STEIGERWALDT
Your confidence lands here.

FORESTLAND MGMT | INVESTMENT & ANALYSIS | APPRAISAL | RIGHT-OF-WAY | ENVIRONMENTAL

Study Extension: Northern Hardwood Single-Tree Selection Order of Removal Procedures – Future Stand Development and Economic Consequences

(SLS 6522)

Prepared for:
Great Lakes Timber Professionals Association

Wisconsin County Forests Association

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

Effective Date:
August 24, 2020

Wisconsin Forest Practices Study – Northern Hardwood Study Extension
Factors Influencing Wisconsin's Forest-Based Manufacturing Competitiveness

Summary of Facts and Conclusions	
Project	Study Extension: Northern Hardwood Single-Tree Selection Order of Removal Procedures – Future Stand Development and Economic Consequences
Prepared for	Great Lakes Timber Professionals Association Wisconsin County Forests Association
Client	Great Lakes Timber Professionals P.O. Box 1278 Rhinelander, WI 54501
Submitted by	Steigerwaldt Land Services, Inc. 856 North Fourth Street Tomahawk, Wisconsin 54487 T: (715) 453-3274 F: (715) 453-8325
Effective Date	August 24, 2020
Project Objectives	We investigated future forest stand conditions as modeled in the 2016 study, investigating the order of removal procedures on state, county, and private forestlands enrolled in the Wisconsin tax law programs. The existing stand conditions and alternative marking scenarios are modeled forward using Forest Vegetation Simulator (FVS) to evaluate the economic consequences of the order of removal (OOR) guidelines.
Results	The projected harvests modeled using the alternative harvest approaches produced greater total present value of harvest revenue in all ownerships for Scenario 1, while Scenario 2 was higher on state and private lands when compared to Scenario 0 (the projected existing stand condition sampled in 2015). The residual forest stumpage value in 2075 averaged 2 percent higher in Scenario 1 and 3 percent lower in Scenario 2 when compared to Scenario 0. The residual forest structure of the scenarios differ more over time, resulting in a final forest condition in 2075 where Scenario 1 and 2 carry ±30 to 56 percent more sawtimber on private and county forest than that of Scenario 0. The residual forest on state lands are ±4 to 13 percent lower for Scenario 1 and 2, respectively.

Results Continued	These results are not intended to compare future outcomes between the ownerships evaluated in this study, or to suggest that one type of forest management is superior to other treatments or systems. In addition, the initial conditions derived from the inventory plots may not be indicative of the average forest conditions on these ownerships.
Conclusions	Harvest volumes of both poletimber and sawtimber varied across the model period. However, harvest value was found to generally increase with time. While the alternative harvest scenarios focused on removing larger trees, the model suggests that the approach can be sustained over time without compromising future harvest opportunities. The study suggests that alternative harvest approaches that focus on tree quality and economics with less focus on stand structure can produce long-term sustainable forest conditions that do not jeopardize forest harvest potential.

Contents

6. Exhibits

1. Project Overview

1.1 Investigators

The project team includes forestry and analysis staff at Steigerwaldt Land Services, Inc. (Steigerwaldt). The primary investigator for the project is Forrest M. Gibeault. Contact information for the investigators is below.

Primary Investigator: **Forrest M. Gibeault, MF, ACF**
Analysis and Technology Solutions 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

Contributors: **Martha J. Sebald**
Forest Analyst
Steigerwaldt Land Services, Inc.
856 N. 4th Street
Tomahawk, Wisconsin 54487
T: 715-453-3274
C: 612-437-2372
Email: martha.sebald@steigerwaldt.com

Richard W. Congdon
Assistant Analyst/Real Estate Specialist
Steigerwaldt Land Services, Inc.
856 N. 4th Street
Tomahawk, Wisconsin 54487
T: 715-453-3274
C: 715-966-0347
Email: richard.congdon@steigerwaldt.com

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.

This project is an extension of the single-tree selection OOR approach in northern hardwood forests, investigating the future stand conditions and economic outcomes of model scenarios developed in the original report.

1.3 Analysis Subject Areas – Objectives and Outcomes

The original analysis investigated two northern hardwood-related studies and red pine economics. The previous study evaluated impacts 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. This study will expand upon the following portion of the 2016 study:

1. *Single-Tree Selection Order-of-Removal (OOR) Approach in Northern Hardwood Forests*
   a. *OOR comparative analysis on state, county, and private forestlands enrolled in tax incentive programs*

1.3.1 Previous Study Summary - Northern Hardwood Order of Removal Analysis

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 a sample of stands marked for harvest under the OOR guidelines on state, county, and private forestlands enrolled in tax incentive programs.

At the time of the 2016 study, the marking guidelines outlined in the WDNR Silvicultural and Forest Aesthetics Handbook (SFAH, HB2431.5) were at the center of much discussion and debate. 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 was 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.

1.3.2 Study Extension – Stand Modeling and Economic Evaluation

This extension to the previous northern hardwood study investigated future stand conditions of the model scenarios and replicated the existing treatment conditions using an individual tree growth model. The objective is to evaluate future stand conditions and economic performance of multiple single-tree selection harvest treatments over time. Modeling was dynamic and includes assumptions for tree regeneration and region settings within the FVS, an open source tree modeling tool developed by the U.S. Forest Service.

2. 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 Literature Review

The basis of the initial study was to compare marking guideline outcomes on lands required to explicitly follow 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 challenging 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). Recent efforts to evaluate northern hardwood silviculture in the Lakes States is underway in the northern portion of Michigan. This research effort looked to leverage partnerships and included larger corporate forest landