches DBH and larger) of 70 $ft.^2$ per acre resulted in optimal growth, while a residual BA of 90 $ft.^2$ per acre resulted in better form and quality. However, Orr, Reed, and Mroz noted that differences in net growth between these two residual stocking levels is relatively small. Their analysis of research at the Ford Forestry Center in Alberta, Michigan, suggests that when discount rates are low, a higher residual BA should be matched with a shorter cutting cycle. Conversely, lower residual stocking would require a longer cutting cycle (Orr, Reed, and Mroz, 1994). Strong, et al. (1995) report that studies conducted at the Argonne Experimental Forest over the past 45+ years suggest that a residual BA of 75 $ft.^2$ per acre results in a greater proportion of trees with grade 1 sawlog material when compared to treatments with lower residual stocking. The experiments at Argonne found the 60 $ft.^2$ per acre treatment to have the highest rates of growth and yield, exceeding the control and even exceeded growth in some of the lighter treatment experiments (Strong et al., 1995). Yet, when timber quality and value is considered, treatments of higher residual stocking should be considered, as was found at the Alberta, Michigan, cutting trials.

Individual tree selection methods have been widely adopted in northern hardwood all-aged management. Marking guides, like the OOR required on lands enrolled in Wisconsin’s forest tax incentive programs, generally focus on removing the worst trees first during periodic entries. In stands of average or below average quality, identifying poor quality trees is quite easy; however, as site quality improves, tree decisions get more difficult. Working in poorer quality stands also requires timber markers to “select the worst of the worst” timber, which is sometimes the majority of the stand, and also poses its own challenges. Strictly following marking guides can create challenges on all northern hardwood sties. As a result, some researchers are looking at new approaches to tree selection. University of Wisconsin – Stevens Point Professor, Michael Demchik, has begun to research a tree selection approach that first identifies crop trees, or the higher quality trees in a stand. This approach focuses on quality trees, not the "poorest." Once future crop trees have been identified and released, additional trees are removed until the desired BA is achieved. His research has found that many students and professionals prefer this approach.

The ecological consequences of strictly following single-tree selection methods have also been documented. Many professionals note that the single-tree selection approach often results in thinning from below, thereby creating a shaded understory environment. It has been observed that the single-tree selection methodology may result in monocultures of sugar maple in some locations, as this management approach favors shade tolerant species in application. Neuendorff, Nagel, Webster, and Janowaik (2005) found that sugar maple BA increased by 16 percent in stands managed using single-tree selection harvest methods in the western Upper Peninsula of Michigan.

Hunter, M. (1990) defines biodiversity as "the diversity of life in all its forms and all its levels of organization, not just the diversity of plant, animal, and microorganism species. At its most elemental level biological diversity encompasses the varied assemblages of organic molecules that comprise the genetic basis of life. On the other end of the spectrum there are biomes – the vast stretches of tundra, desert, forest, ocean etc., that cover a whole region and reflect the planet's diversity of climate and physical form." Obviously, this description includes much more complexity than can be accurately or reasonably measured and evaluated. For this study, we will focus on forest attributes commonly measured during forest inventory that will help to describe changes in diversity at a more general level. The hope is that these general forest components of diversity will represent, or carry along, the more complex myriad of life forms and levels of organization that comprise the underlying basis of diversity.

Hunter's definition of biodiversity also includes a reference to geographic scale which, in practice, we typically refer to as within stand diversity (alpha diversity), between stand diversity (beta diversity), and between region diversity (gamma diversity). The richness or variety of species present in a northern hardwood forest is a major component of diversity in the northern hardwood forest type. Species richness is likely the most important diversity component and is also one of the easiest to measure. Biological legacies are defined as organisms, organic matter (including structures), and biologically-created patterns that persist from the pre-disturbance ecosystem and influence recovery processes in the post disturbance ecosystem (Franklin, et al. 2007). This characteristic includes snag trees, cavity snag trees, cavity live trees, and live retention trees greater than 19 inches DBH. This characteristic would also typically include coarse, and possibly, fine woody debris, stumps, tip-up mounds, and undisturbed tree retention pockets.

2.1.2 Study Components and Background

The initial study scope for this analysis identified the two previously mentioned forest subjects for inclusion in a similar examination - a specific northern hardwood forest on state forestland occurring within a Native Community land management area, and a grouping of northern hardwood forested acreage that fits under more broad forest and timber management objective criteria (referred to as the Order of Removal Case Analysis). The separation recognizes the difference in management objectives for these two study subjects. As stated earlier, the management objective for Native Community lands in state forests, as defined in Wisconsin Administrative Code NR44.06, "…is to represent, restore and perpetuate native plant and animal communities, whether upland, wetland or aquatic, and other aspects of native biological diversity." The second grouping included acreage that fits a broader multiple use forest management objective, equitable to the MFL purpose as stated in Wisconsin State Statute 77.80 and the state forestland management class of forest production area, as defined in NR44.06. This group included state forests, Wisconsin County Forests (WCF), and private forestland enrolled in the MFL. The management for this broader group included sustainable timber management and timber production, and generally weighted this as a primary goal, recognizing compatible recreational uses, watershed protection, wildlife habitat, and other components of natural resource and land stewardship inherent in sound forest management on both public and private lands. Wisconsin County Forest Association members have a comparable multiple use management policy, with a focus of ensuring the long-term health and sustainability of forest ecosystems and top management objectives including resource management, timber management, public recreation, wildlife habitat, and watershed protection.

The difference in the objectives for the Native Community land and the balance of the state, WCF, and MFL lands precluded a direct comparison. However, the study scope objective of examining consequences of a varied timber management approach and selection of trees to be harvested allowed for similar procedures. More on these two study components follows.

2.1.2.1 Native Community Analysis

Management of Wisconsin State Forest lands is determined through a planning process that yields a master plan document. This process is described in Wisconsin Statutes Chapter 28 with details in NR 44. A state forest master plan as directed by NR 44 includes a land management classification system that is used to describe the general management objective for a property or a management area within a property. The DNR is required to assign to each management area on a property the land management classification as described in NR44.06 that most accurately describes the management prescribed for the area by the master plan. Land management classes include forest production area, habitat management area, Native Community management area, special management area, recreational management area, scenic resource management area, and wild resources management area.

In addition to what was noted above for Native Community management area objectives, NR44 states "Management activities shall be designed to achieve land management objectives through natural processes and management techniques that mimic those processes whenever possible. A master plan may authorize any management activity or technique that is consistent with the management objective specified in the master plan for the area and is compatible with the site's ecological capability. Only those management activities or techniques identified by the master plan for the management area may be pursued."

Areas designated as Native Communities are specified in the property master plans. Forest and land cover included within these areas will vary; Native Community areas can contain lowlands and areas that may not be operable for timber management. As an example of the extent of state forestland included under this class designation, the following sample for the three largest state forests is provided below (Table 1).

Table 1 – Native Community Analysis: Proportion of State Forests Requiring Native Community Management

Selected State Forest Native Communities			
Forest	**Property Acres (±)**	**Number of Forest Management Areas**	**Estimated Percent of Property Acres**
Northern Highland/American Legion	226,000	7 out of 22	20
Flambeau River	88,000	10 out of 21	7
Black River	68,000	12 out of 19	15

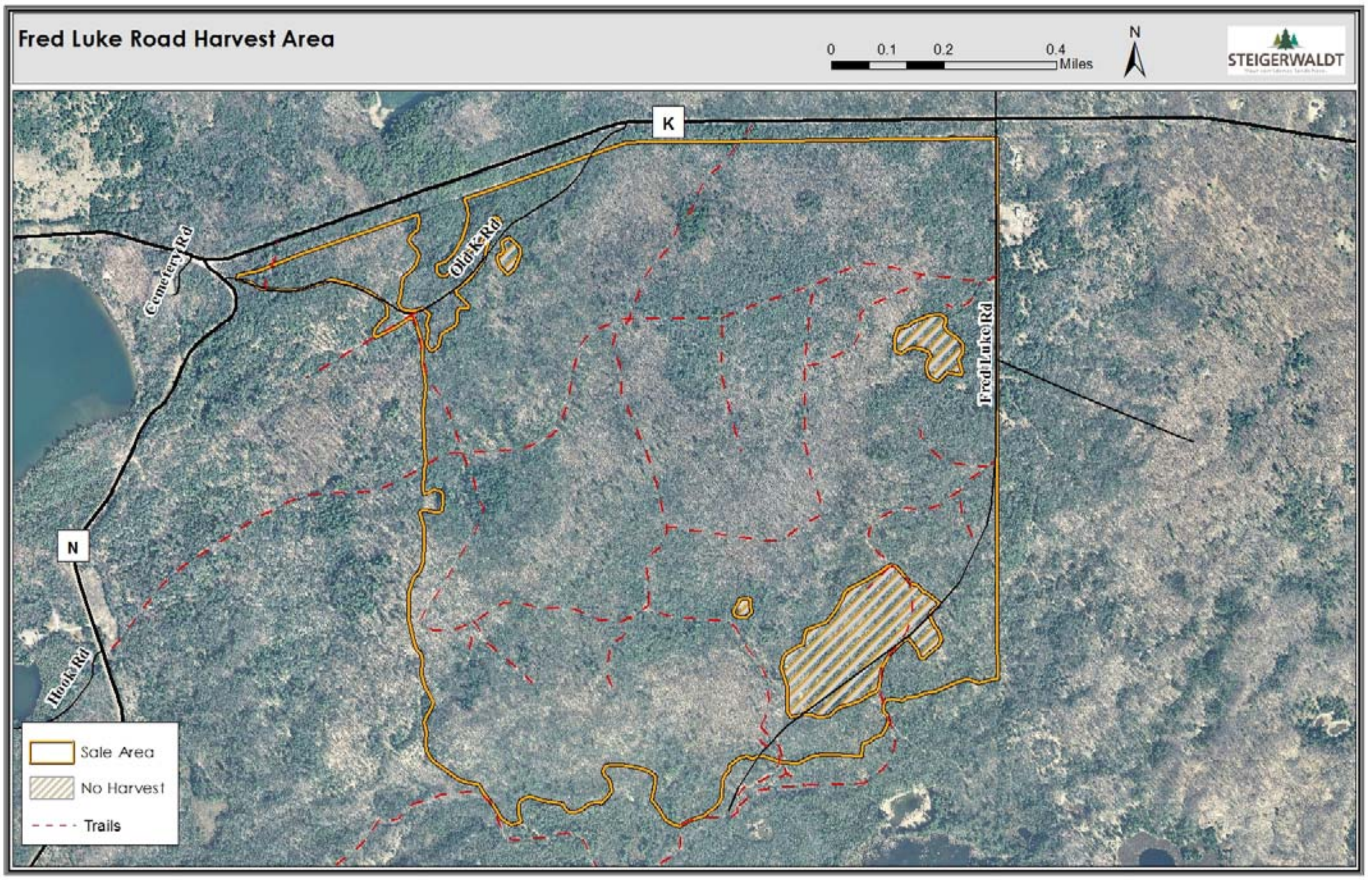
The site identified for analysis for this project as part of the WFPS was presented to the authors as a potential study site during the project design phase. The study site was a 705-acre timber sale put out on a competitive bid to timber producers, and sold and contracted for harvest in mid-2014. It was identified in this process as the "Fred Luke Road" timber sale.

This harvest was located within a particular Native Community area where management objectives include restoring managed old-growth hemlock/hardwood forests with limited active management to increase old-growth forest attributes, such as snags and coarse woody debris, and to enhance the forest composition by, for example, increasing white pine, yellow birch, white cedar, and hemlock components.

The timber harvest included a 19-acre aesthetic zone with cutting and equipment limitations. Over the balance of the acreage, the harvest prescription included cutting all aspen, white birch, balsam fir, and orange marked trees. Five timber producers bid on the sale when it was offered. The highest bid was well above the minimum bid value calculated by state foresters as part of the pre-sale process.
Past forest management and natural disturbance has shaped the Fred Luke Road sale area into a complex and varying northern hardwood forest. WDNR records reported that a partial harvest occurred in 1948, where a 14-inch diameter limit was set for sugar and red maple, and 16-inches was applied to basswood, yellow birch, and red oak. In 1952, a salvage harvest occurred over much of the sale area following a severe wind storm. In 1979, a partial harvest occurred in the western portion of the study area. Historical information prior to 1948 is unknown.

The following map displays the timber sale location and harvest boundaries with an aerial photo background.

Figure 1 – Native Community Analysis: Fred Luke Road Timber Sale Map
Depicting Single-Tree Selection Harvest Area



2.1.2.1.1 Data Collection

The Fred Luke Road timber sale was evaluated by applying 100 1/16th acre fixed plots to collect merchantable forest data. The analysis also included a nested 1/100th acre fixed plot at each sample location to record pre-merchantable trees. Plot locations were determined using a systematic plot grid built from a random starting point. This approach resulted in a plot allocation rate of about one plot per seven acres (705 acres/100 plots).

The 1/16th acre merchantable plots were square plots that measured 52.18 feet on each side. The GPS plot locations were set using a reference point (RP), which was the southwest corner of each plot. Once at the plot, cruisers set the plot corners and recorded the GPS locations of the four plot corners using a sub meter

GPS antenna. The pre-merchantable nested 1/100th acre plot was installed in a similar manner, and was sized 20.87 feet per side (refer to Exhibit 1 – Fred Luke Field Manual, for additional details).

A total of 74 inventory plots were included in the final analysis, based on tree species composition in plot. The final selection of plots occurred within an area stratified as primarily a northern hardwood forest. Figure 2 (see page 16) displays the Fred Luke Timber sale extent, the final plot arrangement, and the stratified study area. Additional details on the stratified plot analysis are provided in section 2.2.1.

The following data was collected for all trees 4.6 inches DBH and larger on the 1/16 merchantable plots (refer to Exhibit 1 for more details).

- Species
- Diameter at breast height (DBH)
- Tree segments - product, grade, and length (including cull deductions)
- Tree Class 1 – Evaluation of a tree's condition as it relates to the current WDNR OOR model: 1-risk, 2-crop tree, 3-vigor, 4-form, 5-undesirable species, and 6-spacing
- Tree Class 2 – Defines a tree's spatial location in reference to surrounding trees
- Growing Stock (GS) – An assessment of growing stock quality and ability to develop into the future
- Tree canopy position classification – 1. Overtopped, 2. Intermediate, 3. Codominant, and 4. Dominant (additional detail provided in the following section)
- Cut/leave designation – as marked for harvest in the stand
- Den/snag or other wildlife value grade (only for cull or standing dead trees). TCruise Codes = 1 - Snag, 2 - Cavity Tree, 3 – Wildlife Tree
- Individual tree location – bearing and distance from RP of plot (Only on Visualization Plots)

The following characteristics were collected for all trees 3 feet in height less than the 4-inch DBH class in the pre-merchantable plots.

- Species
- Total height to the nearest foot

Implementation of the "Tree Class 1" and "Growing Stock" tree classifications were key to this research effort. Cruisers evaluated each tree and applied the Tree Class 1 specifications in an effort that simulated an active marking exercise following the WDNR OOR procedures. For example, low quality trees that were at high risk for decline or mortality would be rated as Risk, Crop Tree Release, or possibly Vigor, and would generally be selected for harvest prior to other more preferred growing stock. Trees falling within the Vigor class would be of mid-quality or a mid-growing stock class that had potential to improve and may have been retained in locations with low BA. The Undesirable Species class was used only for species that were designated for harvest in the sale prescription (aspen, balsam fir, and birch for the Fred Luke Road timber sale). Trees that would have been selected last during a marking exercise would have been coded in the Spacing class. These trees were the top performers and represent the best growing stock, which generally met "Growing Stock" Class 1 and 2. The "Growing Stock" tree classifications, which generally mirror the OOR classification, will be discussed in the following paragraphs. Additional detail is provided in the Fred Luke fieldwork scope (Exhibit 1).

The assessment of growing stock is commonly practiced and implemented by many foresters when assessing a tree's potential to persist in the stand, provide increased biological and economic growth, and forest product grade improvement. During the forest inventory process, a GS tree classification was given to each sampled tree that occurred on the plots. The scheme includes a 5-class system ranging from Class 1, which represented a "trophy" or exceptional tree, to Class 5, which was considered unacceptable and may have had major volume and value loss prior to the next entry (generally 10 to 15 years). This 5-class system was adopted from the University of Wisconsin – Stevens Point assessment developed by Kevin Burns, Treehaven Forest Ecologist. Additional detail of the inventory procedure is outlined in Exhibit 1.

2.1.2.2 Order of Removal Analysis - State, County, and Private Forest Sites

Forest management in northern hardwood stands is generally guided by a set of OOR guidelines on lands guided by WDNR silvicultural principles. As outlined in section 2.1.2, forestlands designated within timber production units on state and county forests, as well as private lands enrolled in the MFL program, must follow the OOR WDNR SFAH guidelines when marking timber for harvest. Northern hardwood forest stands managed using uneven-aged techniques, or managed for uneven-aged forest characteristics, were selected for this study. Single-tree selection harvest methods are typically used to achieve these forest goals.

2.1.2.2.1 Site Selection Process

Stands on state, county, and private MFL lands were sampled and analyzed in the second part of the OOR analysis. This effort included a random selection of all northern hardwood timber sales that met study criteria within the sample extent. Since the timber sale data was queried from various sources, the criteria implemented during the selection process differed slightly for the private MFL sales.

State and County

Timber harvest data was queried from the WDNR WisFIRS forest data management system. WDNR staff provided WisFIRS data filtered according to the following criteria: individual stand polygons that had a sale status of X (established) or A (sold), a sale establishment date after January 1, 2010, a timber sale sold date after January 1, 2013, and, finally, filtered by the study region, which included the following counties in Wisconsin: Forest, Iron, Langlade, Lincoln, Marathon, Oneida, Price, Rusk, Sawyer, Taylor, and Vilas. A goal of ten sample sites per ownership was set for the study.

County and state data was separated into individual databases for identifying sales from each ownership. Timber sale data was then filtered by stand characteristics, with the selected stands meeting the following criteria:

- Sawtimber-sized northern hardwood stands, which included the 11- to 15-inch, and over 15-inch size class
- A minimum timber sale size of 15 acres
- This second filter revised the original date to include sales sold on or after June 1, 2013

The last stand characteristic used as a filter was stand prefix, which related to management objective and the planned harvest approach. Prefixes that limited timber harvest operations required harvest alternatives that would impact the application of the OOR, or required the retention of high BA levels were excluded from the study. The following prefix codes were excluded from the final selection database.

- A = Aesthetic Zone
- B = Fuel Breaks
- C = Extended Rotation
- D = Deer Yard
- E = Erodible Soils
- F = Filter Strip or riparian stands

The WDNR also provided form number 2460, which further described each site's management objectives and prescriptions. Following the timber sale filter process, each site was assigned a random number, then ordered from smallest to largest.

Private MFL

The private MFL ownership was broken up into two distinct groups. For the purpose of this report, we refer to private groups as large private and small private. An allocation between the two groups was based on the percentage of acreage both sites contributed to the entire private MFL ownership bucket. Our analysis resulted in the installation of eight sample sites on small private (roughly 80 percent of the total MFL acreage) and two sample sites on large private ownership.

Small Private

We developed the small private MFL database using an MFL output from WisFIRS. In a similar procedure used to filter the county and state forests timber sale data, the small private MFL database was condensed to include only sawtimber-size classes within the northern hardwood forest type. All other filters outlined in the state and county summary above were applied to this group. In addition, we ensured that the potential sites had an MFL cutting notice approved and may have been flagged for a stand where management services were accepted. Once again, the study area was set to include Forest, Iron, Langlade, Lincoln, Marathon, Oneida, Price, Rusk, Sawyer, Taylor, and Vilas Counties.

Following random number sequencing, additional timber sale data was requested from the local WDNR foresters that managed the MFL order accounts. MFL plans, MFL cutting notices, and MFL enrollment maps were requested during this effort. The MFL order documents allowed for an assessment of adherence to the standard order of removal procedure, verification of harvest status, and identification of whether the timber sale establishment was complete. This data also provided landowner contact information so permission to access the site could be requested. If a sale met all of these conditions, the selection of sites commenced via moving down the final database organized by random number, sorted from smallest to largest.

Large Private

WDNR large block MFL program managers provided Steigerwaldt cutting notice forms and a list of harvests. Since large private owners are not required to provide stand level information, data from these MFL orders is not entered into the WisFIRS system. This data did not include the specific prefix and stand level data provided for county, state, and small private sales, so additional data from the landowners or managers was required to ensure the sales met our study criteria.

In the case of all ownership groups, correspondence with landowners and forest managers was necessary during the verification of the final selection to ensure all selected timber sales were still available and harvesting activity would not limit sampling.

2.1.2.2.2 Data Collection

The selected timber sales for the state, county, and private MFL analysis included a sample set using two methods of data collection. A total of ten timber sales were selected in each ownership group. We used multi-radial fixed plots, which included a 1/5th acre sawtimber only plot, a nested 1/10th acre all-merchantable timber plot, and nested 1/100th acre regeneration plot. A total of 240 plots were applied across the three ownership groups, at a rate of eight per stand. In addition, nine 1-acre plots (three per ownership) were established in each ownership group. Location of the multi-radial plots was determined using a systematic grid with a randomly chosen grid starting point within the chosen timber sales. Three sales from each landowner class were randomly selected to receive 1-acre plots. The location of these 1-acre plots was randomly allocated.

Recorded tree data at the plot level was identical as that measured in the Fred Luke Road timber sale approach. All merchantable tree data was recorded in the 1/10th acre plot, while only trees 11.6 inches DBH and larger were recorded in the 1/5th acre plot. Refer to state, county, and private MFL fieldwork scope for more details (Exhibit 1).

2.1.3 Forest Plot Data Processing

The OOR Analysis and the Native Community Analysis inventory data were managed as two separate datasets. Data from each inventory was managed and processed using TCruise. TCruise is a robust timber volume generating software package that uses tree attributes, species, DBH, and product height to calculate volume using a custom process integrating form class and profile functions. This software package also served as a field plot data entry platform for collecting tree measurements and qualitative data (i.e. GS

classification). After plot processing was completed with TCruise, the data was output in tabular form for further evaluation and modeling.
For the Native Community Analysis, data collected on the 74 1/16th acre plots were analyzed using the TCruise volume calculation software. TCruise created an output table that included attribute data and calculated volumes. Tree volumes were summarized by grade and plot level volume. Final volume tables were developed by joining to the qualitative data used for our alternate harvest scenarios.

The Statewide OOR Analysis data was processed differently as the plots were set up in a multi-radial fashion, including a 1/5th acre sawtimber plot and 1/10th acre pulpwood plot. The process first expanded tree data in sawtimber-sized trees (12-inch DBH class and greater) by five, and all pulpwood trees (5- to 11-inch DBH class) by a factor of 10. The output tables for the plots were joined with the tree characteristics tables, and plot data by ownership was combined into one master table. The 1-acre visualization plot data was handled in a similar manner.

Stand visualization products utilized the individual tree location data collected during the inventory process. Tree locales were measured for all Native Community plots and the Statewide OOR Analysis 1-acre plots. Principal points and tree bearings were used to establish tree locations in the field, and this data was later corrected in the GIS to develop tree locations. The tree data was joined to the GIS attribute table, and tree images were sized by tree characteristics. This process allowed harvest scenarios to be replicated and viewed in a 3D space. The cut and leave status of the existing harvests and each alternative scenario was loaded into the GIS by individual tree. A grid of 64 Native Community plots were randomly selected and arranged to develop a 4-acre mosaic.

2.1.3.1 Statistical Analysis

The residual BA of the established harvests on the state, county, and private MFL OOR sites was evaluated using statistical tests. Our null hypothesis was no difference in residual BA across the three ownership groups. We considered each stand as an observation, estimated stand level statistics based on a rollup of eight plots. We used an ANOVA test to test for differences in variables among the three ownership groups (independent variable).

2.1.4 Modeling Scenarios

2.1.4.1 Alternative Marketing Scenarios

The alternative harvest selections were developed by study dataset: Native Community Analysis and Statewide OOR Analysis. We applied the alternative marking analysis in the nine 1-acre plots (three plots per landowner class: county, private, and state) for the Statewide OOR Analysis. By using the 1-acre plot data, we had the option to display the tree data visually as all trees were tied to a GPS location. Using the 1-acre plots provided a total sample size of 1,752 trees, which provided a robust sample for the comparative modeling. For the Native Community Analysis, we applied them to the 74, 1/16th-acre plots within the Northern Highland American Legion State Forest.

Two alternative selection scenarios were applied to each study. Each alternative marking scenario was primarily defined by maximum tree size and residual BA. These approaches are presented below.

- Scenario 1: Maximum tree size = 17 inches DBH. Residual BA of 75 ft.^{2}.
- Scenario 2: Maximum tree size =19 inches DBH. Residual BA of 82 ft.^{2}.

The cut versus leave designations were determined using a tree selection model built in Microsoft Excel. Trees were prioritized for harvest based on three indices: removing risk (Index 1), harvesting mature (Index 2), and releasing crop trees (Index 3), and were applied in this order of priority. Each index had an associated formula to determine the tree's ranking, which was independently applied to each tree. Trees that received higher ratings were prioritized for harvest first. Selection was determined between trees of equal rating using the random number applied to each tree.

In the selection model, a proportion of total BA to be harvested (current BA minus residual) was assigned to each rule. The following describes the criteria for each index.

Index 1: Remove Risk – 60 to 65 Percent of the Harvest BA
Index 1 was the first selection applied to the trees and accounted for the largest portion of the harvest, ranging from 60 to 65 percent in the models. The model first prioritized trees of high risk as those assigned the poorer GS ratings. The GS classification ranked trees on a scale of 1 to 5, with 5 being the poorest. The formula written for this index had three parts:

1. One point of weight was given to a tree equal to growing stock rating.
2. An additional point was given to the tree if it was 11 to 17 inches DBH for Scenario 1 or 11 to 19 inches DBH for Scenario 2 and was GS 4 or 5. This size class was chosen to focus on poor quality sawtimber-sized trees under the size classes affected by Index 2 (harvest mature).
3. Two additional points were assigned if the tree was 14 to 17 inches DBH for Scenario 1 or 14 to 19 inches DBH for Scenario 2, and had a GS of 3, 4, or 5. This prioritized the mid- to low-quality sawtimber in the mid-saw diameter classes, as these trees are reaching maximum economic maturity.

Index 2: Harvest Mature – 25 Percent of the Harvest BA
Index 2 only applied to trees greater than or equal to 17 inches DBH in Scenario 1 and trees greater than or equal to 19 inches DBH in Scenario 2. This index prioritized trees for harvest that are poor growing stock or the highest GS classes. This allowed us to continue removing risky poor quality trees, while also harvesting the fully mature highest quality trees. It also prioritized trees that have a canopy position of anything less than the dominant position. This index left trees greater than the mature size limit that had a growing stock ranked as desirable (GS 2). The formula for Index 2 had two parts:

1. Trees >= 17 inches DBH for Scenario 1 and >=-19 inches DBH for Scenario 2 received one point if they are a growing stock 1 (Exceptional), 3 (Acceptable), 4 (Undesirable), or 5 (Unacceptable).
2. Trees >= 17 inches DBH for Scenario 1 and >= 19-inches DBH for Scenario 2 with a canopy position of anything less than dominant received a point.

Index 3: Release Crop Trees – 10 to 15 Percent of the Harvest BA
The last index focused on releasing crop trees. During the inventory, cruisers recorded information about each tree, such as nearest neighboring tree and a tree's order of removal. Index 3 focused on removing trees that had an order of removal recorded as the "Release Crop Tree" or "High Risk" in the OOR tree classification assessment. It also prioritized suppressed trees and intermediate trees, trees with another tree close by, and trees with an undesirable or unacceptable growing stock rating. This rule had four parts.

1. Two points were given to trees with an order of removal of either "Release Crop Tree" or "High Risk."
2. One point was given to trees with a canopy position of either overtopped or intermediate.
3. One point was given to trees with a nearest neighbor rating of either multi-stem or 0 to 10 feet from nearest neighbor.
4. One point was given to trees with a GS 4 (undesirable) or 5 (unacceptable).

The model rules determined which trees had priority for harvest. The model first ordered the trees by the ranking Index 1 (Removing Risk) and secondarily by their random number. The model worked down the tree list, changing each tree's harvest designation to cut until it reached the maximum allowable cut for Index 1 (60 to 65 percent of the BA to be harvested). The second step was to order the tree list by their ranking determined by Index 2 (Harvest Mature), followed by their Index 1 ranking, and then their random number. The model once again worked down the tree list, designating trees to cut until it reached the target residual BA.

Trees selected for harvest already by Index 1 were excluded from the Index 2 cut/leave determination. Finally, trees were ordered by Index 3 (Release Crop Trees), followed by Indices 2 and 1, and then their random number. The model once again selected trees to harvest until it reached the BA limit. The master table then read the final selection from the model.

A sensitivity analysis was performed to assess how changes in the percentage of BA harvested from each index affected the "cut" value. Our model bounds were set by determining the percentage of poor GS class trees in the Fred Luke Road sale area. GS 4 and 5 class trees accounted for about 67 percent of the total stand stocking. Since our model was focused on removing poor quality trees, this percent was selected as the Index 1 base model setting. The sensitivity analysis model performed ran 20 percent above and below the base setting for Index 1. The Index 2 and 3 base model settings were set as follows; Index 2 – removed the majority or 60 percent of the remaining BA (20 percent), Index 3 – removed the remaining 40 percent of the BA (13 percent). The results of the test are presented in the following table (Table 2).

Table 2 – Native Community Analysis:
Fred Luke Timber Sale Model Sensitivity Analysis

Index 1 Sensitivity Test					
		Scenario 1		Scenario 2	
	20 Percent Bound	Value/Acre	BA/Acre	Value/Acre	BA/Acre
Upper	80	$802.87	40.09	$741.00	34.64
Mid	67	$701.88	33.29	$621.98	29.06
Lower	53	$539.47	26.46	$469.47	23.18
Index 2 Sensitivity Test					
		Scenario 1		Scenario 2	
	20 Percent Bound	Value/Acre	BA/Acre	Value/Acre	BA/Acre
Upper	12	$146.97	5.55	$112.94	4.91
Mid	20	$238.50	9.47	$323.15	8.44
Lower	28	$442.07	13.80	$409.13	11.68
Index 3 Sensitivity Test					
		Scenario 1		Scenario 2	
	20 Percent Bound	Value/Acre	BA/Acre	Value/Acre	BA/Acre
Upper	8	$ 53.71	3.95	$ 46.35	3.10
Mid	13	$ 99.32	5.97	$ 67.94	5.60
Lower	19	$213.95	9.52	$158.12	8.16
Totals					
		Scenario 1		Scenario 2	
		Value/Acre	BA/Acre	Value/Acre	BA/Acre
Upper	-	$1,003.54	49.60	$ 900.29	42.65
Mid	-	$1,039.70	48.72	$1,013.06	43.10
Lower	-	$1,195.49	49.77	$1,036.72	43.01

In the sensitivity tests, the upper and lower bounds of total value differed by 19.13 percent for the Scenario 1 model and by 15.15 percent for Scenario 2. With the Scenario 1 model, there was only a 3.48 percent difference between the mid and upper bound and a 14.98 percent difference between the mid and lower bound. The percent difference around the base (mid) settings for Scenario 2 differed, as there is an 11.13 percent difference between the mid and upper bound and a 2.33 percent difference between the mid and lower bound. The final settings for the models are presented below.

Scenario 1

- Index 1 = 60 percent
- Index 2 = 25 percent
- Index 3 = 15 percent

Scenario 2

- Index 1 = 60 percent
- Index 2 = 25 percent
- Index 3 = 15 percent

The settings chosen for the models fell between the mid and lower bounds of the sensitivity analysis. Harvest priority for mature timber was key to the silvicultural approach, so the model was set to include a larger removal percentage for Index 2 (25 percent). In an effort to keep the removal ratio for high risk similar to the conditions of the forest, 60 percent was chosen for Index 1, and the remaining percent for Index 3 fell near the mid value of the test and was set to 15 percent.

2.1.5 Economic and Ecological Analysis

We compared pre- and post-harvest timber value for the existing and alternative harvest scenarios. Timber value was set using the winning bid and contracted product rates by species and product. Boltwood and veneer volumes used the poletimber and sawtimber rates. When the alternative scenario model selected tree species for harvest that were not included in the existing marking for the Fred Luke Road timber sale, stumpage values from similar species were applied.

The average stumpage values applied to the OOR Analysis were weighted average winning bid results from the spring 2014 county forest bid openings from the following counties; Forest, Iron, Langlade, Lincoln, Marathon, Oneida, Price, Sawyer, Taylor, and Vilas.

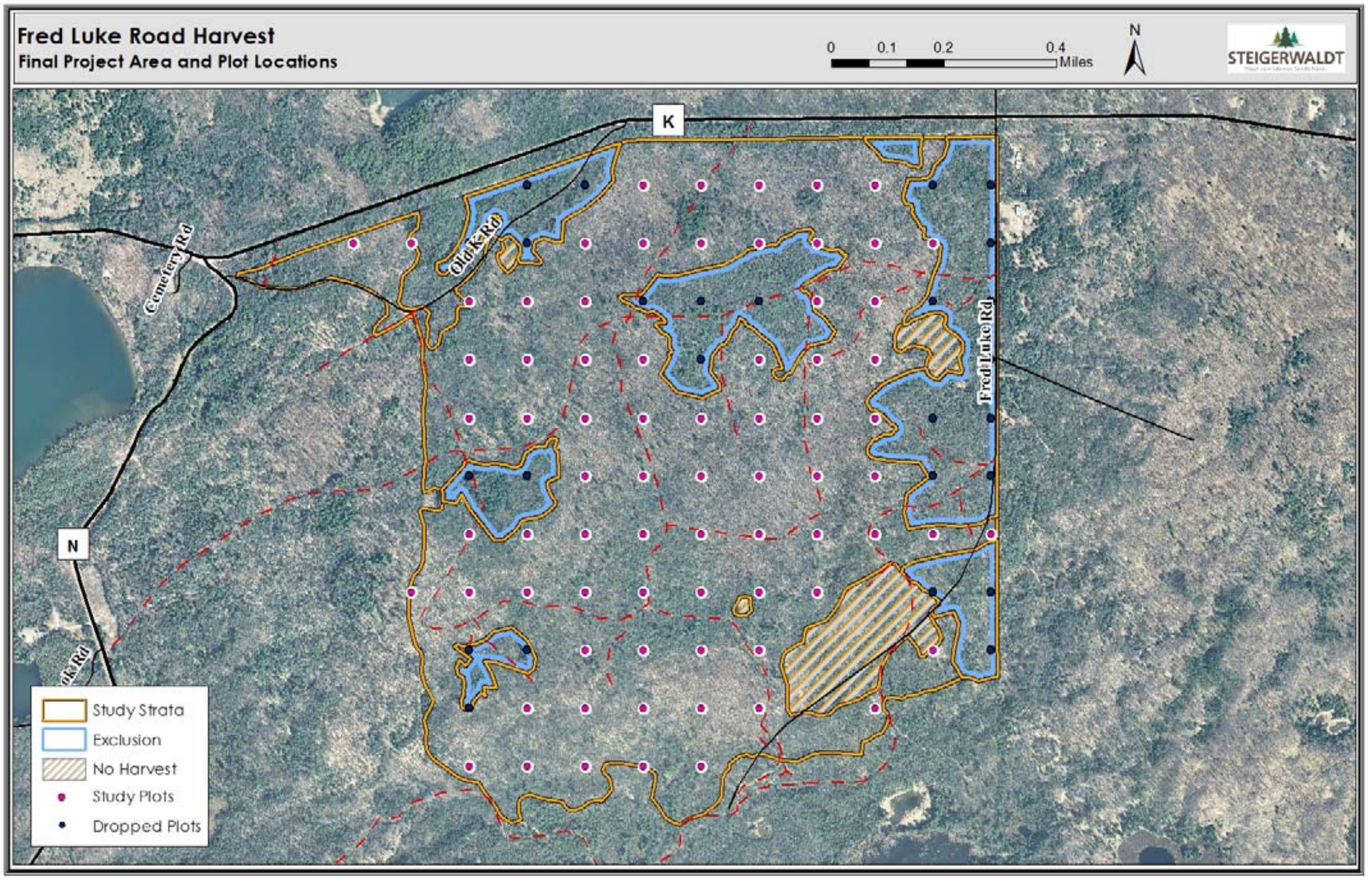
Rates of value growth (RVG) for hard maple sawtimber-sized trees were adopted from Webster et al. (2007) and used to evaluate the future value potential of the post-harvest conditions. The RVG values from the Webster, et al. study were applied to all sawtimber-sized hard maple inventory trees (site index 60). Assumptions were applied to the trees based on GS class and size class. All hard maple trees 13 inches DBH and greater that did not have sawtimber volume were applied a negative growth rate, representing a decrease in tree grade (Grade 1 dropping to Grade 2).

2.2 Results

2.2.1 Native Community Analysis

As outlined in section 2.1.2.1.1, 74 of the 100 plots installed and measured on the Fred Luke Road timber sale were included in the final analysis. Due to the large size of this timber sale, many inclusions of fir/spruce, aspen, and birch-dominated forest occurred throughout the sale area. Plots were excluded from the study in a two-stage approach. The final study area was initially identified using leaf-off 2010 aerial imagery, where plots in areas dominated by conifers were selected. Plots were removed from the final study strata if they occurred in areas identified in the spatial analysis, had a low stocking of hard maple and other common northern hardwood associated species, or were generally dominated by balsam fir and aspen. Within the area excluded from the study, approximately 45 percent of the plot stocking was balsam fir and aspen. The final Fred Luke Road sale study area totaled approximately 529 acres. Figure 2 displays the final study strata within the Fred Luke Road timber sale.

Figure 2 – Native Community Analysis: Fred Luke Road Timber Sale Study Strata and Plot Allocation



2.2.1.1 Cut and Leave Tree Summary

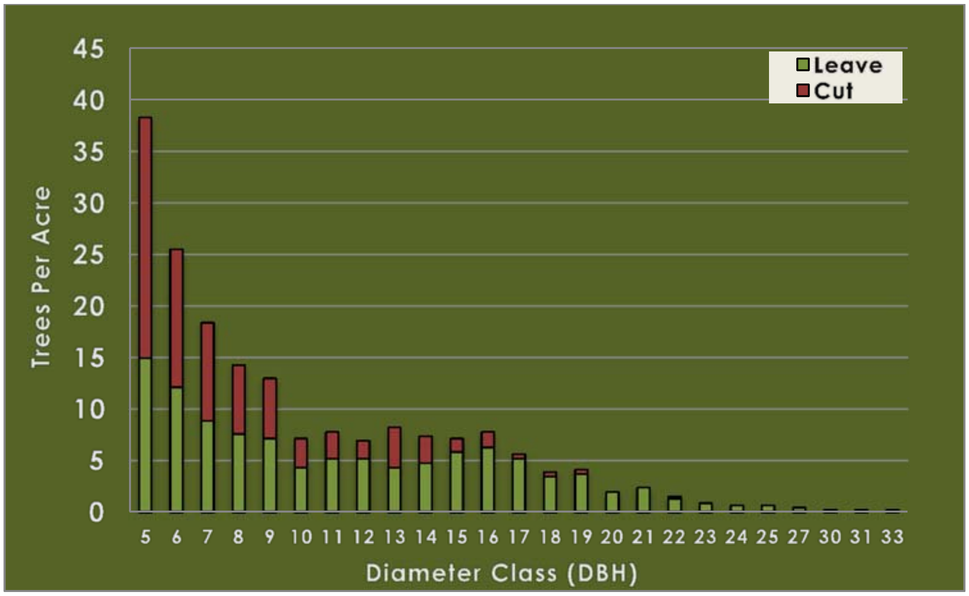
The 74 study plots resulted in an average total stand stocking of 125.1 ft.^{2} (or approximately 125 ft.^{2}) per acre of BA. At the 95 percent confidence level, stand stocking was 114.7 to 135.5 ft.^{2} per acre (Table 3).

Table 3 – Native Community Analysis:
Total Stand Stocking Statistics

Fred Luke Road Harvest Descriptive Statistics (Basal Area – ft.^{2} per acre)	
No. of Plots	74
Mean	125.10
Standard Error	5.20
Standard Deviation	44.76
Sample Variance	2,003.69
Confidence Level (95 percent)	10.37

Based on existing marking, approximately 31 ft.^{2} per acre was designated for harvest, while residual BA was approximately 94 ft.^{2} per acre. Figure 3 displays the distribution of trees by diameter class and harvest designation in the existing sale.

Figure 3 – Native Community Analysis: Existing Selection –
Harvest Distribution by Diameter Class (TPA)



The distribution of size classes in the existing sale generally followed a rotated sigmoid curve shape. Distribution curves with this shape are common in northern hardwood forests of Wisconsin and Upper Peninsula of Michigan. The Fred Luke Road study area was somewhat deficient in the 10- to 12-inch DBH classes, while larger sawtimber-sized classes were represented and generally adequate in stocking (Figure 3). The decrease in stocking within the 10- to 12-inch DBH classes may have been due to competition for light in this stand. Although mortality typically decreases as trees grow through these size classes, long-term suppression may have weakened these diameter classes. Further, many trees could have been the same age as the larger size classes, so the 10- to 12-inch DBH trees may have represented the poor performers in a stand with a one- or two-aged structure. Tree age was not sampled, so stand age structure is unknown.

Table 4 displays further summarizes stocking by size class.

Table 4 – Native Community Analysis:
Diameter Distribution by Cut and Leave Status (TPA)

Trees Per Acre by DBH				
DBH	**Cut**	**Leave**	**Percent Cut**	**Percent Leave**
5	23.35	14.92	61	39
6	13.41	12.11	53	47
7	9.51	8.86	52	48
8	6.70	7.57	47	53
9	5.84	7.14	45	55
10	2.81	4.32	39	61
11	2.59	5.19	33	67
12	1.73	5.19	25	75
13	3.89	4.32	47	53
14	2.59	4.76	35	65
15	1.30	5.84	18	82
16	1.51	6.27	19	81
17	0.43	5.19	8	92
18	0.43	3.46	11	89
19	0.43	3.68	11	89
20	0.00	1.95	0	100
21	0.00	2.38	0	100
22	0.22	1.30	14	86
23	0.00	0.86	0	100
24	0.00	0.65	0	100
25	0.00	0.65	0	100
27	0.00	0.43	0	100
30	0.00	0.22	0	100
31	0.00	0.22	0	100
33	0.00	0.22	0	100

Pre-harvest stand structure was approaching Agrogast's desirable stand structure. The desired stand conditions to facilitate continuous growth are as follows: 5 to 10 inches DBH = 72 trees per acre (TPA), 11 to 15 inches DBH = 25 TPA, 16 to 20 inches DBH = 15 TPA, and 21 inches DBH and greater = 6 trees per acre (Arbogast, 1957). Compared to Arbogast, the residual Fred Luke forest has lower residual TPA in the poletimber classes, but has comparable TPA in the larger size classes following the harvest (Table 5).

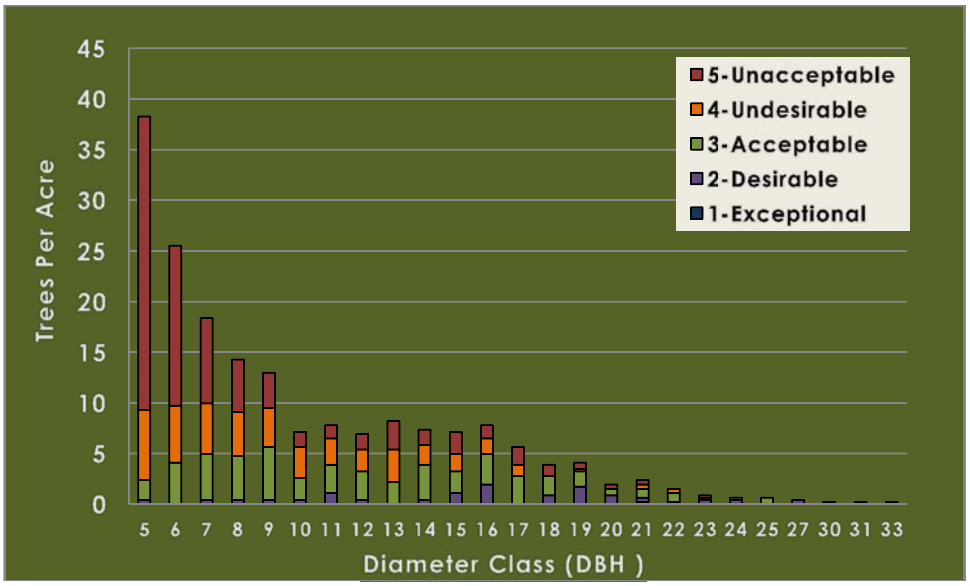
Table 5 – Native Community Analysis: Diameter Groups
by Cut and Leave Status (TPA)

Cut and Leave Trees per Acre by DBH Class				
	5 to 10 inch	**11 to 15 inch**	**16 to 20 inch**	**21+ inch**
Cut	61.62	12.11	2.81	0.22
Leave	54.92	25.30	20.54	6.92

Analysis of the existing stand structure reveals that much of the tree removal would occur in the poletimber-size classes (5 to 10 inches DBH). As expected, trees marked for removal decrease with increasing tree size, with about three percent of the trees 21 inches DBH and greater selected for harvest, compared to over 50 percent of the trees in the 5- to 10-inch DBH classes. We discuss stand structure in the following sections, primarily in the context of tree quality and cut versus leave stocking (Table 5).

Tree quality was defined in this study by a 5-class GS rating system. The growing stock designations suggest that a higher ratio of poor quality trees (GS 4 and 5) occurred in the small diameter classes. Approximately 94 percent of trees in the 5-inch DBH class had a GS class of Undesirable (4) or worse. The poletimber-size classes (5 to 10 inch DBH) had the highest ratio of poor growing stock, with approximately 73 percent of stocking considered Undesirable (4) or worse. Only 21 percent of stocking in the larger size classes (21 inches DBH and larger) was considered poor quality (GS 4 and 5). The best growing stock (GS 1 and 2) occurred in the larger size classes; with the best quality found in the 33-, 27-, 24-, 23-, 21-, 20-, 19-, and 16-inch DBH class. The 33- and 27-inch DBH classes were 100 percent Exceptional (1) and Desirable (2) quality trees (Figure 4).

Figure 4 – Native Community Analysis:
Diameter Distribution by Growing Stock Classification (TPA)



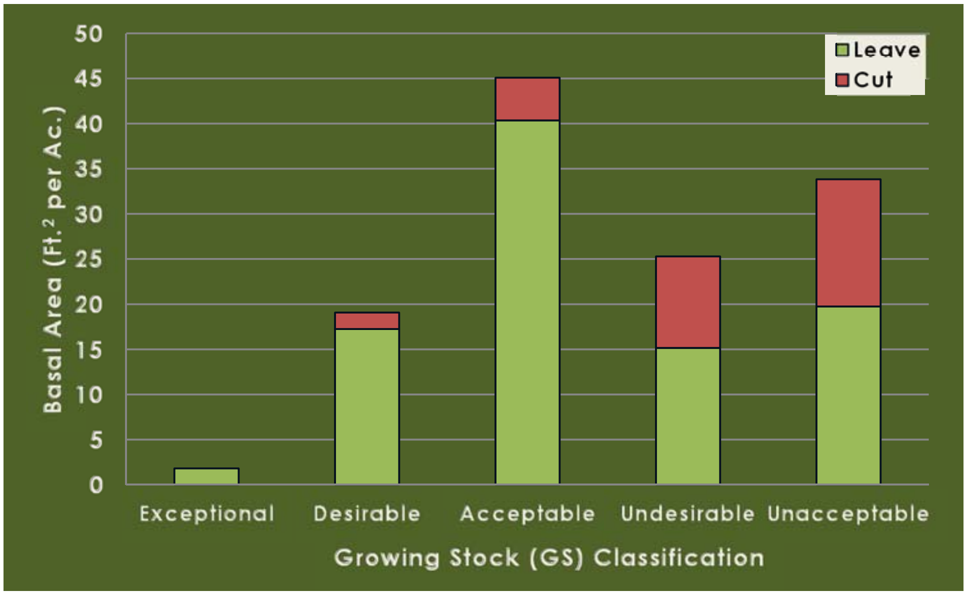
The small sawtimber-size classes, generally ranging from 11 to 13 inches DBH, were primarily composed of poor quality timber. About three-quarters of growing stock in the 13-inch DBH class was considered Undesirable (4) and Unacceptable (5). As stated earlier, these DBH classes were understocked and may be suppressed, as evidenced by their lower GS value.

Based on the harvest ratio by GS class, poorer quality growing stock was selected for harvest. Of Unacceptable class trees, 61 percent were selected for harvest, no Exceptional trees were designated, and only 10 percent of the Desirable trees were selected (Table 6). Much of the BA also would be removed from these lower quality GS designations providing further evidence that poor quality and unacceptable trees were selected for harvest (Figure 5).

Table 6 – Native Community Analysis:
Growing Stock Category by Cut and Leave Status (TPA)

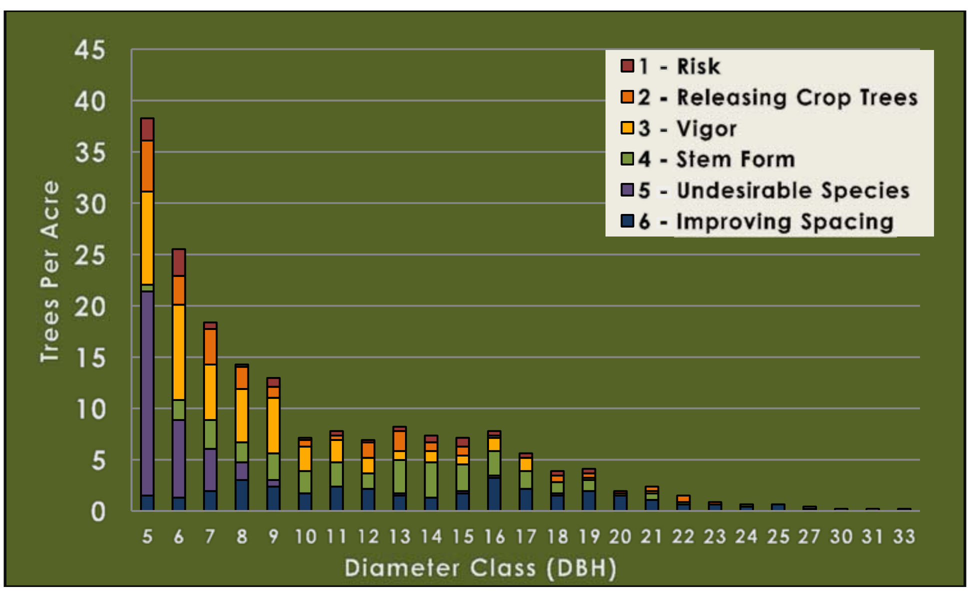
Trees Per Acre by Growing Stock		
Tree Category	**Percent Cut**	**Percent Leave**
Exceptional	0	100
Desirable	10	90
Acceptable	19	81
Undesirable	42	58
Unacceptable	61	39

Figure 5 – Native Community Analysis:
Existing Selection Harvest Distribution by Growing Stock Classification (BA)



Following the WDNR OOR, most trees in smaller size classes were coded as Risk (1), Releasing Crop Trees (2), Vigor (3), and Undesirable Species (5). The 5-inch DBH class was dominated by Undesirable Species (5), and trees designated as such decrease considerably with increasing diameter class. Few trees 10 inches DBH and larger were Undesirable Species (5). Many smaller trees designated as Undesirable Species (5) were balsam fir, birch, and aspen, which were species selected for harvest in the Fred Luke Road timber harvest prescription (Figure 6).

Figure 6 – Native Community Analysis:
WDNR OOR Tree Classification by Diameter Class (TPA)



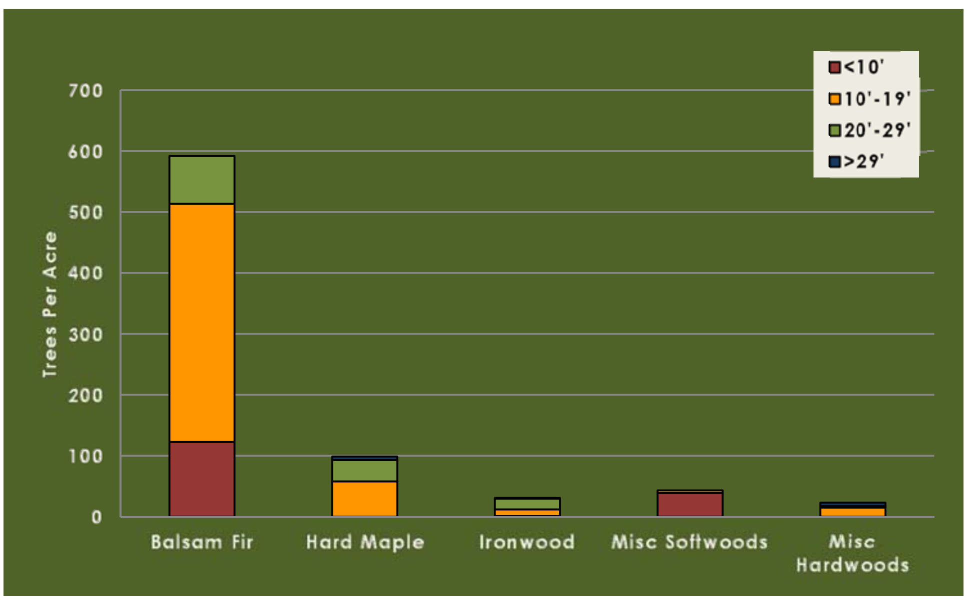
Trees marked for harvest were predominantly in the 5, 1, and 3 tree class categories (Table 7). These categories generally represented poor quality trees and species that needed removal to meet silvicultural goals. In practice, removal of trees in descending order of OOR category is required to follow the WDNR silvicultural principles.

Table 7 – Native Community Analysis:
OOR Tree Classification by Cut and Leave Status (TPA)

Order Of Removal		
Tree Category	**Percent Cut**	**Percent Leave**
1 - Risk	46	54
2 - Releasing Crop Trees	37	63
3 - Vigor	42	58
4 - Stem Form	27	73
5 - Undesirable Species	88	12
6 - Improve Spacing	10	90

Trees smaller than 5 inches DBH (regeneration) were recorded in nested 1/100th acre plots. Regeneration stocking averaged 788 TPA with nearly 600 TPA of balsam fir, or 76 percent, of the total regeneration stocking. Only 122 TPA were hard maple and other hardwood species, or only about 15 percent, of regeneration stocking. All hard maple regeneration was 10 feet tall or and taller. Younger trees less than 10 feet were nearly absent in the study area (Figure 7). For comparison, the 5-inch merchantable size class was only 38 percent hard maple.

Figure 7 – Native Community Analysis:
Pre-Harvest Regeneration by Species and Average Total Height



We estimated harvest value using all trees marked or otherwise designated for harvest per the timber sale prescription (Table 8). A total of 8,235 tons, or 15.6 tons per acre of pulpwood, and 314.7 MBF or 0.595 MBF per acre, were selected for harvest (Table 8). The harvest value averaged $529.40 per acre over the 529-acre study area. Mixed hardwood poletimber and hard maple sawtimber comprise the majority of the value (Table 8).

Table 8 – Native Community Analysis: Existing Harvest Value
by Species and Product Using Fred Luke Road Timber Sale Bid Results

Poletimber (Pulpwood and Boltwood)				
	Ton/Acre	Total Tons	$/Ton	Total Value
Mixed Hardwood	12.52	6,629	$17.19	$ 113,960.94
Fir	1.63	861	$ 5.65	$ 4,862.61
Oak	0.76	401	$13.91	$ 5,573.73
Basswood	0.35	183	$ 4.40	$ 804.82
Aspen	0.26	140	$18.43	$ 2,582.98
Spruce	0.03	14	$11.95	$ 169.60
White Pine	0.01	6	$11.95	$ 77.44
Total	15.56	8,235		$128,032.11
Grade Sawtimber and Veneer				
	MBF/Acre	Total MBF	$/MBF	Total Value
Hard Maple	0.36	193.04	$604.00	$116,593.44
Red Oak	0.09	47.17	$539.00	$ 25,426.53
Basswood	0.09	46.21	$402.00	$ 18,576.99
Mixed Hardwood	0.05	25.53	$402.00	$ 10,264.54
White Pine	0.01	2.79	$150.00	$ 417.85
Total	0.59	314.74		$171,279.35
Grand Total				**$299,311.46**

2.2.1.2 Alternative Scenarios

The development and background of the alternative scenarios are presented in Section 2.1.4. The harvest model scenarios generally were as follows.

- Scenario 1: Maximum tree size equal to 17 inches DBH. Residual BA of 75 ft.^{2} per acre.
- Scenario 2: Maximum tree size equal to 19 inches DBH. Residual BA of 82 ft.^{2} per acre.

The maximum tree size criteria used for this study were similar to northern hardwood stands on the higher end of the site quality spectrum. Average to good sites typically produce trees that reach financial maturity around 16 to 17 inches DBH, as 16-inch DBH trees may meet prime veneer log specifications. As sites improve, larger trees can be retained and, as a result, the better sites can support stems in the 18- to 20-inch DBH range. Webster, Reed, Orr, Schmeirer, and Pickens (2009) found that, “trees on a high-quality site should be retained longer than trees on poorer sites.” These authors also suggested, “retaining grade 1 trees that increase to veneer grade regardless of DBH calls will yield between 5.1 and 7.8 percent RVG (rate of value growth) for 14- to 18-inch DBH trees on differing SQs (site index)…retaining 18-inch DBH veneer grade trees and letting them growing into the larger DBH classes on the higher-quality sites because the probability of degrading is low” (Webster, Reed, Orr, Schmeirer, and Pickens, 2009). Therefore, even on a conservative financial basis, trees 18 inches DBH and larger should only be retained on the best sites. The risk of holding these trees on poorer sites is not justified financially. Our study chose maximum tree diameters comparable to those on higher quality sites, selecting 17 inches DBH for average to good sites, and 19 inches DBH for the best sites.
Residual BA guidelines were paired with the maximum tree size criteria to mimic varying levels of harvest intensity and application of specific silvicultural goals. The minimum stocking criteria of 75 ft.^{2} BA per acre represented a residual stocking level that maximizes productivity and tree quality. Strong, et al. (1995) identified that 75 ft.^{2} BA per acre has a greater proportion of trees grade 1 than 60 ft.^{2} BA per acre treatments. Further works found that 75 ft.^{2} per acre treatments provided higher value from trees during harvests when compared to higher residual stocking levels (Niese, et al, 1995). The 75 ft.^{2} BA per acre residual stocking level

also provided an opportunity to remove larger trees, which occupy a larger percentage of BA in the stand, while still providing additional BA to achieve other silvicultural goals. In addition, the removal of dominant and/or larger canopy trees created more advantageous sunlight conditions throughout the stand for tree establishment, recruitment, and value growth.

The alternative marking scenario prescriptions are summarized below.

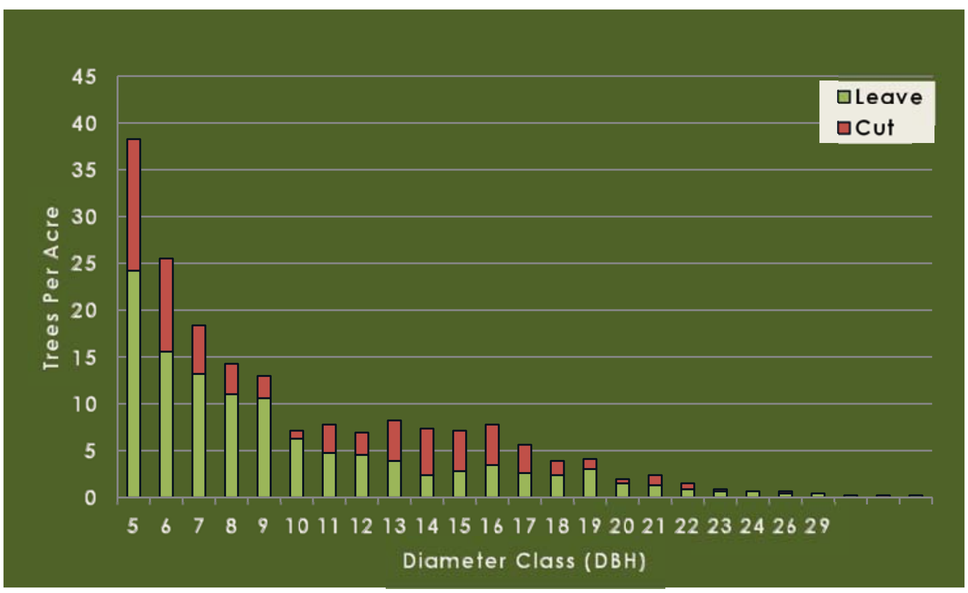
- Scenario 1: The model simulated uneven-aged single-tree selection on average to good sites using the maximum tree size diameter of 17 inches DBH. GS 1, 3, 4, and 5 trees 17 inches DBH and greater were given higher priority for removal, as poor growing stock was removed and the best trees were assumed to have reached financial maturity. As outlined in the methods section, the OOR for this scenario occurred in this order: removal risk, harvesting mature (17 inch DBH maximum tree size), and releasing crop trees. Residual stocking was set at a minimum of 75 ft.^{2} per acre to create increased sunlight conditions in the understory, mimicking the use of canopy gaps and the removal of larger financially mature timber.

- Scenario 2: This uneven-aged single-tree selection approach emulated management on the best sites using a maximum tree size diameter of 19 inches DBH. The removal of trees in the maximum tree size class and the OOR approach were conducted in the same manner as Scenario 1. This approach retained more sawtimber-sized trees and created more shaded understory conditions. Large trees that may have been financially mature were given priority for removal; however, the higher residual stocking level of 82 ft.^{2} BA per acre limited removals and, consequently, led to less volume of sawtimber harvested.

2.2.1.2.1 Analysis

The majority of the trees harvested occurred in the 5- to 7-inch DBH class and in the larger 13- to 16-inch DBH class (Figure 8). The 10- and 24-inch DBH class had the lowest ratio of "cut."

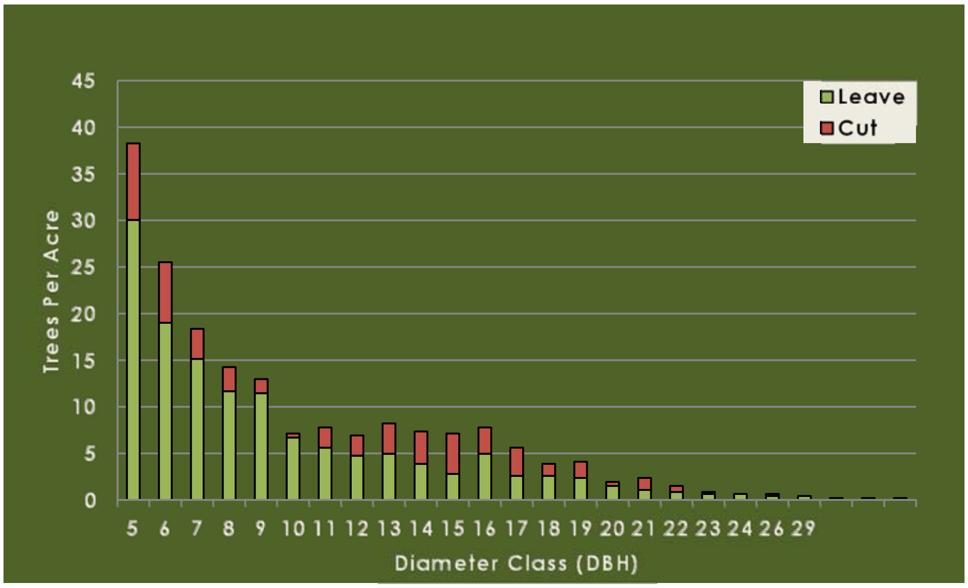
Figure 8 – Native Community Analysis: Scenario 1
Harvest Distribution by Diameter Class (TPA)



Compared to the existing marking on the Fred Luke Road timber sale, more stocking was removed with Scenario 1 in the mid to upper diameter classes, especially in the 14 inch DBH and greater size classes (Figure 8). Over three times as many trees were harvested in the 14-inch DBH and larger classes in Scenario 1(Figure 8).

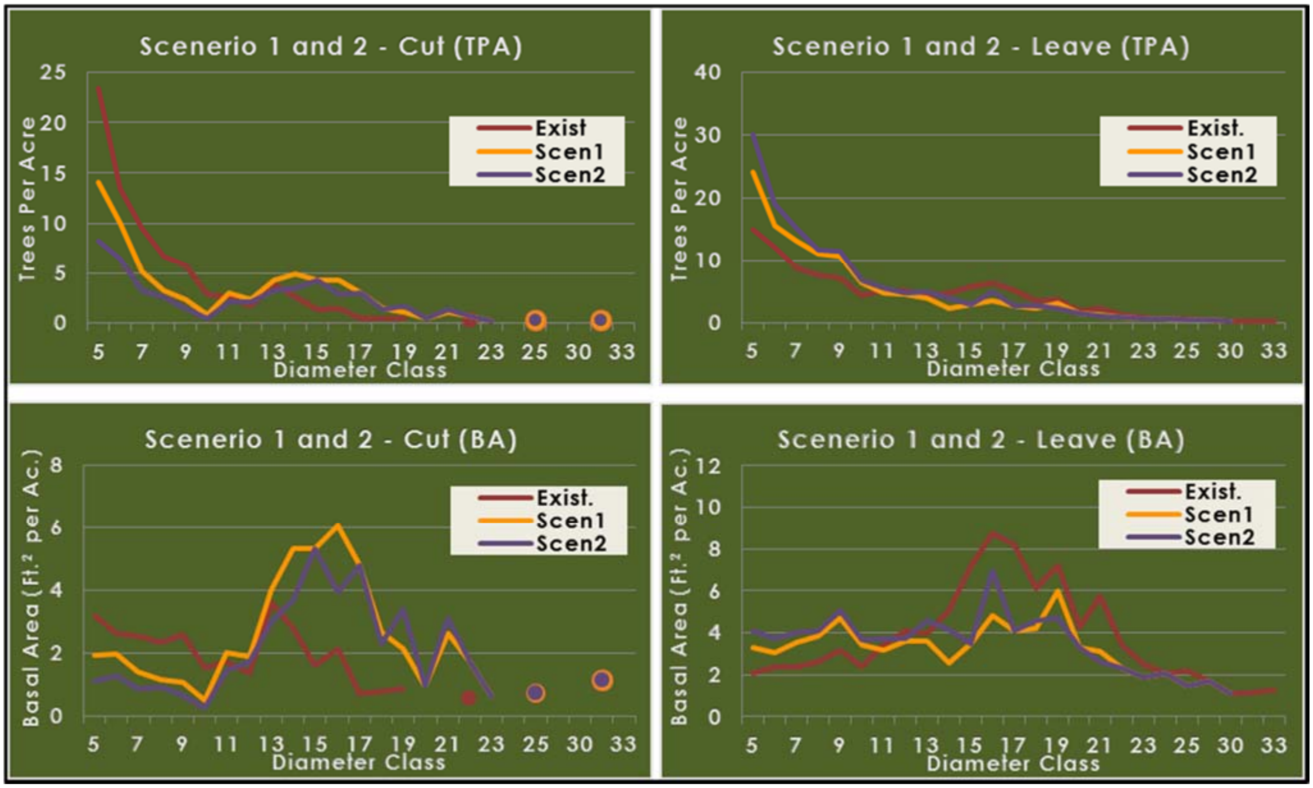
Scenario 2 removed trees in a pattern similar to that observed in Scenario 1; however, much less timber was removed from the smaller size classes. The primary reason that fewer trees were removed from the smaller size classes in Scenario 2 was the higher residual stocking threshold. Scenario 2 left a residual of 82.25 ft^2 BA per acre, compared to 94.3 ft^2 BA per acre with the existing harvest marking. A higher residual stocking level minimized harvest from Index 1(Remove Risk) and Index 3 (Release Crop Trees), which was where the small size classes were removed (Figure 9).

Figure 9 – Native Community Analysis:
Scenario 2 Harvest Distribution by Diameter Class (TPA)



Over twice as many trees were removed from the 5- to 10-inch DBH class in the existing Fred Luke Road timber sale when compared to the Scenario 2 model. The Scenario 2 model harvested much more timber in the larger size classes. The majority of the Scenario 2 harvest was from sawtimber size classes, and about 39 percent more BA was removed compared to the existing harvest (Figure 9). With the alternative scenarios, the majority of harvest occurred in the sawtimber-size classes (11-inches DBH class and larger) (Figure 10).

Figure 10 – Native Community Analysis: Existing Selection and Alternative Harvest Scenarios Comparison (BA and TPA)



The "cut" BA for the alternative scenarios deviated considerably from the existing cut (Figure 10). Scenario 1 produced a large increase in BA removed at the 14-inch DBH class, while Scenario 2 removed less BA with a peak in the 15-inch DBH class. The alternative scenarios retained more trees in the smaller size classes (Figure 10). Both alternative scenarios removed more TPA than in existing harvest beginning at the 12- and 13-inch DBH classes. The alternative scenario models produced a more pronounced reverse J-shaped curve structure as well. This occurred unintentionally as a result of our model first removing trees with poor GS classification, and because one-quarter of the harvest consisted of trees meeting the maximum tree size index (Index 2). Additionally, more BA was retained in the 14- to 19-inch DBH class in the existing selection. In size classes larger than 19 inches DBH, the alternative scenarios retained either a smaller or an equal number of trees in each size class compared to the existing selection (Figure 10).

Alternative scenario models produced harvest peaks in both BA and TPA removed at each maximum tree size criteria. For Scenario 1, a peak occurred at the 17-inch maximum DBH class, while a similar increase was noted for Scenario 2 at the 19-inch DBH class. Scenario 2 removed more BA from the 19-inch and larger diameter classes, because the Scenario 1 model considered a larger group of trees in the Index 2 harvest criteria. In addition, Scenario 2 retained higher stocking in the 16-inch DBH class than Scenario 1, because Index 1 prioritized poor GS trees greater than 11 inch DBH, but less than 17 inches DBH, while Scenario 2 prioritized poor GS trees greater than 11 inches DBH, but less than 19 inches DBH. Scenario 2 prioritized a larger range of size classes and removed less BA, so the model left more residual trees in this size class range.

The removal of trees by GS classification was similar in both alternative scenarios. More trees classified as Unacceptable and Undesirable were removed in both harvest models than in the existing marking. Removal of these poorest GS classes represented a 50 percent increase over the tree selection in these categories in the existing marking. Scenario 1 removed fewer trees classified as desirable, and neither removed trees rated as exceptional. Exceptional trees were prioritized for harvest by Index 2 (Remove Mature), but only a few exceptional trees were large enough to meet the preliminary model requirements (Figures 11 and 12).

Figure 11 – Native Community Analysis: Scenario 1
Harvest by Growing Stock Classification (BA)

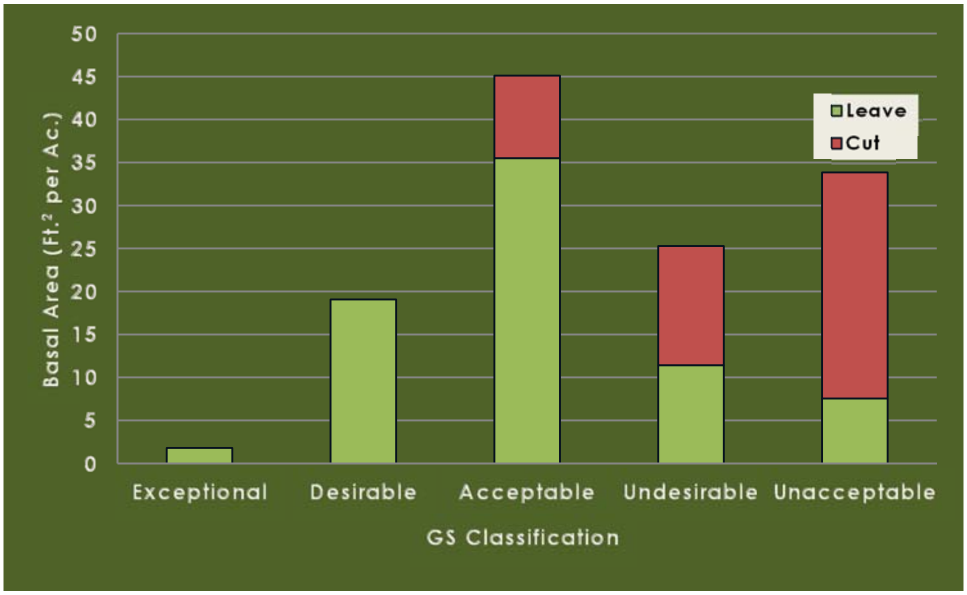


Figure 12 – Native Community Analysis:
Scenario 2 Harvest by Growing Stock Classification (BA)

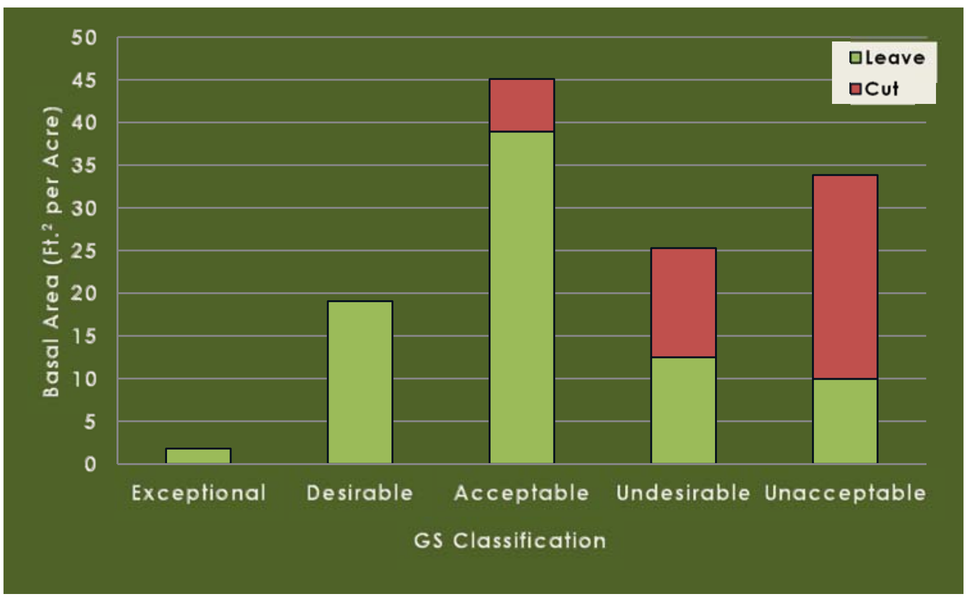


Exhibit 2 displays comparison figures for Tree Class 1 (OOR Classification), Tree Class 2 (Nearest Neighbor Classification), and Canopy Position. The alternative scenarios removed a greater percentage of BA from poor OOR Classification groups (Risk through Stem Form) relative to the existing marking. More BA was also removed from trees designated as Intermediate, Codominant, and Dominant, when compared to the existing Fred Luke Road timber sale. A smaller proportion of BA was removed from Overtopped trees, which is consistent with earlier findings that a higher percentage of small trees were selected for harvest in the existing harvest (Exhibit 2).

The following images display the existing, pre-harvest forest condition in the Fred Luke Road timber sale area, the post-harvest condition based on the existing marking, and the post-harvest alternative scenario conditions. These images are within the 64 plot matrix and provide a view west through the hypothetical stand arrangement. The pre-harvest conditions represent a forest that averages 125 ft.^{2} BA per acre, with the existing post-harvest condition totaling about 94 ft.^{2} BA per acre. The alternative scenario conditions are presented in the following sections (Figures 13 to 16).

Figure 13 – Native Community Analysis: Fred Luke Pre-Harvest Condition

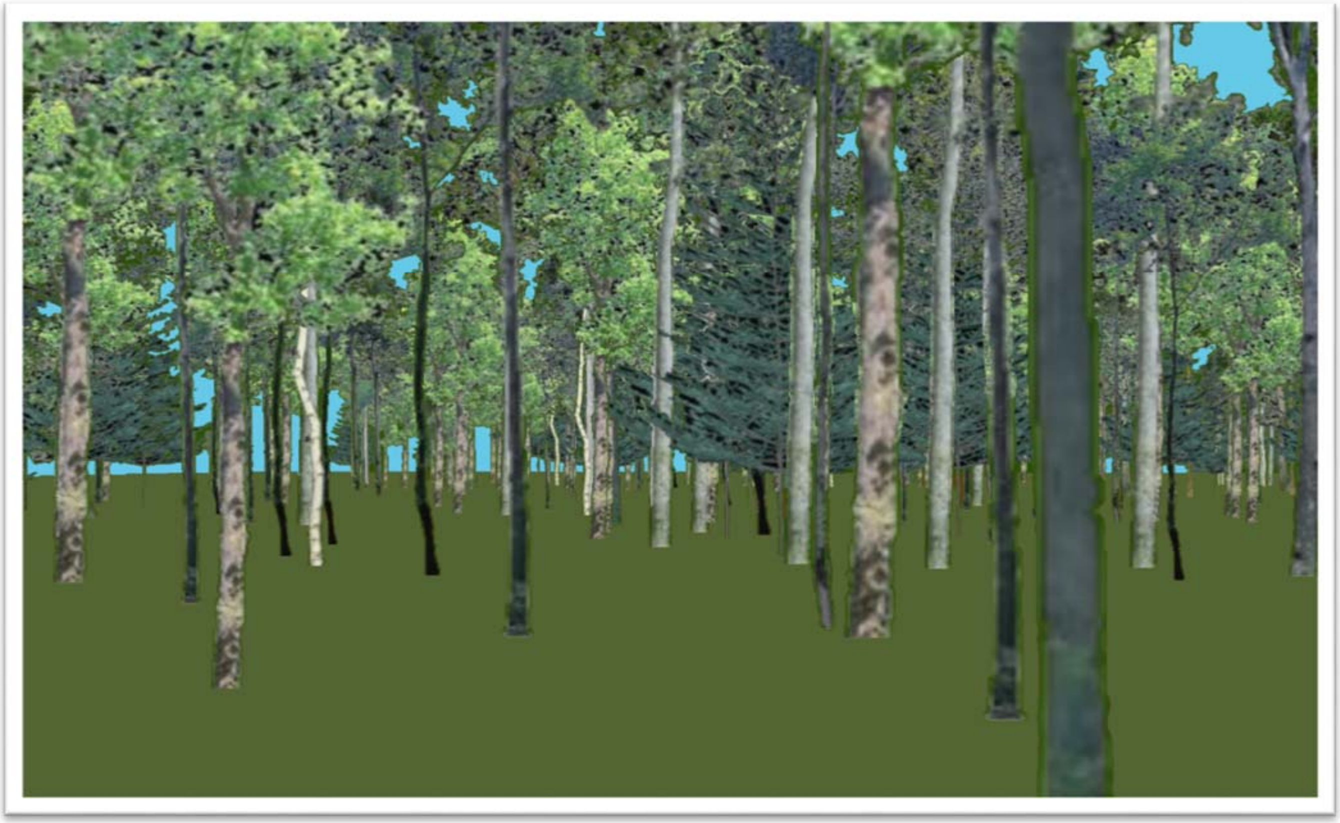


Figure 14 – Native Community Analysis: Fred Luke Post-Harvest Condition

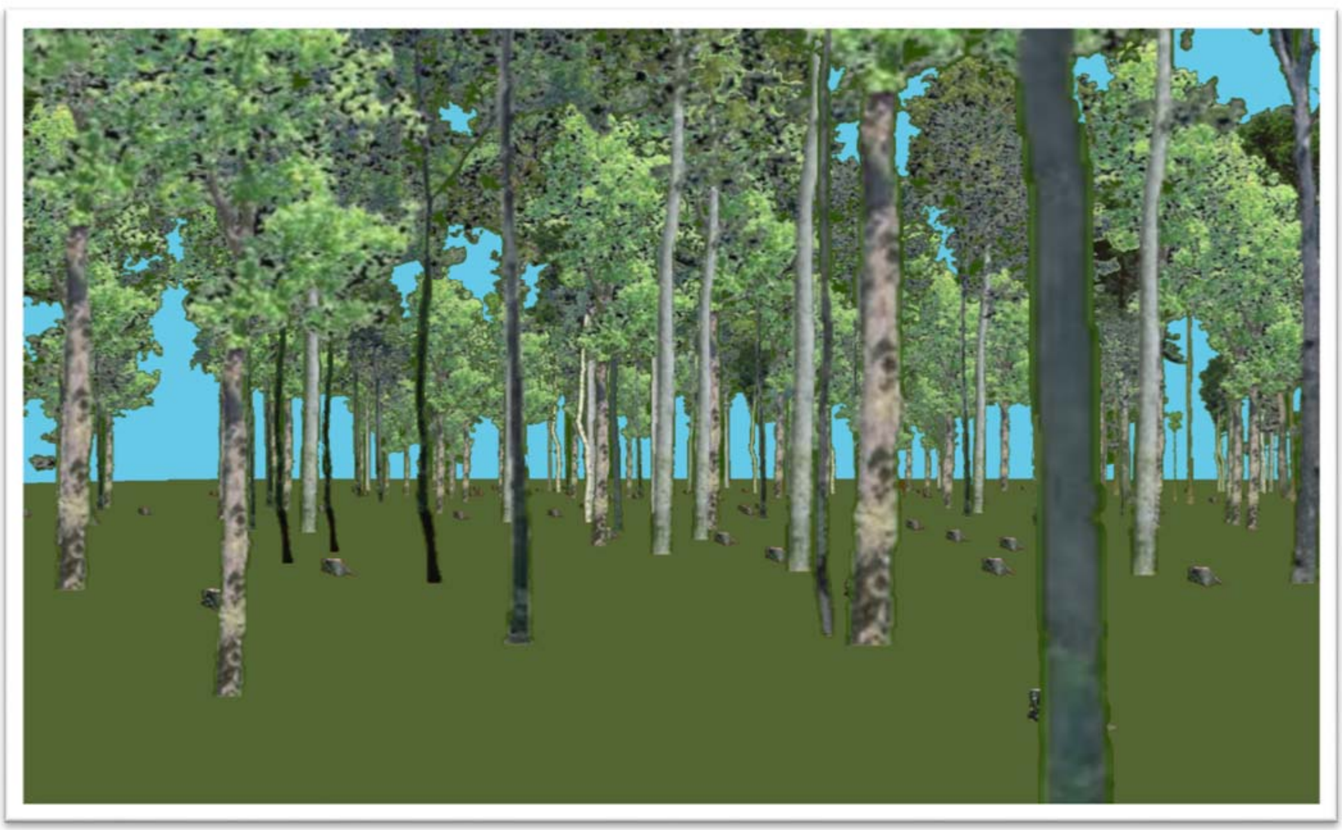


Figure 15 – Native Community Analysis: Scenario 1 Post-Harvest Condition

Figure 16 – Native Community Analysis: Scenario 2 Post-Harvest Condition

The stand visualization images provide some insight into the spatial arrangement and height or canopy position of the residual forest. Stumps are displayed in the location of harvested trees, which allows for better comparison between images. Individual tree images represent species and total height derived from the tree level inventory data (Figures 13 to 16).

The harvest based on the existing marking removed all understory balsam fir, while alternative Scenarios 1 and 2 retained a proportion of these trees following the modeled harvests (Figures 13 to 16). The alternative scenarios did not select against balsam fir, but, as an alternative, focused on removal of low GS class in the larger diameter classes. As a result, more species and structure diversity may have occurred in the residual stand (Figures 13 to 16).

Figure 15 displays the Scenario 1 post-harvest conditions with a residual BA of approximately 75 ft.^{2} per acre. This image clearly displays more stumps and shows the harvest of sawtimber-sized trees in the foreground. The foreground of Figure 15 may represent a mid-sized canopy gap in Scenario 1, while in Figure 16 a small gap typical single-tree selection outcome is evident with Scenario 2, providing improved growing conditions for the remaining growing stock.

2.2.1.2.2 Economic

The timber value of the alternative harvest scenarios was about twice that of the existing tree selection. These increases were largely driven by increases in removal of sawtimber-sized trees during the modeled Scenario 1 and 2 harvests. The Scenario 1 harvest increased in value by approximately 110 percent compared to the existing marking by removing more BA in larger diameter classes, and because about 25 percent more BA was removed in Scenario 1. By comparison, Scenario 1 and 2 sawtimber volumes were about 135 percent and approximately 90 percent higher than the existing timber sale, respectively. Pulpwood volumes selected for removal also increased by over 40 percent in both scenarios relative to the existing marking (Table 9).

Table 9 – Native Community Analysis: Comparison of Existing Harvest and Alternative Scenarios

Native Community Harvest Comparison					
	Existing	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	Percent Dif. From Existing	Value Per Acre	Percent Dif. From Existing
Cut	$565.43	$1,192.48	110.9	$1,008.30	78.3
Leave	$3,225.2	$2,598.14	-19.4	$2,782.31	-13.7
Total	$3,790.6	$3,790.61	-	$3,790.61	-
	Pulp (Tons)	Pulp (Tons)	Percent Dif. From Existing	Pulp (Tons)	Percent Dif. From Existing
Cut	15.6	25.4	63.1	22.8	46.9
Leave	39.7	29.9	-24.7	32.4	-18.4
Total	55.2	55.2	-	55.2	-
	Sawtimber (MBF)	Sawtimber (MBF)	Percent Dif. From Existing	Sawtimber (MBF)	Percent Dif. From Existing
Cut	594.6	1399.4	135.4	1130.6	90.1
Leave	5293.2	4488.4	-15.2	4757.2	-10.1
Total	5887.8	5887.8	-	5887.8	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	Percent Dif. From Existing	Basal Area (Sq. Ft.)	Percent Dif. From Existing
Cut	30.8	49.7	61.4	42.9	39.1
Leave	94.3	75.4	-20.1	82.2	-12.8
Total	125.1	125.1	-	125.1	-

Product breakdown between the harvest scenarios is reported in Table 10. The value of boltwood and pulpwood removed during the two scenarios was similar, differing by only 8 percent. The value of harvested sawtimber differed more, as Scenario 1 removed 19 percent more value than Scenario 2 (Table 10).

Table 10 – Native Community Analysis: Harvest Product Comparison of Alternate Scenarios

Poletimber (Pulpwood and Boltwood)					
		Scenario 1		Scenario 2	
	$/Ton	Tons/Acre	Total Value	Tons/Acre	Total Value
Mixed Hardwood	**$17.19**	19.78	$ 180,023.34	18.44	$167,774.99
Red Oak	**$13.91**	2.21	$ 16,289.64	1.86	$ 13,712.10
Aspen	**$18.43**	0.61	$ 5,964.65	0.61	$ 5,963.52
Balsam Fir	**$ 5.65**	0.65	$ 1,935.84	0.19	$ 557.06
Hemlock	**$11.95**	1.68	$ 10,620.75	1.60	$ 10,146.52
White Pine	**$11.95**	-	-	0.05	$ 292.02
Basswood	**$ 4.40**	0.44	$ 1,027.09	0.10	$ 234.53
Total		25.37	$215,861.30	22.85	$198,680.75
Grade Sawtimber and Veneer					
	$/MBF	MBF/Acre	Total Value	MBF/Acre	Total Value
Hard Maple	**$604.00**	0.92	$293,947.56	0.79	$ 253,352.50
Red Oak	**$539.00**	0.27	$ 76,023.74	0.19	$ 55,433.74
Mixed Hardwood	**$402.00**	0.15	$ 31,479.13	0.11	$ 23,694.42
Basswood	**$402.00**	0.07	$ 13,966.82	-	-
White Pine	**$150.00**	-	-	0.03	$ 2,584.54
Total		1.40	$415,417.25	1.13	$ 335,065.20
Grand Total			**$631,278.55**		**$533,745.95**

Boltwood and veneer volumes varied by post-harvest condition. The percentage of boltwood volume was greater for both alternative scenarios than the existing marking, with Scenario 2 removing more trees with boltwood volume than the existing and Scenario 1 harvests. With the existing harvest, a greater percentage was veneer when compared to the alternative scenarios. Only 19 trees in the entire inventory included veneer volume, and the Scenario 1 and 2 harvests cut a very small percentage of these trees. The existing harvest removed only three veneer trees, Scenario 1 removed two, and Scenario 2 retained all of them. Therefore, the veneer harvest percentage was based on very few trees and may not be a useful statistic for the study (Table 11).

Table 11 – Native Community Analysis: Boltwood and Veneer Proportion of Harvest Analysis

Percent of Poletimber Harvest that is Boltwood (based on tons per acre volume)			
	Existing Selection Percentage of Bolts	Scenario 1 Percentage of Bolts	Scenario 2 Percentage of Bolts
Mixed Hardwood	6.8	8.9	10.3
Balsam Fir	0.0	0.0	0.0
Red Oak	0.6	0.6	0.4
Basswood	0.5	0.0	0.0
Aspen	0.1	0.7	0.8
Hemlock	0.0	0.0	0.0
Spruce	0.0	0.0	0.0
White Pine	0.0	0.0	0.0
Total	**8.1**	**10.2**	**11.5**
Percent of Sawtimber Harvest that is Veneer (based on MBF per acre volume)			
	Existing Selection Percentage of Veneer	Scenario 1 Percentage of Veneer	Scenario 2 Percentage of Veneer
Hard Maple	0.0	0.0	0.0
Red Oak	0.0	0.0	0.0
Basswood	8.2	1.9	0.0
Mixed Hardwood	7.8	0.0	0.0
White Pine	0.0	0.0	0.0
Total	**15.9**	**1.9**	**0.0**

In a separate analysis, we evaluated average rate of value growth (RVG) for post-harvest conditions. An increase in RVG equates to a higher potential for stand value improvement through growth of trees that contain higher grades of sawable material. All hard maple trees in the sawtimber-size classes (11 inches DBH and greater) were applied RVG percentages derived from Webster, et al. (2007). In this study, expected rates of value growth were derived for hard maple crop trees, with the results providing an expected rate of value movement from veneer and grade 1 status. Reed, et al. (1985) suggest that the probability of grade 2 trees staying grade 2 or becoming grade 3 increases with increasing diameter class. To provide an estimate of potential in the future stand conditions, we applied the RVG values in Table 12 to hard maple trees in the sample. For example, a 14-inch hard maple with a GS 3 (Acceptable GS class) coded as a co-dominate tree would have a RVG of 3.1 percent. This tree would be assigned a probability equivalent to a grade 1 tree remaining grade 1 over a 10-year period. Higher quality GS2 and GS1 trees were assigned the largest RVG, which would be equivalent to a grade 1 tree improving to veneer. All veneer trees were assigned the probability of a veneer tree retaining its value. Results of this analysis are provided in Table 13.

Table 12 – Native Community Analysis: Rate of Value Growth (RVG) Analysis Assumptions

Rate of Value Growth Analysis Settings - Sawtimber-Sized Hard Maple Trees							
Product by Growing Stock	Site Index	Crown Class	Change in Product	RVG by Size Class (inches) 11 to 14	15 to 17	18 to 24	24+
Saw: GSS 1	**60**	All	Grade 1 to Veneer	0.059	0.06	0.072	0
Saw: GSS 2	**60**	All	Grade 1 to Veneer	0.059	0.06	0.072	0
Ven: GSS 2-3 (Ven.)	**60**	All	Veneer to Veneer	0.039	0.03	0.041	0
Saw: GSS 3	**60**	Dom. and Co-Dom.	Grade 1 to Grade 1	0.031	0.02	0.016	0
Saw: GSS 3	**60**	Inter. And Supp.	Grade 1 to Grade 2	-0.013	-0.021	-0.007	0
Saw: GSS 4	**60**	Dom. and Co-Dom.	Grade 1 to Grade 1	0.031	0.02	0.016	0
Saw: GSS 4	**60**	Inter. And Supp.	Grade 1 to Grade 2	-0.013	-0.021	-0.007	0
Saw: GSS 5	**60**	All	Grade 1 to Grade 2	-0.013	-0.021	-0.007	0

*All trees greater than 13-inches that did not contain sawtimber were assigned RVG values of Grade 1 dropping to Grade 2.

Table 13 – Native Community Analysis:
RVG Post-Harvest Condition

RVG Average Stand Conditions	
Scenario	RVG of Residual Trees
Before Harvest	0.015
Existing Selection	0.017
Scenario 1	0.029
Scenario 2	0.028

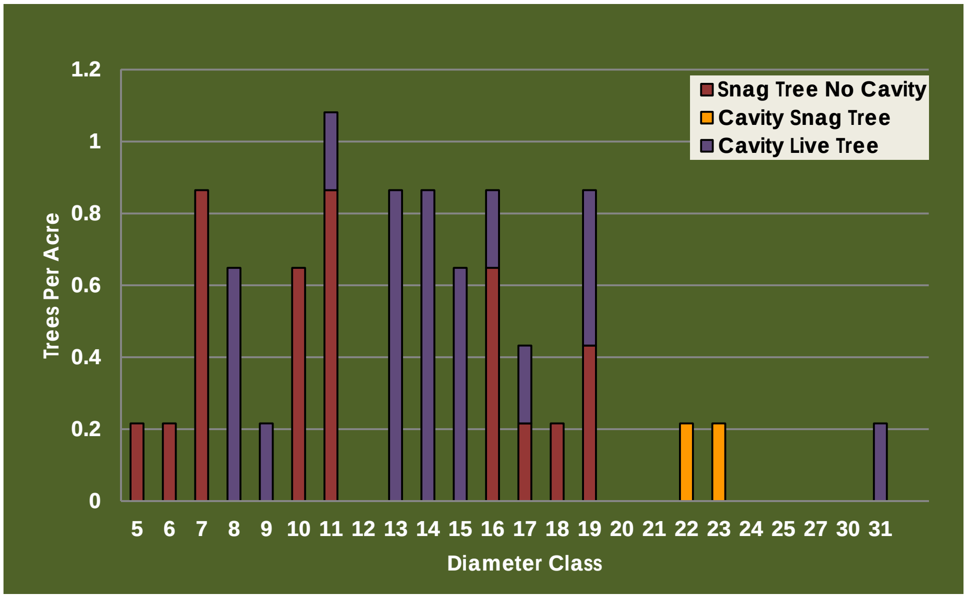
The residual forest hard maple growth potential changed little for the existing selection, while Scenarios 1 and 2 retained trees that improved the RVG by 87 to 93 percent. This analysis did not identify the present value of future harvests and only suggested that RVG will be improved by removing larger trees classified as low GS grade. In the case of the Fred Luke Road timber sale, many of the trees removed in the modeled scenarios were likely economically mature, based on the ocular estimates made at the time of the inventory. This conclusion was supported by results of the RVG analysis.

2.2.1.2.3 Ecological

The forest on the Fred Luke Road timber sale area appeared to be adequately stocked in most of the size classes (Figure 3). However, stocking of preferred hardwood species in the regeneration size classes (less than 5 inches DBH) were well below preferred levels, as only 99 TPA of hard maple were present. Only 15 TPA of hard maple occurred in the 5-inch DBH class. Thus, the current pre-harvest forest was quite shaded and regeneration of preferred species was lacking.

Although tree age class information was not recorded, the inventory data suggested that this northern hardwood stand might not have been all-aged. GS class of the small- and mid-sized sawtimber was low, suggesting these trees may have been suppressed and the same age as some of the larger sawtimber. This stand may have been unable to perpetuate itself in the absence of more intensive regeneration focused management. Live cavity trees and snags occurred in all size classes smaller than 20 inches DBH (Figure 17).

Figure 17 – Native Community Analysis: Pre-Harvest Wildlife Tree Summary (TPA)



Because cavity trees often received a low GS rating, the alternative scenarios were more likely to select them for harvest. This decrease in cavity tree stocking was a tradeoff between removing low GS trees and retaining more trees with higher GS that would yield better future economic value. The alternative scenarios reduced stocking of live cavity trees by 64 to 80 percent (Table 14). Scenarios 1 and 2 greatly reduced stocking of live cavity trees in the 13- and 14-inch DBH class. It should be noted that Scenario 2 retained cavity trees in the 17-inch DBH class (Figure 18).

Figure 18 – Native Community Analysis: Comparison of Post-Harvest Live Cavity Tree Summaries (TPA)

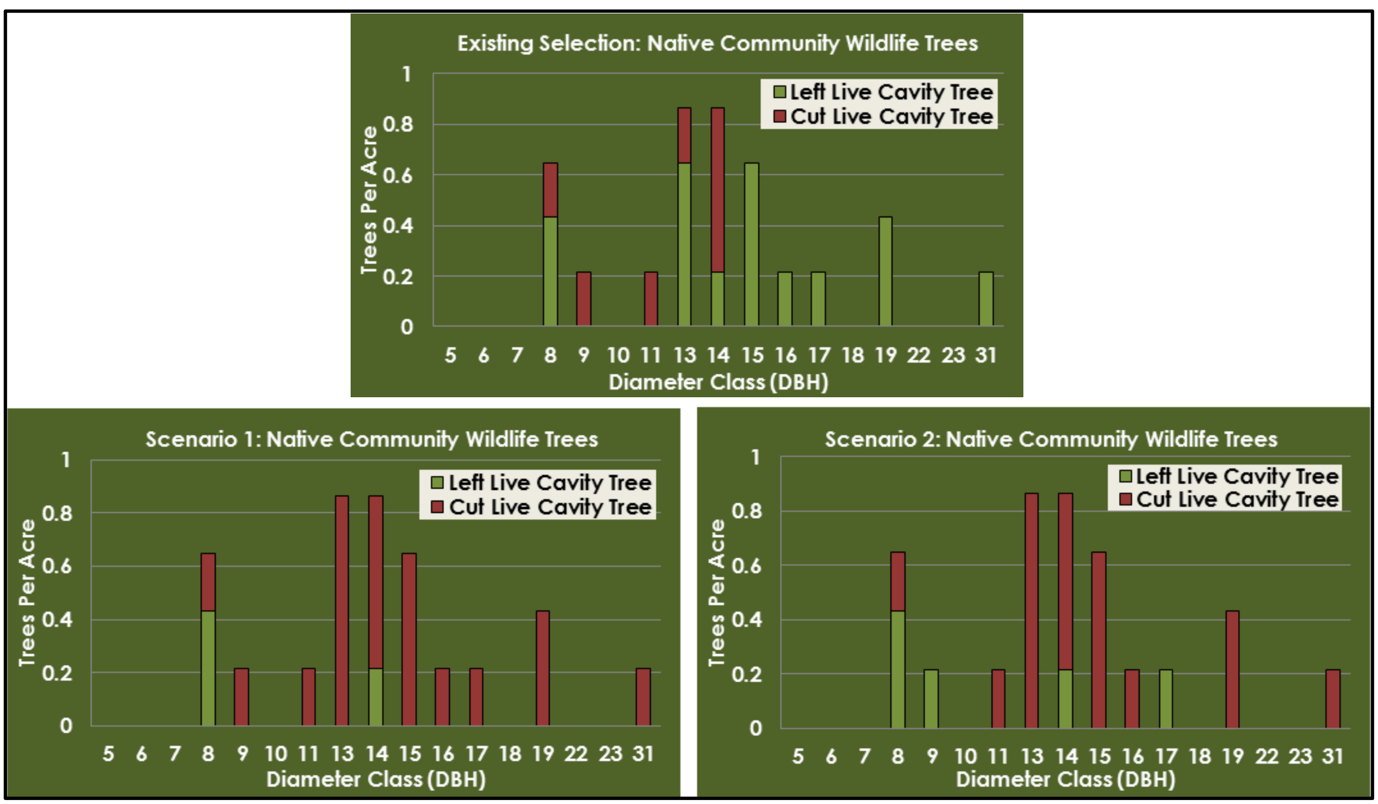
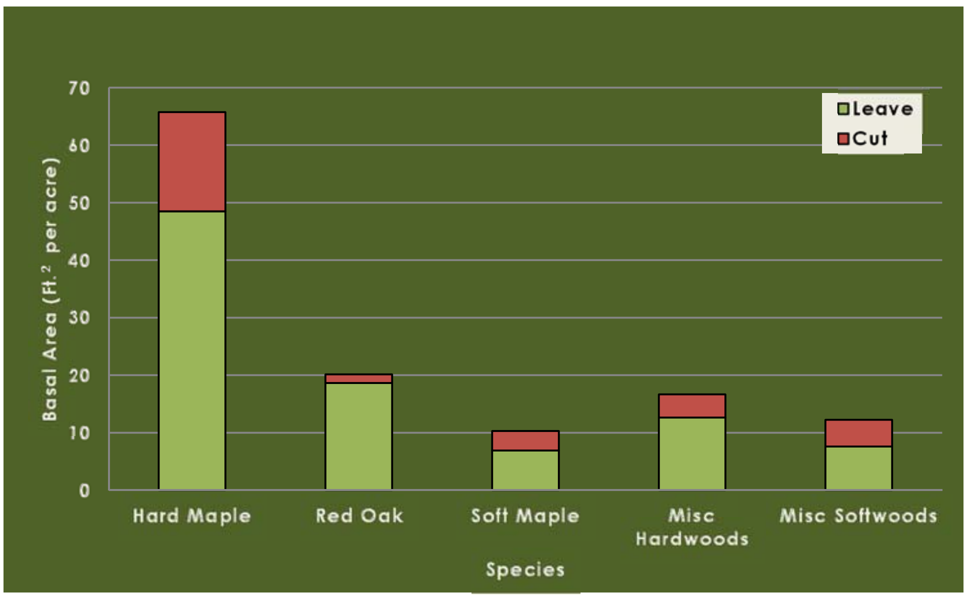


Table 14 – Native Community Analysis: Live Cavity Tree Comparison by Cut and Leave Status (TPA)

Native Community: Live Cavity Tree Analysis (TPA)			
	Existing Selection Percent	Scenario 1 Percent	Scenario 2 Percent
Cut	33.33	85.71	76.19
Leave	66.67	14.29	23.81

The existing selection appeared to remove a proportional amount of BA within each species (Figure 19). The only major difference in the selection modeled in the alternative scenarios was that slightly more BA was removed from each species group. This primarily resulted from more BA being removed in the alternative scenarios. This difference in BA removed was greatest for hard maple, where the alternative scenarios removed approximately 10 ft.[2] BA per acre more than the existing selection (Figure 19).

Figure 19 – Native Community Analysis: Existing Selection Harvest Distribution by Species (BA)



2.2.1.3 Summary and Conclusions

The Fred Luke Road timber sale occurred on the Wisconsin State Forest and was in an area designated as Native Community management. Forestlands managed under this designation are not common, and occupy 7 to 20 percent of the largest state forest properties. The pre-harvest forest averaged 125 ft.[2] BA per acre, while the post-harvest stocking averaged 94 ft.[2] per acre. Our analyses indicate that the existing harvest selection would develop the following conditions.

- Over 40 percent of the Undesirable (4) and Unacceptable (5) GS class trees were selected for removal
- Post-harvest conditions would mimic the “Arbogast” stocking structure in the larger size classes
- At least 45 percent of trees in the 5- to 9-inch DBH class were selected for removal
- Only 2 percent of the harvested BA removed trees 21 inches DBH and larger
- The estimated average value of the existing harvest value was $529.40 per acre

The modeled harvest scenarios used tree selection criteria that focused on removing financially mature trees with maximum tree size ranging from 17- to 19-inches, harvesting the poorest growing stock, and removing low GS grade trees in close proximity to others to mimic a release of crop trees. The OOR modeled in both scenarios removed trees in this order, (1) remove risk, (2) harvest mature, and (3) release crop trees. This harvest methodology used a basic tabular model approach that used the inventory data to control harvest selection. The model approach did not attempt to correct or develop a specific diameter distribution, but focused on removing trees with specific growth, size, and value characteristics. Tree species distribution, both pre- and post-harvest, was also not controlled by the model. The model scenarios developed the following forest conditions.

- The alternative scenarios harvested about 15 to 25 percent more BA than the existing marking
- The alternative scenarios removed 24 to 35 percent more unacceptable and undesirable growing stock, compared to the existing harvest
- Scenario 2 led a decrease in harvest of small diameter trees, as the existing harvest removed over twice as many trees in the 5- to 10-inch DBH class compared to Scenario 2
- Compared to the existing harvest, Scenario 1 removed over 3 times more trees in the 14-inch and larger classes
- Scenario 1 removed 2.5 times more BA in the 15- to 18-inch DBH class than the existing harvest
- Compared to the existing harvest, both scenarios removed about half as much BA in the 5- to 10-inch DBH class
- Harvest value increased by 111 percent and 78 percent for Scenario 1 and 2, respectively, compared to the existing harvest
- Trees with lower RVG were removed in Scenarios 1 and 2, as the estimated average hard maple RVG improved by 87 percent and 93 percent over the pre-harvest forest

An increase in the removal of large, low GS class trees played a significant role in the results of this study. High RVG potential was estimated using inventory data and was essentially an extension of GS tree classification for hard maple trees. Many recent studies evaluating northern hardwood management and forest product development suggested removing trees that have likely reached economic maturity, as rates of value growth decrease quickly for poor growing stock. In our study, we assumed that GS class does not change during the life of a tree, and that trees of mid to low GS class should be removed early. This is generally consistent with the findings of Webster, et al. (2007), where stems were found to have a high probability of staying at the same grade.

The results of the OOR Analysis also suggested that trees of low GS class should be considered for removal as trees approach the 17-inch diameter class. Our review of existing financial studies indicated that lower maximum tree size criteria, even less than 17-inches, were most applicable on sites with low to mid site quality.

2.2.2 OOR Analysis

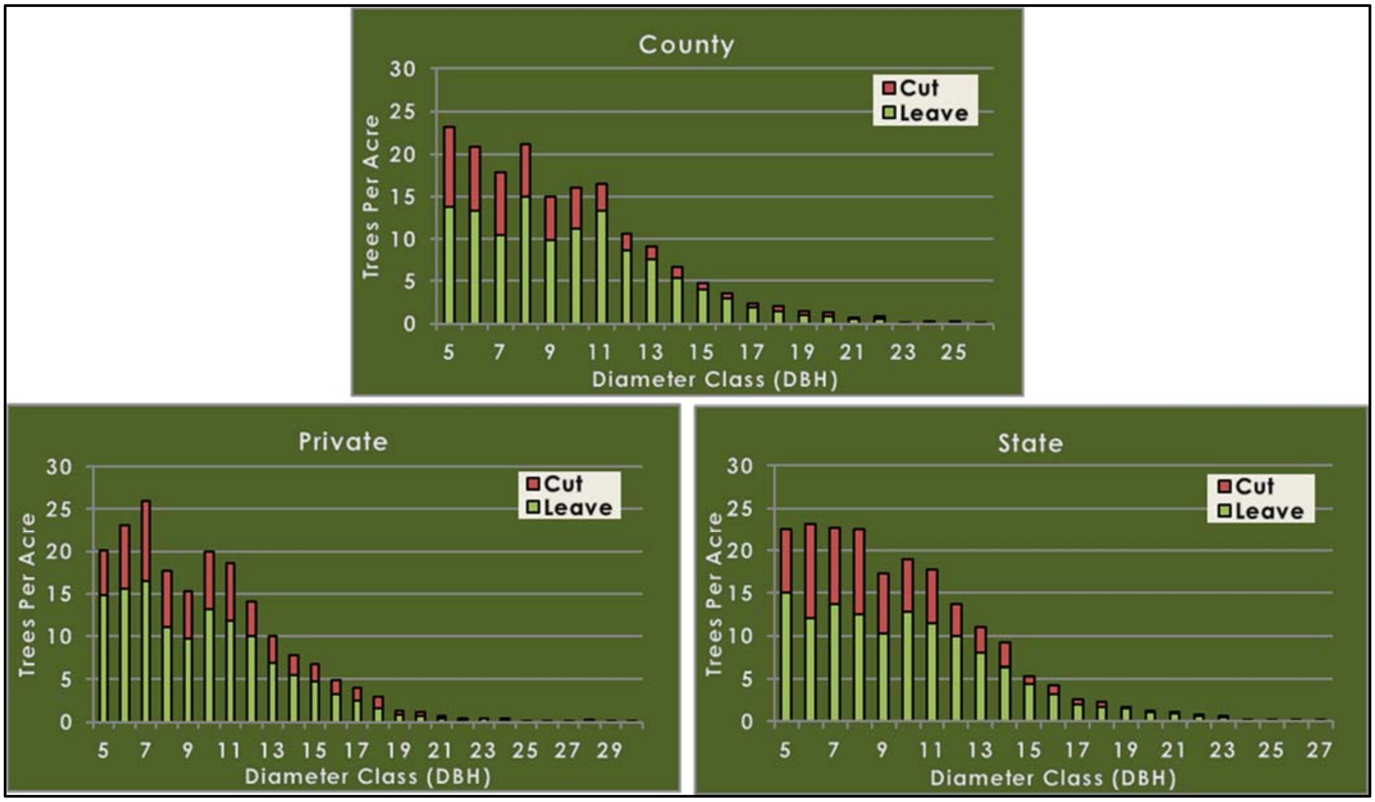
The OOR Analysis compared conditions resulting from the existing marking and two modeled alternative scenarios in a randomly selected set of northern hardwood stands on state, county, and private MFL properties statewide. Stand maps, including plot locations, are provide in Exhibit 3 for all state and county stands. Private forest information is kept confidential.

The results of this comparative analysis are presented in the following sections.

2.2.2.1 Cut and Leave Tree Summary

This section of the report summarizes pre- and post-harvest forest conditions on the 240 multi-radial plots situated within 30 randomly sampled stands (Figure 20).

Figure 20 – OOR Analysis: Comparison by Landowner Class of Harvest Distribution by Diameter Class (TPA)



Forest structure varied among the three ownership groups; however, stocking appeared to dip in the 9-inch DBH class for all owners. Yet, the 9-inch stocking remained above the Arbogast recommendations. As DBH class increased, stocking tapered off quickly after the 11-inch DBH class, especially for private and county forests. Diameter distribution stocking curves were somewhat unimodal for the private stands, while curves for the county and state ownerships resembled an increasing q shape. The increasing q shape is common in both managed and unmanaged stands, while the unimodal shape of the private forests is somewhat less common and suggests an even-aged structure. The unimodal curve is normally described as a curve increasing in the smaller DBH classes, peaking in stocking in the mid-size classes, followed by somewhat shallow negative exponential structure in the larger size classes (Figure 20).

As discussed earlier in the report, we did not measure stand age, so the age structure of this sample-set is unknown. Yet, the varied management approaches employed on private forests likely produced the uncommon structure observed above. The "cut" or harvest displayed in Figure 20 also suggests that this structure may persist, as the existing marking was heavy in the smaller size classes.

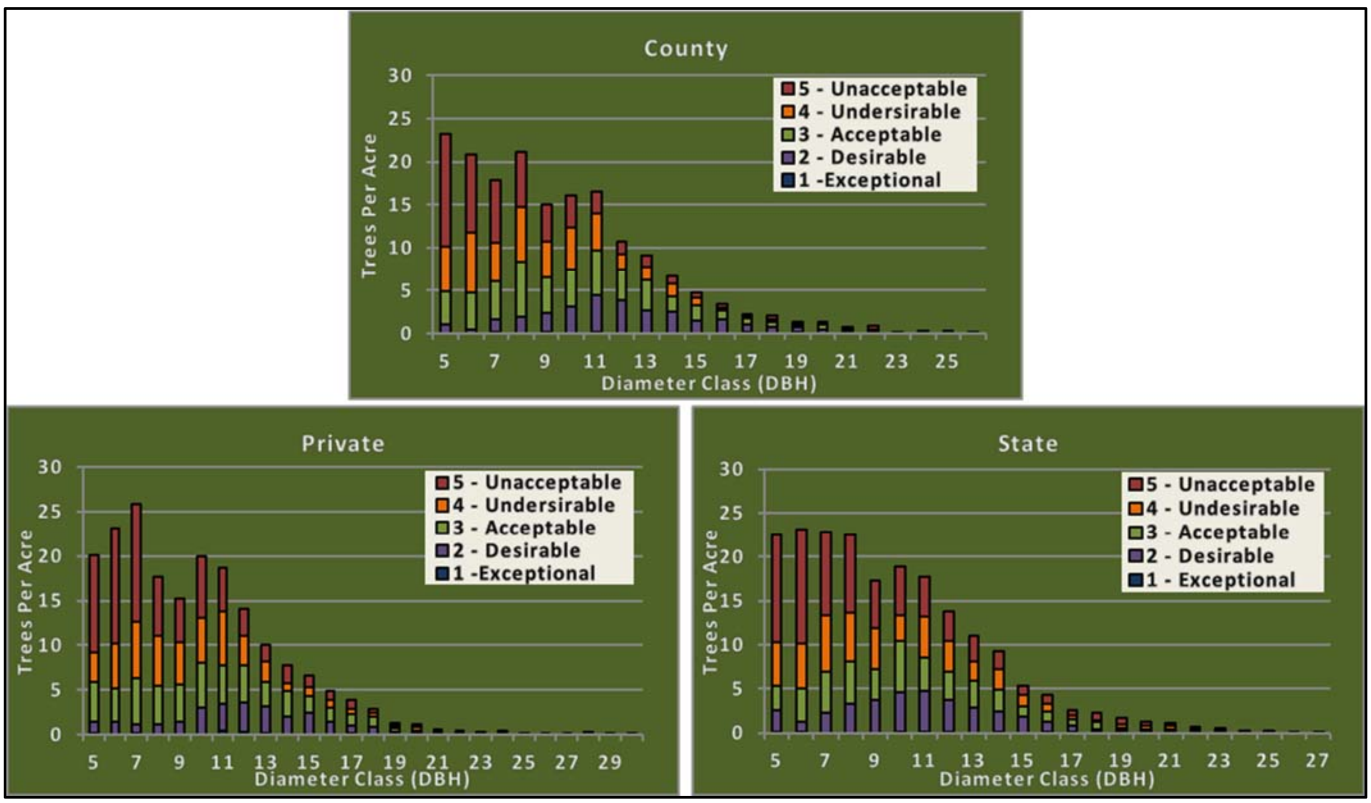
Harvest percentage by size class is presented in Table 15. County forests had the highest rate of removal in the 5- to 10-inch DBH class, while the state consistently had the highest rate of removal in larger size classes. (Table 15).

Table 15 – OOR Analysis: Comparison by Landowner Class of Harvest Distribution by Diameter Class (TPA)

Cut and Leave Percent DBH Class (TPA)				
County	**5 to 10 inch**	**11 to 15 inch**	**16 to 20 inch**	**21 inch**
Cut	39.8	29.1	20.6	9.1
Leave	60.2	70.9	79.4	90.9
Private	**5 to 10 inch**	**11 to 15 inch**	**16 to 20 inch**	**21 inch**
Cut	35.0	19.0	23.0	29.7
Leave	65.0	81.0	77.0	70.3
State	**5 to 10 inch**	**11 to 15 inch**	**16 to 20 inch**	**21 inch**
Cut	33.6	31.6	36.2	36.6
Leave	66.4	68.4	63.8	63.4

GS class distribution by diameter class was similar for all ownership. County forests differed from other ownerships by having a higher ratio of trees in the Exceptional, Desirable, and Acceptable categories. The county forests had only 3 to 5 percent more stocking in these categories. The number of best quality trees peaked in the 11- to 13-inch DBH class for all owners (Figure 21).

Figure 21 –OOR Analysis: Comparison by Landowner Class of Pre-Harvest Diameter Distribution by GS Classification (TPA)



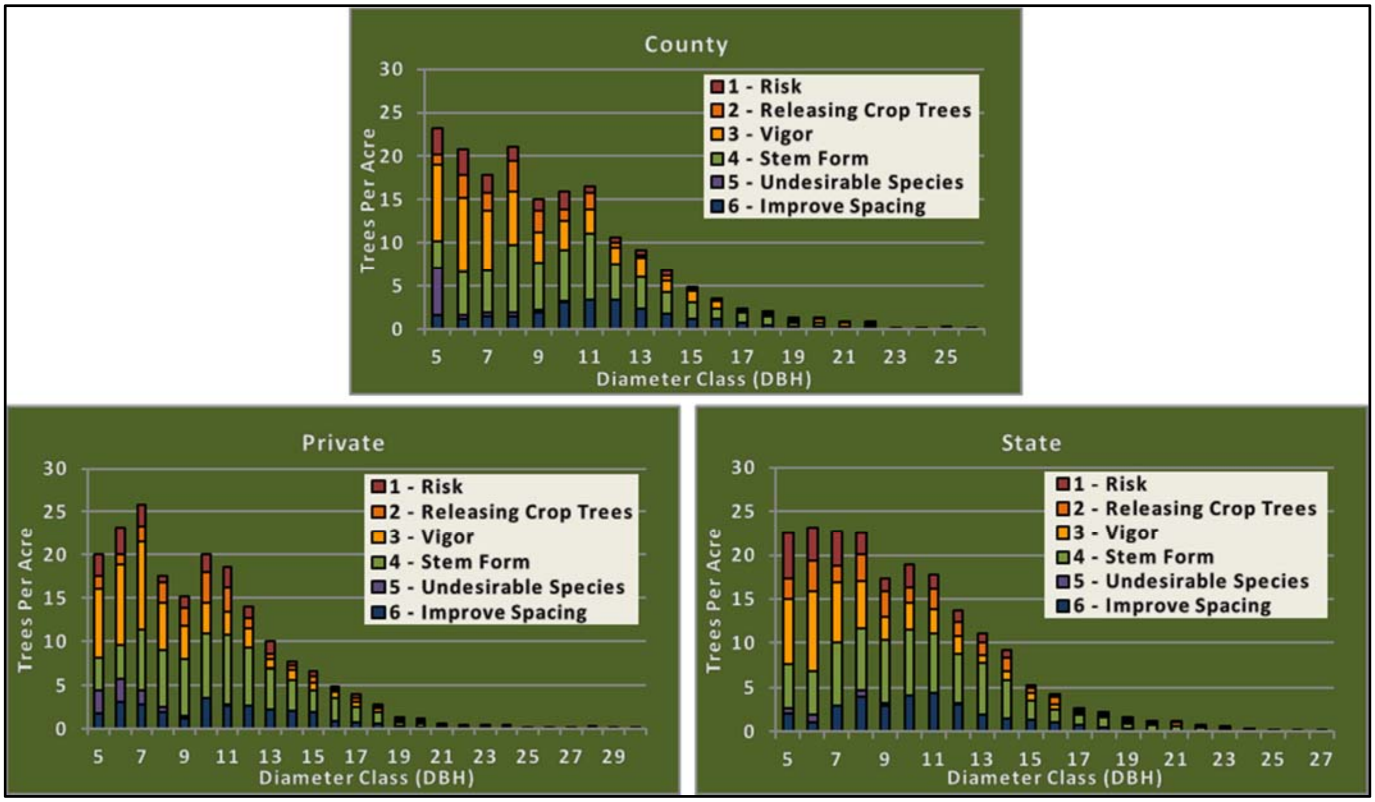
Similar to the distribution of trees by GS, the harvest ratios were very similar across the ownerships. No substantial difference was noted between the groups (Table 16).

Table 16 –OOR Analysis: Existing Selection Harvest Ratio by GS and Ownership Class (TPA)

Cut and Leave Percent of TPA by GS Class		
County	**Cut**	**Leave**
Exceptional	2	98
Desirable	5	95
Acceptable	16	84
Undesirable	37	63
Unacceptable	50	50
Private	**Cut**	**Leave**
Exceptional	0	100
Desirable	11	89
Acceptable	19	81
Undesirable	36	64
Unacceptable	53	47
State	**Cut**	**Leave**
Exceptional	2	98
Desirable	7	93
Acceptable	19	81
Undesirable	39	61
Unacceptable	54	46

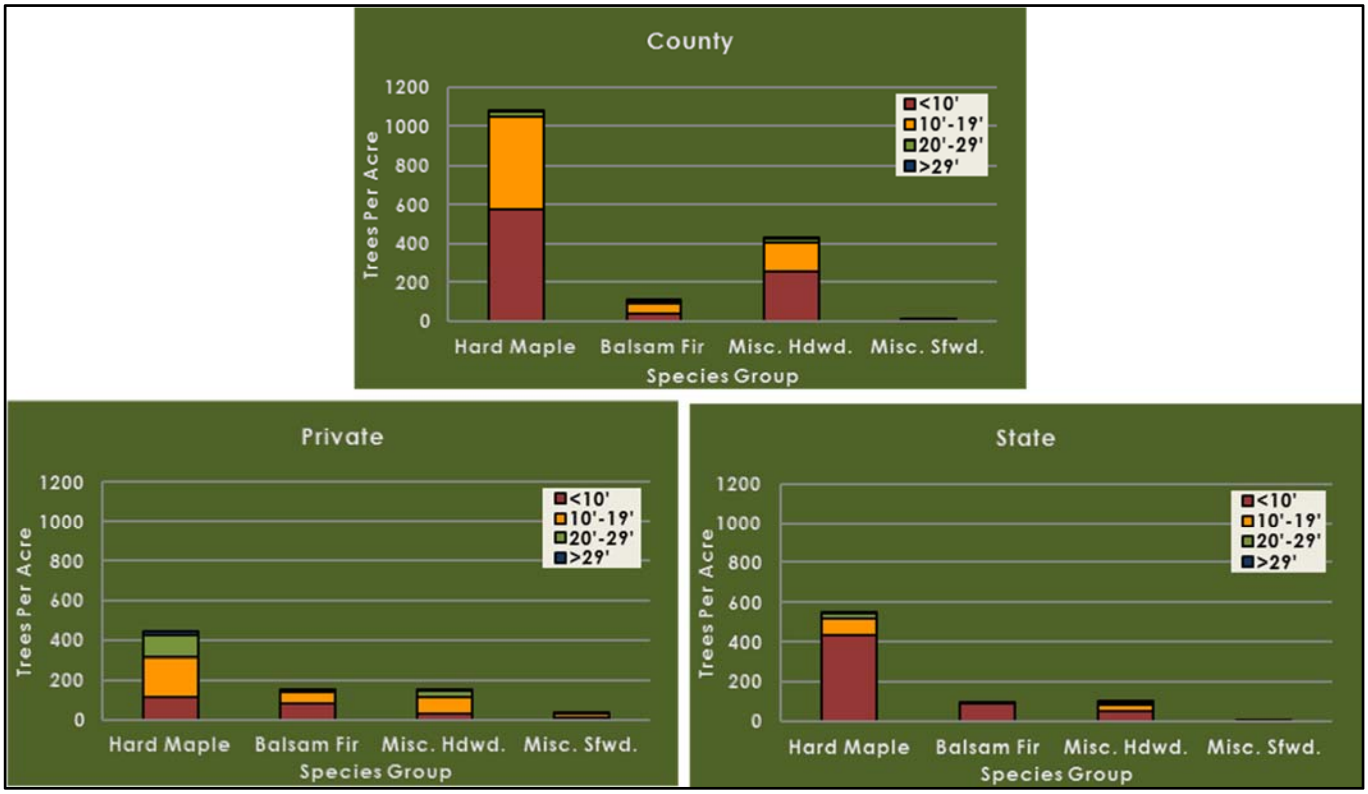
Figure 22 displays OOR classification by diameter class and owner. As expected, the OOR classifications were similar, and the ratios by DBH class resembled results of the GS analysis (Figure 21).

Figure 22 – OOR Analysis: Comparison by Landowner Class
of Pre-Harvest Diameter Distribution by OOR Classification (TPA)



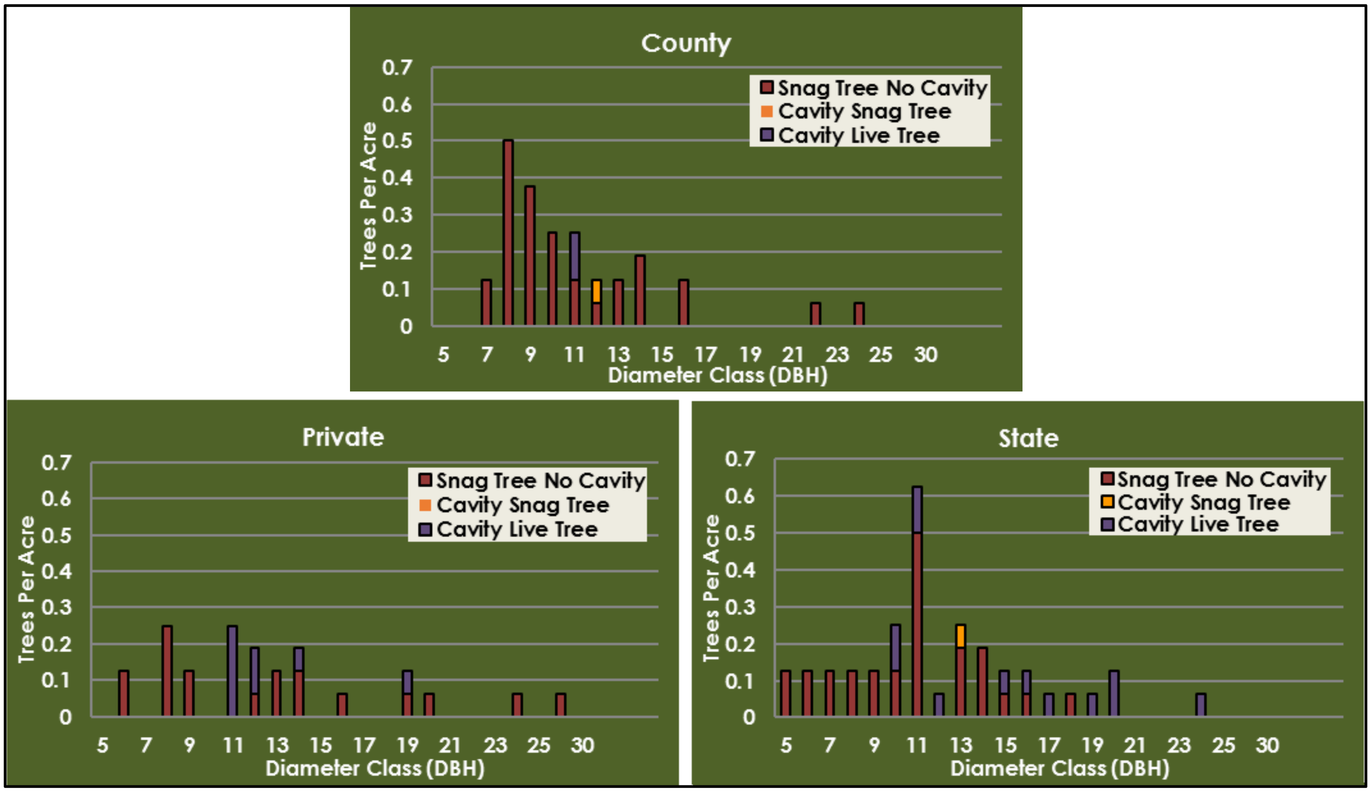
There were significant differences in forest regeneration between ownerships before harvest. On county forests plots, hard maple stocking was over 1,000 TPA, compared to just over 400 TPA on private ownerships, and approximately 550 TPA on state lands (Figure 23). County forests also had the greatest stocking of miscellaneous hardwoods, which included soft maple, basswood, white ash, black ash, red oak, bur oak, yellow birch, white birch, black cherry, hickory, aspen, and elm. Miscellaneous hardwoods, however, was dominated by white ash. Although not included in the regeneration summary figure, ironwood was quite common in sample plots. Ironwood stocking was just over 400 TPA on county forests, about 200 TPA on state forests, and slightly over 100 TPA on private forestlands. Regeneration less than 10 feet in height was most common. However, county and private forest plots had the highest proportion of established regeneration, defined as trees that exceeded 10 feet in height (Figure 23).

Figure 23 – OOR Analysis: Comparison by Landowner Class of Pre-Harvest Regeneration Summaries (TPA)



Tree characteristics related to wildlife habitat quality were measured on the 240 multi-radial plots. Densities and distributions of cavity tree stocking differed among ownerships pre-harvest. County forest plots had high stocking of snag trees in the 8- to 10-inch DBH class, while state stands had a large pulse of snag and live cavity trees in the 11-inch DBH class. Private forest plots had fewer snag trees than other ownerships, but they were distributed across most size classes (Figure 24).

Figure 24 – OOR Analysis: Comparison by Landowner Class of Pre-Harvest Wildlife Tree Composition (TPA)



2.2.2.1.1 Ownership Results Comparison

We used a one-way ANOVA to test for differences in residual BA with the existing marking among ownerships. For this analysis, we averaged plots in each stand and considered each stand to be an observation. Each ownership category included 10 observations (stands). Residual BA did not differ among ownership groups (Tables 17, 18, 19).

Table 17 – OOR Analysis: Post-Harvest Basal Area Statistics by Ownership Class

Residual Forest Basal Area Statistics			
Descriptive Statistics	**Private**	**County**	**State**
No. of Plots	80	80	80
Mean BA	78.96	75.11	82.94
Standard Error	3.53	3.37	3.37
Standard Deviation	11.18	10.66	10.66
Sample Variance	124.89	113.63	113.55
Confidence Level (95.0 percent)	7.99	7.63	7.62

A further evaluation of the ownership groups was completed to determine if there was a statistical difference between the average residual stocking levels. For the purpose of this analysis, a pseudo-replication approach was used where each stand was considered an observation. Each sample is essentially the average of the plots in one stand, as each owner included 10 observations (stands). A single factor (or one-way) ANOVA test was completed to test the null hypothesis, i.e., there is no difference in the residual BA between the ownerships. This test found differences across the three groups. A further analysis evaluating the separation of the means of the various combinations of owner combinations was completed using the

Tukey test. This second analysis found no differences between ownership combinations. Summary statistics and the ANOVA results are summarized in the following tables (Tables 18 and 19).

Table 18 – OOR Analysis: Post-Harvest
Basal Area Summary by Ownership Class

Residual Forest Basal Area Summary			
Groups	**Count**	**Average BA**	**Variance**
County	10	75.11	113.63
Private	10	78.96	124.89
State	10	82.94	113.55

Table 19 – OOR Analysis: Post-Harvest
Basal Area Statistical Comparison among Ownership Classes

Results of ANOVA Test on Basal Area of Residual Forest						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	305.89	2	152.94	1.30	0.29	3.35
Within Groups	3,168.59	27	117.36			
Total	3,474.49	29				

Comparing the pre-harvest forest conditions found the ownerships to differ using the ANOVA statistical test (Tables 20 and 21).

Table 20 – OOR Analysis: Pre-Harvest
Basal Area Summary by Ownership Class

Pre-Harvest Forest Basal Area Summary			
Groups	**Count**	**Average BA**	**Variance**
County	10	100.70	91.37
Private	10	118.88	320.38
State	10	117.29	169.00

Table 21 – OOR Analysis: Pre-Harvest
Basal Area Statistical Comparison among Ownership Classes

Results of ANOVA Test on Basal Area of Pre-Harvest Forest						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	2,027.87	2	1,013.93	5.24	0.01	3.35
Within Groups	5,226.80	27	193.59			
Total	7,254.67	29				

Using the Tukey difference of means test found that the pre-harvest BA stocking on county forest differed from both the private and state forest data.

2.2.2.2 Alternative Scenarios

We compared the existing marking for plots in the OOR Analysis to alternative scenarios using only the nine 1-acre plots. Methods for the alternative scenario harvest models are described in detail in Section 2.2.1.2. However, the alternative marking scenarios are summarized below.

- Scenario 1: Uneven-aged single-tree selection for use on average to good sites using a maximum tree size of 17 inches DBH. GS 1, 3, 4, and 5 trees 17 inches DBH and greater were given higher priority for removal, as poor growing stock were removed and the best trees were assumed to have reached financial maturity. The OOR for this scenario occurred in this order: removing risk, harvesting mature (17-inch DBH maximum tree size), and releasing crop trees. Residual stocking was set at a minimum of 75 ft.^{2} BA per acre to increase sunlight conditions in the understory, mimicking the use of canopy gaps and the removal of larger financially-mature timber.

- Scenario 2: This uneven-aged single-tree selection approach emulated management on the best sites using a maximum tree size diameter of 19-inches. The removal of trees in the maximum tree size class and the OOR approach were conducted in the same manner as Scenario 1. This approach retained more sawtimber-sized trees and created more shaded understory conditions. Large trees that may be financially mature were given priority for removal; however, the higher residual stocking level of 82 ft.^{2} BA per acre limited removals and, consequently, reduced volume of sawtimber harvested.

Table 22 displays the proportion of BA set for each OOR index. This removal “weight” was flexible to accommodate different stand structures, though no proportion changed more than 5 percent from the baseline sensitivity analysis (Index 1: 60 percent, Index 2: 25 percent, Index 3: 15 percent). For example, on county and state forests, 5 percent was not included in Index 3 and moved to Index 1 due to low stocking in OOR classification Release Crop Tree, and low stocking of mid- to large-sized sawtimber. In a similar process, greater weight was given to Index 1 (removed from Index 2) on private forests because larger sawtimber was understocked.

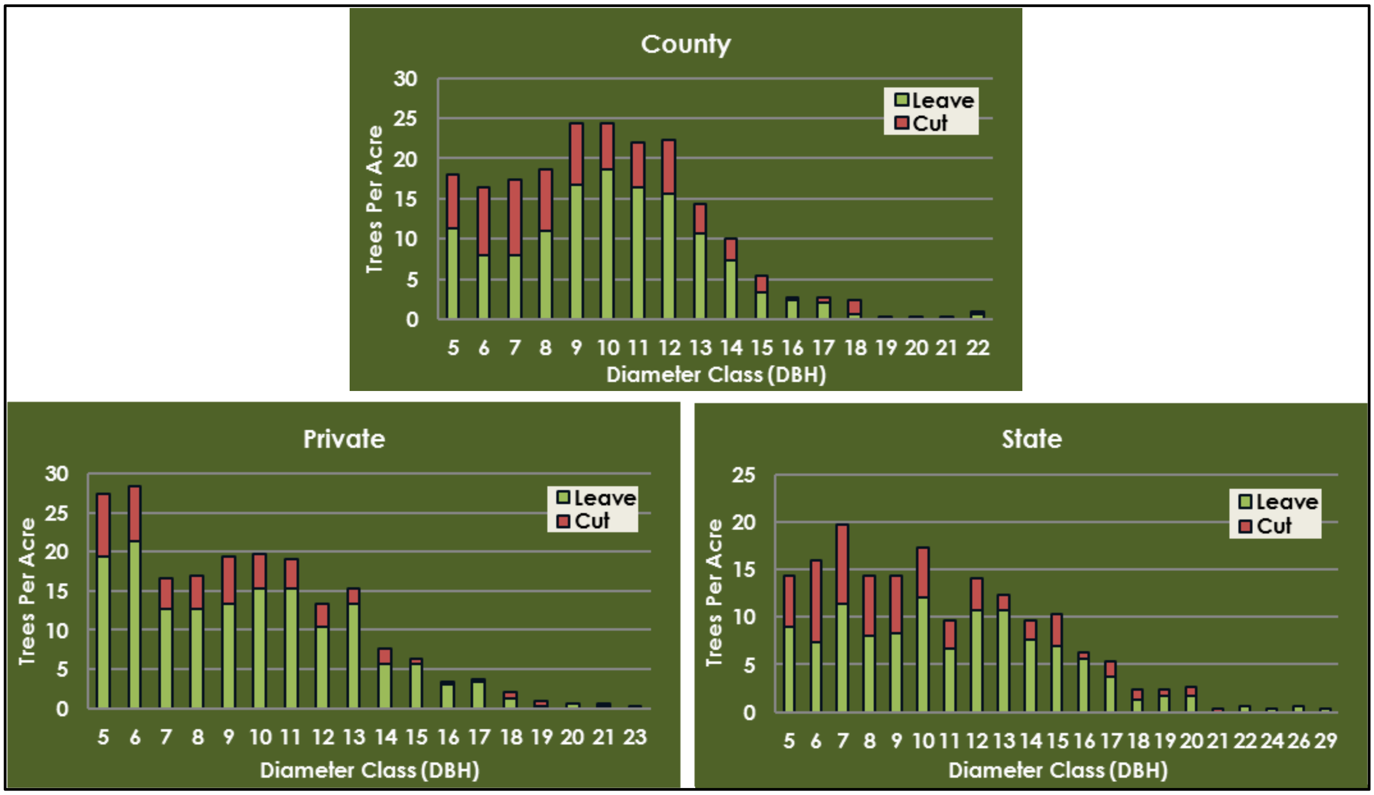
Table 22 –OOR Analysis: Alternative Selection Indices' Percent of Basal Area Harvested

Percent BA Removal by Index				
		Index 1	**Index 2**	**Index 3**
All Plots	**Scenario 1**	60	25	15
	Scenario 2	60	25	15
County	**Scenario 1**	65	25	10
	Scenario 2	65	25	10
Private	**Scenario 1**	60	25	15
	Scenario 2	65	20	15
State	**Scenario 1**	65	25	10
	Scenario 2	65	25	10

2.2.2.2.1 Analysis

Alternative harvest results are summarized in Exhibit 4. For this part of the analysis, we used all nine 1-acre plots (All Plots), in addition to county, private, and state individually. The existing pre- and post-forest conditions are summarized in Figure 25.

Figure 25 – OOR Analysis: Comparison by Landowner Class
of Harvest Distribution by Diameter Class using 1-Acre Plot Data (TPA)



The diameter distributions of the 1-acre plots differed from the larger sample of multi-radial plots. The distribution for county and state plots was unimodal, while the private forests distribution resembled a hybridization of both unimodal and increasing q. Overall, these results suggested that distributions varied within stands, and also highlighted the challenges of trying to manage towards a specific form. The q-factor is a measure of stand structure, and is a diminution quotient over the diameter classes. Larger q-factor values typically represent stands with higher stocking of small diameter growing stock and fewer trees in the large diameter classes. The opposite is true for stand structure with a lower q-factor (Table 23).

State forests had the lowest q-factor, while private forests had the highest, for all modeled scenarios (Table 23). The q-factor for the Native Community differed little among the original harvest, Scenario 1, and Scenario 2, because this forest had a negative exponential curve and adequate stocking in smaller diameter classes. Scenario 1 and 2 increased the q-factor for county and private forests, but slightly decreased the factor from the pre-harvest condition for the state ownership.

Table 23 – OOR Analysis: Q-Factor Comparison among Ownership Classes

Q-Factor Comparison					
	County	**Private**	**State**	**All Plots**	**Native Community**
Before Harvest	1.17	1.29	1.02	1.21	1.24
Original Selection	1.17	1.44	1.05	1.23	1.18
Scenario 1	1.37	1.38	0.99	1.29	1.22
Scenario 2	1.20	1.46	0.97	1.84	1.24

Harvest levels were greater in larger size classes (Figures 26 and 27). The harvest on county and private ownerships peaked in the 11-inch DBH class, and the importance of the removal in this size class was evident in the BA distribution (Figure 26). Removals in smaller size classes, generally less than 10 inches, were typically below those for the existing harvest (Figures 26 and 27).

Figure 26 – OOR Analysis: Basal Area Comparison of Alternative Harvests by Ownership

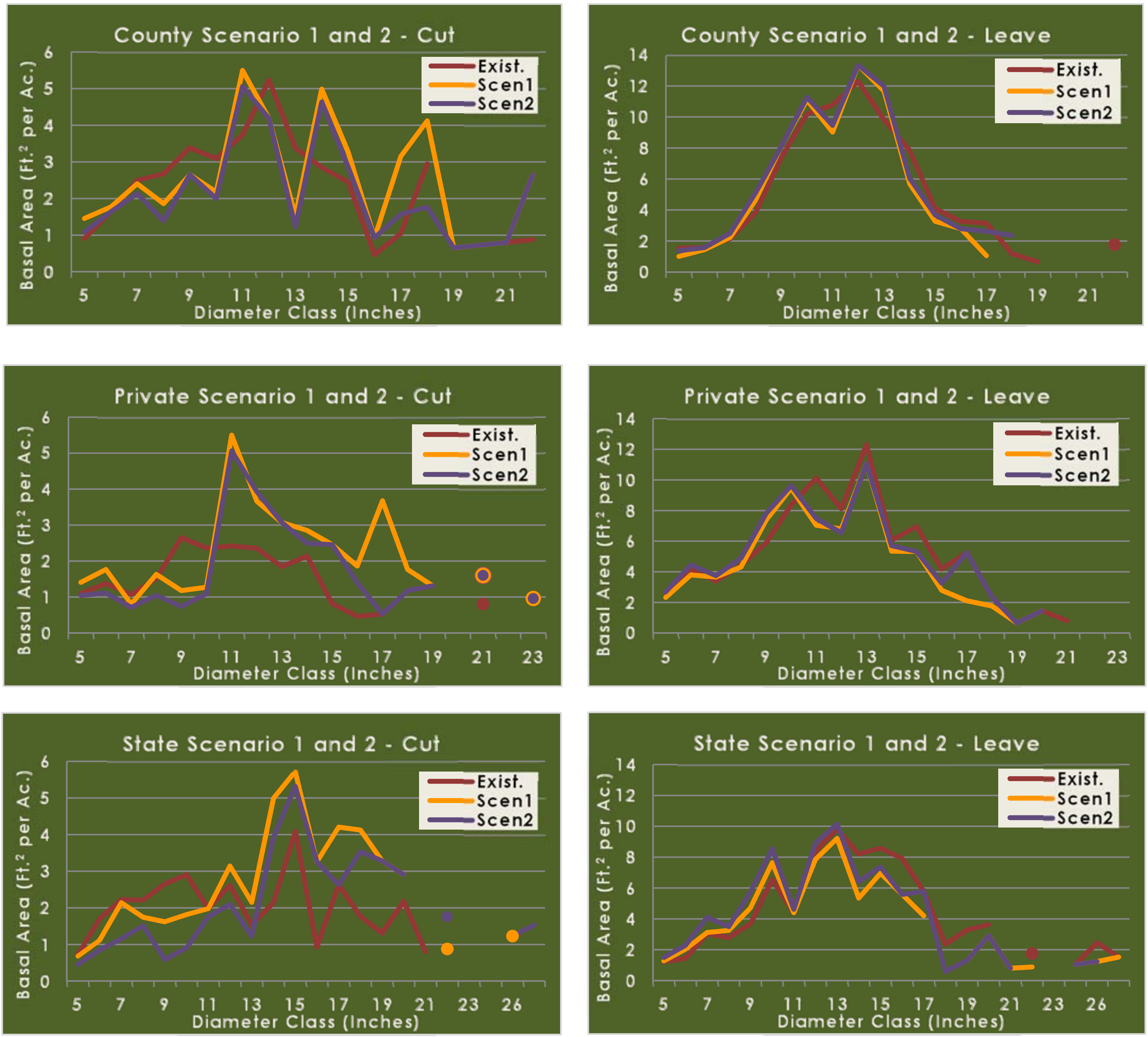
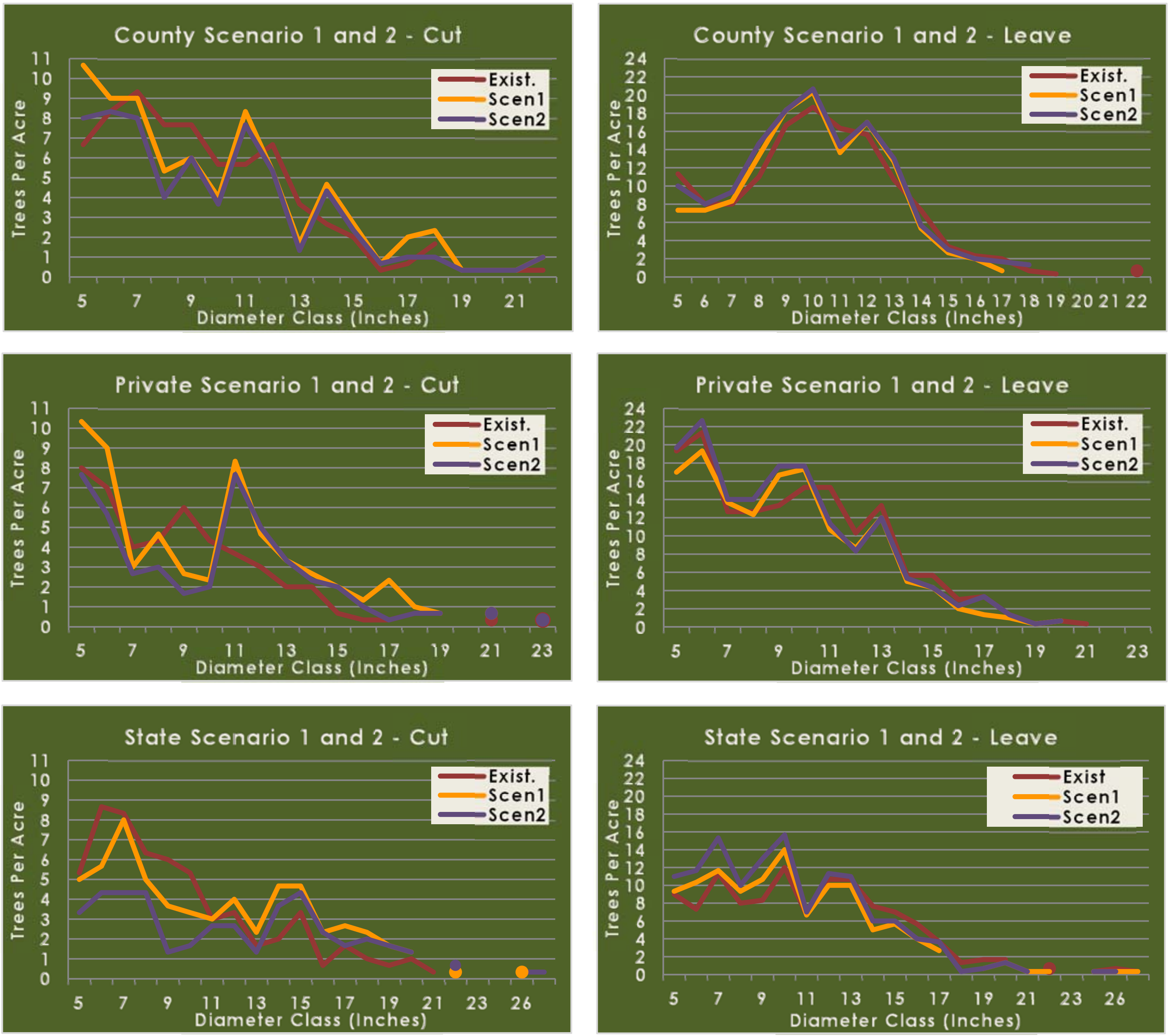
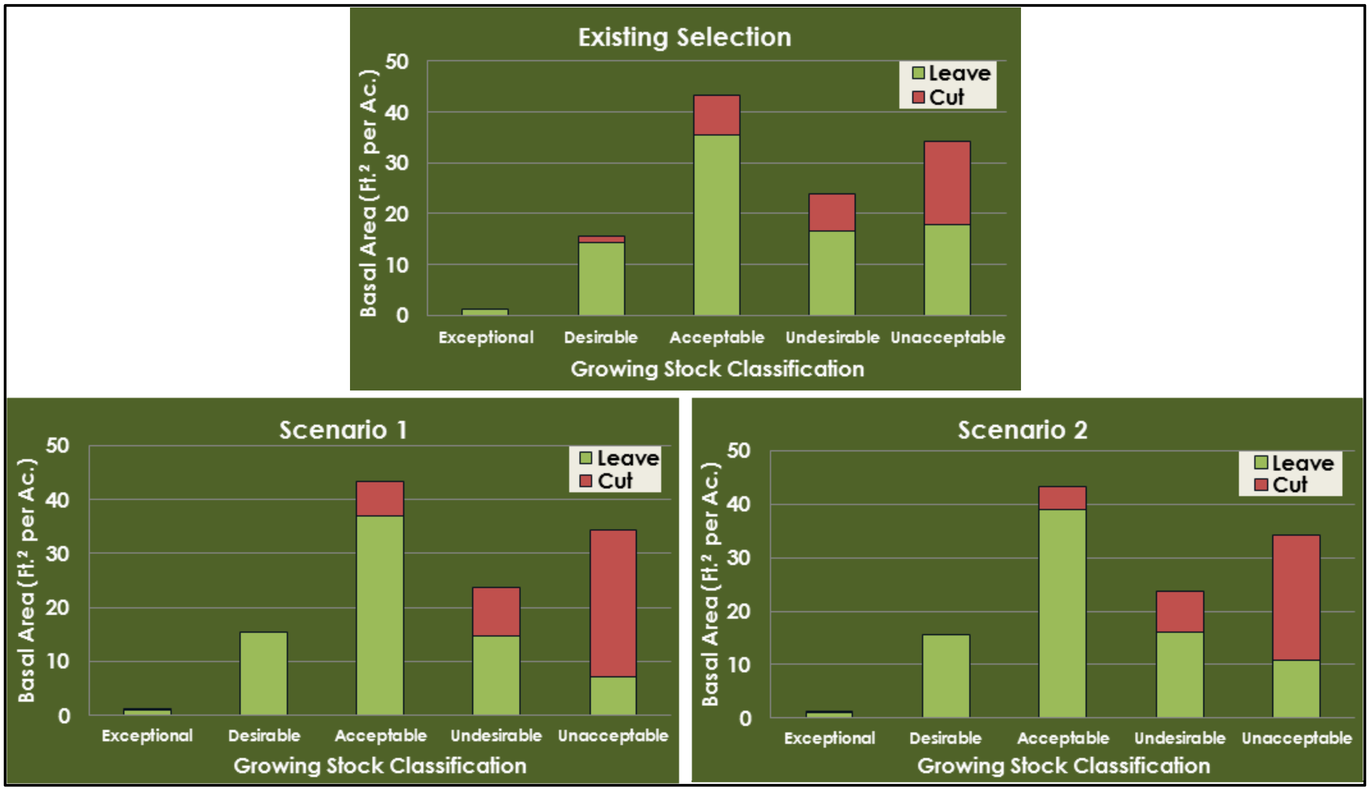


Figure 27 – OOR Analysis: Trees per Acre Comparison of Alternative Selection by Ownership



GS class by harvest designation differed little between Scenario 1 and 2 (Figure 28). Compared to the existing selection, the alternative scenarios removed a higher proportion of the Unacceptable and Undesirable trees. This result was expected, as the model scenarios were designed to remove large, low quality trees (Figure 28).

Figure 28 – OOR Analysis: Comparison of Alternative Selection by Growing Stock Classification Using All Ownership Classes (BA)



Compared to the existing harvest, the two alternative harvest scenarios changed forest quality and structure very little (Exhibit 5). The most notable difference was that Scenario 1 and 2 removed a slightly higher ratio of Risk and Releasing Crop Tree classes (the lowest classes in the order). Similarly, there was very little difference in the residual forest condition for the Nearest Neighbor and Tree Canopy Position tree assessment classes (Exhibit 5).

2.2.2.2.2 Economic

In the nine 1-acre plots, average harvest value increased by 38 percent and 16 percent for the Scenario 1 and 2, respectively, compared to the existing marking. Poletimber and sawtimber volumes increased in Scenario 1. For Scenario 2, about 8 percent less sawtimber volume was removed when compared to the existing harvest (Table 24).

Table 24 – OOR Analysis: All Ownership Classes Alternative Harvest Comparison

Harvest Comparison All Plots					
	Existing	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	Percent Dif.	Value Per Acre	Percent Dif.
Cut	$ 641.38	$ 884.84	38.0	$ 740.63	15.5
Leave	$2,499.70	$2,256.20	-9.7	$2,400.40	-4.0
Total	$3,141.00	$3,141.00	-	$3,141.00	-
	Poletimber (Tons)	Poletimber (Tons)	Percent Dif.	Poletimber (Tons)	Percent Dif.
Cut	19.2	26.9	40.2	23.3	21.3
Leave	43.0	35.2	-18.0	38.9	-9.5
Total	62.1	62.1	-	62.1	-
	Sawtimber (MBF)	Sawtimber (MBF)	Percent Dif.	Sawtimber (MBF)	Percent Dif.
Cut	885.8	1,014.1	14.5	812.4	-8.3
Leave	4,366.3	4,238.1	-2.9	4,439.7	1.7
Total	5,252.2	5,252.2	-	5,252.2	-
	Basal Area (Ft.2)	Basal Area (Ft.2)	Percent Dif.	Basal Area (Ft.2)	Percent Dif.
Cut	32.7	43.0	31.64	35.8	9.67
Leave	85.5	75.2	-12.09	82.3	-3.70
Total	118.2	118.2	-	118.2	-

Tables 25, 26, and 27 summarize the valuation of the modeled harvests by ownership. Scenario 1 increased sawtimber volume harvested and total harvest value relative to the existing marking. The greatest increase in harvest value occurred on private forests. Scenario 2 increased harvest value on all ownerships except for county forests, where the model produced a loss of approximately 10 percent. Because many lower growing stock trees lacked sawtimber volume, Scenario 2 harvested a higher ratio of trees with pulpwood and boltwood volume.

Table 25 – OOR Analysis: County Forest Alternative Harvest Comparison

County Harvest Comparison					
	Existing Selection	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	Percent Dif.	Value Per Acre	Percent Dif.
Cut	$ 740.80	$ 897.20	21.10	$ 665.40	-10.18
Leave	$2,225.60	$2,069.30	-7.02	$2,301.00	3.39
Total	$2,966.40	$2,966.40	-	$2,966.40	-
	Poletimber (Tons)	Poletimber (Tons)	Percent Dif.	Poletimber (Tons)	Percent Dif.
Cut	22.0	25.1	14.22	23.1	4.92
Leave	39.5	36.4	-7.92	38.4	-2.74
Total	61.5	61.5	-	61.5	-
	Sawtimber (MBF)	Sawtimber (MBF)	Percent Dif.	Sawtimber (MBF)	Percent Dif.
Cut	1,022.2	1,118.3	9.40	661.6	-35.27
Leave	3,858.3	3,762.2	-2.49	4,218.9	9.35
Total	4,880.5	4,880.5	-	4,880.5	-
	Basal Area (Ft.2)	Basal Area (Ft.2)	Percent Dif.	Basal Area (Ft.2)	Percent Dif.
Cut	38.7	44.8	15.79	38.0	-1.91
Leave	81.5	75.4	-7.50	82.2	0.91
Total	120.2	120.2	-	120.2	-

Table 26 – OOR Analysis: Private Forest Alternative Harvest Comparison

Private Harvest Comparison					
	Existing Selection	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	Percent Dif.	Value Per Acre	Percent Dif.
Cut	$ 457.40	$ 755.98	65.28	$ 498.50	8.99
Leave	$2,484.00	$2,185.50	-12.02	$2,442.90	-1.65
Total	$2,941.40	$2,941.40	-	$2,941.40	-
	Poletimber (Tons)	Poletimber (Tons)	Percent Dif.	Poletimber (Tons)	Percent Dif.
Cut	16.4	25.3	54.82	22.5	37.44
Leave	45.3	36.3	-19.81	39.2	-13.53
Total	61.7	61.7	-	61.7	-
	Sawtimber (MBF)	Sawtimber (MBF)	Percent Dif.	Sawtimber (MBF)	Percent Dif.
Cut	554.6	783.3	41.24	335.5	-39.51
Leave	4,405.5	4,176.8	-5.19	4,624.6	4.97
Total	4,960.1	4,960.1	-	4,960.1	-
	Basal Area (Ft.2)	Basal Area (Ft.2)	Percent Dif.	Basal Area (Ft.2)	Percent Dif.
Cut	24.9	36.8	47.84	29.7	19.49
Leave	87.1	75.2	-13.66	82.3	-5.56
Total	112.0	112.0	-	112.0	-

Table 27 – OOR Analysis: State Forest Alternative Harvest Comparison

State Harvest Comparison					
	Existing Selection	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	Percent Dif.	Value Per Acre	Percent Dif.
Cut	$ 725.90	$1,103.50	52.02	$ 938.00	29.22
Leave	$2,789.30	$2,411.70	-13.54	$2,577.20	-7.60
Total	$3,515.20	$3,515.20	-	$3,515.20	-
	Poletimber (Tons)	**Poletimber (Tons)**	**Percent Dif.**	**Poletimber (Tons)**	**Percent Dif.**
Cut	19.2	28.8	50.21	25.8	34.15
Leave	44.1	34.4	-21.88	37.5	-14.88
Total	63.3	63.3	-	63.3	-
	Sawtimber (MBF)	**Sawtimber (MBF)**	**Percent Dif.**	**Sawtimber (MBF)**	**Percent Dif.**
Cut	1,080.7	1,453.4	34.49	1,150.2	6.44
Leave	4,835.1	4,462.4	-7.71	4,765.6	-1.44
Total	5,915.8	5,915.8	-	5,915.8	-
State	**Basal Area (Ft.2)**	**Basal Area (Ft.2)**	**Percent Dif.**	**Basal Area (Ft.2)**	**Percent Dif.**
Cut	34.4	47.0	36.55	39.9	16.02
Leave	87.9	75.3	-14.31	82.4	-6.27
Total	122.3	122.3	-	122.3	-

Harvest volume and value summaries by ownership are provided in Exhibit 6. For Scenario 2, sawtimber harvest value on county forests was almost $100.00 per acre, or 25 percent lower than the existing harvest scenario. Hard maple sawtimber volumes were higher for both alternative scenarios than the existing marking, with the exception of Scenario 2 on private and county forests. Total harvest value of sawtimber on private ownerships was about 35 percent lower for Scenario 2 than the existing harvest. Mixed hardwood poletimber accounted for the majority of the poletimber harvest volume and value for both alternative scenarios (Exhibit 6).

The RVG assumptions used in this report are summarized in Section 2.2.1.2.2, Table 12. The average RVG for hard maple sawtimber trees 11-inches and larger are summarized by harvest scenario and ownership in Table 28.

Table 28 – OOR Analysis: Average Hard Maple Rate of Value Growth (RVG) Comparison

County	
Scenario	**RVG of Residual Trees**
Before Harvest	.022
Existing Selection	.028
Scenario 1	.033
Scenario 2	.032
Private	
Scenario	**RVG of Residual Trees**
Before Harvest	.013
Existing Selection	.018
Scenario 1	.028
Scenario 2	.027
State	
Scenario	**RVG of Residual Trees**
Before Harvest	.020
Existing Selection	.024
Scenario 1	.031
Scenario 2	.030

As in the Native Community Analysis, the existing marking modestly improved RVG following harvest, while the alternative scenarios resulted in larger increases. On private lands, the alternative scenarios resulted in an increase of over 100 percent, while RVG improvement averaged around 50 percent for state and county. Once again, higher RVG values did not suggest that value will improve at these levels indefinitely. Rather, RVG provided an estimate of potential increase in value for hard maple growing stock resulting from the various harvest scenarios (Table 28).

2.2.2.2.3 Ecological

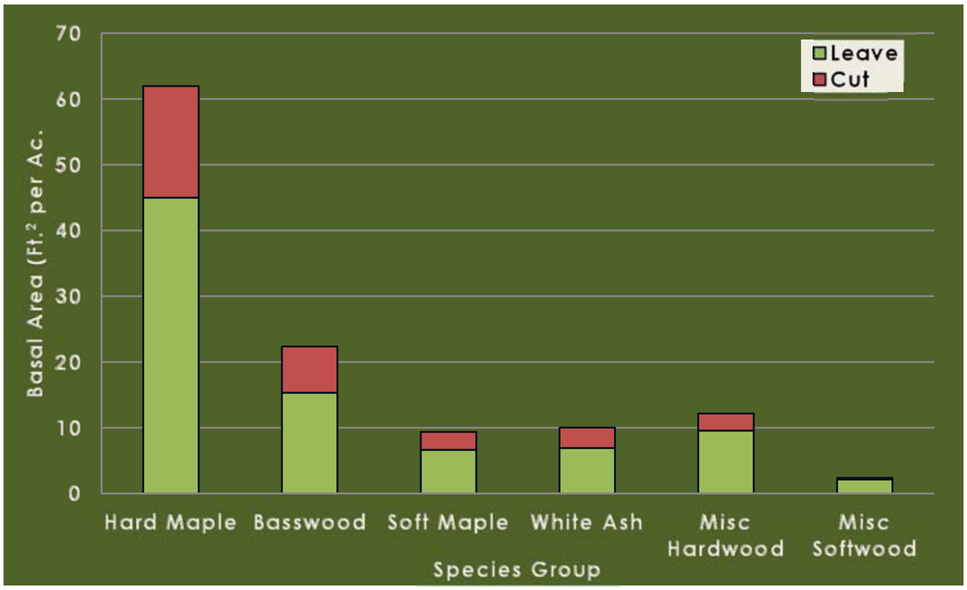
Quadratic mean diameter (QMD) is defined as a tree of average BA and is useful in comparing stand size. Prioritizing removal of mature trees did not have a large effect on QMD (Table 29). Although the alternative scenarios reduced QMD in all landowner classes, the change was minimal. Scenario 2 on the state timber sale had the largest effect on QMD reducing it by a little more than 1 inch.

Table 29 - OOR Analysis: Post Harvest QMD Comparison between Scenarios

QMD Comparison by Landowner						
Landowner	**Before Harvest**	**Existing Selection**	**Scenario 1**		**Scenario 2**	
	QMD	**QMD**	**QMD**	**Percent Dif.**	**QMD**	**Percent Dif.**
County	10.4	10.6	10.4	-2.34	10.4	-1.74
Private	10.1	10.2	9.8	-3.35	9.9	-3.13
State	11.4	11.9	11.1	-6.75	10.8	-8.72

The existing selection in the Statewide OOR Analysis removed a similar proportion of BA for each species. However, the selections made by the alternative scenarios differed from the existing marking in two ways. First, on average, the alternative scenarios removed more BA from each species group due to their overall lower targeted residual BA. Second, the alternative scenarios selected nearly all miscellaneous softwood for harvest, while the existing selection removed very little. This reduced stocking of hemlock in both scenarios. In contrast, in the existing selection, very few hemlocks were selected for harvest, even though many of the hemlocks had low growing stock ratings. However, the alternative scenarios selected many low growing stock hemlock for harvest, thus greatly increasing the number of trees selected for harvest in the miscellaneous softwoods category (Figure 29).

Figure 29– OOR Analysis: Existing Selection Harvest Distribution by Species Using All Ownership Classes (BA)



We found very few cavity trees on the 1-acre plots used for modeling the alternative scenarios (Figure 24). Therefore, we did not analyze wildlife tree data because the alternative scenarios' effect on wildlife trees would not be accurately represented. The existing forest conditions on county, private, and state ownerships suggest that initial forest structure and management varies across ownerships. County forests had the most trees of wildlife character in the 5- to 10-inch DBH class, while state forests appeared to have the most cavity trees and more wildlife trees in the larger size classes.

2.2.2.3 Summary and Conclusions

For the OOR Analysis, we compared state, county, and private forests enrolled in the tax incentive programs. These ownerships all complete forest management in agreement with the WDNR silvicultural handbook guidelines and, more importantly, follow the designated OOR for marking trees when implementing single-tree selection harvest methodology. Our results indicate the following about conditions in these forests.

- Forest structure was quite variable in northern hardwood stands, as evidenced by the varying diameter distribution results
- The sampled stands on state, county, and private MFL lands had diameter distributions resembling unimodal and increasing q-shaped curves
- Of the existing marking, 63 to 77 percent was in the 5- to 10-inch DBH class
- A little more than 43 percent of the trees in the Unacceptable and Undesirable GS class were designated as "cut"

A comparison of ownerships supports the following conclusions.

- Pre-harvest stand conditions were not similar amongst owners. The ANOVA statistical test found the pre-harvest stocking was statistically different on the state, county, and private MFL lands (private = 119 ft.^{2} BA per acre, county = 101 ft.^{2} BA per acre, state = 117 ft.^{2} BA per acre)

- A separation of means test found the pre-harvest condition on county forest to be statistically different from both the state and private forest.
- Post-harvest stocking was found to be the same through an ANOVA statistical test
- Residual stand stocking of the existing harvest ranged from 75.11 $ft.^2$ BA per acre on county lands to 82.94 $ft.^2$ BA per acre on state forests

The existing marking on county forests removed the most BA in the sawtimber-size classes, and also had significantly higher tree regeneration stocking of preferred hardwood species. This may suggest that harvest techniques on county forests are more advantageous to hardwood regeneration when compared to state and private MFL forestlands.

Pre-harvest conditions likely introduced variability into the study. Past harvest methods, or the timing of previous harvest entries, was not evaluated in this study, nor was this considered in selecting the pool of potential stand observations.

As presented earlier, the modeled harvest scenarios used tree selection criteria that focused on removing financially mature trees using maximum tree size ranging from 17 to 19 inches DBH, harvesting the poorest growing stock, and removing low GS grade trees in close proximity to others to mimic a release of crop trees. The OOR modeled in both scenarios removed trees in this order, (1) remove risk, (2) harvest mature, and (3) release crop trees. The models did not have a target diameter distribution or species composition. The model scenarios developed the following forest conditions.

- Scenario 1 resulted in a 16 to 48 percent increase in "cut" BA relative to the existing harvest. Scenario 2 increased "cut" BA by 16 to 19 percent for state and private compared to the existing marking, but decreased it by 2 percent for county
- Removal of low GS class (class 4 and 5) stocking (BA) increased by approximately 54 and 32 percent for Scenario 1 and 2, respectively, compared to the existing harvest
- Compared to the existing harvest, removal of trees greater than or equal to 14 inches DBH increased by 72 percent on county, 106 percent on private, and 91 percent on state for the Scenario 1 model. Scenario 2 resulted in a 36 percent increase in removal of trees $\geq$14 inches DBH for County, 50 percent increase for private, and 72 percent increase for state, relative to the existing harvest.
- Compared to the existing harvest, removals in smaller size classes decreased by 20 percent for Scenario 1 and 41 percent for Scenario 2
- Compared to the existing harvest, Scenario 1 resulted in a 46 percent average increase in harvest value per acre; the highest increase was observed on private forestland (65 percent increase)
- Compared to the existing harvest, Scenario 2 harvest value increased by only 9 percent on average, with harvest value on county forests decreasing by 10 percent
- Compared to the pre-harvest condition, the alternative scenarios resulted in an RVG increase of over 100 percent for private forests, while RVG improvement averaged approximately 50 percent for state and county

The OOR Analysis model settings are summarized in Section 2.2.2.2. Large, low GS class trees were the focus of the OOR tree selection process. However, model settings were adjusted from the base settings to account for deficiencies in size classes, as well as higher stocking in specific qualitative characteristics, such as poor GS class. These model adjustments could be analogous to marking procedure changes made at the stand level in a real world situation.

The diameter distributions of the sample plots suggest that many of the sampled stands were likely even-aged forests. In many cases, current marking approaches for northern hardwood forests do little more than "tend" large diameter trees as in an even-aged conifer stand. Not surprisingly, poor tree regeneration success is observed in many cases. Our model approach focused on removing larger trees to improve understory light conditions, increase growing space for recruiting stems, and develop an all-aged forest. We used a marking guide developed for sites with medium site quality. The guideline removed trees in the following order of priority (refer to 2.1.4.1 for more details).

1. Remove Risk – Remove trees in the worst GS class trees, with additional weight given to sawtimber-sized trees, especially mid-sized trees 14-inches and greater
2. Remove Mature – Harvest trees equal to and greater than the maximum tree size criteria, removing poor GS and the top performers, which are likely considered economically mature
3. Release Crop Trees – Use the remaining BA to remove trees in close proximity to other growing stock and those of low canopy position with poor GS class

This approach is similar to marking guides being developed by others, such as Michael Demchik (University of Wisconsin-Stevens Point), which first remove risk, then focuses on developing the future forest by selecting crop trees. Since removing large, mature trees removes BA quickly, a forester needs to evaluate a greater area and identify future crop trees so that residual density does not drop below the goal for the stand. Our final guideline criteria (index), referred to as "Release Crop Trees," uses the remaining BA to improve stand quality and release future crop trees. These future crop trees should not all be larger diameter trees, but should include pole-sized trees of good quality (likely containing bolt material) that are most likely to recruit in the future forest. Leak, Yamasaki, and Holleran (2014) state, "AGS (acceptable growing stock) should comprise the bulk of the residual stocking after harvest." The models created superior future forests by improving average stand GS classification and hard maple RVG.

Removing trees when they have reached their peak present value can be modeled and analyzed when individual tree records are known; however, this approach is sensitive to the applied interest rate (landowner specific value), growth rate (SI), and product jump potential. In practice, a forester must make an objective decision when a tree is ready for harvest within seconds during a for-profit marking exercise. Therefore, simplifying the decision criteria utilized in the woods, and allowing for flexibility in the use of a marking guide, is reasonable and necessary. The methods used in this study may be simplified, but the practice of coupling financial objectives with long-term sustainability are closely linked. Godman and Mendel (1978) suggest retaining trees that may increase in merchantable height, have potential for tree grade improvement, and may exhibit increased rates of DBH growth. These concepts pair well with the approach used in the alternative scenarios and the model criteria used to assess the GS class of an individual tree

Regeneration of preferred hardwood species, such are hard maple, is a concern of many forest managers. In this study, regeneration was lacking on the state and private forests, and was about 1.5 times more abundant on the county forests, compared to the other owners. This may suggest that county forest managers are achieving improved tree regeneration success when compared to the other owners sampled. Our results suggest that true, all-aged northern hardwood stands are rare, and more intensive regeneration techniques are likely necessary to develop seedlings in the average northern hardwood stand, especially given the growing list of tree damaging agents and current challenges resulting from past disturbance, human and natural alike.

With the alternative harvest scenarios, harvest volumes of both poletimber and sawtimber increased. Increases in poletimber volumes were generally due to the lower residual stocking level modeled under Scenario 1. Across the three ownership classes, Scenario 1 resulted in a 14.5 percent increase in sawtimber MBF volumes. This rate of volume increase probably would not occur in all northern hardwood stands, as this study included only sawtimber-sized stands. However, removal of medium to large sawtimber, 14 inches DBH and greater, would likely increase in stands with average to below average site quality with application of a marking approach that more strictly followed maximum tree size management at sizes smaller than typically applied (24 inches DBH).

3. Red Pine and Aspen Forest Rotation Ages

3.1 Methods

This analysis simulated yields and economic returns from typical even-aged management of aspen and red pine on a representative range of site quality classes in Wisconsin and explored the economic impact of the minimum rotation age requirements. The study included these components.

1. Individual Stand Simulation – Land Expectation Value (LEV) analysis for optimum rotation length by species
2. Woodstock Optimization Model – simulating the impact of the presence or absence of mandatory minimum rotation lengths

3.1.1 Literature Review

Quality growth and yield estimation is necessary to accurately assess economic impacts of management consideration for even-aged tree species such as aspen. The Manager's handbook for Aspen in the North Central States (1977) provides estimates of aspen yield by site class (SI = 40, 50, 60, and 70) every 10 years, beginning at age 20. Ek and Brodie (1975) developed a prediction formula that is site sensitive and projects yield and stocking in early stages of stand development, and provides yield appropriate for roundwood wood product application.

Red pine growth and yield and genetics have not been studied to the same extent as other species in the *Pinus* family. A recently released technical report titled, A Revised Managers Handbook for Red Pine in the North Central Region states, "Generally, for production management purposes, the rotation age for red pine is between 60 to 90 years, as defined by culmination of mean annual growth increment." Additional focus is necessary to evaluate if mean annual increment (MAI) occurs at an age where current roundwood stumpage prices, and management, and holding costs result in the maximization of financial return on timberland investment.

3.1.2 Data Acquisition

For the modeling components of this analysis, we complied data on aspen and red pine stands from the WI tax law programs (MFL and FCL). Stand attribute data for small private ownerships enrolled in the tax law programs is stored in the WDNR central database (WisFIRS) and was requested for this analysis. Requests also were made to owners and managers of large industrial lands enrolled in the tax law programs, since this data is not stored in WisFIRS. The datasets included stand acres, age, site index, average size class, and average stocking level.

3.1.3 Modeling

3.1.3.1 Model Selection

Land Expectation Value (LEV) - Definition
The current value of any capital asset can be viewed as the discounted value of the future net income stream it is capable of producing. Forestland buyers and owners with economic objectives often examine anticipated cost outlays, timber growth, and timber sale revenue using discounted cash flow (DCF) analysis.

Land expectation value (LEV) is a special application of DCF analysis that looks at a *continuous cycle* of hypothetical forest rotations. LEV is also known as soil expectation value (SEV), since it expresses the value of the bare forest land apart from any standing timber or regeneration. LEV is important and widely accepted as a tool not only for determining the value of the bare land (for a particular forest management scenario), but also for *maximizing* the returns to forest management, i.e. the value of the land. A textbook for foresters states "LEV …is the main tool used to identify optimal even-aged management regimes, including rotation decisions, thinning regimes, stand establishment effort, and intermediate treatments (McDill, 2015)."

The discount rate is a particularly important parameter in LEV calculations. Higher discount rates lead to shorter rotations, while a zero discount rate leads to maximum revenue without regard to timing, which normally means the rotation length that maximizes physical yield per year, or the point of maximum mean annual increment.

Aspen Yield Model Selection:

LEV analysis for optimum rotation length requires year-by-year standing volume estimates for each site quality class, most often using a set of yield prediction equations. We examined a number of alternative equation systems using the following criteria.

- Predicts merchantable yield at all ages. Most aspen is harvested as roundwood, not whole tree chips, so the total biomass yield is not the key parameter affecting rotation length.
- Biologically reasonable, having inflection points and the "crossover" of mean annual increment and current annual increment at roughly expected ages by site quality.
- Operationally reasonable – consistent with widely used normal yield tables such as the one included in the Manager's Handbook for Aspen.

The yield system developed by Ek and Brodie (1975) best fit these criteria. It is very broad based, and the authors incorporated a number of measured datasets from government and private industry. Conventional yield to a 3-inch DBH (inside bark) top diameter is expressed in cubic feet; we converted to cords at 79 cubic feet per cord.

Red Pine Yield Model Selection:

The "Resinosa" model developed in 2002 by Tim Mack and others at the University of Minnesota is widely regarded as the most appropriate tool for questions about red pine plantation management. A spreadsheet software implementation is available, which includes both the biological and economic modeling procedures. Resinosa includes a "bounded" simulation option that automatically schedules thinnings when stand density reaches a specified boundary. The "custom" option allows the user to specify the thinning ages and residual densities. This analysis made use of the "custom" option and applied typical thinning regimes provided by foresters who manage red pine.

3.1.3.2 Assumptions

Aspen Model:

To simplify the aspen analysis, we ignored species (*P. tremuloides* vs. *P. grandidentata*) and ignored the fact that aspen stands are rarely made up of 100 percent aspen species. These assumptions are compatible with the yield equations that were used. Economic assumptions for aspen are summarized in Table 30.

Table 30 – Aspen Rotation Age Analysis: Economic Assumptions for Aspen

Economic Assumptions for Aspen		
Parameter	**Value**	**Comment**
Discount rate	5.5 percent (real)	Currently used in timberland valuations
Stand establishment cost	$0.00	No treatment is required
Annual management cost	$3.73 per acre per year	Property taxes
Harvest administration cost	$40.00 per acre	Not logging cost – this is for the setup and admin. It also includes severance tax.
Stumpage price	$40.00 per cord	Net to the landowner

Resource Area by Site Index:

The development of forest stands over time is strongly affected by site quality or site productivity. This is typically measured as "site index," or the expected height of the trees at a given age, which, for aspen, is 50 years. The resource data assembled for the regional Woodstock model was used to segment the aspen resource into site quality classes, as follows.

Table 31 – Aspen Rotation Age Analysis: Aspen Area
By Site Quality on WI MFL/FCL Forests

Aspen Area by Site Quality		
Site Quality	**Modeled Site Index**	**Percent of Area**
Low	60	28
Average	70	57
High	80	15

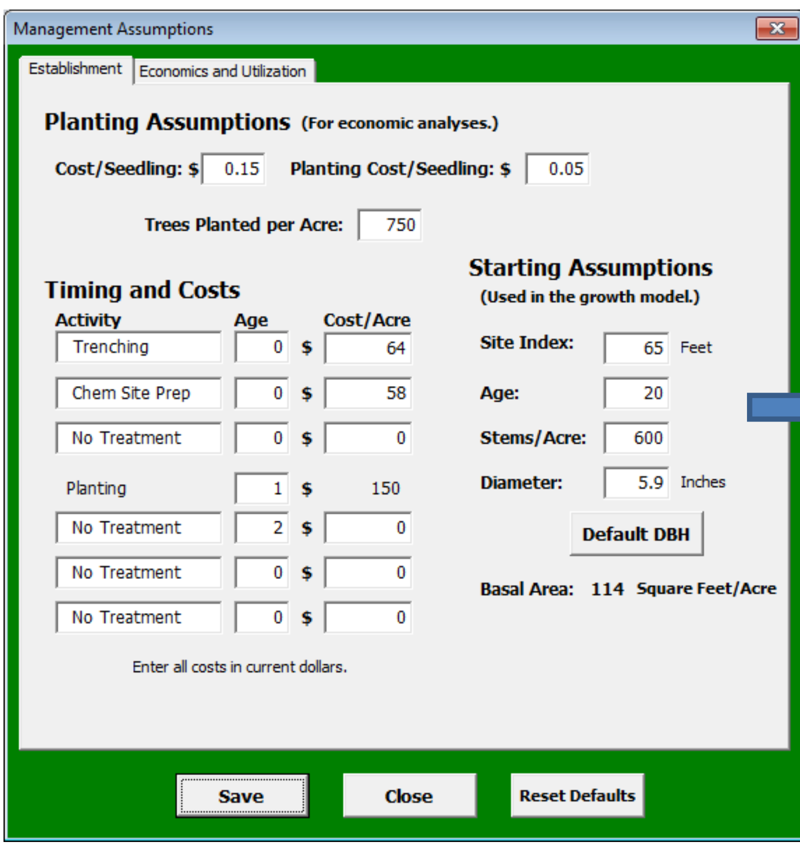
The resource data assembled for the regional Woodstock model was used to segment the red pine resource into site quality classes as follows.

Table 32 – Red Pine Rotation Age Analysis:
Red Pine Area by Site Quality on WI MFL/FCL Forests

Red Pine Plantations by Site Quality		
Site Quality	**Representative Site Index**	**Percent of Area**
Low	62	20
Average	65	60
High	72	20

Red Pine Model:
To facilitate replication of the red pine results, we illustrate some parameters using screen captures of the Resinosa software. The model author recommended the use of SEV rather than LEV, as the LEV calculation in Resinosa lacks the subsequent rotations (Figure 30).

Figure 30 - Red Pine Rotation Age Analysis: Resinosa Stand Establishment Assumptions

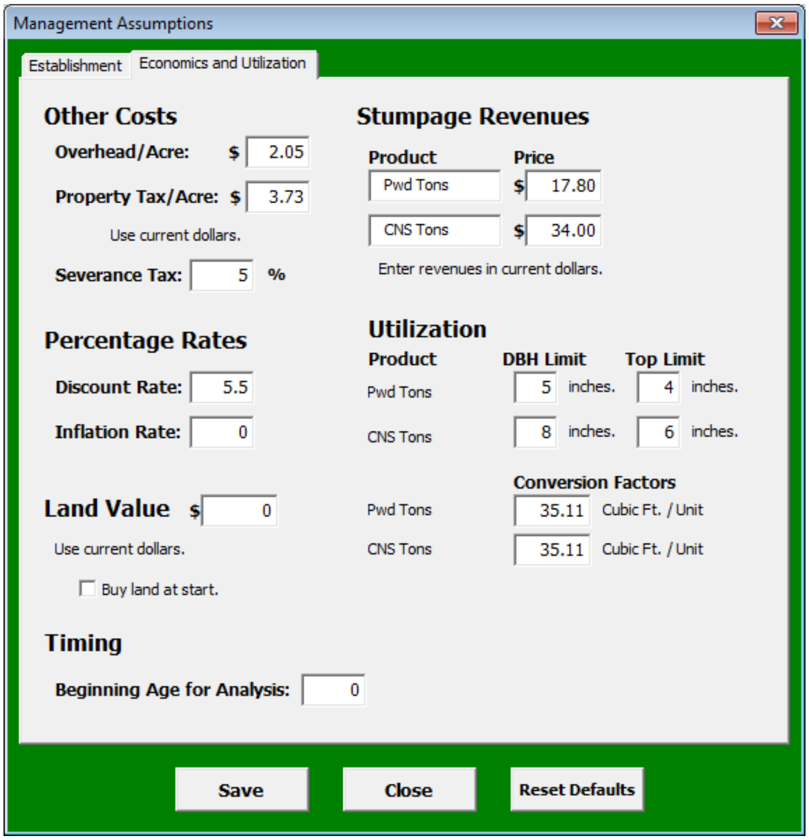


	Low	Avg.	High
Site Index	62	65	72
Age	20	20	20
Stems/Acre	600	600	600
Diameter	5.4	5.5	5.9
Basal Area	95	99	114

Stand establishment practices and costs were supplied by practicing foresters from Wisconsin. The stand conditions at age 20 were the defaults calculated by the model for 750 trees planted for each site index (Figure 30).

The native yields in Resinosa were expressed in cubic feet. These were converted to tons at 35.11 cubic feet per ton. Administrative overhead costs actually occur each time a thinning or final harvest is conducted, ranging from $25.00 per acre to as high as $74.00 per acre for marked thinnings. Because Resinosa lacks a parameter for harvest administration cost per acre, the typical costs were amortized at 5.5 percent discount rate, which led to the equivalent value of $2.05 per acre per year (Figure 31).

Figure 31 - Red Pine Rotation Age Analysis:
Resinosa Economics and Utilization Assumptions



The typical four-thinning regime for average sites included thinnings at ages 25, 35, 45, and 55, with the first thinning to BA 100 and then higher BA over time. This schedule was slowed somewhat for low quality sites and accelerated for high quality sites to reflect the most likely management practices (Table 33).

Table 33 - Red Pine Rotation Age Analysis:
Red Pine Thinning Schedule by Site Index

Red Pine Thinning Schedule by Site Index				
Treatment	Age by Site Quality			Residual Basal Area
	Low (62)	Avg. (65)	High (72)	
First thinning	25	25	23	100
Second thinning	37	35	32	100
Third thinning	49	45	41	110
Fourth thinning	-	55	50	120

3.2 Results

3.2.1 Aspen

The Manager's Handbook for Aspen states: "The species grows rapidly, thins itself naturally from competition, insects, and diseases, and matures in 30 to 70 years: occasional trees will survive 100 years or more. Without disturbance, aspen stands will be replaced by more tolerant or longer-lived associates....The recommended silvicultural system for growing and reproducing aspen is complete clearcutting at rotation age to regenerate pure, fully stocked stands of suckers" (Perala, 1977). A sucker is a strong shoot that rises from a root or the base of a stump. Aspen grows on a wide range of sites and is available throughout the year due to its ability to establish on virtually any disturbed site.

LEV Findings:
LEV analysis predicts merchantable yield at all ages that are operationally reasonable, as the results are consistent with widely used tables. On low quality sites, using a 5.5 percent discount rate, the financially optimal rotation was at age 40, which is the required minimum (WDNR, SFAH, HB2431.5). Returns from aspen management at Site Index 60 were quite low, and many such dry, sandy sites would be candidates for conversion to pine. Based on these results, the aspen rotation length regulation does not appear to impose economic constraints on low quality sites (Figure 32).

Figure 32 – Aspen Rotation Age Analysis: LEV for Aspen on Low Quality Sites (Site Index 60)

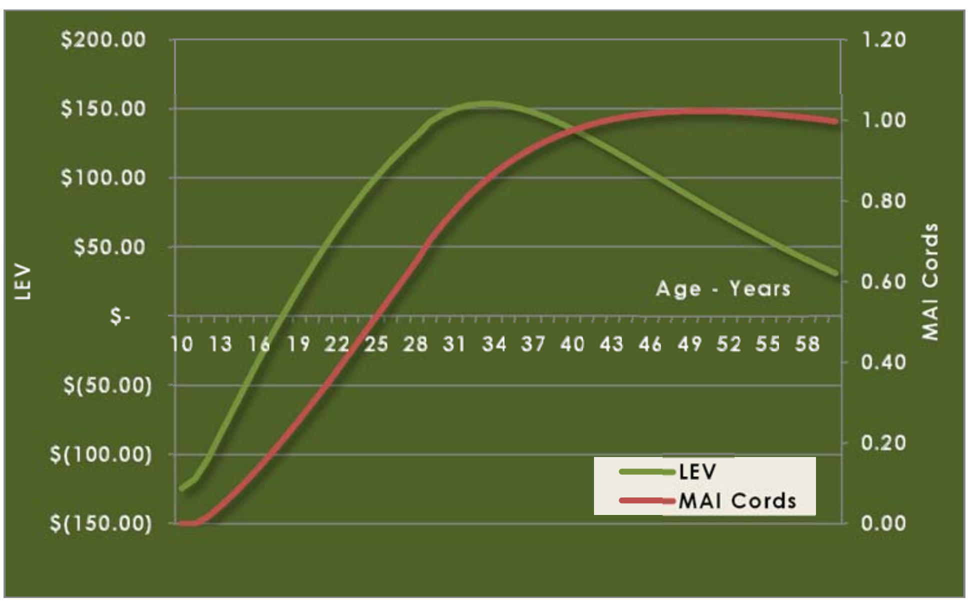
Stands on low and very low quality aspen sites are subject to "early break-up" when subject to repeated drought years or insect or disease problems. While there are many anecdotal accounts, we could not find any data documenting the extent of the phenomenon. If and when early break-up occurs on MFL lands, the landowner's economic returns are definitely reduced when he or she is prevented from harvesting a distressed stand prior to age 40.

For Site Index 70 at a 5.5 percent discount rate, the financially optimum rotation length was 36 years, with a physical yield of 0.63 cords per acre per year. The value per acre was $78.75, or 388 percent of the value for Site Index 60 ($20.31). At age 40, the LEV was $74.50, or $4.25 per acre less than at age 36. Age 40 is still in the relatively "flat" region of the LEV and, given the limitations of yield models, the modest difference between age 36 and age 40 in terms of economic productivity does not suggest that the regulation has a significant impact (Figure 33).

Figure 33 - Aspen Rotation Age Analysis: LEV for
Aspen on Average Quality Sites (Site Index 70)

For Site Index 80 at 5.5 percent discount rate, the financially optimum rotation length was 33 years, with a physical yield of 0.84 cords per acre per year. The value per acre was $153.54, or 195 percent of the value for Site Index 70 ($78.85). At age 40, the LEV declined to $134.69, or $18.85 per acre less than at age 33. Age 40 is clearly in the downward-sloping part of the value curve. Given the assumptions and yields, the age 40 minimum prevented optimum management and optimum returns on high quality aspen sites (Figure 34).

Figure 34 - Aspen Rotation Age Analysis: LEV for
Aspen High Quality on High Quality Sites (Site Index 80)



A tabular summary of the LEV analyses are provided in Exhibit 7.

Effect of Discount Rate:
Discount rates vary between investors and over time. We tested the effect of 100 basis points up and down from the current typical rate of 5.5 percent (Table 34).

Table 34 – Aspen Rotation Age Analysis: Sensitivity Analysis of Discount Rate

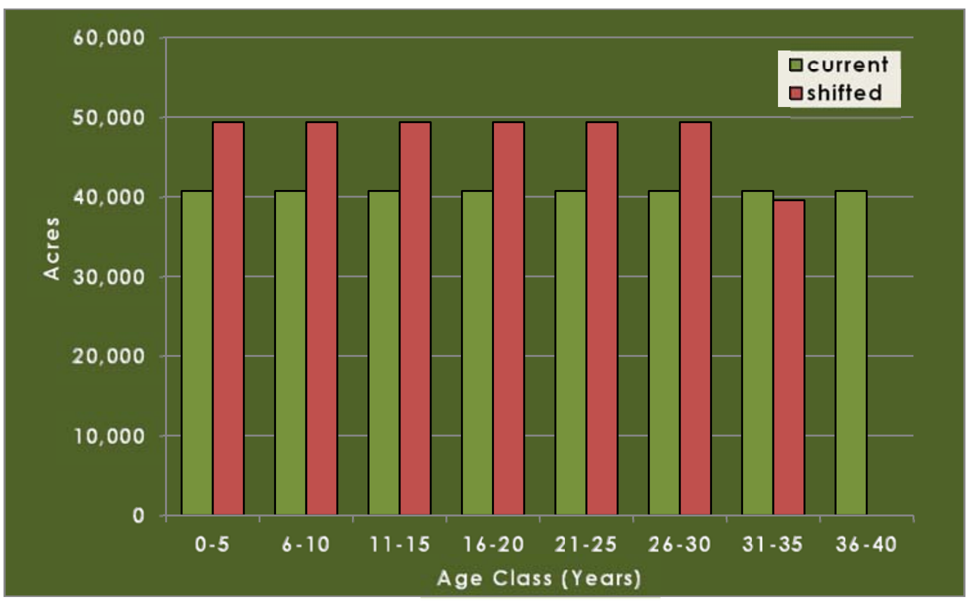
Aspen Sensitivity Analysis - Discount Rate						
	4.5 Percent Discount Rate		5.5 Percent Discount Rate		6.5 Percent Discount Rate	
Site Index	Optimum Rotation (Years)	LEV Per Acre Diminution at Age 40	Optimum Rotation (Years)	LEV Per Acre Diminution at Age 40	Optimum Rotation (Years)	LEV Per Acre Diminution at Age 40
60	42	$ -	40	$ -	39	$ (0.61)
70	38	$ (1.74)	36	$ (4.24)	35	$ (6.15)
80	35	$(14.56)	33	$(18.85)	32	$(20.84)

At 4.5 percent, optimum rotations were two years longer than the base case, but rotation lengths remained below 40 years for both site index 70 and 80. At 6.5 percent, the rotations were one year shorter. We concluded that, although the magnitude of the economic impact correlates positively with the discount rate, the negative impact is apparent across a reasonable range of rates.

3.2.1.1 Aspen LEV Ecological Considerations

Our results suggested that the regulation serves to lengthen rotations beyond the economic optimum only on better quality sites and only by about seven years. If the minimum rotation age restriction was removed, and if all tax law landowners took advantage of that fact, then, over time, there would be a shift in the age class distribution on high-quality aspen sites (Figure 35). The theoretical reduction in the upper two age classes would be 42,000 acres, which is 13 percent of the total aspen acres. It is not likely that such a modest shift would have significant ecological consequences.

Figure 35 - Aspen Rotation Age Analysis: Hypothetical Age Class Distribution of Fully Regulated Aspen Sites on WI MFL/FCL Forests



Another ecological perspective to consider is that aspen is shade intolerant and disturbance dependent. Maintaining aspen requires its complete removal by fire or clear-cutting before the aspen component in the stand declines in favor of other species. The acreage of aspen in Wisconsin has been in decline for decades, due, in part, to the lack of the disturbance needed to maintain (regenerate) these stands and allow forest succession to other species and, ultimately, forest type.

3.2.1.2 LEV Summary and Conclusions

There are approximately 326,000 acres of aspen on MFL lands in Wisconsin. The impacts of the minimum rotation age requirement of 40 years are summarized as follows.

Table 35 – Aspen Rotation Age Analysis: Summary of Impact

Summary of Impact - Aspen						
Site Quality	Proportion	Acres	LEV Per Acre	Total LEV	Diminution in LEV Per Acre	Total Diminution in LEV
Low	28	91,220	$ 20.31	$ 1,852,668	$ -	$ -
Average	57	185,697	$ 78.75	$14,623,629	$ (4.25)	$ (789,212)
High	15	48,868	$153.54	$ 7,503,131	$(18.85)	$ (921,154)
Total	100	325,784	$ 73.61	$23,979,429	$ (5.25)	$ (1,710,366)

Our results indicated that financial returns are negatively impacted by the 40-year minimum rotation length on primarily high quality sites. In reality, however, the impact on value is continuous, increasing with site quality rather than discrete in three classes as shown. Although better quality sites make up only 15 percent of the acreage, they represent 31 percent of the value. From this perspective, approximately 31 percent of the value of the aspen resource is being negatively impacted by the rotation age regulation. Prudent investors will seek to either acquire lands or manage lands in such a way as to skew their aspen portfolio toward the higher range of productivity and, thus, they would be even more affected by the regulation.

3.2.2 Red Pine

The Manager's Handbook for Red Pine (Gilmore, et al., 2005) states, "Red pine (*Pinus resinosa Ait.*), also known as Norway pine has been the most widely planted species in the Lake States region of North America over the past 70 years. As a result, the red pine cover type in the Lake States has increased more than fivefold to almost 1.9 million acres. Because of its widespread occurrence and economic value, red pine has long received close attention from researchers and forest managers." Not only is red pine widely planted, it is also intensively managed with multiple thinning regimes to maximize total return by capturing what would otherwise be mortality from self-thinning and to accelerate diameter growth. As with aspen, development of red pine stands over time is strongly affected by site quality or site productivity. This is typically measured as "site index," or the expected height of the trees at age 50.

SEV Findings:

For all three site quality classes (at the 5.5 percent discount rate), a shorter, three-thinning regime produced more value than a 60-year, four-thinning regime (Table 36). The difference was more pronounced for the high quality sites. Our results suggest that, when rotation length is constrained (by regulation) to 60 years or longer, regimes with four thinnings are optimal (except for Site Index 62, which requires three thinnings). Without the constraint, regimes with three thinnings, followed by an earlier clearcut, are more productive in financial terms.

Table 36 – Red Pine Rotation Age Analysis:
Red Pine SEV Results by Site Index

Red Pine SEV Results by Site Index			
Result	Low (62)	Avg. (65)	High (72)
Unconstrained, 3-thin Max. SEV	$ 7.18	$ 76.22	$120.93
Rotation (Years) at Max. SEV	54	50	48
SEV When Constrained to 60 Years	($2.02)	$ 63.23	$99.24
Reduction in SEV	($9.20)	($12.99)	($21.69)

Discount rates vary between investors and over time. Thus, for site index 65, we tested the effect of 100 basis points up and down from the current typical rate of 5.5 percent (Table 37). At 4.5 percent, the optimum rotation was two years longer than the base case, but still shorter than 60 years. At 6.5 percent, the rotation was two years shorter. As with aspen, we conclude that, although the magnitude of the economic impact correlated positively with the discount rate, the negative impact was apparent across a reasonable range of rates.

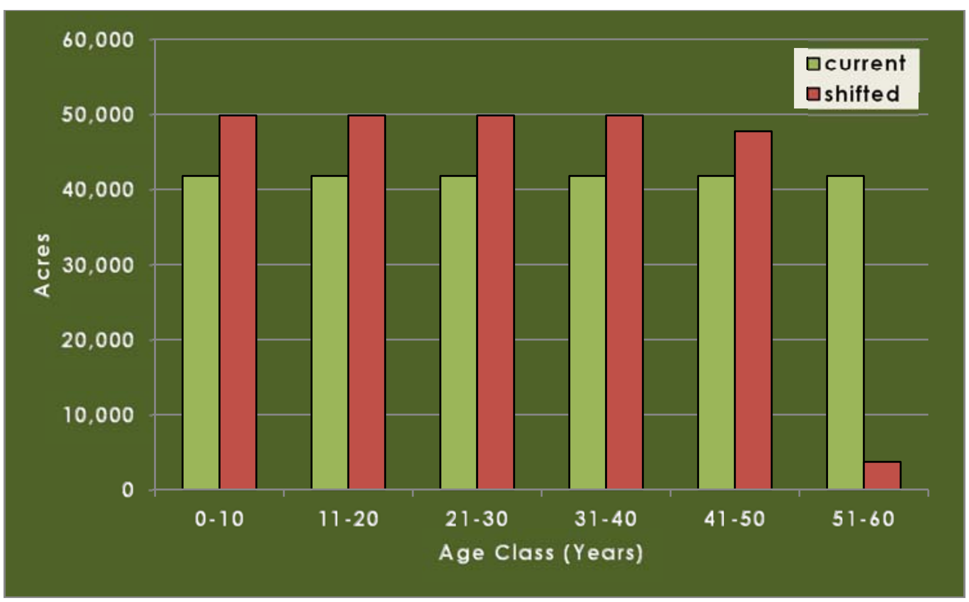
Table 37 – Red Pine Rotation Age Analysis:
Sensitivity Analysis of Discount Rate (Site Index 65)

Effect on Discount Rate on Optimums for Site Index 65					
4.5 Percent Discount Rate		5.5 Percent Discount Rate		6.5 Percent Discount Rate	
Optimum Rotation (Years)	SEV Per Acre Diminution at Age 60	Optimum Rotation (Years)	SEV Per Acre Diminution at Age 60	Optimum Rotation (Years)	SEV Per Acre Diminution at Age 60
52	($3.88)	50	($12.99)	48	($23.93)

3.2.2.1 Red Pine SEV Ecological Considerations

The age class distribution for red pine plantations in Wisconsin is already severely truncated at age 60. Apparently, landowners do not wait many years beyond 60 to clearcut the plantations. If the rule was relaxed, over time, one would expect age class distribution to shift to the left somewhat, with the "worst case" shown in Figure 36. The net long-term effect would be to shift about 38,000 acres from the age 51 to 60 class uniformly across the younger age classes. This modest shift in the age of plantations would create approximately $3.5 million in land value and improve the relative attractiveness of red pine silviculture in Wisconsin.

Figure 36 – Red Pine Rotation Age Analysis: Hypothetical Age Class Distribution of Fully Regulated Red Pine Plantation Resource on WI MFL/FCL Forests



3.2.2.2 SEV Summary and Conclusions

There are approximately 251,000 acres of red pine plantations on tax law lands in Wisconsin. The estimated statewide impact of the minimum rotation length rule can be summarized as follows.

Table 38 – Red Pine Rotation Age Analysis: Red Pine SEV Economic Impact

Red Pine SEV Economic Impact						
Site Quality	Percent of Area	Acres	Optimal SEV Per Acre	Total SEV	Diminution in SEV Per Acre Due to 60 Years	Total Diminution in SEV
Low	20	50,172	$ 7.18	$ 360,238	($ 9.20)	$ (461,586)
Average	60	150,517	$ 76.22	$11,472,421	($12.99)	$(1,955,218)
High	20	50,172	$120.93	$ 6,067,348	($21.69)	$(1,088,239)
Total	**100**	**250,862**	$ 71.35	**$17,900,007**	($13.97)	**$(3,505,044)**

Although the red pine acreage is only 77 percent of the aspen acreage, the estimated total economic impact of the regulation is twice as large ($3.5 million vs. $1.7 million). The 60-year policy requirements for red pine affect a *greater proportion* of the red pine acreage, and at a higher absolute reduction per acre for average sites, than does the 40-year rule for aspen (Table 38).

3.2.3 Long-Term Potential Wood Availability – Wood Stock Analysis

In a second component of the rotation age analysis, we studied potential benefits from relaxing minimum harvest age standards for both aspen and red pine. This was analyzed using the Woodstock harvest scheduling software platform. Two models were developed, one for aspen and one for red pine. The purpose of the modeling was:

1. To compare potential harvest volume availability for each species under the current tax law guidelines (regulation) versus scenarios in which final harvest age guidelines were relaxed, by allowing for harvest at the optimum economic ages described previously; and
2. To develop estimates of potential value gains to landowners of these cover types, resulting from relaxation in the harvest age guidelines.

We built Woodstock models using data assembled from tax law ownership data sources. Data was provided for both "small block" and "large block" owners. Small block owners include small non-industrial private landowners, while the large block owners represented larger ownerships typically held by institutional investors or the few remaining forest products firms still owning timberland. As noted, area information was complete in the case of the small block owners, but incomplete for 47 percent of large block owners. To develop a more complete picture of overall tax law ownership, we extrapolated data for the missing large block owners from the known large block data. For purposes of modeling, we assumed that unknown timberland areas would be similar in terms of age and site distribution to their known large block counterparts (Table 39). We also assumed that the large block lands would share common establishment and management histories, given that most originated under the control of industrial owners with common objectives, and most continue to be managed under primarily economic intents. The analysis was based on assumed MFL acreages of 325,784 acres of aspen and 250,862 acres of red pine dominated forest.

Table 39 – Aspen and Red Pine Rotation Age Analysis:
Summary of Modeled Area (WI MFL/FCL Forests)

Summary of Modeled Area		
	Forest Type	
Owner	Aspen Acres	Red Pine Acres
Small Block	205,153	98,890
Large Block Known	64,198	80,877
Large Block Extrapolated	56,433	71,095
Total:	325,784	250,862

Beginning age and site class distributions assumed in the models were based on the data described above. For purposes of modeling, we assumed a generic set of yield curves, identical to those described above for the SEV analyses for the respective species. Beginning and projected yields used in the models were assigned based on stand age and site class.

We developed two models for each cover type, one subject to current tax law rotation age guidelines (40 years for aspen, 60 years for red pine), and a second based on relaxed minimum harvest ages. Rotation ages for aspen under the Relaxed MFL ("Relaxed MFL") scenario were set as reported above at 40, 36, and 33 years, respectively, for the low, average, and high site classes. Rotation ages for red pine under the relaxed tax law scenario were set as reported above at 54, 50, and 48 years, respectively, for the low, average, and high site classes.

Beginning age class distributions assumed in the analyses are shown in Figures 37 and 38. Age classes 30-39 years were eligible for harvest under the respective Relaxed MFL scenarios. The aspen model identified 94,977 acres eligible for immediate harvest under the current guidelines. This area increased to 118,040 acres when minimum harvest ages were relaxed because the aspen type had a significant acreage already above the guideline age. Relaxing harvest ages resulted in a 24 percent increase in harvest-eligible area. The red pine model identified only 9,042 acres eligible for immediate harvest under the current guidelines. This area increased to 43,273 with relaxed minimum harvest ages, a 378 percent increase. The immediate impact to pine was relatively greater than for aspen, based on its present age class distribution (Figures 37 and 38).

Figure 37 – Aspen Rotation Age Analysis:
Modeled Aspen Age Class Distribution on WI MFL/FCL Forests

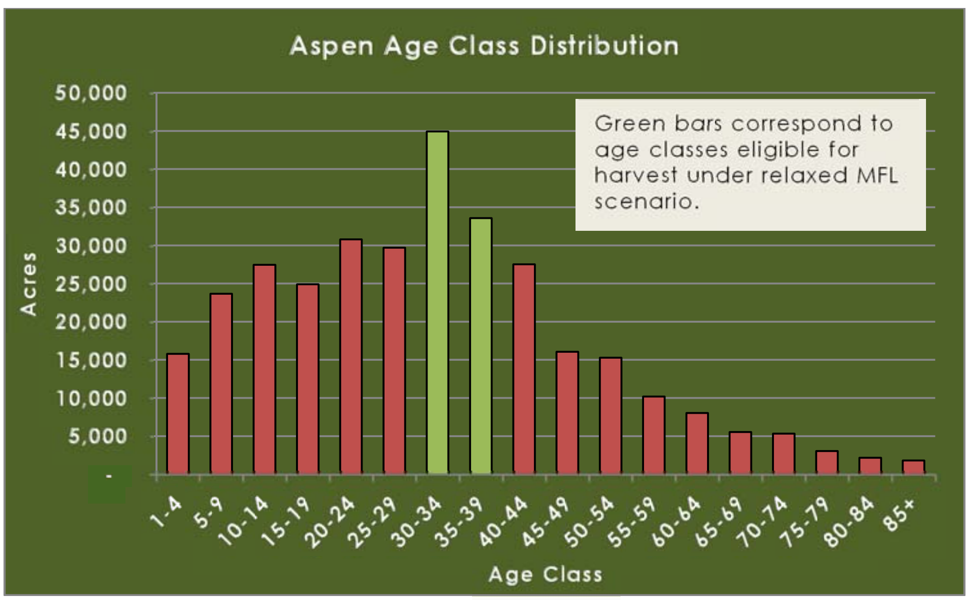


Figure 38 – Red Pine Rotation Age Analysis:
Modeled Red Pine Age Class Distribution on WI MFL/FCL Forests

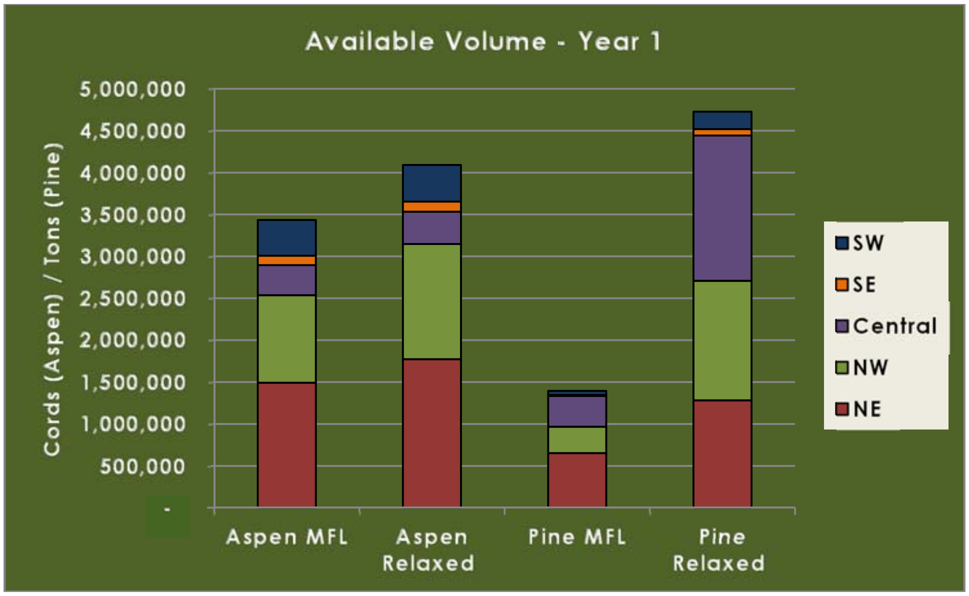
Each scenario modeled was set up to collectively maximize the present value of future cash flows over a 40-year period from the perspective of individual landowners. Yields, price, and cost assumptions used in the models were as described for the SEV analyses. All models used a discount rate of 5.5 percent and were run unconstrained, except for the rotation age parameters just described.

The models were designed to simulate the hypothetical condition under which each stand was managed to maximize economic value to the timberland owner. Wood flows, therefore, should not be viewed from the perspective of a typical "woodbasket" analysis, whereby harvest volumes are interpreted in terms of their relationship to market-related factors such demand and price. Rather, it must be emphasized that the outputs serve to illustrate the potential volumes available for harvest at any given time under the various scenarios, assuming economic return as the primary goal. In actual practice, "real-world" wood flows would reflect the interaction between supply, demand, prevailing prices, and other factors. Thus, projected wood flows reflect potential volumes that could be made available to the market, not those that would be expected under current or near-future market conditions.

In actual practice, for many landowners, such as institutional investors, economics is a driving factor; however, for others, such as families and individuals, economics often take a back seat to non-economic objectives. Owners with important non-economic objectives are often inclined to hold back wood, regardless of minimum rotation age. Once again, the purpose of this analysis was to compare potential wood flows and economic returns as opposed to project likely on-the-ground practice.

Model Output:
The most striking differences between the two scenarios occurred in the first year for both aspen and pine. This is not surprising, as there were areas for both types on the cusp of merchantability under the current harvest guidelines. Relaxing the guidelines instantaneously released these acres and their corresponding volumes for harvest. Relaxing the tax law guidelines for red pine released significant acreage in the 45- to 59-year age classes for immediate harvest (Figure 38). Figure 39 illustrates the differences, showing potential harvest volume by region. The difference is most striking in the case of red pine, which had fewer acres eligible for final harvest.

Figure 39 – Aspen and Red Pine Rotation Age Analysis:
Year 1 Potential Volumes on WI MFL/FCL Forests



Figures 40 and 41 show potential harvest volumes by decade for the 40-year analysis horizon by cover type. Potential aspen harvest increased in the first decade, decreased in the second and third, then more than doubled in the fourth. The second and third decade declines were due to shifts in harvests to the first decade, coupled with lower average yields resulting from earlier harvest ages. The fourth decade increase resulted from average and high site stands becoming eligible for harvest once again in less than 40 years (Figure 40).

Figure 40 – Aspen Rotation Age Analysis:
Potential Aspen Harvests by Decade on WI MFL/FCL Forests

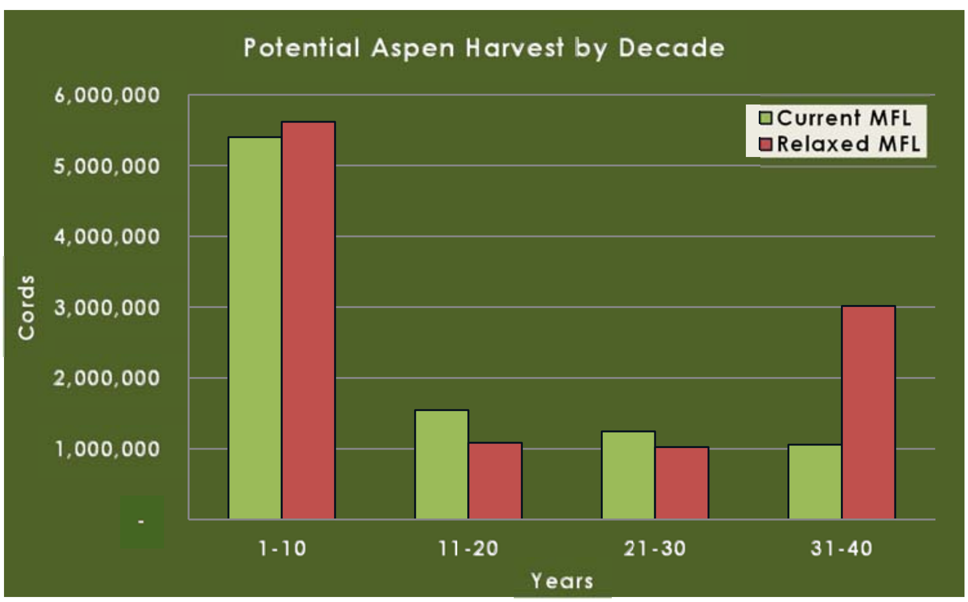


Figure 41 – Red Pine Rotation Age Analysis:
Potential Pine Harvests by Decade on WI MFL/FCL Forests

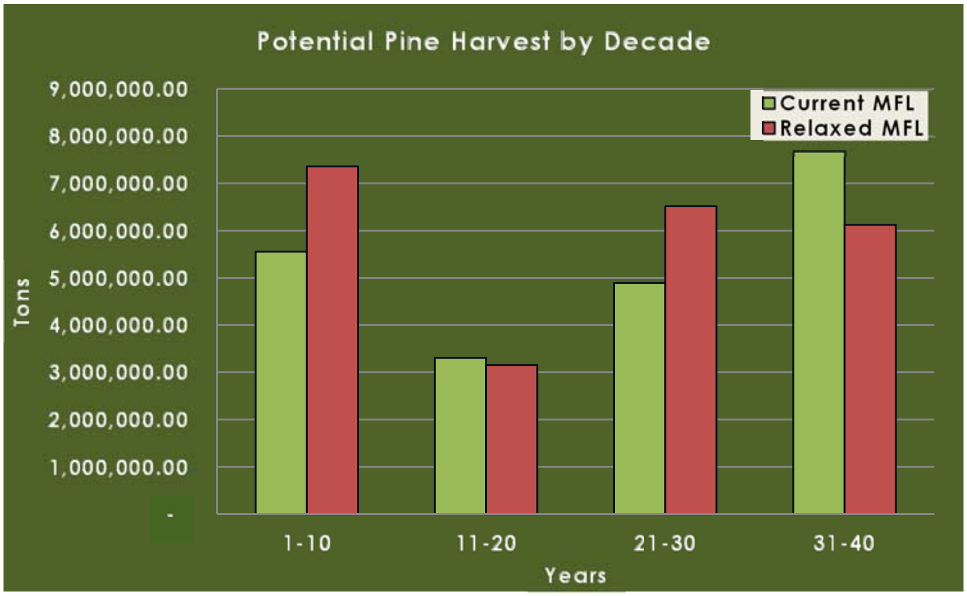


Figure 41 shows a similar graph for red pine. The first decade's volume increase was largely due to increased potential harvest in year one. The second decade exhibited little change in potential harvest, while volume from the fourth decade was shifted into the third under the Relaxed MFL scenario.

Relaxing the "MFL" harvest ages in the case of aspen increased potential harvest for the 40-year period from 9.2 to 10.7 million cords, a 16 percent increase in volume. Potential pine volume increases over the period by 6.5 percent, going from 21.5 to 22.9 million tons.

Future harvest age averaged 40 and 60 years in the case of aspen and red pine, respectively, at year 40 of the two model runs, assuming current MFL guidelines. Not surprisingly, average harvest ages dropped in the two relaxed scenarios as the Woodstock model allowed harvest earlier. Aspen harvest ages dropped by 3 years from 40 to 37 years, while red pine ages declined by 5 years from 60 to 55 years.

Table 40 presents cumulative present value of cash flows for the aspen type, as maximized by Woodstock, for the scenarios by zone. Not surprisingly, the northwest and northeast zones, with the highest concentrations of timberland, had the highest present values. Present value under the current MFL guidelines totaled $196.0 million over the 40-year period. Relaxing the guidelines increased present value to $209.6 million, a 6.9 percent increase in value for an average of $42.00 per acre. Figures 42 and 43 show the evolution of the final cumulative present values for the two aspen scenarios by region.

Table 40 – Aspen Rotation Age Analysis:
Aspen Cumulative Present Values by Scenario and Zone

Cumulative Present Value - Aspen						
Zone	**Acres**	**MFL**	**Relaxed MFL**	**Difference**	**Per Acre**	**Percent Basis**
Central	15,894	$ 14,747,045.00	$ 15,749,430.00	$ 1,002,384.00	$63.00	6.8
NE	149,963	$ 85,257,215.00	$ 91,245,708.00	$ 5,988,493.00	$40.00	7.0
NW	143,868	$ 75,996,277.00	$ 81,263,886.00	$ 5,267,609.00	$37.00	6.9
SE	4,098	$ 4,474,290.00	$ 4,750,203.00	$ 275,913.00	$67.00	6.2
SW	11,961	$15,566,567.00	$ 16,559,372.00	$ 992,805.00	$83.00	6.4
Total	**325,784**	**$196,041,394.00**	**$209,568,598.00**	**$13,527,204.00**	**$42.00**	**6.9**

Figure 42 – Aspen Rotation Age Analysis:
Current MFL Present Value Evolution on WI MFL/FCL Forests

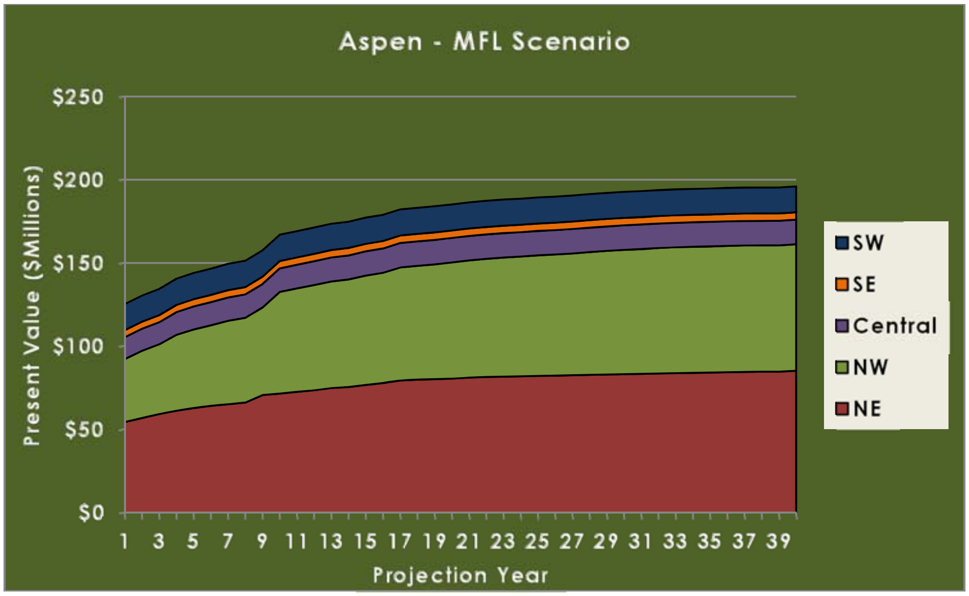


Figure 43 – Aspen Rotation Age Analysis:
Relaxed MFL Present Value Evolution on WI MFL/FCL Forests

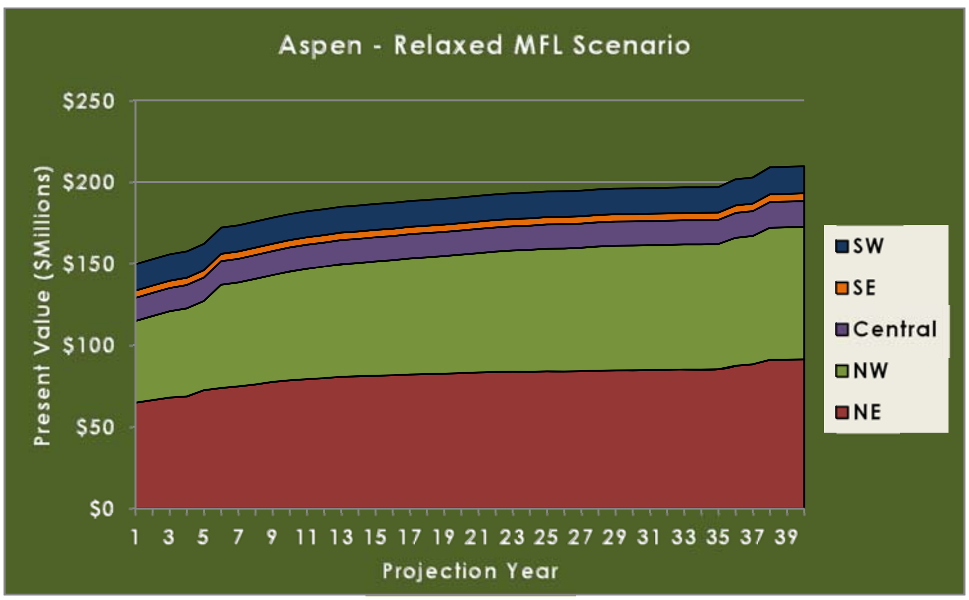


Table 41 summarizes cumulative present value of red pine, both by total and region. Present value under the current MFL guidelines totaled $374.4 million over the 40-year period. Relaxing the guidelines increased present value to $396.7 million, a 6 percent increase in value for an average of $89.00 per acre. Figures 44 and 45 show the evolution of the final cumulative present values for the two aspen scenarios by region. First year present value began for the current MFL scenario at approximately $50 million, and climbed to the $374.4 million maximum by age 40. The relaxed MFL scenario began near $150 million, and culminated in a $396.7 million maximum. As discussed earlier, relaxation of the harvest age guidelines resulted in significant volumes of wood becoming eligible for harvest in year one of the scenario. Not surprisingly, this resulted in a significant increase in up-front present value.

Table 41 – Red Pine Rotation Age Analysis: Cumulative Present Values by Scenario and Zone

Cumulative Present Value - Pine						
Zone	**Acres**	**MFL**	**Relaxed MFL**	**Difference**	**Per Acre**	**Percent Basis**
Central	79,844	$128,052,889.00	$134,331,657.00	$6,278,768.00	$ 79.00	4.9
NE	41,966	$ 77,762,090.00	$ 80,695,056.00	$2,932,966.00	$ 70.00	3.8
NW	119,025	$148,080,826.00	$160,244,530.00	$12,163,704.00	$102.00	8.2
SE	3,322	$ 6,682,437.00	$ 6,958,675.00	$ 276,237.00	$ 83.00	4.1
SW	6,706	$ 13,791,303.00	$ 14,430,654.00	$ 639,350.00	$ 95.00	4.6
Total	**250,862**	**$374,369,546.00**	**$396,660,571.00**	**$22,291,025.00**	**$ 89.00**	**6.0**

Figure 44 – Red Pine Rotation Age Analysis:
Current MFL Present Value Evolution on WI MFL/FCL Forests

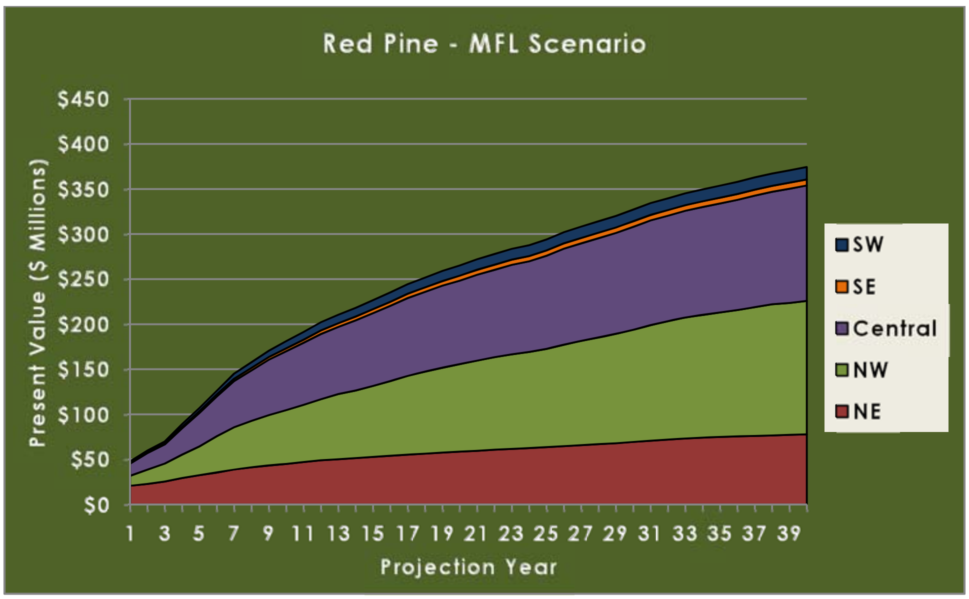
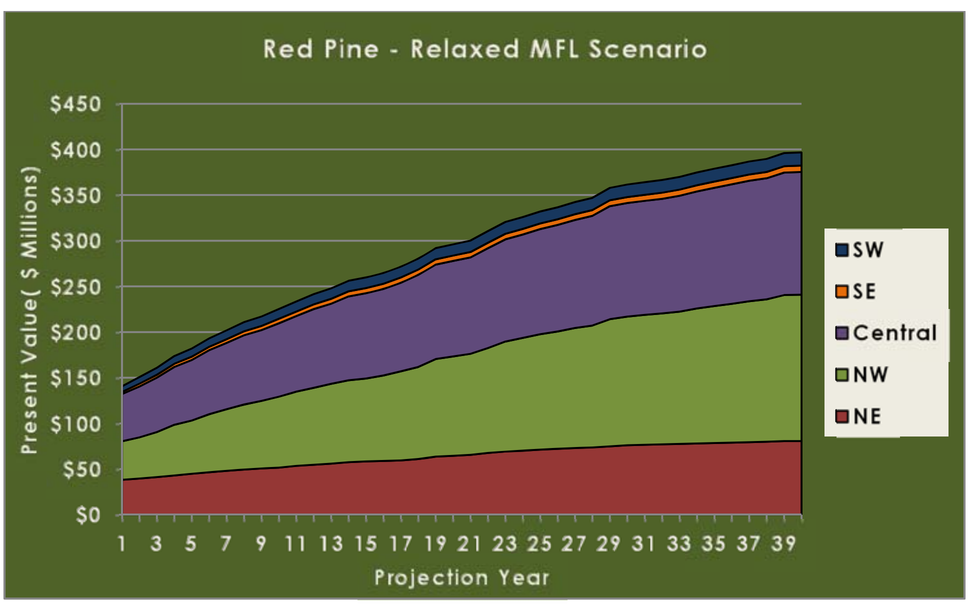


Figure 45 – Red Pine Rotation Age Analysis:
Relaxed MFL Present Value Evolution on WI MFL/FCL Forests



It is interesting to consider the implications of the present value analysis in light of potential land value increases brought about by relaxing minimum harvest ages. While not all owners of aspen or red pine would be expected to pursue economic maximization as their primary reason for owning timberland, all would benefit from land value gains resulting from a relaxation of the standards. Appraisal theory holds that bare land will transact based on that intended use resulting in the highest present value of the land, commonly referred to as highest and best use. Potential timberland buyers wishing to put a property to its highest and best use are therefore likely to pay more for a property under the relaxed scenario than the current. The prospect of the improvement in the present value of future cash flows would encourage them to do so. This would be true regardless of past or current use on the part of the seller. Thus, current timberland owners, regardless of individual ownership objectives, would likely benefit were they to offer their properties for sale on the open market.

3.2.4 Rotation Age Analysis Summary and Conclusions

A goal of the tax law programs is to incentivize and promote good forest management by offering a special property tax rate for properties enrolled. In that context, both economic (timber) and ecological (water, air, soil, wildlife) benefits are legitimate concerns when setting criteria for well-managed forests.

This study has shown that the two criteria for minimum rotation age actually serve to prevent optimum timber management practices for higher quality aspen sites and for the full range of red pine plantation sites. At the same time, it is unlikely that the criteria achieve any significant ecological benefits compared to allowing better sites to be harvested somewhat earlier in order to maximize economic productivity. Since a relaxed minimum rotation age in aspen was found to impact only 13 percent of the total acres, it is unlikely that this change would adversely impact a wide range of ecological considerations.

Analysis of the collective tax law ownership finds that relaxation of the guidelines would result in an increase in potential wood supply across the state. While not all owners would necessarily respond by releasing wood to market at lower rotation ages, many would, thereby increasing potential supply. Secondly, relaxing the guidelines increases the present value of future cash flows thereby increasing land value. This benefit would apply to all landowners, regardless of current management objectives.

In the absence of any restriction on rotation lengths, one would not expect to see radically shorter rotations. The underlying economics of value growth versus discount rate would steer most rotation length decisions so that they would cluster around the ages defined in this report. This effect can be seen in the U.S. South, where pine plantations are not subject to any regulations regarding rotation length, and landowner behavior can be collectively shown to be roughly optimizing the value of the enterprise.

If changes are desired, an alternative to completely removing the restrictions would be to alter them to recognize the difference in the timing of biological and economic maturity that occurs for different classes of site quality. The aspen guideline could be approximately 30 years for SI 80 or higher, approximately 35 years for SI 70-79, and approximately 40 years for site 69 and under, with exceptions for salvaging “early break-up” stands or stands impacted by damaging agents, shifts in climatic conditions, or natural disaster. According to this study, the red pine guideline could be 45 years for SI 72 or higher, 50 years for SI 64-71, and 55 years for SI 63 and under.

4. Summary

4.1 Project Overview

We evaluated two distinct topics that concern forest managers and timber industry stakeholders in Wisconsin, as well as throughout the Lake States region. The evaluation of marking guides in northern hardwood forests investigated the appropriateness of strictly following the WDNR OOR guidelines, while the rotation age analysis evaluated LEV and SEV, comparing the maximized financial rotation age to that of MAI. An overview of our finding is summarized in the following section.

4.2 Conclusions

Order of Removal in Northern Hardwood Stands:
Our evaluation of the WDNR OOR guidelines occurred in two sample sets. The first component was the *Native Community Analysis* (Fred Luke Road timber sale) that occurred on Wisconsin State Forestlands on acreage designated as Native Community management. Forestlands managed under this designation are generally managed less intensively. In a second effort (*OOR Analysis*), a randomly selected sample of county, state, and private MFL timberlands was studied; these lands have different management objectives and are multiple-use forests that also have timber production objectives. These stands were marked for harvest based on the WDNR OOR guidelines. For both analysis components, we compared the existing tree marking to alternative harvest scenarios. The modeled alternative harvest scenarios used tree selection criteria that focused on removing financially mature trees with maximum tree size ranging from 17- to 19-inches, harvesting the poorest growing stock, and by removing low GS grade trees in close proximity to others to mimic release of crop trees. The OOR modeled in both alternative scenarios removed trees in this order: (1) remove risk, (2) harvest mature trees, and (3) release crop trees.

Our primary findings of the *Native Community Analysis* include:

- The alternative scenarios harvested about 15 to 25 percent more BA
- The alternate scenarios removed 24 to 35 percent more unacceptable and undesirable growing stock compared to the existing harvest
- Scenario 1 removed 2.5 times more BA in the 15- to 18-inch DBH class
- Harvest value increased by 111 percent and 78 percent for Scenario 1 and 2, respectively
- Trees with lower RVG were removed in Scenario 1 and 2, as the estimated average hard maple RVG improved by 87 percent and 93 percent, respectively, over the pre-harvest forest

The OOR Analysis compared state, county, and private forests enrolled in the tax incentive programs. These ownerships all complete forest management in agreement with the WDNR silvicultural handbook guidelines and, more importantly, follow the designated OOR for marking trees when implementing single-tree selection harvest methodology.

The following conclusions can be made from the ownership comparisons.

- Since harvest history varies by stand, pre-harvest stand conditions are not similar amongst the owners. Pre-harvest stocking on county forest differed from both the state and private forest condition.
- Post-harvest stocking did not differ among the tree landowner classes.
- Residual stand stocking of the existing harvest ranged from approximately 75.11 ft.^{2} BA per acre on county to 82.94 ft.^{2} BA per acre on state forests.

The model scenarios developed the following forest conditions in the OOR Analysis.

- Scenario 1 resulted in a 16 to 48 percent increase in “cut” BA, while Scenario 2 increased by 16 to 19 percent for state and private forests, but decreased “cut” BA by 2 percent for county.
- The removal of low GS class (class 4 and 5) stocking (BA) increased by 54 and 32 percent for Scenario 1 and 2, respectively.
- Compared to the existing harvest, Scenario 1 resulted in a 46 percent average increase in harvest value per acre; the greatest increase was on private forestland (65 percent increase).
- Scenario 2 harvest value increased by only 9 percent on average, with a 10 percent decrease on county forests.
- Compared to the pre-harvest condition, the alternative scenarios resulted in a RVG increase of over 100 percent for private forests, while RVG improvement averaged about 50 percent for state and county forests.

Harvest volumes of both poletimber and sawtimber products increased with application of the alternative marking guide. Increases in poletimber volumes generally resulted from the lower residual stocking level modeled (75 ft.^{2} per acre). Sawtimber volume increased primarily when the model used a lower residual stocking and maximum tree size criteria (17 inches DBH). It can be assumed that removal of medium to large sawtimber, 14 inches DBH and greater, would increase by applying a marking approach that more strictly follows maximum tree size management and emphasizes removal of financially mature trees of low growing stock.

These model approaches focused on removing larger trees that will improve understory light conditions and increase growing space for recruiting stems, working to truly develop an all-aged forest. The results of the modeled scenarios suggest that removal of trees of low GS class should be considered as trees approach the 17-inch diameter class. Following this approach, the models created superior future forests, as GS quality increased and the estimate of hard maple RVG improved; however, the presence of cavity trees would most likely decrease.

Rotation Age Analysis:
Our results indicate that the two criteria for minimum rotation age prevent optimum timber management practices for higher quality aspen sites and for the full range of red pine plantation sites. Further, an analysis of the collective tax law ownership finds that relaxation of the guidelines would result in an increase in potential wood supply across the state. This increase would benefit all landowners, regardless of current management objectives.

An alternative to completely removing restrictions would be to alter them to recognize the difference in the timing of biological and economic maturity for different classes of site quality. The aspen guideline could be approximately 30 years for SI 80 or higher, 35 years for SI 70 to 79, and 40 years for SI 69 and under, with exceptions for salvaging “early break-up” stands, or stands impacted by damaging agents, shifts in climatic conditions, or natural disaster. The red pine guideline could be 45 years for SI 72 or higher, 50 years for SI 64 to 71, and 55 years for SI 63 and under.

Submitted by:

STEIGERWALDT LAND SERVICES, INC.

Forrest M. Gibeault

Forrest Gibeault, ACF
Analysis and Investments Operations Director
Steigerwaldt Land Services, Inc.

G. Mullaney

Gary Mullaney
Forest Economist and Senior GIS Consultant
James W. Sewall Company

5. Statement of Limiting Conditions

I certify that, to the best of my knowledge and belief:

a. The statements of fact contained in this report are true and correct.

b. The reported analyses, opinions, and conclusions are limited only by the source data, reported assumptions and limiting conditions, and are my personal, impartial, and unbiased professional analyses, opinions, and conclusions.

c. We have no present or prospective interest in the subject of this report and no personal interest with respect to the outcomes.

d. I have no bias with respect to the subject of this report or the outcomes of this assignment.

e. Our engagement in this assignment was not contingent upon developing or reporting predetermined results.

f. The compensation for completing this assignment is not contingent upon the development or reporting of predetermined results or directions that favor the cause of the client, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this report.

STEIGERWALDT LAND SERVICES, INC.

Forrest M. Gibeault

Forrest Gibeault, ACF
Analysis and Investments Operations Director
Steigerwaldt Land Services, Inc.

GE Mullaney

Gary Mullaney
Forest Economist and Senior GIS Consultant
James W. Sewall Company

Exhibit 1

Inventory Manuals
Native Community and Order of Removal Analysis

Exhibit 1
Inventory Manuals

Wisconsin Forest Practices Study – Topic 2: *Native Community Study*

Work Scope

Project Title – *Single Tree Selection Order-of-Removal Procedures in Northern Hardwood Forests Native Community Component - Fred Luke Timber Sale: NHAL State Forest*

Overview:

The goal of this inventory is to collect detailed tree data to examine the supply chain economic and ecological consequences of single-tree selection harvesting. A review of Native Community objectives on state lands will also be evaluated in a separate analysis.

Sampling procedures:

Sampling will be completed using 100 - 1/16th and nested 1/100th acre fixed area plots. Accurately implementing the field procedure is necessary to this project, as detailed tree and location data must be recorded in a consistent manner. Details on the tree data collection and the plot setup procedure are outlined in the following sections.

Plot installation instructions:

Merchantable Plot Installation – 1/16th acre: The fixed area plot shall be square and 52.18 feet on each side. All plots will be developed around the Reference Point (RP), which will be the southwest corner of each plot. The RPs have been established using a pre-located equilateral grid. The RP shall be the plot location built with a pre-located equilateral grid and integrated into ArcPad for field operations. Cruisers can navigate to this point with the Flint units, so that RTI can be used in conjunction with TCruise. More accurate coordinates of the RP location must be taken with the sub-meter GPS. Log this point so that the unit averages 75 to 100 points. Save the RP point as the corresponding plot number. The four corners of the plot should be marked with flagging as part of the setup process. Using a compass, measure out corner 2 - 52.18 feet due east of the RP, followed by corner 3 - 52.18 feet due north, and then corner 4 - 52.18 feet due west.

Pre-Merchantable Plot Installation: The 1/100th acre nested plots will be developed in an identical fashion (square and within the 1/16th acre plot) from the RP; however, this plot should be 20.87 feet per side.

If any portion of a plot, when setup, occurs outside of the harvest area, the plot must be moved one chain in a cardinal direction perpendicular to the boundary. Interior woods roads will not require plot movement – take these plots where they fall.

All flagging and stake flags shall be removed when the plot is completed.

Exhibit 1
Inventory Manuals

Tree Data Collection Overview:

Tree data to be collected at each 1/16th acre merchantable plot location includes:

- Species – standard Stegierwaldt species codes
- Diameter at breast height (DBH) – 1 inch classes
- Tree segments - product, grade, and length (including cull deductions)
- Tree Class 1 – evaluation of a tree's condition as it relates to the current OOR model: 1-risk, 2-crop tree, 3-vigor, 4-form, 5-undesirable species, and 6-spacing (additional detail provided in following section)
- Tree Class 2 – tree classification that will relate to a tree's spatial adjacency to surrounding trees
- Growing Stock Designation – each merchantable tree will be given an assessment of growing stock (five categories of growing stock class will be implemented)
- Tree canopy position classification – 1-overtopped, 2-intermediate, 3-codominant, and 4-dominant (additional detail provided in the following section)
- Cut/leave designation – as marked for harvest in the stand. TCruise codes are C or L
- Den/snag or other wildlife value grade (only for cull or standing dead trees). TCruise codes are 1-snag, 2-cavity Tree, 3–wildlife Tree
- Individual tree location – bearing and distance from reference point (RP) of plot

A nested 1/100th acre pre-merchantable plot will be located at the RP of each plot as well.

Tree Data Collection Detail:
(Refer to data entry screen images on Pages 7-10)

1/16th acre plot:
<u>Diameter</u>
1-inch classes, record all merchantable trees 4.6 inches and greater. Diameter groups are as such: 5 inch class = 4.6 to 5.5 inches, 6 inch class = 5.6 to 6.5, etc.

<u>Tree Segments</u>
Record tree segments using the following product specifications:

- **Hardwood veneer** logs will be tallied in trees that meet the minimum 13-inch DBH class (12.6 to 13.5 inch trees) to a 12-inch diameter inside bark (dib) top. **<u>Veneer will be cruised as (VEN); see TCruise Operating Procedures.</u> Veneer logs are classified as having four faces that are clear of defect and no sweep or crook.**
- **Hardwood woodsrun sawlog** material will be tallied in trees that meet the 11-inch DBH class (10.6 to 11.5 inch trees) to a 10-inch diameter inside bark (dib) top. **<u>Sawtimber grades 1,2, and 3 will be cruised as (WR); see TCruise Operating Procedures.</u> Grade 3 logs are classified as segments that have a clear cutting yield of at least 2/3 in the log lengths three best faces (three best faces must each have at least 3 feet clear of defect). No more than 50 percent of the log segment can be considered cull (including deductions for sweep and crook).**
- **Hardwood bolt** material will be tallied in trees that meet the 9-inch DBH class (8.6 to 9.5 inch trees) to an 8-inch diameter inside bark (dib) top. **<u>Bolts will be cruised as (B); see TCruise Operating Procedures.</u> Bolts are classified as straight and sound with no clear faces. Bolts are to be called in all hardwood species, including aspen.**
- **Red pine sawlogs** will be tallied in trees $\geq$ 8 inches DBH to a 6-inch dib top. Pine sawlogs in 8-inch DBH trees must have a minimum of 12 feet of sawproduct to the top dib. The 12-foot

minimum length does not apply to pine larger than 8 inches DBH. **Red pine sawtimber will be cruised as (WR); see TCruise Operating Procedures.** **Sawlog specifications for all other sawable softwood species will be a minimum DBH of 9 inches DBH to an 8-inch dib (and minimum product length of 8 feet).**

No saw tally in the following species:
aspen and balsam poplar (bolts can be called in aspen), ironwood, balsam fir, black spruce, tamarack/larch, cottonwood, willow, jack pine, Scotch pine. Be cautious of soundness when tallying logs in cedar and hemlock.

- Cull trees include all trees that have 50 percent or more volume loss.
- Record the total height of merchantable product/products to the nearest 2 feet.

Cut/Leave Designation

Trees that are marked for harvest or designated for harvest (i.e. birch, aspen, etc.) should be marked as cut trees in the cut/leave category. All trees not marked for harvest or designated for harvest should be marked as leave trees in the cut/leave category.

Tree Class 1

This classification relates to an individual tree's position within the current Order-of-Removal (OOR), as defined by the WDNR Silvicultural Handbook. The current order of removal for northern hardwood trees is as follows (in the order of tree selection): 1-risk, 2-release crop trees, 3-vigor, 4-stem form, 5-undesirable Species, 6-spacing. Details on tree classes and instructions for class assignment are outlined below.

TC Code Class and Description

1. Risk – these trees would be selected as risk trees during marking. They are likely to significantly degrade or die by the next cutting cycle.
2. Releasing Crop Trees – this class is for poorer quality trees competing with nearby higher quality or crop trees.
3. Vigor – this assignment is for trees with low vigor and poor crown size or have an inferior crown class or stem decay.
4. Stem form – poorly formed stem, affecting the grade potential of the tree.
5. Undesirable species – species that may inhibit the prescribed management or are specifically identified for removal. In this case, the Fred Luke Road sale requires that all **aspen, white birch, and balsam** fir be harvested.
6. Improve spacing – these trees are likely higher quality trees that would be taken last during a marking exercise using this system.

Tree Class 2

Tree class 2 will analyze a tree's spatial adjacency to surrounding trees.

Details on tree class assignments are below.

TC Code Class and Description

1. Multi-stem tree
2. 0 to 10 feet from nearest neighbor
3. 10 to 20 feet from nearest neighbor
4. 21+ from nearest neighbor

Nearest neighbors can occur outside of plot

Exhibit 1
Inventory Manuals

Growing Stock Classification
The growing stock classification will be used to evaluate a tree's condition and appropriateness for harvest in a given entry. The following table outlines the tree criteria for this analysis. **Use the top four criteria as the main determinant and the bottom portion of the table only when needed.**

Table 1 – Evaluation Criteria

GSS **Quality Rank** ***Marking Rule***	**1** **Exceptional** ***"Trophy" Tree***	**2** **Desirable** ***Crop Tree***	**3** **Acceptable**	**4** **Undesirable**	**5** **Unacceptable**
Poorest of the following four criteria determines the best quality ranking					
Risk of Loss or Degrade	No risk of volume or value loss *(degrade)* anticipated within the next 10 YEARS	Low risk of volume or value loss *(degrade)* anticipated within the next 10 YEARS	Minor volume or value loss *(degrade)* anticipated within the next 10 YEARS	Moderate volume or value loss *(degrade)* anticipated within the next 10 YEARS	Major volume or value loss *(degrade)* anticipated within the next 10 YEARS
Growth Potential	Displays superior growth potential. Will respond well to release.	Displays very good growth potential. Will respond well to release.	Displays good growth potential. Should respond well to release.	Displays fair growth potential. May not respond well to release.	Displays poor growth potential. Will not respond well to release.
Log Height Potential	Should produce 3 or more 16 foot sawlogs *(48'+)* at financial maturity.	Should produce at least 2 16 foot sawlogs *(33')* at financial maturity.	Should produce at least 1 16 foot sawlog *(17')* at financial maturity.	Should produce at least 1 8 foot sawlog *(9')* at financial maturity.	Will likely not produce any sawlogs at financial maturity.
Hdwd Grade Potential	Should produce One or more 16 foot Grade 1 or better sawlogs (17') at financial maturity.	Should produce at least one 16 foot Grade 1 or better sawlog (17') at financial maturity.	Should produce at least one 8 foot Grade 2 or better sawlog (9') at financial maturity.	Will likely produce only Grade 3 sawlogs at financial maturity.	Will only produce pulpwood or cull.
Use the following criteria for further clarification					
Crown Class	Dominant	Codominant	⟷	Intermediate	Suppressed
Crown Condition	Well-developed symmetrical crown. Occasional dead branches in the outer crown. Healthy leaves and densely foliated.	⟷	Less than well developed, or oblong crown. Some dead branches in the outer crown. Good leaf condition. Indications of minor crown competition.	⟷	"Flat topped" or poorly developed "basket" crown. Considerable dieback in outer crown. Poor leaf condition. Indications of major crown competition.
Bole Form	Superior form, with no crook, sweep, seams, or spiral grain.	⟷	Good form, with only minor crook, sweep, seams, or spiral grain.	⟷	Poor form with major crook, sweep, seams, or spiral grain.
Forking	Free of acute forking in the main stem and crown.	⟷	Acute forking confined to the upper bole and crown.	⟷	Acute forking on the lower bole.
Rot and Decay	No cull loss present. No indications of heart rot or staining.	⟷	Cull loss less than 15%. Minor indications of heart rot or staining in the early stages.	⟷	Cull loss greater than 30%. Obvious indications of major heart rot or staining.
Lean	No noticeable lean.	⟷	Less than 20 degrees.	⟷	Greater than 30 degrees.

Tree Canopy Position
The position of each tree's canopy position provides additional detail for further analysis of a trees ability to respond to disturbance/harvesting. The following categories outline the crown classes to be evaluated.

TC Code Class and Description
1. Overtopped: crown entirely below the main canopy and covered by branches of taller trees, no direct sunlight strikes the crown, small crown that is sparse, and tree diameter is generally smaller
2. Intermediate: crown extends to lower part of main canopy, gathers sunlight at a few places on crown, narrow, and generally short crown with low live crown ratio
3. Codominant: crown is part of main canopy, intercepts light at the top of crown, crown is well-developed, but is crowned in the canopy and of medium size
4. Dominant: crown extends above the general canopy area, gathers light on top and sides of crown, large crown that is long crowned at the bottom, generally equates to large tree diameter

Individual Tree Location
The location of all merchantable trees will be related back to the RP of the plot. Bearing and distance of each tree must be recorded. Distance to tree can be derived by using the DME in most cases, but measurement by loggers tape may be necessary. The distance should be recorded down to the nearest tenth.

Wildlife Grade
Trees with wildlife significance should be coded as follows:
1. Snag – cull or standing dead trees that will serve as a snag for at least ten years
2. Cavity Tree – cull or standing dead trees that have a cavity any place on the stem
3. Wildlife Tree – living trees that have cavities any place on the stem

1/100th Acre Plot:
Regeneration Plot Procedures
At each RP location, establish a 1/100th acre fixed radius plot as outlined on page 1. Tally all saplings that are **at least 3 feet in height through the 4-inch DBH class** (4.5 inches) by species. Record regeneration's species, DBH class, average height of that DBH inch class, and how many seedlings/saplings of that inch class and species are on the plot.

For trees greater than 12 feet tall, record 12 for height. For trees shorter than 12, record 6.

For saplings that are highly suppressed, record as a growing stock of 5.

TCRUISE OPERATING PROCEDURES

1. Start with a new .tcc template each day.
2. Save each day's work using the Saving Plot Data procedure outlined below (save to SD card).
3. Submit plots for analysis – download to project folder.
4. If you are out of town, download your plots to your laptop hard drive daily.

File Name Extensions

1. ".tct" = TCruise template created on desktop TCruise program
2. ".tcc" = a converted .tct template for export to the handheld
3. ".tce" = a .tcc with data collected in the field
4. ".tcd" = a TCruise desktop file after the .tce has been imported and processed

Starting a new cruise:

Initial Start-Up

1. Load a .tcc file in TCruisePK (Page 2 in LM Training Manual)
   a. Choose "Import a Code-Param File" from the initial action box when you open TCruise on handheld.

      Or

   b. Cancel initial action box and choose "Import Params File" under the "File" list menu in the lower left hand corner of screen
2. Enter Tract Info – choose "Tract Info" under the "Edit" list menu (Page 3 in LM Training Manual).
3. Check "Current Params" under the "Edit" list menu – Be sure you have the correct .tcc file open (Page 3 in the LM Training Manual).

Saving Plot Data

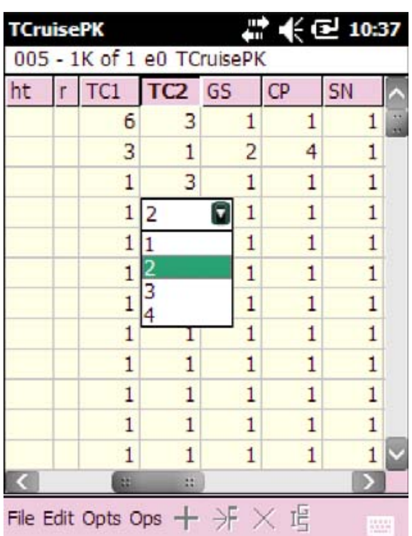
1. Choose "Save as" under the "File" list menu on the bottom of the screen (four fields will appear – Name, Folder, Type, and Location)
2. Name should be completed as follows:
   "Job_date_cruiser initials", Example: "RMKTWINLAKES_01202009_DLD". The ".tce" file extension will automatically be included on your file name by TCruise.

3. *Optional Step* - Folder: create a "tce document" folder on your SD Card (TCruise field will use the My Documents folder on the handhelds main memory as a default – create a new folder on your SD Card to redirect the file location).
4. Type: leave as (*.tce)
5. Location: SD Card
6. Select **Save**.

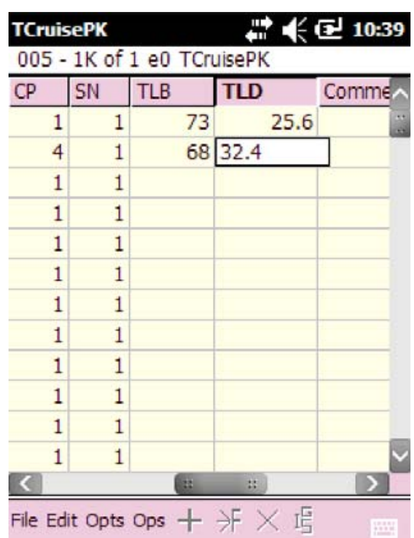
Collecting Field Data

1. Click the "**+**", new plot button, located in the center of the menu bar at the bottom of the screen to start a plot. **RTI will automatically complete this step.**
2. A plot entry screen will first appear. Fill in the stratum information **(stand number)**, **plot number,** and **cruiser initials** *(if you put your initials in the Tract Info screen, this will automatically be completed, see above).* Finish by clicking OK. **When using ArcPad RTI, this information will be automatically entered.**
3. The data entry screen will appear.
4. Fill out the tree data using the drop down columns for each tree.
5. Choose the GAA value in the **Prod** column when recording a merchantable tree – this will automatically take you to the Segment Length screen. Your cursor will automatically be placed in the stump height box (leave this blank, TCruise assumes 1 foot), then select the grade and fill in the length of each segment of the tree; click okay, and finish the remainder of the tree information in the data entry screen.
    a. **TCruise product codes: "WR" = woodsrun sawtimber, "VEN" = Veneer sawtimber, "B" = Boltwood and "PW" = pulp/cordwood**
6. After selecting the product and filling out the segment information, select "cut" or "leave" from the "leave/cut" column. Remember that trees designated for harvest should also be classified as "cut" trees along with trees that are marked for harvest.
7. For the following columns, select the appropriate numeric code from the dropdown.
    a. **TC1 = Tree Category 1 (1,2,3,4,5,6)**
    b. **TC2 = Tree Category 2 (1,2,3,4)**
    c. **GS = Growing Stock Classification (1,2,3,4,5)**
    d. **CP = Tree Canopy Position (1,2,3,4)**
    e. **SN = Den/Snag/Wildlife Tree Designation (1,2,3)**
8. For the following columns, fill in the necessary information.
    a. **TLB = Tree Location, Bearing (Fill in to the nearest degree)**
    b. **TLD = Tree Location, Distance (Fill in to the nearest .1 ft)**
9. When you are finished with a plot, click the plot finished button, **->F**, located to the right of the new plot button. Doing this will save your edits for each plot.
10. "X" button can be used to clear all edits for the current plot.

Example of drop down selection



Example of numerical entry

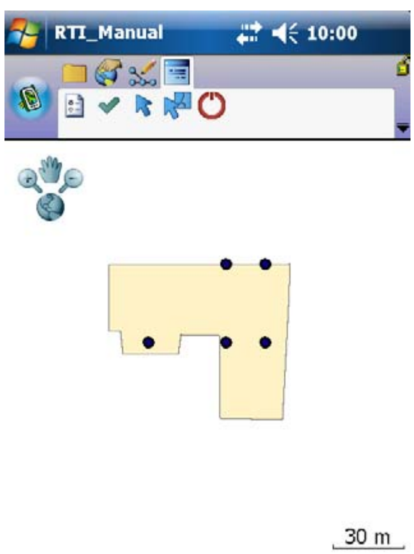


Entering Trees on the Tree Data Screen - *see merch. spec. on page 1 (bullet 2)*

1. **Merchantable Trees** = trees 5 inches in diameter (DBH) and larger on a BAF plot
    a. Enter Species (SPP), (DBH), Product (Prod), and Number (N=) if applicable, in the tree data screen.
2. **Sub-Merchantable and Pre-Merchantable Trees** = established trees on a 1/100 acre plot that are 0 to 4.99 inches in diameter DBH and least 3 feet in height.
    a. Enter Species (SPP), leave Prod field as “AA”, put the number of trees in the Number (N=) field, and place a “1” in the reproduction **(r)** column to indicate that this tree is pre-merchantable and was recorded on a 1/100th acre reproduction plot.

<u>Collecting Field Data Using RTI</u>

1. First, open TCruise and prepare for collecting data – See **<u>Starting a New Cruise</u>**
2. Next, start ArcPad and open your project
3. Setting up **ArcPad** and the **RTI** interface
    a) Add the RTI tool bar to your display – click the black arrow located in the lower right hand corner of the main tool bar > under Toolbars; select **tblRTI**
    b) Now the RTI Menu is available for use. **The screen shots below identify the menu icons and their uses.**



<u>RTI Menu</u>

Settings button

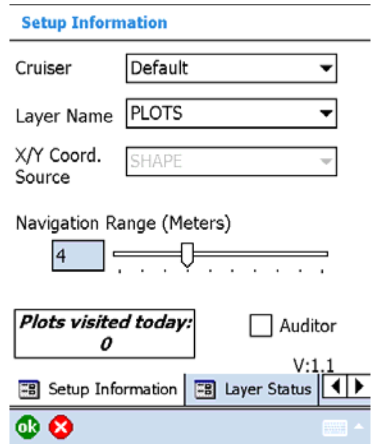
Manually Select and Edit Plot

Navigate To Plot

Clear Navigation Target

Close and Save Map

c) Before you begin to navigate to a point and begin cruising, you must first set the RTI setting Click the settings button and open the **Setup Information** window; see below.



d) In the **Setup Information** window, set the *Cruiser*, *Layer Name*, and *Navigation Range*. The Layer Name will be set to the plot layer with the correct schema, which, in this case, is **"Plots"**. The Navigation range shall be set to **10 meters.**

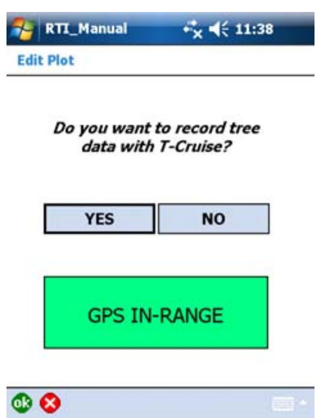
4. **Navigating to a plot**

a) Select the Navigate To Plot button , then select the plot you would like to navigate to.

b) After the plot is selected, it will be "highlighted" and the plot number will appear.

c) Navigate to the selected plot as you normally would – you can use the go-to function or any other method.

d) Once you get within the set tolerance (Navigation Range set in the Setup Information window), an **Edit Plot** window will appear (you will also hear a chime). You will be asked if you want to record the plot. Choose YES.



e) After selecting YES you will be automatically sent to **TCruise** (only if you have already opened TCruise and setup a new cruise).

5. Recording tree data – See the **Entering Trees on the Tree Data Screen** section.
   a) You will notice that you are automatically taken to the data entry screen (if the "Plot Info Prompt" is left off - unchecked under the **Opts** menu) – you will no longer need to enter the plot and stratum information.
   b) After you have recorded the required tree information, save the plot, and then manually go back to ArcPad – keep your TCruise project running.
6. After you have selected a plot, navigated to it, recoded tree data, and gone back to ArcPad, you will notice that the cruised plots will have different symbology. Plots already cruised will now display as stars.
7. Editing a plot
   a) If you would like to revisit a plot or make changes after you have saved a plot in TCruise, you can access that plot via the ArcPad/RTI interface. Choose the edit plot button , then select the plot you would like to edit. Doing so will automatically take you to the data entry screen in TCruise and bring up the chosen plot's tree data. Make edits, save, and then return to ArcPad (plots can be chosen and edited in TCruise without using the ArcPad/RTI interface).
8. At the end of the day, choose the close and save button . You will need to save and close your TCruise project separately.

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Wisconsin Forest Practices Study – Topic 2: *Order of Removal Cast Study*

Work Scope

Project Title – *Single Tree Selection Order-of-Removal Procedures in Northern Hardwood Forests.*

Overview:

The goal of this inventory is to collect detailed tree data to examine the supply chain economic and ecological consequences of single-tree selection harvesting tree selection. *This analysis focuses on three ownership groups: county forest, state forest, and private – small block MFL forests. Stands managed for timber products will be evaluated in this study, and the metrics will be used to model harvest scenarios.*

Sampling procedures:

Sampling will be completed using multi-radial fixed plots, which include a 1/5th acre sawtimber only plot, a nested 1/10th acre all merchantable timber plot, and nested 1/100th acre regeneration plot. A total of ±240 plots will be applied across the three ownership groups at a rate of approximately eight per stand. A total of nine 1-acre plots (three per ownership) will also be established across the ownership groups. Accurately implementing the field procedure is necessary to this project as detailed tree and location data must be recorded in a consistent manner. Details on the tree data collection and the plot setup procedure are outlined in the following sections.

Plot installation instructions:

If any portion of a plot, when set up, occurs outside of the harvest area, the plot must be moved one chain in a cardinal direction perpendicular to the boundary.

All flagging and stake flags shall be removed when the plot is completed.

Plots shall be moved from roads and inclusions within the sale such as aspen clear cut areas, large gaps, or other areas that are not marked as northern hardwood single tree selection. Plots shall be moved in one-chain increments perpendicular to and away from the inclusion and into the sale area.

The plots should be installed in tandem process, working from the inside (smallest plot) outwards, collecting tree data according the various plot size requirements. Details on the plot collection procedures for the components of the multi-radial plot scheme are outlined below.

Pre-Merchantable Plot Installation- 1/100th acre: The pre-merchantable nested plots shall be installed using a radius of 11.8 feet around the plot center.

Merchantable Plot Installation – 1/10th acre: The merchantable timber plot shall be installed using a radius of 37.2 feet around the plot center.

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Sawtimber Plot Installation – 1/5th acre: The sawtimber plot shall be installed using a radius of 527 feet.

Visualization plots – 1 acre: Three 1-acre visualization plots will be randomly established within each ownership for a total of nine plots across the total study area. The corners will be established by implementing GPS points for each corner. This will allow for tree measurements from multiple points. The RPs have been established prior to the inventory. Cruisers can navigate to this point with the Flint units so that RTI can be used in conjunction with TCruise. More accurate coordinates of the RP location must be taken with the sub-meter GPS. The RP will be considered the southwest corner of the plot (corner 1). Log this point, so that the unit averages 75 to 100 points. Save the RP as the corresponding plot number.

The four corners of the plot should be marked with **flagging and logged with the sub-meter GPS unit.** Using a compass, measure out corner 2 – 208.71 feet due east of the RP, followed by corner 3 – 295.16 feet northeast (45 degrees) from the RP, and then corner 4 – 208.71 feet due north of the RP.

Tree data collection overview:

Pre-merchantable plots:

On all nested 1/100th acre pre-merchantable plots, the following data shall be collected.

1. Tally all saplings that are **at least 3 feet in height, up to 4.5 inches DBH.** For each species, record the count of that species by diameter class (0-1.5 = 1 inch class, 1.6-2.5 = 2 inch class, etc.). There will be a separate column for regeneration DBH in the TCruise template. For each class, enter the average height for that class.
2. Regeneration growing stock – record the growing stock grade of each record in TCruise (species and size class). Enter the grade of each class based on the average condition. Regeneration growing stock grades are:
    1. Suppressed/Unacceptable Growing Stock - stock that are heavily browsed, multi-stemed, in an area with poor availability of light and nutrients, or are not likely to respond to release.
    2. Acceptable Stock – stock that could respond to release, are not heavily browsed, and have good form
    3. Exceptional Stock – stock that are in an area of open canopy with availability to light and nutrients

Merchantable plots:

Tree data to be collected at each of the 1/10th acre merchantable plot location includes -

- All trees 4.6 inches DBH and larger shall be tallied on all 1/10th acre plots.
- Species – standard Steigerwaldt species codes
- Diameter at breast height (DBH) – 1-inch classes
- Tree segments - product, grade, and length (including cull deductions)
- Tree Class 1 – evaluation of a tree's condition as it relates to the current OOR model: 1-risk, 2-crop tree, 3-vigor, 4-form, 5-undesirable species, and 6-spacing (additional detail provided in following section)
- Tree Class 2 – tree classification that will relate to a tree's spatial adjacency to surrounding trees
- Growing Stock Designation – each merchantable tree will be given an assessment of growing stock (five categories of growing stock class will be implemented)
- Tree canopy position classification – 1-overtopped, 2-intermediate, 3-codominant, and 4-dominant (additional detail provided in the following section)
- Cut/leave designation – as marked for harvest in the stand. TCruise codes are C or L
- Den/snag or other wildlife value grade (only for cull or standing dead trees). TCruise Codes = 1-snag, 2-cavity tree, 3–wildlife tree **(Snag DBH will be recorded in the comments field)**
- Individual tree location – bearing and distance from reference point (RP) of plot **(Only on Visualization Plot)**

Sawtimber plots:

Tree data to be collected at each 1/5th acre merchantable plot location includes the same data as the 1/10th acre nested plot, but only for trees from the 12-inch size class and larger (11.6 inch+).

Visualization Plots:

All trees 4.6 inches DBH and larger will be collected in these plots. The bearing and distance of each tree must be recorded for all "in" trees. These measurements must be made from the nearest plot corner to ensure accuracy. The plot corner used for each tree record measurement shall be entered on the handheld. The southwest corner shall be corner 1, followed by the southeast (corner 2), the northeast (corner 3), and the northwest corner (corner 4).

Borderline trees:

On the radial sample plots, distance from the center bole of the tree must be within the radius distance from the plot center and, for the fixed area visualization plot, the center line of the bole of the tree must be on the plot to count the tree.

Tree Data Collection Detail:
(Refer to data entry screen images on Pages 8-12)

1/5th and 1/10th Acre Plot:

Diameter–
1-inch classes: Diameter groups are as such 5 inch class = 4.6 to 5.5 inches, 6 inch class = 5.6 to 6.5, etc.

Tree Segments
Record tree segments using the following product specifications:

- **Hardwood veneer** logs will be tallied in trees that meet the minimum-13 inch DBH Class (12.6 to 13.5 inch trees) to a 12-inch diameter inside bark (dib) top. **Veneer will be cruised as (VEN); see TCruise Operating Procedures.** **Veneer logs are classified as having four faces that are clear of defect and no sweep or crook.** Pulpwood will also be called above sawtimber minimum top diameter to a 4-inch top.
- **Hardwood woodsrun sawlog** material will be tallied in trees that meet the 11-inch DBH class (10.6 to 11.5 inch trees) to a 10-inch diameter inside bark (dib) top. **Sawtimber grades 1,2, and 3 will be cruised as (WR); see TCruise Operating Procedures.** **Grade 3 logs are classified as segments that have a clear cutting yield of at least 2/3 in the log lengths three best faces (three best faces must each have at least 3 feet clear of defect). No more than 50 percent of the log segment can be considered cull (including deductions for sweep and crook).** Pulpwood will also be called above sawtimber minimum top diameter to a 4-inch top.
- **Hardwood bolt** material will be tallied in trees that meet the 9-inch DBH Class (8.6 to 9.5 inch trees) to an 8-inch diameter inside bark (dib) top. **Bolts will be cruised as (B); see TCruise Operating Procedures.** **Bolts are classified as straight and sound with no clear faces. Bolts are to be called in all hardwood species, including aspen (ONLY ON 1/10th ACRE PLOT).**
- **Red pine sawlogs** will be tallied in trees $\geq$ 8 inches DBH to a 6-inch dib top. Pine sawlogs in 8-inch DBH trees must have a minimum of 12 feet of sawproduct to the top dib. The 12-foot minimum length does not apply to pine larger than 8 inches DBH. **Red pine sawtimber will be cruised as (WR); see TCruise Operating Procedures.** **Sawlog specifications for all other sawable softwood species will be a minimum DBH of 9 inches DBH to an 8-inch dib (and minimum product length of 8 feet) (ONLY ON 1/10th ACRE PLOT).**
- **Hardwood and softwood poletimber** will be tallied as pulpwood in all trees 4.6 to 11.5 inches DBH to a 4-inch top **(ONLY ON 1/10th ACRE PLOT).**
  No Saw Tally in the Following Species:
  aspen and balsam poplar (bolts can be called in aspen), ironwood, balsam fir, black spruce, tamarack/larch, cottonwood, willow, jack pine, Scotch pine.
  Be cautious of soundness when tallying logs in cedar and hemlock.

- Cull trees include all trees that have 50 percent or more volume loss.
- Record the total height of merchantable product/products to the nearest 2 feet.

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Cut/Leave Designation
Trees that are marked for harvest or designated for harvest (i.e. birch, aspen, etc.) should be marked as cut trees in the cut/leave category. All trees not marked for harvest or designated for harvest should be marked as leave trees in the cut/leave category.

Tree Class 1–
This classification relates to an individual tree’s position within the current order-of-removal (OOR), as defined by the WDNR Silvicultural Handbook. The current order of removal for northern hardwood trees is as follows (in the order of tree selection): 1-risk, 2-release crop trees, 3-vigor, 4-stem form, 5-undesirable species, 6-spacing. Details on tree classes and instructions for class assignment are outlined below.

TC Code Class and Description
1. Risk – these trees would be selected as risk trees during marking. They are likely to significantly degrade or die by the next cutting cycle.
2. Releasing crop trees – this class is for poorer quality trees competing with nearby higher quality or crop trees.
3. Vigor – this assignment is for trees with low vigor and poor crown size or have an inferior crown class or stem decay.
4. Stem form – poorly formed stem, affecting the grade potential of the tree.
5. Undesirable species – species that may inhibit the prescribed management or are specifically identified for removal.
6. Improve spacing – these trees are likely higher quality trees that would be taken last during a marking exercise using this system.

Tree Class 2
Tree class 2 will analyze a tree’s spatial adjacency to surrounding trees.
Details on tree class assignments are below.

TC Code Class and Description
1. Multi-stem tree
2. 0 to 10 feet from nearest neighbor
3. 10 to 20 feet from nearest neighbor
4. 21+ from nearest neighbor

Nearest neighbors can occur outside of plot

Growing Stock Classification–
The growing stock classification will be used to evaluate a tree’s condition and appropriateness for harvest in a given entry. The following table outlines the tree criteria for this analysis. **Use the top four criteria as the main determinant and the bottom portion of the table onlywhen needed.**

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Table 1 – Evaluation Criteria

GSS **Quality Rank** ***Marking Rule***	**1** **Exceptional** ***"Trophy" Tree***	**2** **Desirable** ***Crop Tree***	**3** **Acceptable**	**4** **Undesirable**	**5** **Unacceptable**
Poorest of the following four criteria determines the best quality ranking					
Risk of Loss or Degrade	No risk of volume or value loss *(degrade)* anticipated within the next 10 YEARS	Low risk of volume or value loss *(degrade)* anticipated within the next 10 YEARS	Minor volume or value loss *(degrade)* anticipated within the next 10 YEARS	Moderate volume or value loss *(degrade)* anticipated within the next 10 YEARS	Major volume or value loss *(degrade)* anticipated within the next 10 YEARS
Growth Potential	Displays superior growth potential. Will respond well to release.	Displays very good growth potential. Will respond well to release.	Displays good growth potential. Should respond well to release.	Displays fair growth potential. May not respond well to release.	Displays poor growth potential. Will not respond well to release.
Log Height Potential	Should produce 3 or more 16 foot sawlogs *(48'+)* at financial maturity.	Should produce at least 2 16 foot sawlogs *(33')* at financial maturity.	Should produce at least 1 16 foot sawlog *(17')* at financial maturity.	Should produce at least 1 8 foot sawlog *(9')* at financial maturity.	Will likely not produce any sawlogs at financial maturity.
Hdwd Grade Potential	Should produce One or more 16 foot Grade 1 or better sawlogs (17') at financial maturity.	Should produce at least one 16 foot Grade 1 or better sawlog (17') at financial maturity.	Should produce at least one 8 foot Grade 2 or better sawlog (9') at financial maturity.	Will likely produce only Grade 3 sawlogs at financial maturity.	Will only produce pulpwood or cull.
Use the following criteria for further clarification					
Crown Class	Dominant	Codominant	⟷	Intermediate	Suppressed
Crown Condition	Well-developed symmetrical crown. Occasional dead branches in the outer crown. Healthy leaves and densely foliated.	⟷	Less than well developed, or oblong crown. Some dead branches in the outer crown. Good leaf condition. Indications of minor crown competition.	⟷	"Flat topped" or poorly developed "basket" crown. Considerable dieback in outer crown. Poor leaf condition. Indications of major crown competition.
Bole Form	Superior form, with no crook, sweep, seams, or spiral grain.	⟷	Good form, with only minor crook, sweep, seams, or spiral grain.	⟷	Poor form with major crook, sweep, seams, or spiral grain.
Forking	Free of acute forking in the main stem and crown.	⟷	Acute forking confined to the upper bole and crown.	⟷	Acute forking on the lower bole.
Rot and Decay	No cull loss present. No indications of heart rot or staining.	⟷	Cull loss less than 15%. Minor indications of heart rot or staining in the early stages.	⟷	Cull loss greater than 30%. Obvious indications of major heart rot or staining.
Lean	No noticeable lean.	⟷	Less than 20 degrees.	⟷	Greater than 30 degrees.

Tree Canopy Position

The position of each tree's canopy position provides additional detail for further analysis of a tree's ability to respond to disturbance/harvesting. The following categories outline the crown classes to be evaluated.

TC Code — Class and Description

1. Overtopped: crown entirely below the main canopy and covered by branches of taller trees, no direct sunlight strikes the crown, small crown that is sparse, and tree diameter is generally smaller
2. Intermediate: crown extends to lower part of main canopy, gathers sunlight at a few places on crown, narrow, and generally short crown with low live crown ratio
3. Codominant: crown is part of main canopy, intercepts light at the top of crown, crown is well-developed, but is crowned in the canopy and of medium size
4. Dominant: crown extends above the general canopy area, gathers light on top and sides of crown, large crown that is long crowned at the bottom, generally equates to large tree diameter

Individual Tree Location **(Visualization Plots Only)**

The location of all merchantable trees will be related back to the RP of the plot. Bearing and distance of each tree must be recorded. Distance to tree can be derived by using the DME in most cases, but measurement by loggers tape may be necessary. The distance should be recorded down to the nearest tenth.

Wildlife Grade–

Trees with wildlife significance should be coded as follows.

1. Snag – cull or standing dead trees that will serve as a snag for at least ten years
2. Cavity Tree – cull or standing dead trees that have a cavity any place on the stem
3. Wildlife Tree – living trees that have cavities any place on the stem

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TCRUISE OPERATING PROCEDURES

1. Start with a new .tcc template each day.
2. Save each day's work using the Saving Plot Data procedure outlined below (save to SD card).
3. Submit plots for analysis – download to project folder.
4. If you are out of town, download your plots to your laptop hard drive daily.

File Name Extensions

1. ".tct" = TCruise template created on desktop TCruise program
2. ".tcc" = a converted .tct template for export to the handheld
3. ".tce" = a .tcc with data collected in the field
4. ".tcd" = a TCruise desktop file after the .tce has been imported and processed

Starting a new cruise:

Initial Start-Up

1. Load a .tcc file in TCruisePK (Page 2 in LM Training Manual)
    a. Choose "Import a Code-Param File" from the initial action box when you open TCruise on handheld.

        Or

    b. Cancel initial action box and choose "Import Params File" under the "File" list menu in the lower left hand corner of screen.
2. Enter Tract Info – choose "Tract Info" under the "Edit" list menu (Page 3 in LM Training Manual).
3. Check "Current Params" under the "Edit" list menu – Be sure you have the correct .tcc file open (Page 3 in the LM Training Manual).

Saving Plot Data

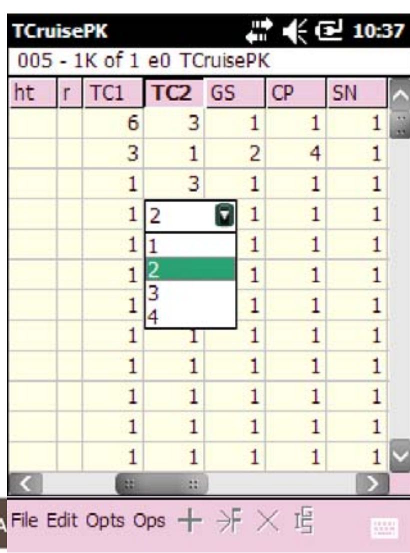
1. Choose "Save as" under the "File" list menu on the bottom of the screen (four fields will appear – Name, Folder, Type, and Location)
2. Name: should be completed as follows:
    "Job_date_cruiser initials", Example: "RMKTWINLAKES_01202009_DLD". The ".tce" file extension will automatically be included on your file name by TCruise.

3. *Optional Step* - Folder: create a "tce document" folder on your SD Card (TCruise field will use the My Documents folder on the handhelds main memory as a default – create a new folder on your SD Card to redirect the file location).
4. Type: leave as (*.tce)
5. Location: SD Card
6. Select **Save**.

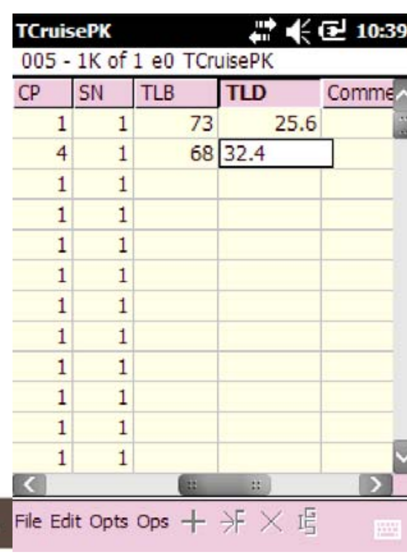
Collecting Field Data

1. Click the "**+**", new plot button, located in the center of the menu bar at the bottom of the screen to start a plot. **RTI will automatically complete this step.**
2. A plot entry screen will first appear. Fill in the stratum information **(stand number)**, **plot number,** and **cruiser initials** *(if you put your initials in the Tract Info screen, this will automatically be completed, see above).* Finish by clicking OK. **When using ArcPad RTI, this information will be automatically entered.**
3. The data entry screen will appear.
4. Fill out the tree data using the drop down columns for each tree.
5. Choose the GAA value in the **Prod** column when recording a merchantable tree – this will automatically take you to the Segment Length screen. Your cursor will automatically be placed in the stump height box (leave this blank, TCruise assumes 1 foot), then select the grade and fill in the length of each segment of the tree; click okay, and finish the remainder of the tree information in the data entry screen.
   a. **TCruise product codes: "WR" = woodsrun sawtimber, "VEN" = Veneer sawtimber, "B" = Boltwood and "PW" = pulp/cordwood**
6. After selecting the product and filling out the segment information, select "cut" or "leave" from the "leave/cut" column. Remember that trees designated for harvest should also be classified as "cut" trees along with trees that are marked for harvest.
7. For the following columns, select the appropriate numeric code from the dropdown.
   a. **TC1 = Tree Category 1 (1,2,3,4,5,6)**
   b. **TC2 = Tree Category 2 (1,2,3,4)**
   c. **GS = Growing Stock Classification (1,2,3,4,5)**
   d. **CP = Tree Canopy Position (1,2,3,4)**
   e. **SN = Den/Snag/Wildlife Tree Designation (1,2,3)**
8. For the following columns, fill in the necessary information.
   a. **TLB = Tree Location, Bearing (Fill in to the nearest degree)**
   b. **TLD = Tree Location, Distance (Fill in to the nearest .1 ft)**
9. When you are finished with a plot, click the plot finished button, **->F**, located to the right of the new plot button. Doing this will save your edits for each plot.
10. "X" button can be used to clear all edits for the current plot.
11. For regen., record the species as normal, but enter the count (**n=**) for each diameter class (**RDBH**) of each species.

Example of drop down selection



Example of numerical entry



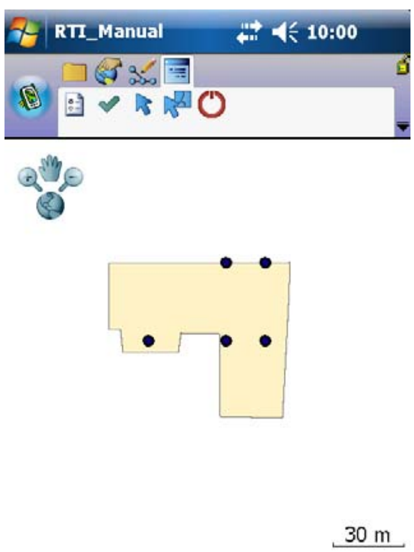
Entering Trees on the Tree

Data Screen - *see merch. spec. on page 1 (bullet 2)*

1. **Merchantable Trees** = trees 5 inches in diameter (DBH) and larger on a BAF plot
   a. Enter Species (SPP), (DBH), Product (Prod), and Number (N=) if applicable, in the tree data screen.
2. **Sub-Merchantable and Pre-Merchantable Trees** = established trees on a 1/100th acre plot that are 0 to 4.99 inches in diameter DBH and least 3 feet in height.
   a. Enter Species (SPP), leave Prod field as "AA", put the number of trees in the Number (N=) field, and place a "1" in the reproduction **(r)** column to indicate that this tree is pre-merchantable, record the DBH class of that species group in **(RDBH)** and, if you think the class would not produce acceptable growing stock, change the growing stock code to 5.

Collecting Field Data Using RTI

1. First, open TCruise and prepare for collecting data – See **Starting a New Cruise**
2. Next, start ArcPad and open your project
3. Setting up **ArcPad** and the **RTI** interface
   a. Add the RTI tool bar to your display – click the black arrow located in the lower right hand corner of the main tool bar > under Toolbars; select **tblRTI**
   b. Now the RTI Menu is available for use. **The screen shots below identify the menu icons and their uses.**



RTI Menu

Settings button

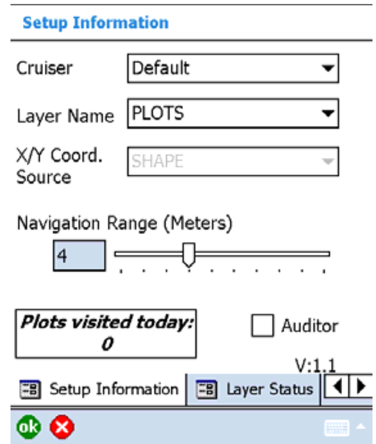
Manually Select and Edit Plot

Navigate To Plot

Clear Navigation Target

Close and Save Map

c. Before you begin to navigate to a point and begin cruising, you must first set the  l settings. Click the settings button and open the **Setup Information** window; see below.



d. In the **Setup Information** window, set the *Cruiser*, *Layer Name*, and *Navigation Range*. The Layer Name will be set to the plot layer with the correct schema, which, in this case, is **"Plots"**. The Navigation range shall be set to **10 meters**

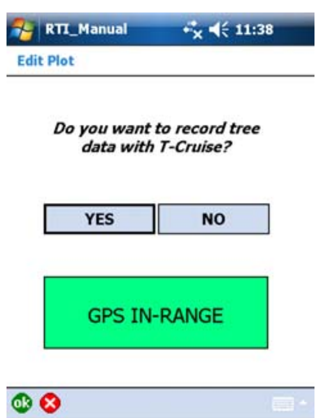
4. **Navigating to a plot**

a. Select the Navigate To Plot button  , then select the plot you would like to navigate to.

b. After the plot is selected, it will be "highlighted" and the plot number will appear.

c. Navigate to the selected plot as you normally would – you can use the go-to function or any other method.

d. Once you get within the set tolerance (Navigation Range set in the Setup Information window), an **Edit Plot** window will appear (you will also hear a chime). You will be asked if you want to record the plot. Choose YES.



e. After selecting YES, you will be automatically sent to **TCruise** (only if you have already opened TCruise and setup a new cruise).

5. Recording tree data – See the **Entering Trees on the Tree Data Screen** section.
   a. You will notice that you are automatically taken to the data entry screen (if the “Plot Info Prompt” is left off - unchecked under the **Opts** menu) – you will no longer need to enter the plot and stratum information.
   b. After you have recorded the required tree information, save the plot, and then manually go back to ArcPad – keep your TCruise project running.
6. After you have selected a plot, navigated to it, recoded tree data, and gone back to ArcPad, you will notice that the cruised plots will have different symbology. Plots already cruised will now display as stars.
7. Editing a plot
   a. If you would like to revisit a plot or make changes after you have saved a plot in TCruise, you can access that plot via the ArcPad/RTI interface. Choose the edit plot button , then select the plot you would like to edit. Doing so will automatically take you to the data entry screen in TCruise and bring up the chosen plot’s tree data. Make edits, save, and then return to ArcPad (plots can be chosen and edited in TCruise without using the ArcPad/RTI interface).
8. At the end of the day, choose the close and save button . You will need to save and close your TCruise project separately.

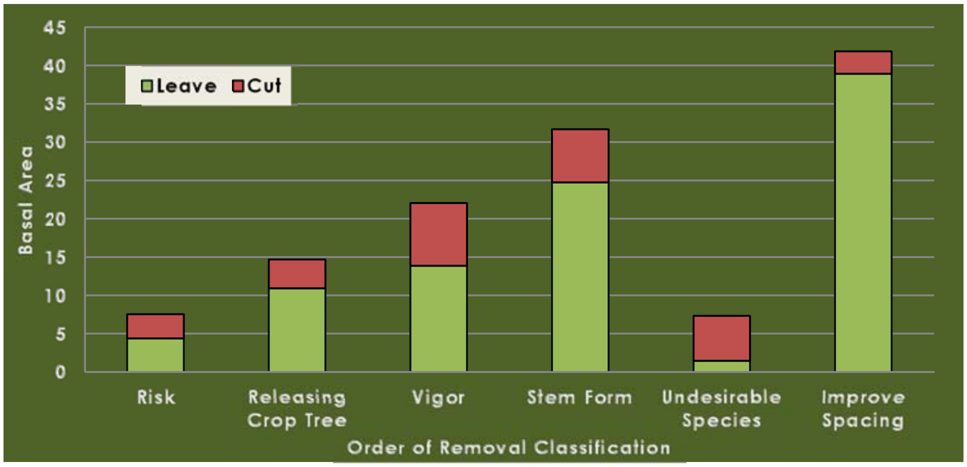
Exhibit 2

Native Community Analysis
Harvest Comparison

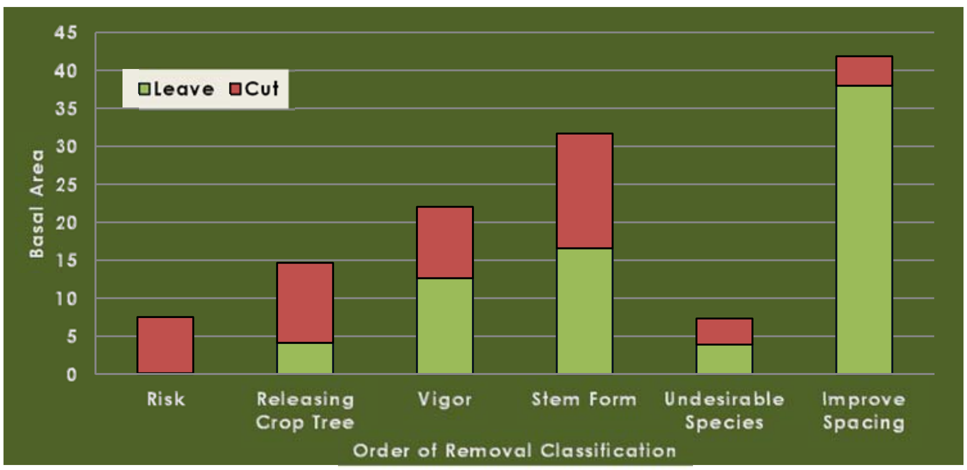
Exhibit 2
Native Community Study Harvest Comparison

Order of Removal Analysis

Existing Harvest



Scenario 1



Scenario 2

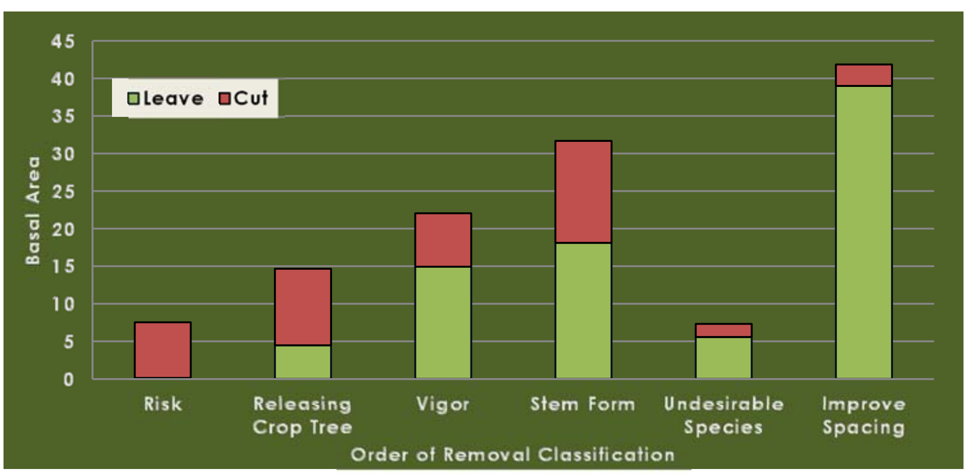
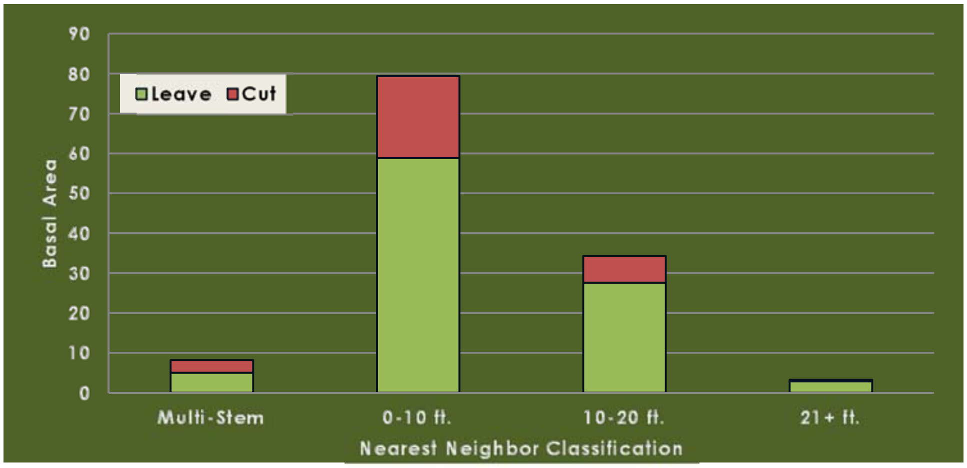


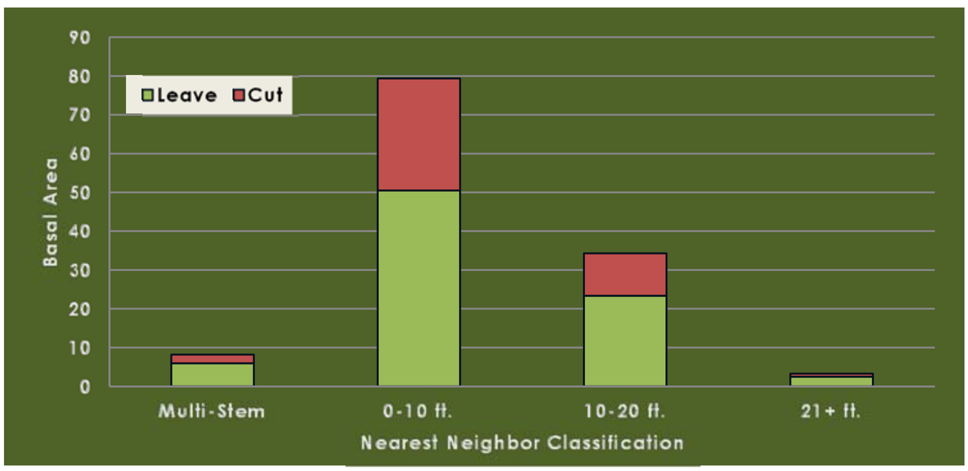
Exhibit 2
Native Community Study Harvest Comparison

Nearest Neighboring Tree Analysis

Existing Harvest



Scenario 1



Scenario 2

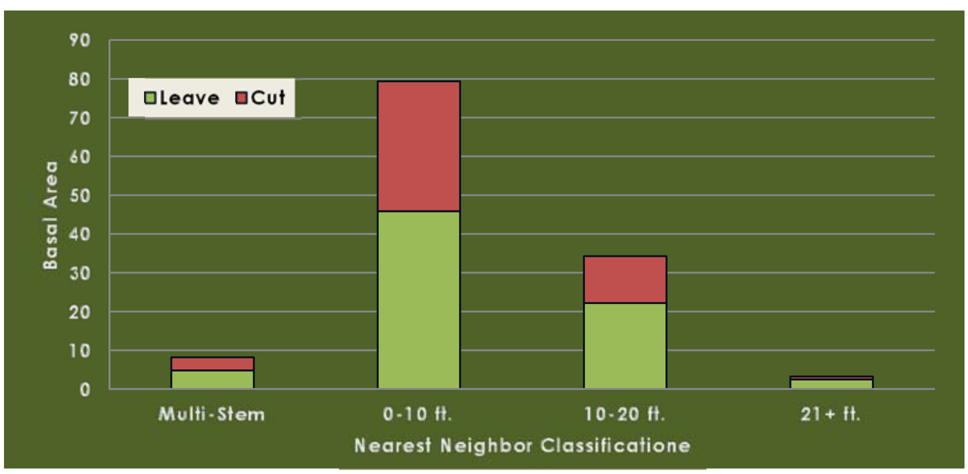
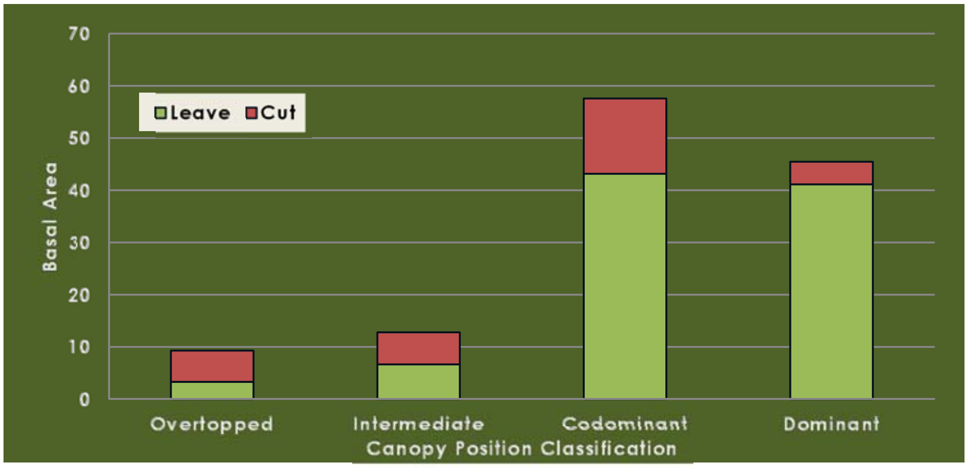


Exhibit 2
Native Community Study Harvest Comparison

Tree Canopy Position Analysis

Existing Harvest



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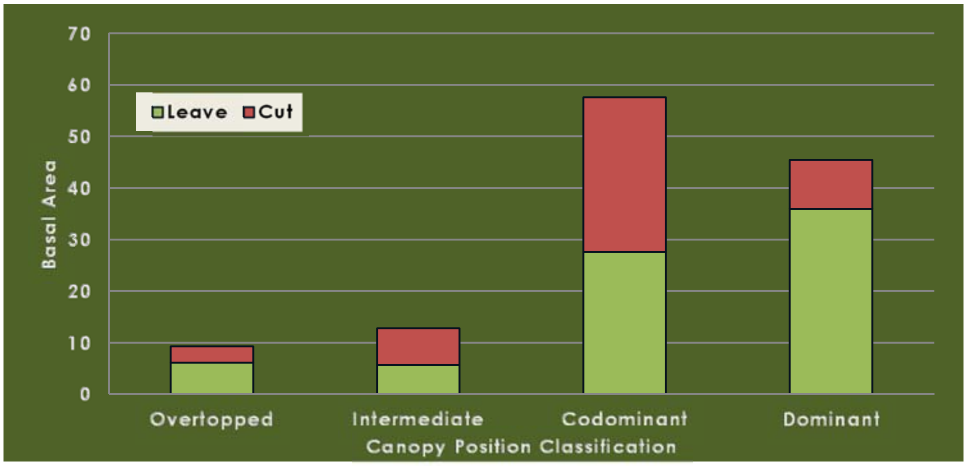

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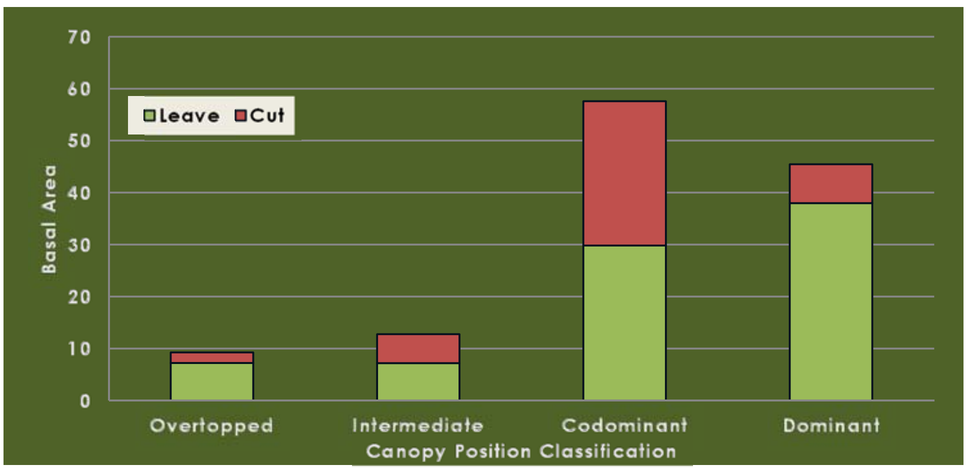
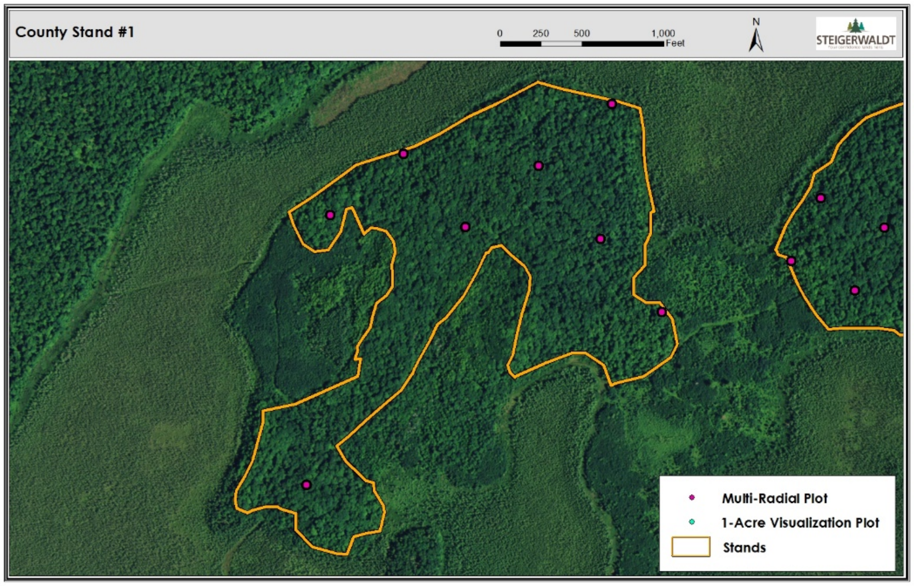


Exhibit 3

Order of Removal Analysis
County and State Timber Sale Maps

Exhibit 3
Order of Removal Case Study Timber Sale Maps



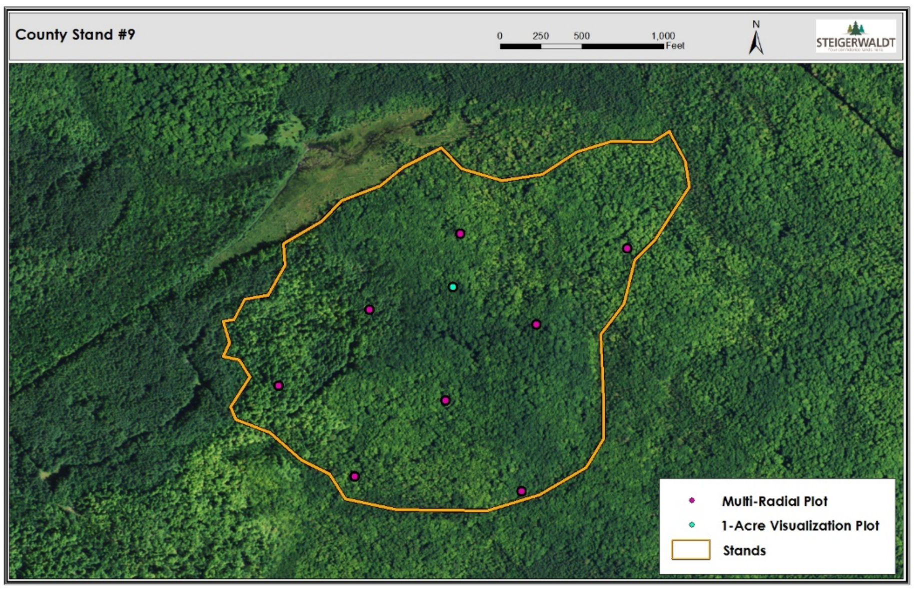
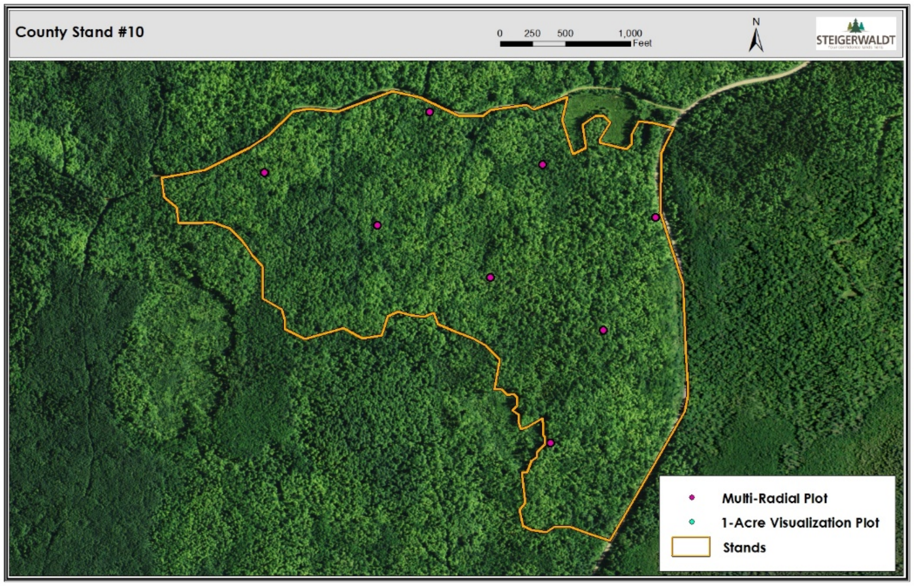


Exhibit 3
Order of Removal Case Study Timber Sale Maps



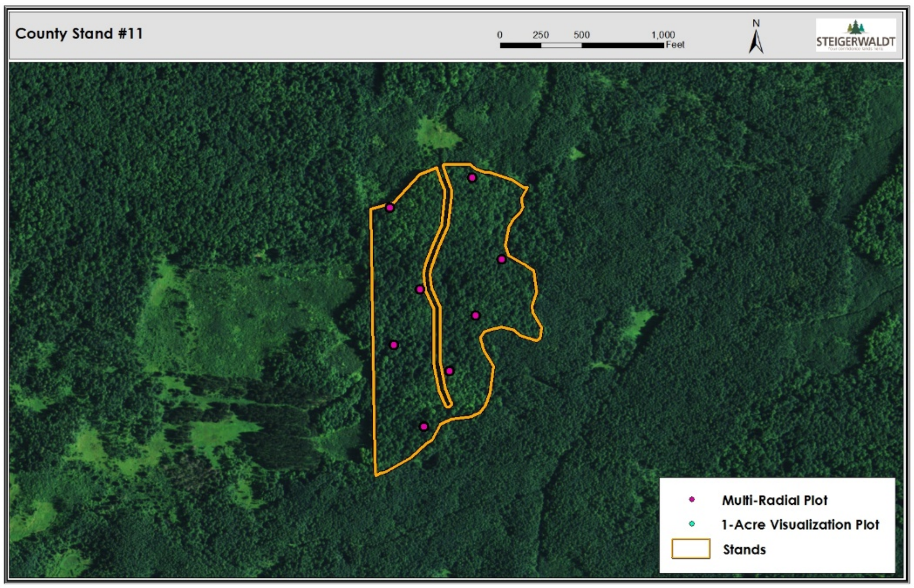
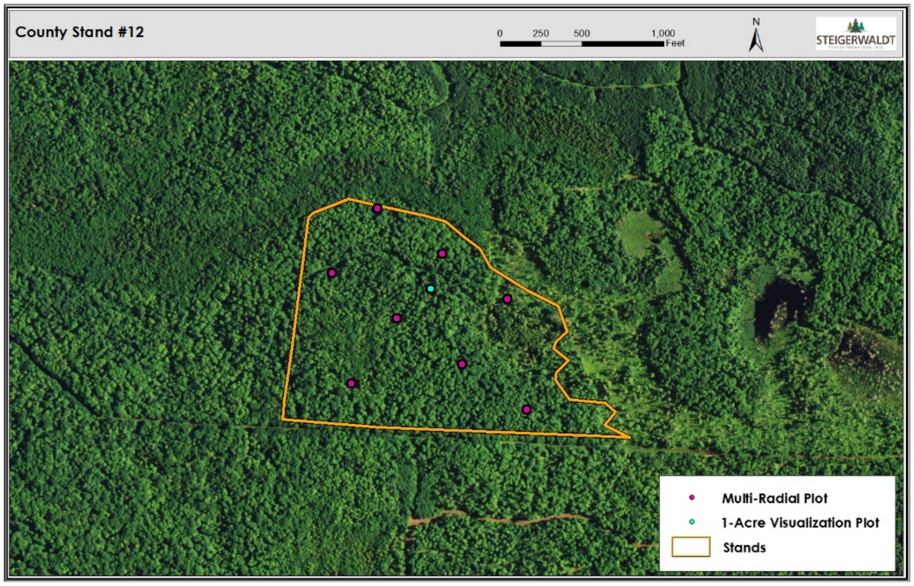


Exhibit 3
Order of Removal Case Study Timber Sale Maps



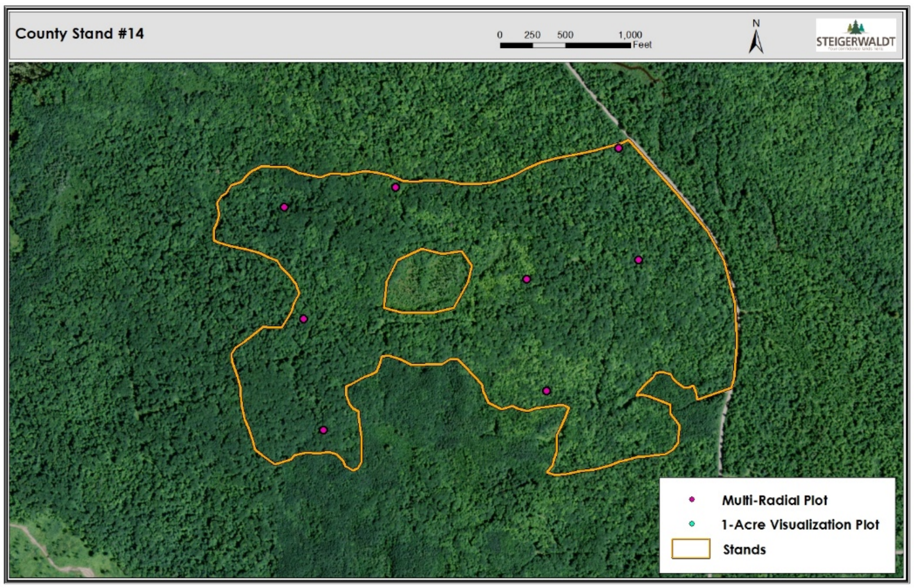
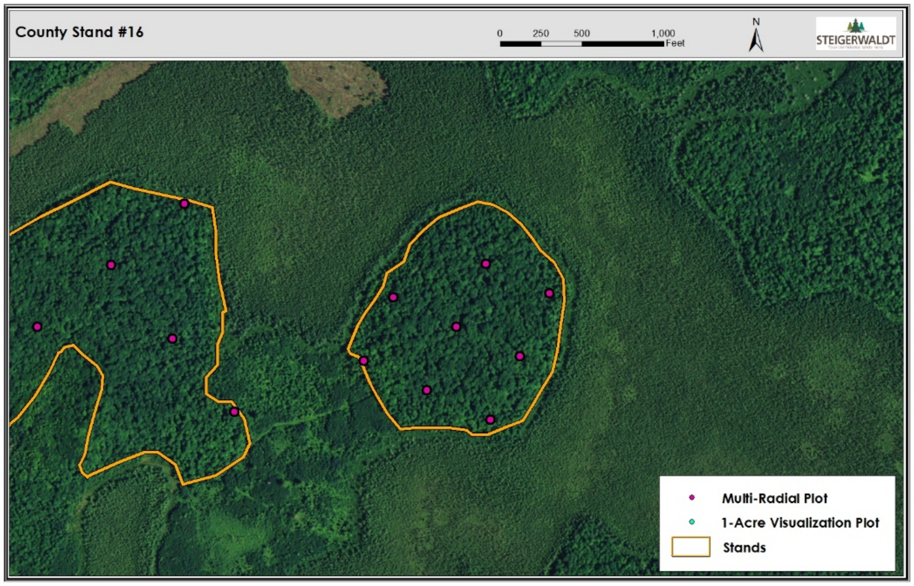
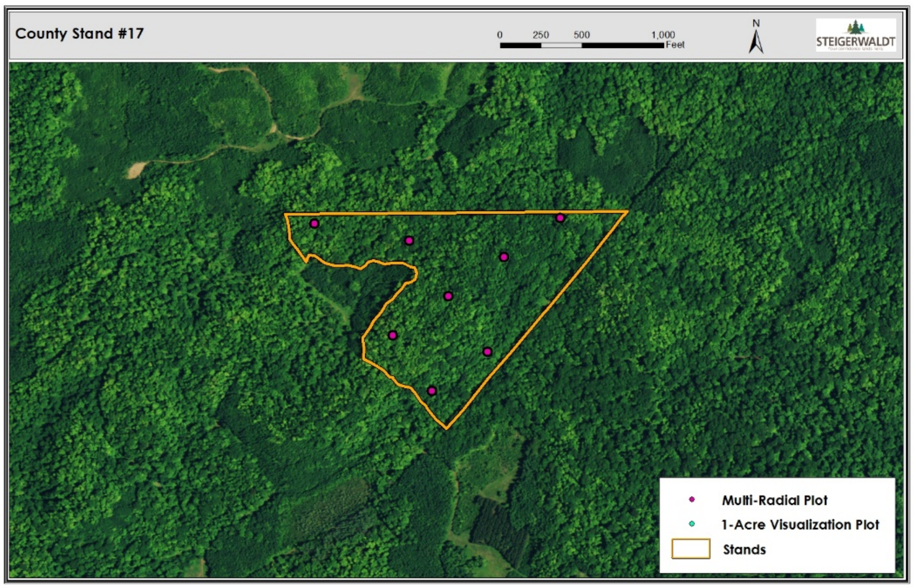


Exhibit 3
Order of Removal Case Study Timber Sale Maps





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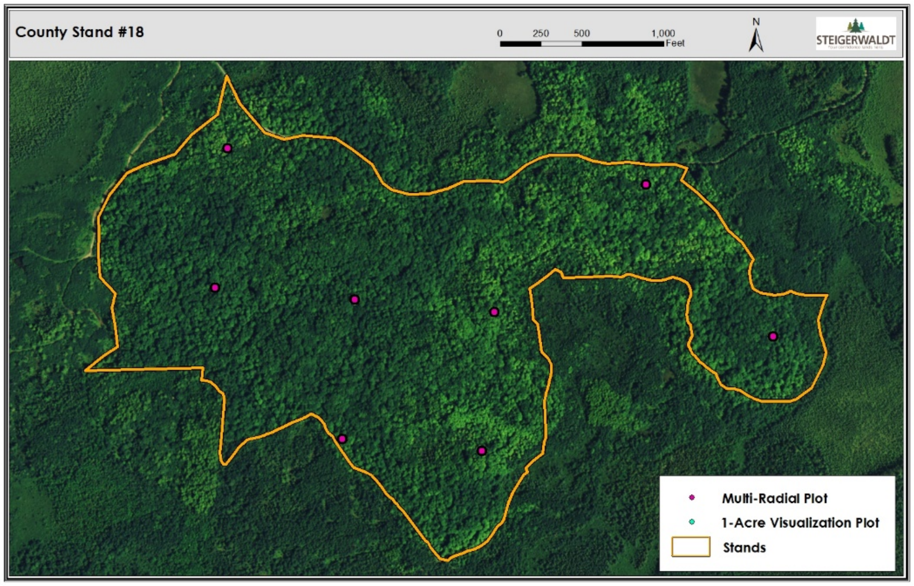
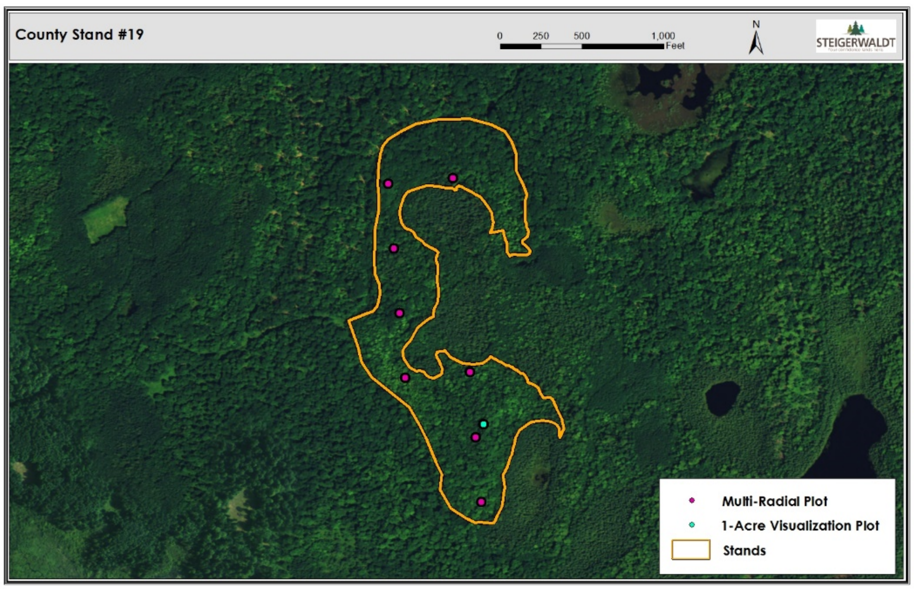
Order of Removal Case Study Timber Sale Maps





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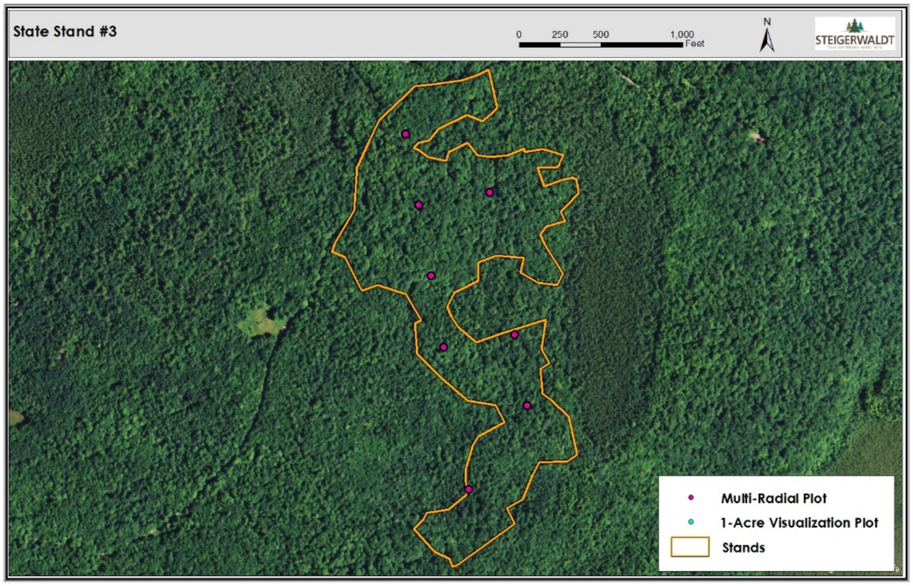
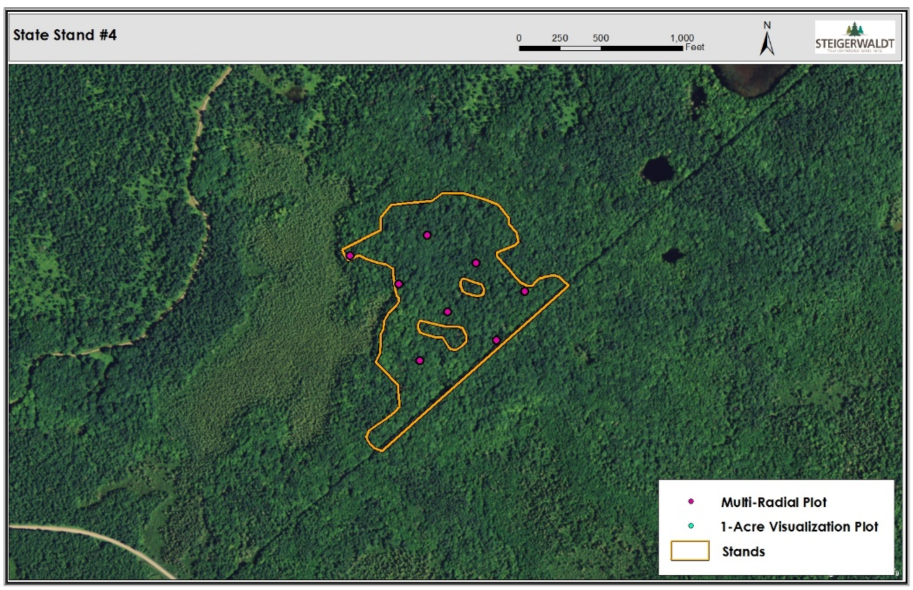
Order of Removal Case Study Timber Sale Maps





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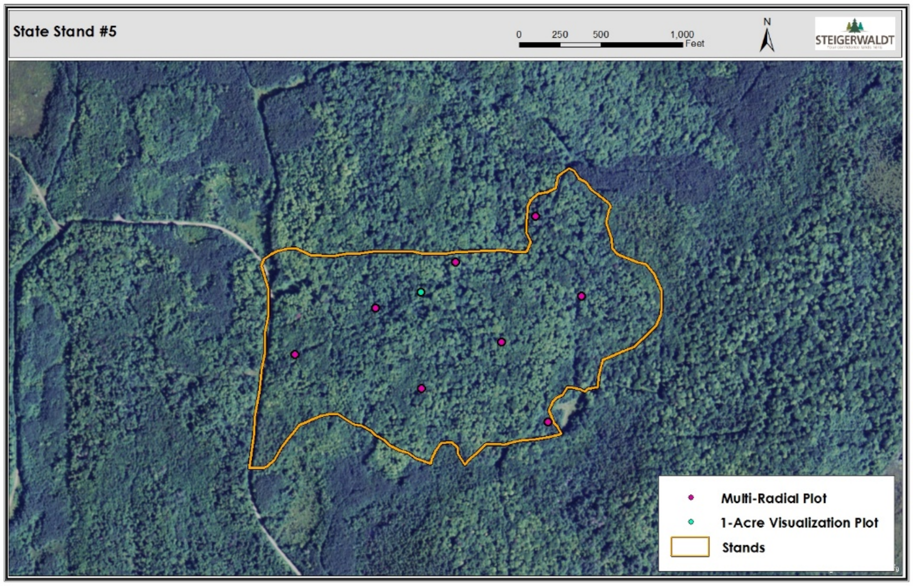
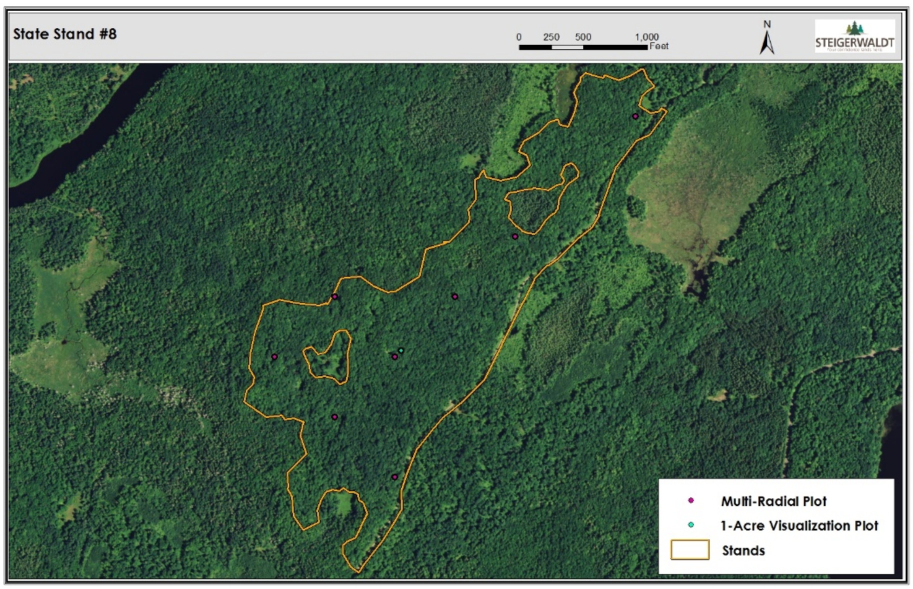
Order of Removal Case Study Timber Sale Maps





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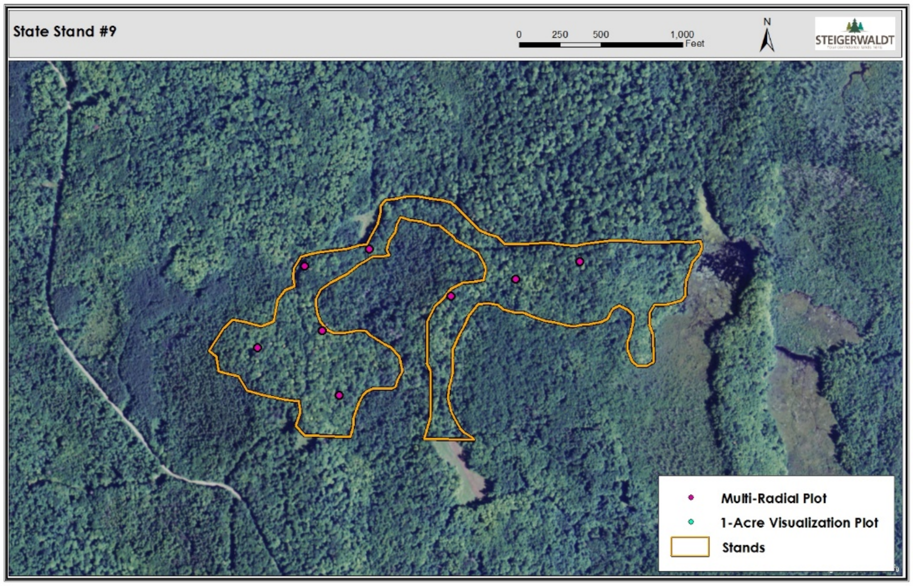
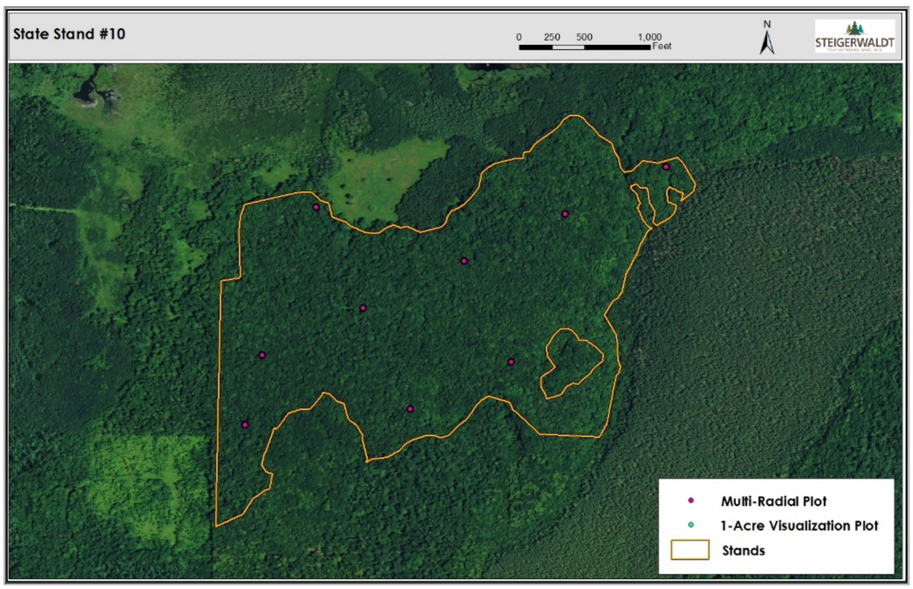
Order of Removal Case Study Timber Sale Maps





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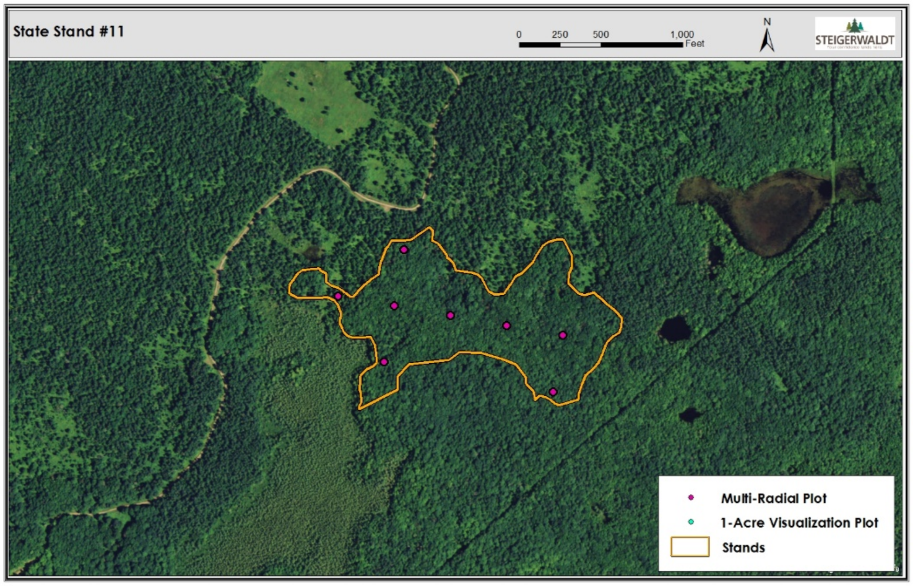
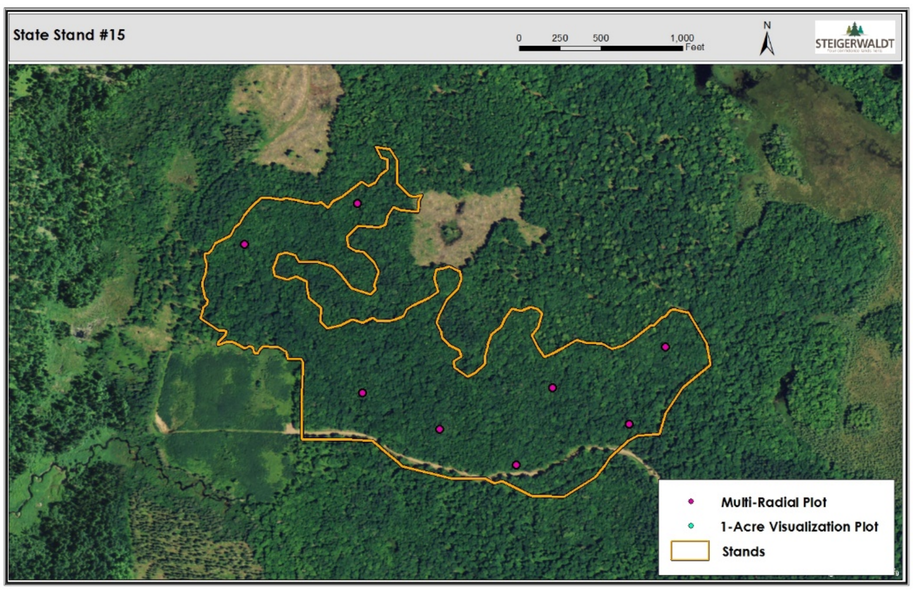
Order of Removal Case Study Timber Sale Maps





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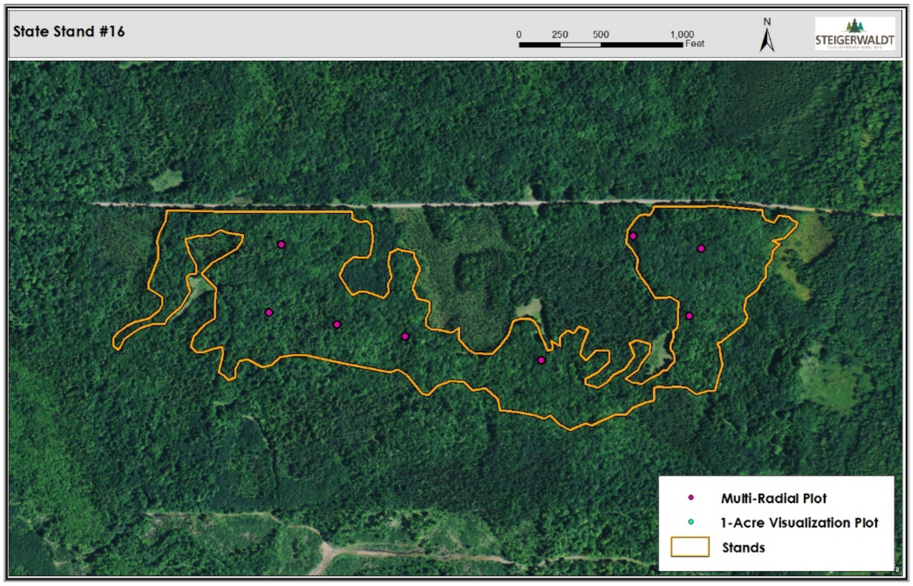
Order of Removal Case Study Timber Sale Maps



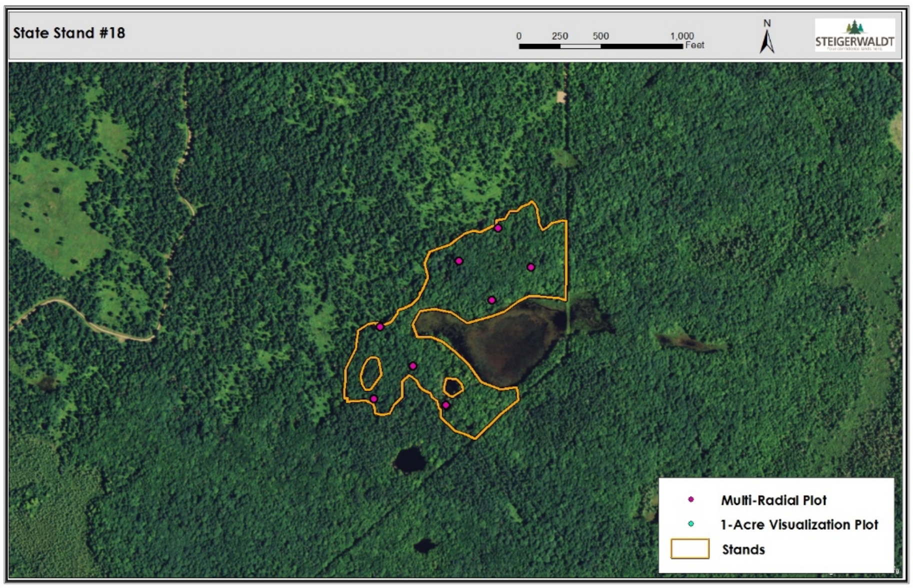


Exhibit 4

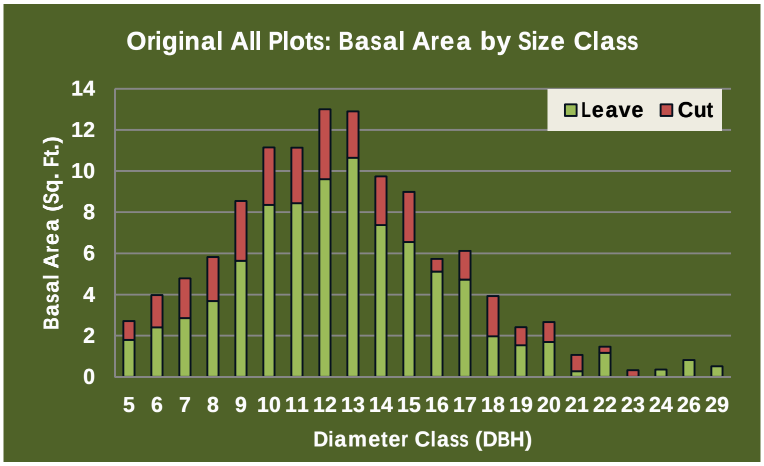
Order of Removal Analysis
Harvest Comparison

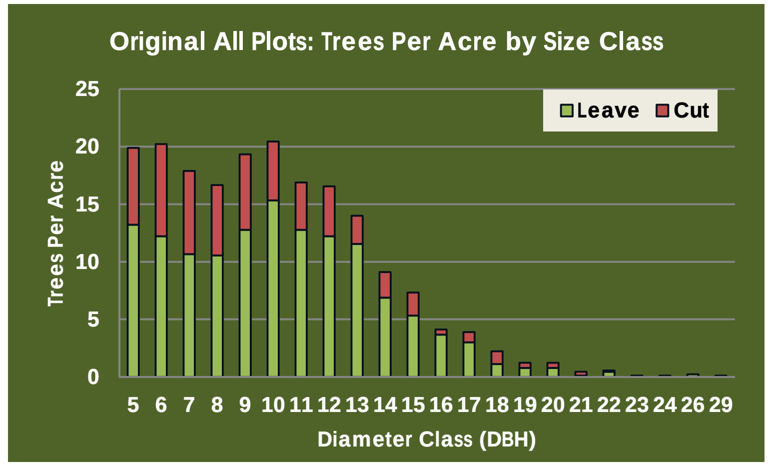
Exhibit 4
Order of Removal Case Study Harvest Comparison

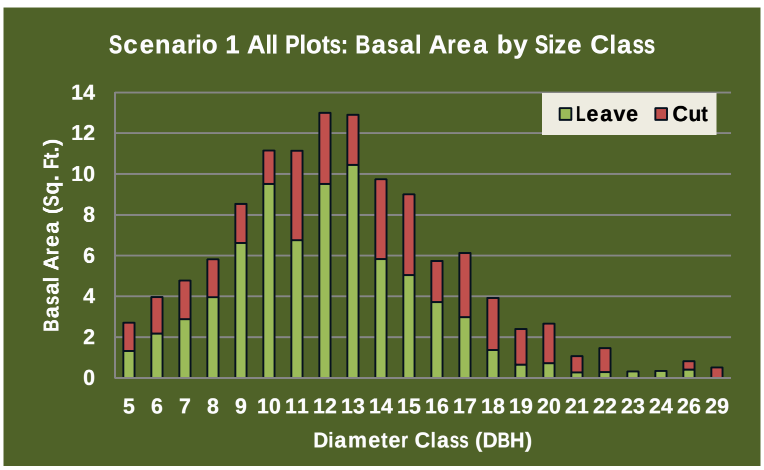
All Plots

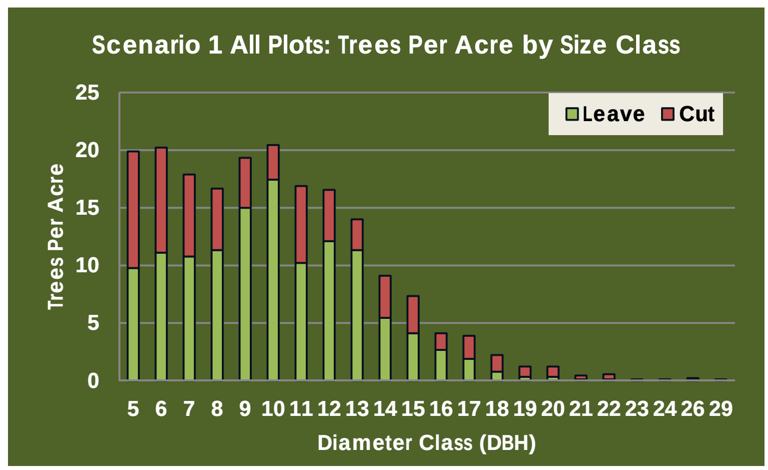
Basal Area

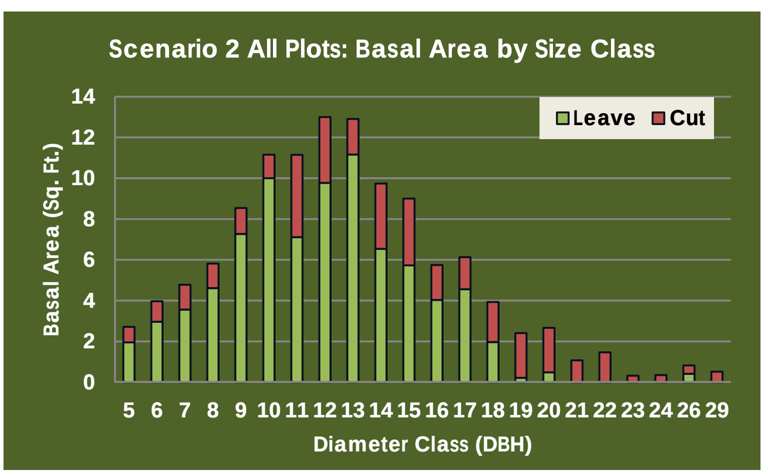
Trees per Acre











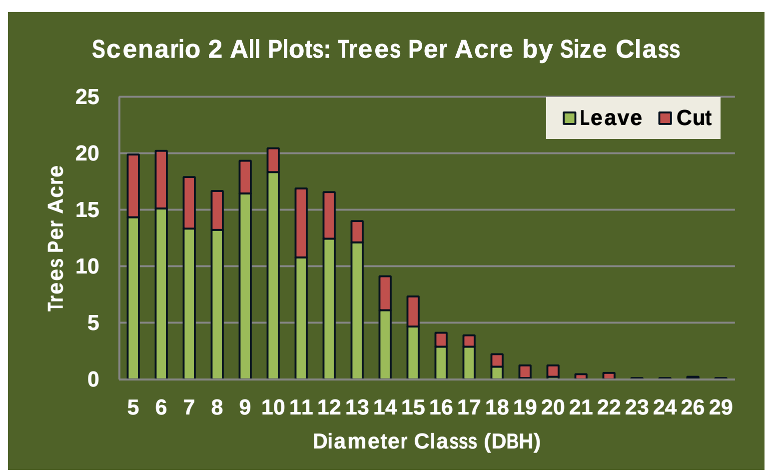
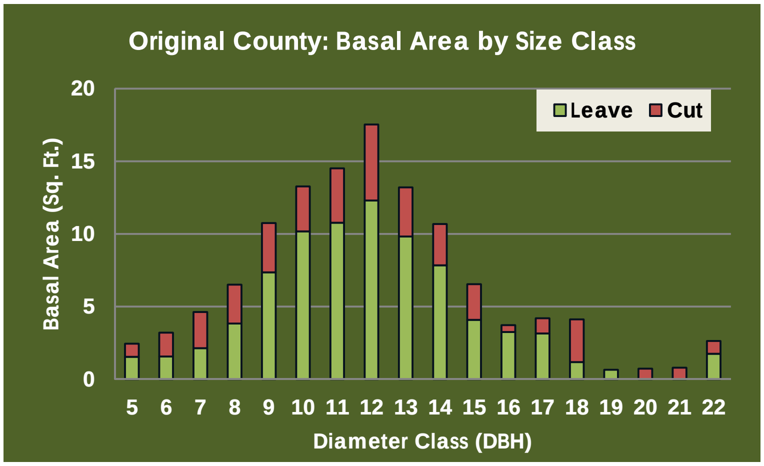
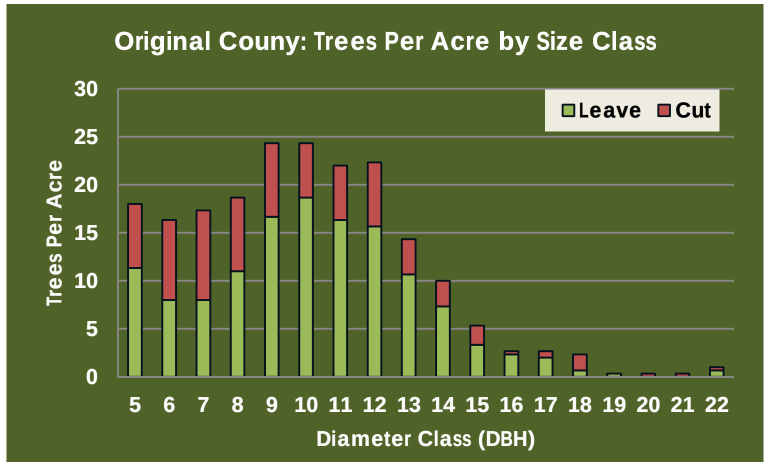


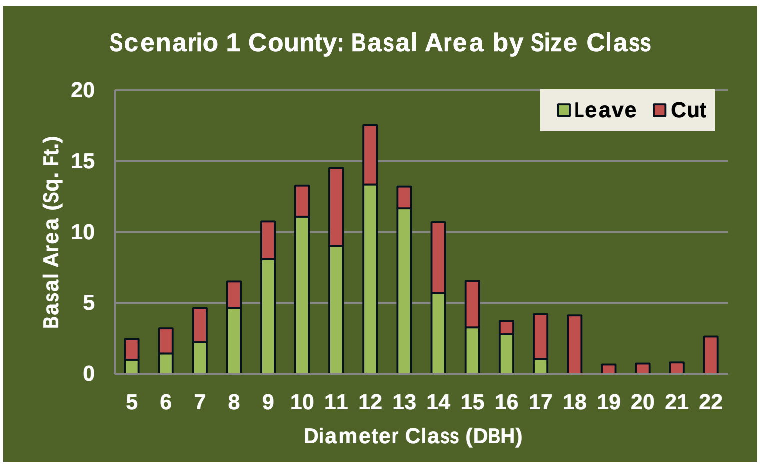
Exhibit 4
Order of Removal Case Study Harvest Comparison

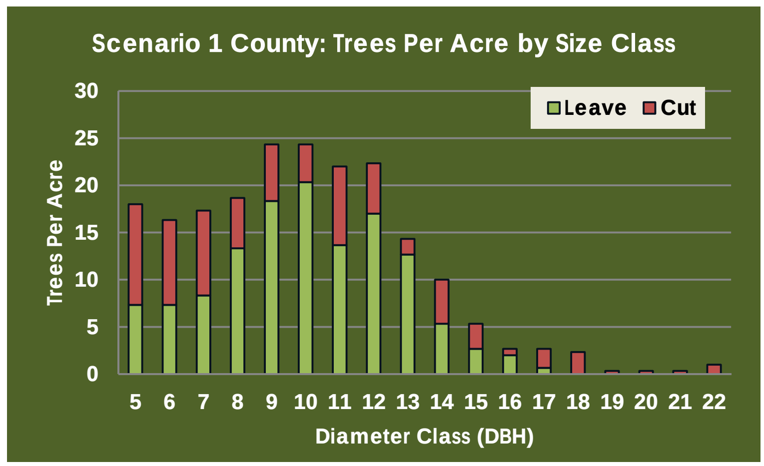
County

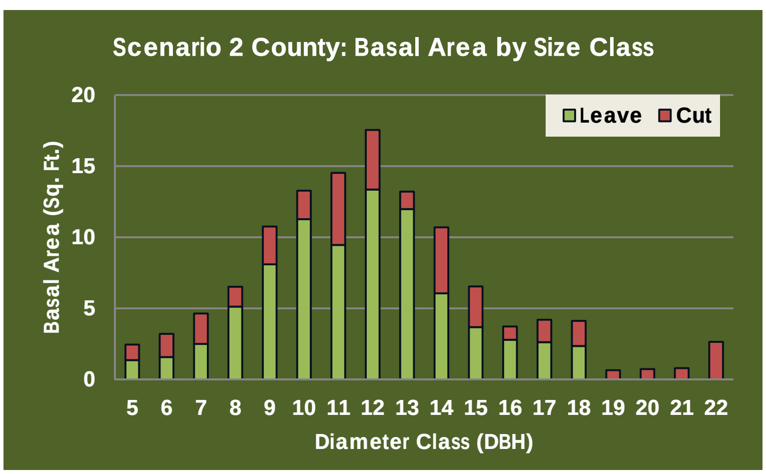
Basal Area | Trees per Acre











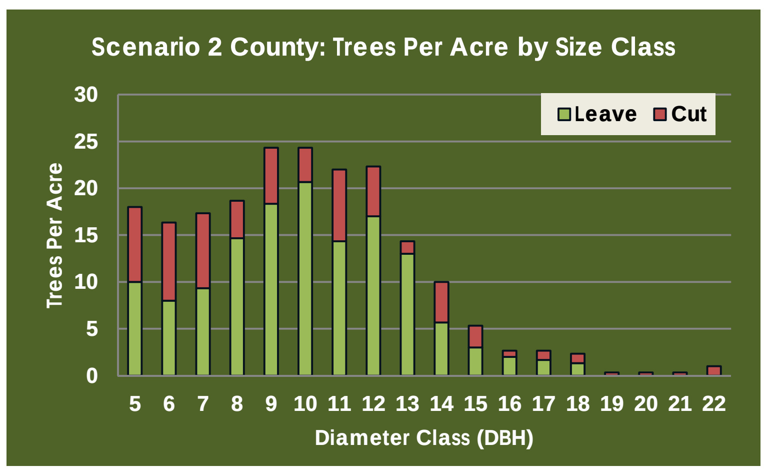
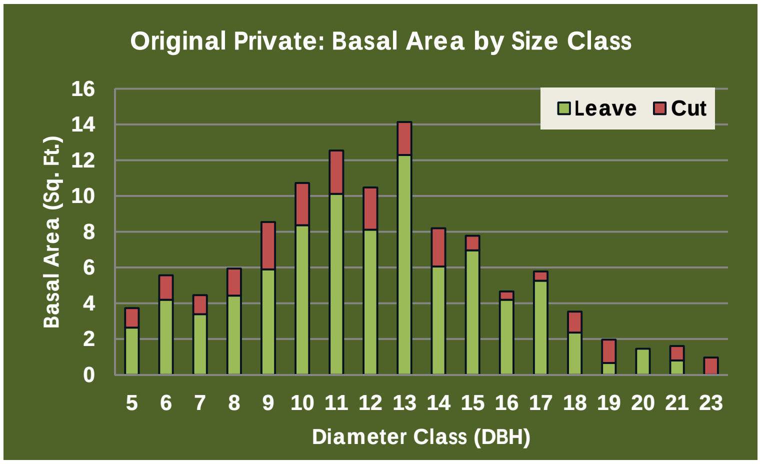
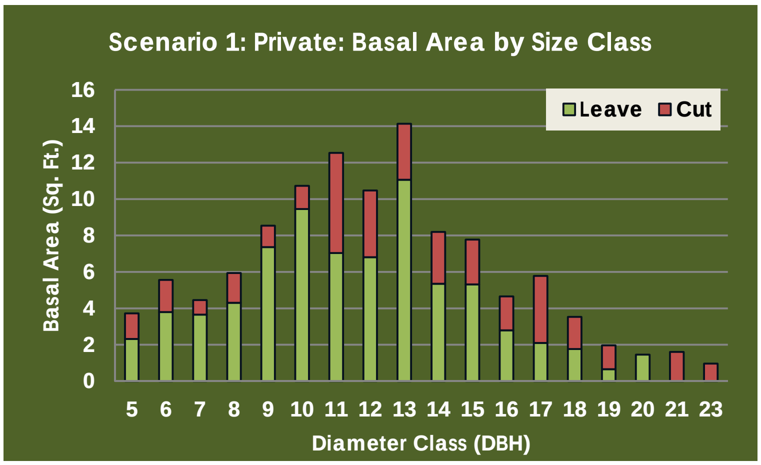


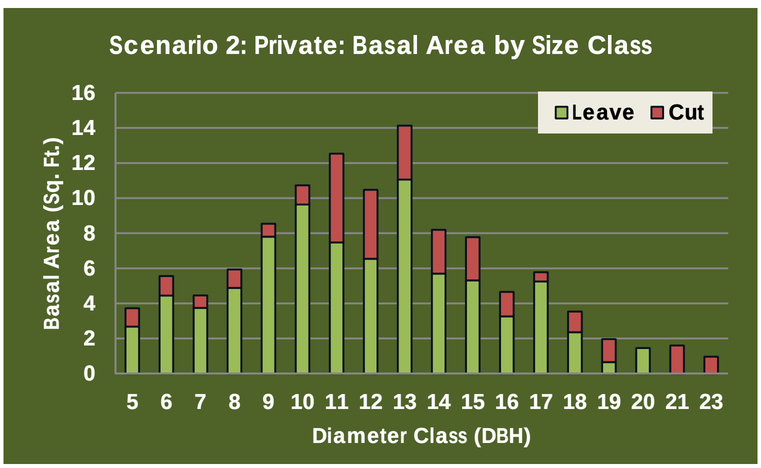
Exhibit 4
Order of Removal Case Study Harvest Comparison

Private

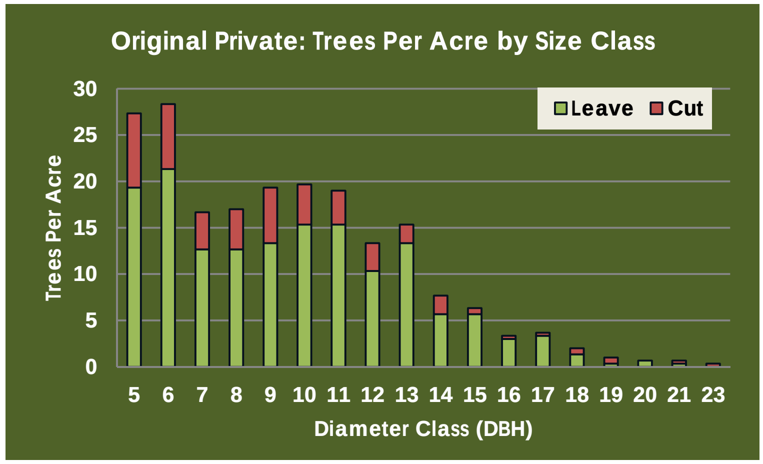
Basal Area

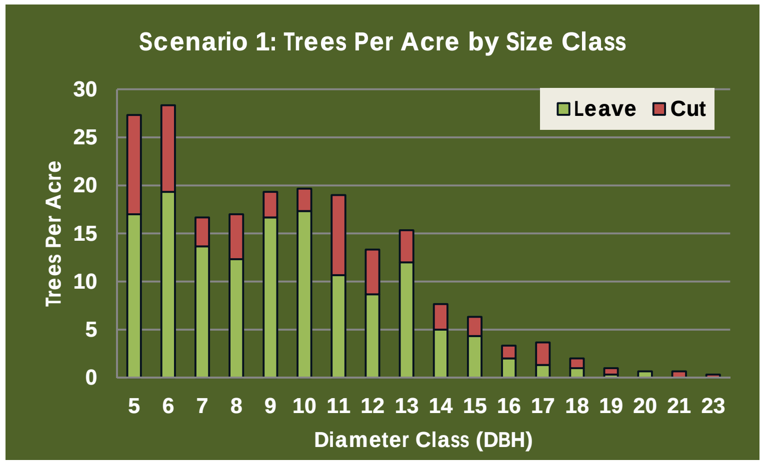






Trees per Acre





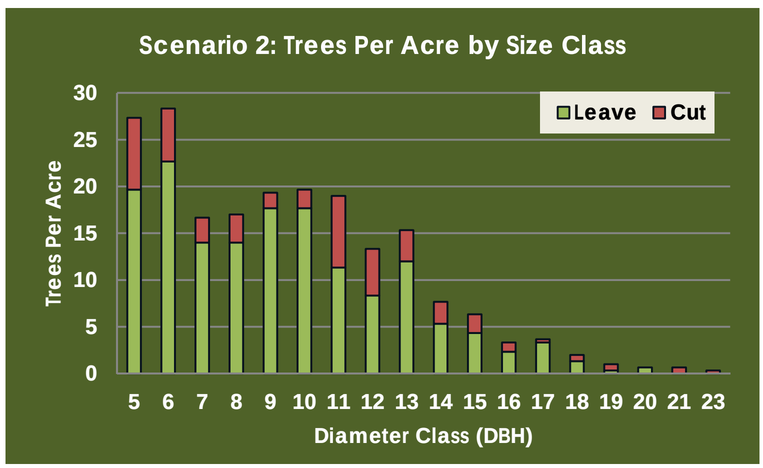
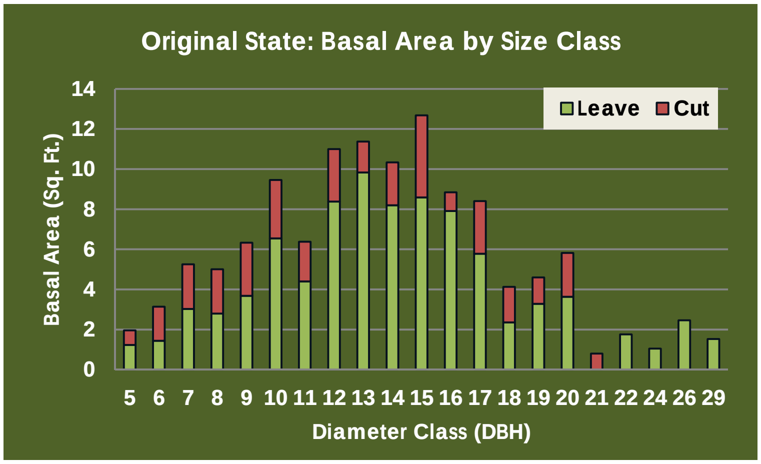
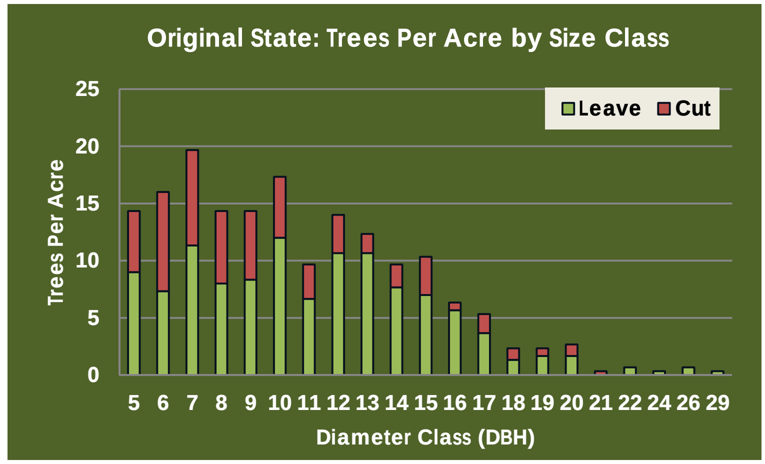


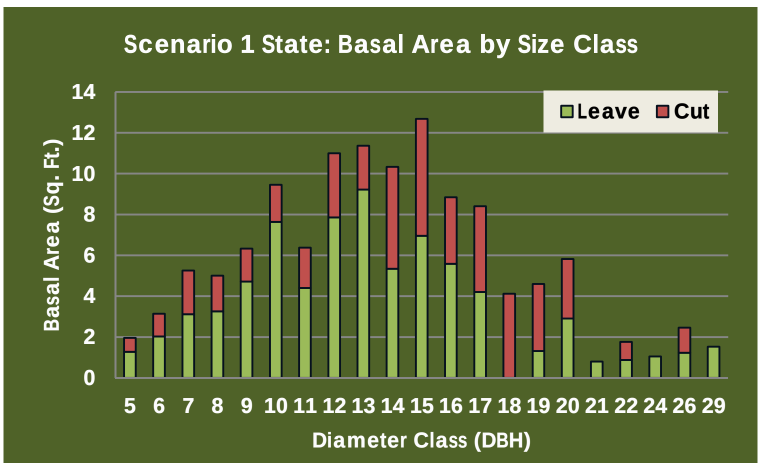
Exhibit 4
Order of Removal Case Study Harvest Comparison

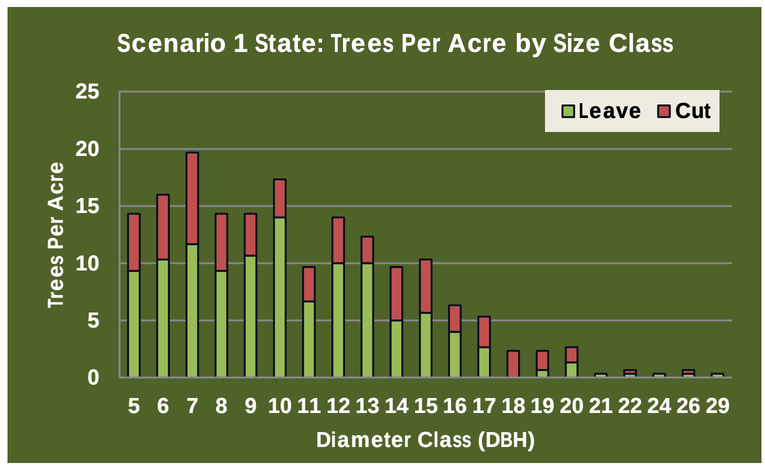
State

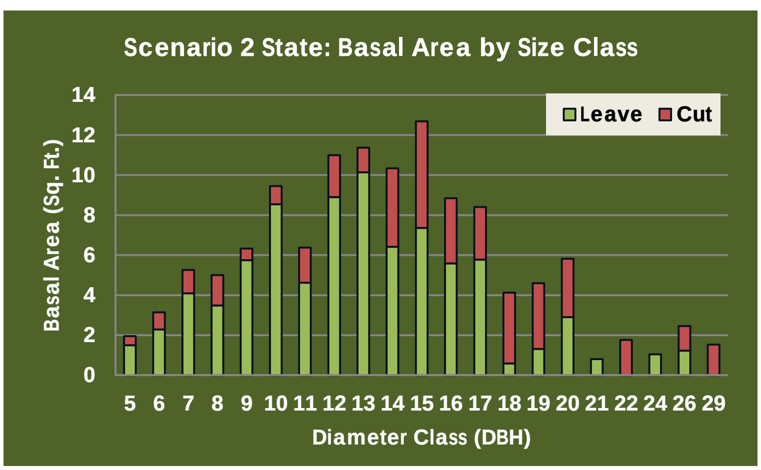
Basal Area | Trees per Acre











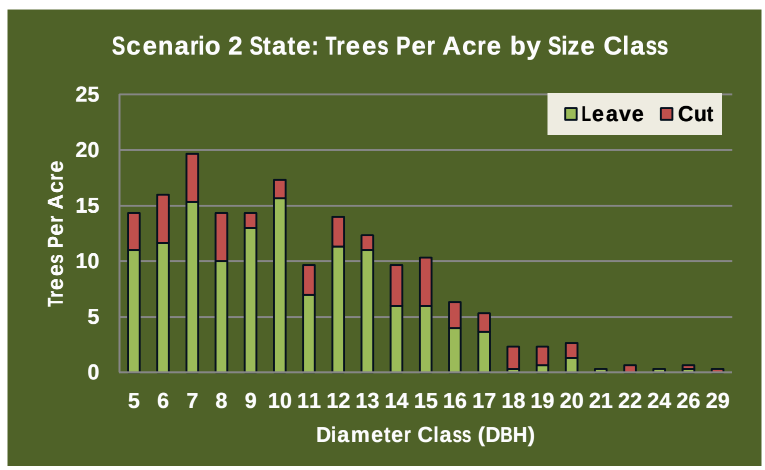


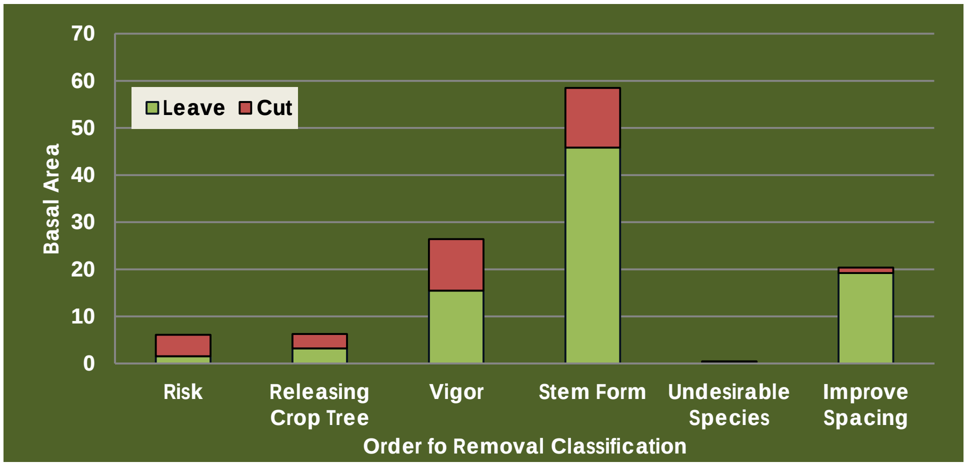
Exhibit 5

Order of Removal Analysis
All Landowners Harvest Comparison

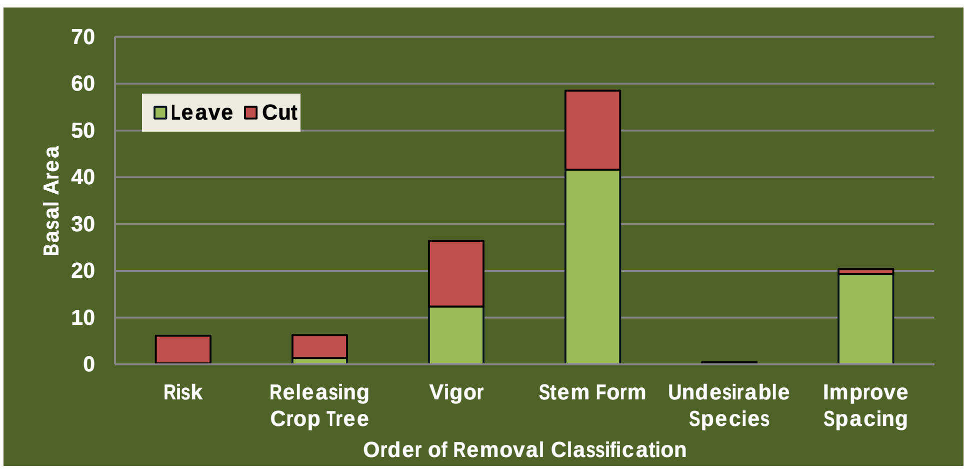
Exhibit 5
Order of Removal Case Study, All Landowners Harvest Comparison

Order of Removal Analysis

Existing Harvest



Scenario 1



Scenario 2

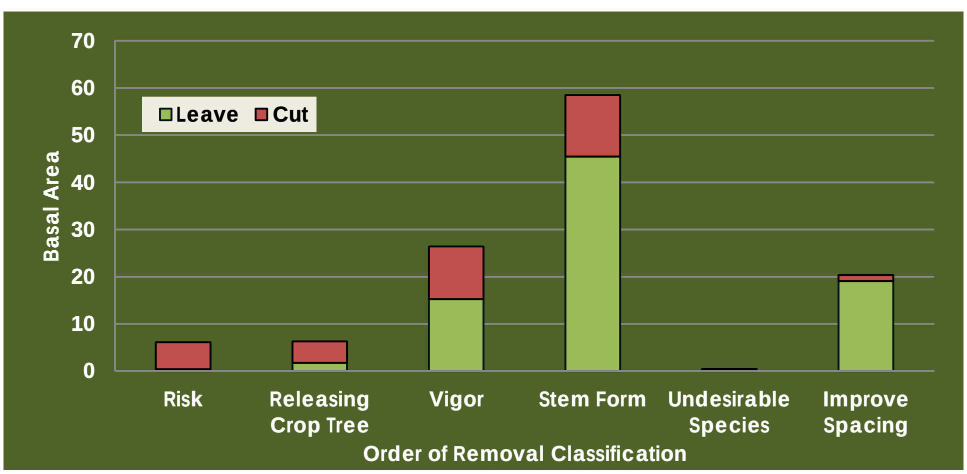
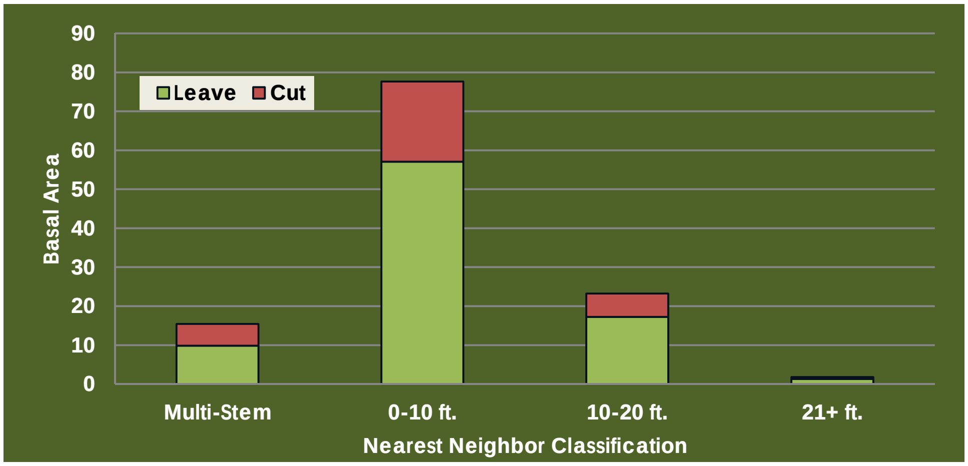


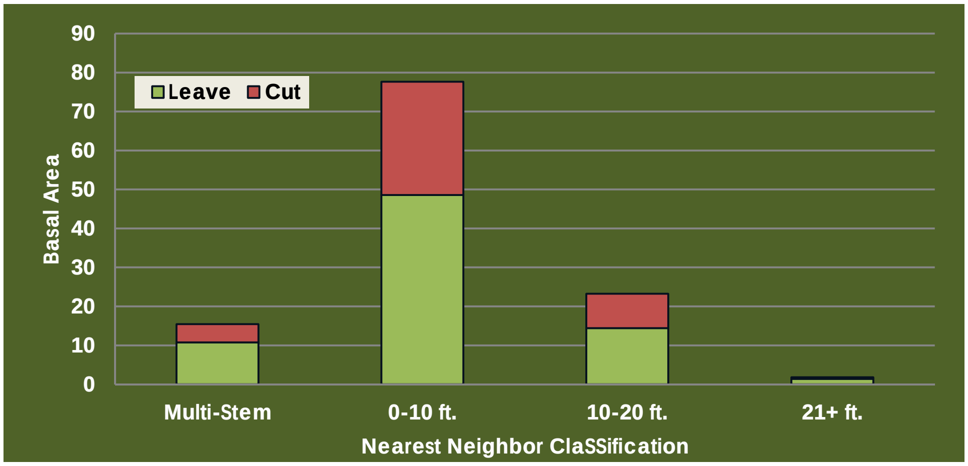
Exhibit 5
Order of Removal Case Study, All Landowners Harvest Comparison

Nearest Neighboring Tree Analysis

Existing Harvest



Scenario 1



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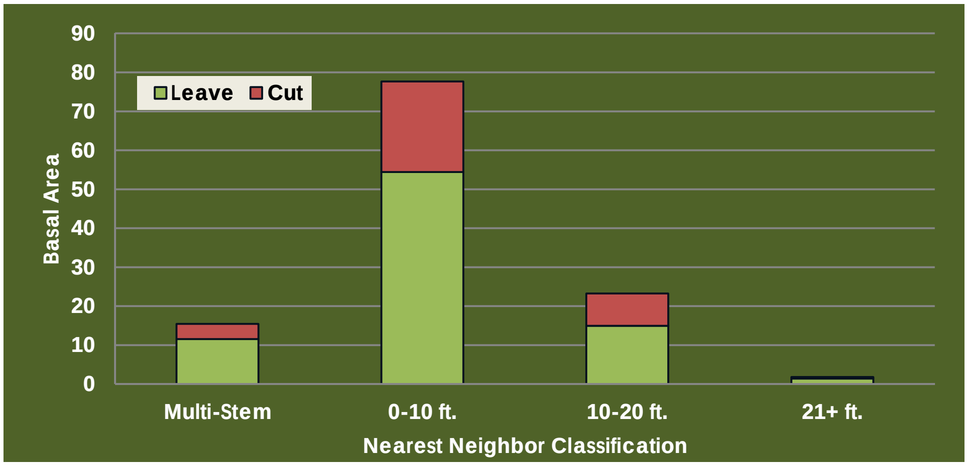
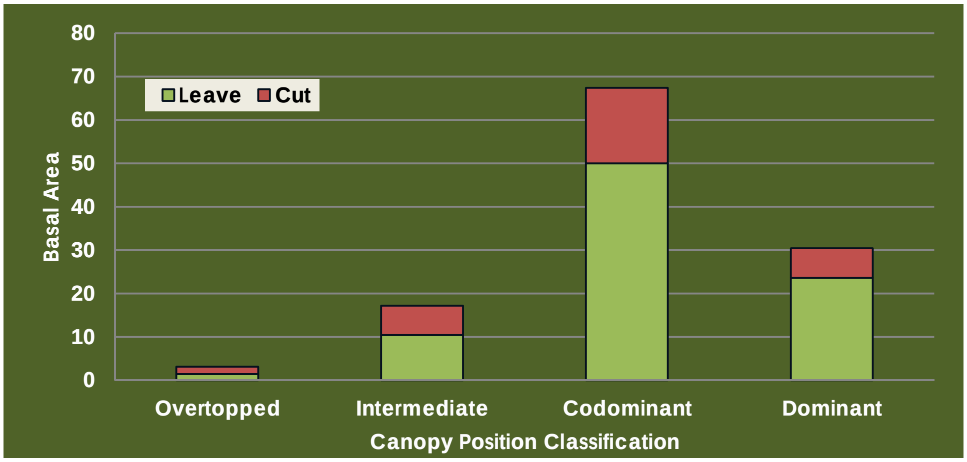


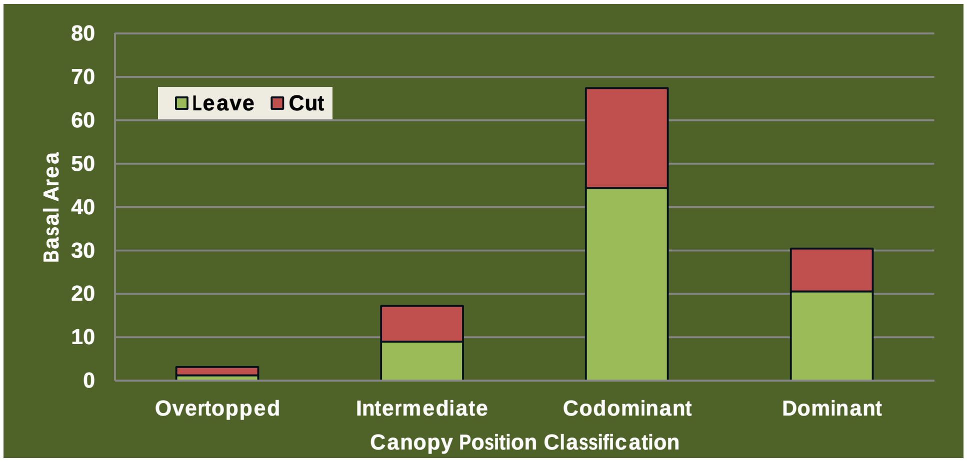
Exhibit 5
Order of Removal Case Study, All Landowners Harvest Comparison

Tree Canopy Position Analysis

Existing Harvest



Scenario 1



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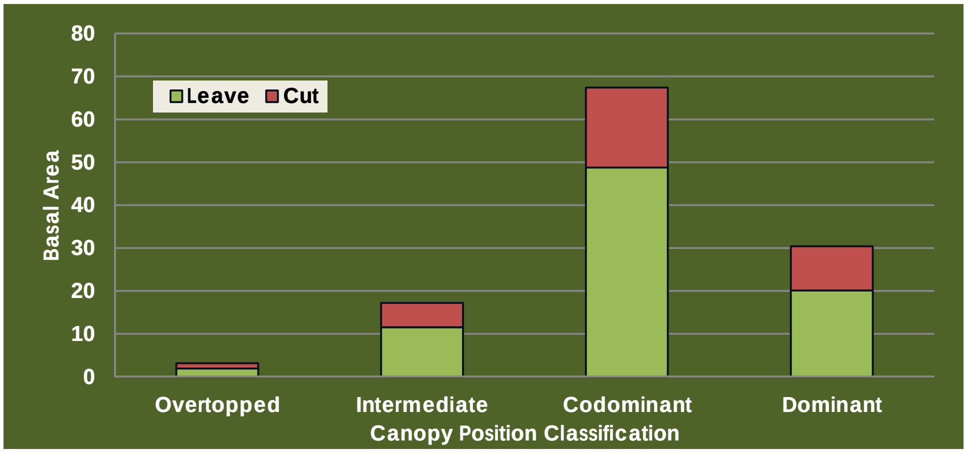

Exhibit 6

Order of Removal Analysis
Harvested Value Comparison by Species

Exhibit 6
Order of Removal Case Study, Harvested Products by Species Comparison

County: Poletimber (Pulpwood and Boltwood)						
	Existing Selection		Scenario 1		Scenario 2	
	Ton/Acre	Value/Acre	Ton/Acre	Value/Acre	Tons/Acre	Value/Acre
Mixed Hardwood	16.70	$313.03	19.64	$368.18	17.68	$331.46
Balsam Fir	0.07	$0.63		$0.00		$0.00
Basswood	4.54	$32.93	2.53	$18.35	2.46	$17.84
Oak	0.71	$9.18	0.81	$10.58	0.81	$10.58
Hemlock		$0.00	2.16	$16.19	2.14	$16.06
Total	**22.01**	**$355.77**	**25.14**	**$413.29**	**23.10**	**$375.94**
County: Grade Sawtimber and Veneer						
	MBF/Acre	Value/Acre	MBF/Acre	Value/Acre	MBF/Acre	Value/Acre
Hard Maple	217.09	$108.55	460.07	$230.04	265.48	$132.74
Soft Maple	341.34	$136.54	361.61	$144.64	181.42	$72.57
Red Oak		$0.00	109.86	$52.18	109.86	$52.18
Mixed Hardwood	36.66	$10.08		$0.00		$0.00
White Ash	69.80	$22.69	38.93	$12.65	19.44	$6.32
Basswood	357.33	$107.20	147.85	$44.35	85.44	$25.63
Total	**1,022.22**	**$385.05**	**1,118.32**	**$483.87**	**661.64**	**$289.44**
Grand Total		**$740.82**		**$897.16**		**$665.38**

Private: Poletimber (Pulpwood and Boltwood)						
	Existing Selection		Scenario 1		Scenario 2	
	Ton/Acre	Value/Acre	Ton/Acre	Value/Acre	Tons/Acre	Value/Acre
Aspen	0.20	$4.26	0.58	$12.08	0.58	$12.08
Mixed Hardwood	12.52	$234.66	19.72	$369.80	17.27	$323.76
Spruce	0.24	$3.44	0.16	$2.24	0.16	$2.24
White Birch	0.21	$3.02	0.19	$2.76	0.19	$2.76
Basswood	2.96	$21.46	2.80	$20.27	2.91	$21.09
Oak	0.24	$3.10	1.16	$15.02	0.65	$8.50
Hemlock		$0.00	0.74	$5.54	0.74	$5.54
Total	**16.37**	**$269.94**	**25.34**	**$427.70**	**22.49**	**$375.97**
Private: Grade Sawtimber and Veneer						
	MBF/Acre	Value/Acre	MBF/Acre	Value/Acre	MBF/Acre	Value/Acre
Hard Maple	79.57	$39.79	275.24	$137.62	78.21	$39.11
Soft Maple		$0.00	47.64	$19.06		$0.00
Red Oak	15.29	$7.26	182.68	$86.77	33.60	$15.96
White Ash	57.96	$18.84	59.54	$19.35	13.82	$4.49
Yellow Birch	20.35	$7.12		$0.00		$0.00
Basswood	381.43	$114.43	218.24	$65.47	209.87	$62.96
Total	**554.60**	**$187.44**	**783.34**	**$328.27**	**335.50**	**$122.52**
Grand Total		**$457.38**		**$755.98**		**$498.49**

Exhibit 6
Order of Removal Case Study, Harvested Products by Species Comparison

State: Poletimber (Pulpwood and Boltwood)						
	Existing Selection		Scenario 1		Scenario 2	
	Ton/Acre	Value/Acre	Ton/Acre	Value/Acre	Tons/Acre	Value/Acre
Mixed Hardwood	17.03	$319.37	25.98	$487.20	23.28	$436.43
Balsam Fir		$0.00		$0.00		$0.00
Spruce		$0.00		$0.00		$0.00
White Birch	0.46	$6.71	0.23	$3.28	0.10	$1.44
Basswood	1.71	$12.39	1.66	$12.06	1.29	$9.38
Oak		$0.00	0.27	$3.52	0.39	$5.05
Hemlock		$0.00	0.70	$5.25	0.70	$5.25
Total	**19.20**	**$338.47**	**28.84**	**$511.32**	**25.76**	**$457.56**
State: Grade Sawtimber and Veneer						
	MBF/Acre	Value/Acre	MBF/Acre	Value/Acre	MBF/Acre	Value/Acre
Hard Maple	285.95	$142.97	661.17	$330.58	489.18	$244.59
Soft Maple	45.48	$18.19	123.07	$49.23	77.59	$31.04
Red Oak		$0.00	13.45	$6.39	141.83	$67.37
Mixed Hardwood	158.65	$43.63	63.56	$17.48	38.58	$10.61
White Ash	219.52	$71.34	418.03	$135.86	237.63	$77.23
Yellow Birch		$0.00	8.70	$3.04		$0.00
Basswood	371.07	$111.32	165.41	$49.62	165.41	$49.62
Total	**1,080.67**	**$387.46**	**1,453.39**	**$592.21**	**1,150.22**	**$480.46**
Grand Total		**$725.93**		**$1,103.53**		**$938.01**

Exhibit 7

Aspen LEV Analysis

Exhibit 7
Aspen Results by Year and Site Index

Age	Site Index 60			Site Index 70			Site Index 80		
	Yield Ft^3	Yield Cds	LEV	Yield Ft^3	Yield Cds	LEV	Yield Ft^3	Yield Cds	LEV
10	-	0.0	($124.30)	-	0.0	($124.30)	-	0.0	($124.30)
11	-	0.0	($117.69)	-	0.0	($117.69)	-	0.0	($117.69)
12	-	0.0	($112.20)	-	0.0	($112.20)	16	0.2	($103.07)
13	-	0.0	($107.59)	3	0.0	($106.03)	46	0.6	($84.41)
14	-	0.0	($103.66)	24	0.3	($92.78)	83	1.1	($65.89)
15	7	0.1	($97.41)	50	0.6	($79.74)	128	1.6	($47.62)
16	23	0.3	($88.63)	81	1.0	($66.99)	181	2.3	($29.73)
17	43	0.5	($80.12)	118	1.5	($54.57)	242	3.1	($12.30)
18	66	0.8	($71.88)	160	2.0	($42.54)	311	3.9	$4.57
19	92	1.2	($63.95)	208	2.6	($30.95)	388	4.9	$20.79
20	122	1.6	($56.34)	261	3.3	($19.84)	473	6.0	$36.31
21	156	2.0	($49.07)	319	4.0	($9.25)	567	7.2	$51.06
22	193	2.4	($42.16)	384	4.9	$0.79	669	8.5	$65.01
23	233	3.0	($35.61)	453	5.7	$10.27	778	9.9	$78.12
24	277	3.5	($29.44)	528	6.7	$19.17	896	11.3	$90.38
25	324	4.1	($23.65)	609	7.7	$27.48	1,021	12.9	$101.76
26	375	4.7	($18.24)	694	8.8	$35.19	1,154	14.6	$112.26
27	429	5.4	($13.22)	785	9.9	$42.30	1,295	16.4	$121.89
28	486	6.2	($8.58)	880	11.1	$48.82	1,442	18.3	$130.66
29	546	6.9	($4.32)	981	12.4	$54.76	1,610	20.4	$140.38
30	609	7.7	($0.43)	1,086	13.7	$60.12	1,763	22.3	$146.21
31	675	8.5	$3.09	1,195	15.1	$64.93	1,912	24.2	$150.20
32	744	9.4	$6.27	1,309	16.6	$69.18	2,058	26.1	$152.57
33	816	10.3	$9.09	1,439	18.2	$74.14	2,200	27.9	$153.54
34	890	11.3	$11.59	1,555	19.7	$76.64	2,338	29.6	$153.28
35	967	12.2	$13.77	1,668	21.1	$78.14	2,473	31.3	$151.99
36	1,047	13.3	$15.64	1,779	22.5	$78.75	2,603	32.9	$149.80
37	1,129	14.3	$17.22	1,886	23.9	$78.59	2,729	34.5	$146.86
38	1,213	15.4	$18.52	1,991	25.2	$77.77	2,851	36.1	$143.29
39	1,306	16.5	$20.06	2,092	26.5	$76.38	2,970	37.6	$139.21
40	1,387	17.6	$20.31	2,191	27.7	$74.50	3,084	39.0	$134.69
41	1,465	18.5	$20.13	2,286	28.9	$72.21	3,195	40.4	$129.84
42	1,542	19.5	$19.59	2,379	30.1	$69.58	3,302	41.8	$124.72
43	1,617	20.5	$18.73	2,469	31.2	$66.67	3,405	43.1	$119.39
44	1,690	21.4	$17.60	2,555	32.3	$63.53	3,506	44.4	$113.92

Exhibit 7
Aspen Results by Year and Site Index

Age	Site Index 60			Site Index 70			Site Index 80		
	Yield Ft^3	Yield Cds	LEV	Yield Ft^3	Yield Cds	LEV	Yield Ft^3	Yield Cds	LEV
45	1,760	22.3	$16.23	2,639	33.4	$60.21	3,602	45.6	$108.35
46	1,829	23.1	$14.67	2,721	34.4	$56.74	3,696	46.8	$102.73
47	1,895	24.0	$12.95	2,799	35.4	$53.17	3,786	47.9	$97.08
48	1,959	24.8	$11.09	2,875	36.4	$49.53	3,874	49.0	$91.44
49	2,022	25.6	$9.13	2,949	37.3	$45.84	3,959	50.1	$85.84
50	2,082	26.4	$7.08	3,020	38.2	$42.13	4,040	51.1	$80.30
51	2,141	27.1	$4.97	3,088	39.1	$38.42	4,119	52.1	$74.83
52	2,197	27.8	$2.82	3,155	39.9	$34.73	4,196	53.1	$69.45
53	2,252	28.5	$0.63	3,219	40.7	$31.07	4,270	54.1	$64.18
54	2,305	29.2	($1.57)	3,280	41.5	$27.45	4,342	55.0	$59.03
55	2,357	29.8	($3.77)	3,340	42.3	$23.89	4,411	55.8	$54.00
56	2,406	30.5	($5.97)	3,398	43.0	$20.39	4,478	56.7	$49.10
57	2,454	31.1	($8.15)	3,454	43.7	$16.97	4,543	57.5	$44.33
58	2,500	31.6	($10.31)	3,508	44.4	$13.62	4,606	58.3	$39.70
59	2,545	32.2	($12.44)	3,560	45.1	$10.36	4,667	59.1	$35.21
60	2,588	32.8	($14.53)	3,610	45.7	$7.18	4,725	59.8	$30.87

Exhibit 8

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Exhibit 8

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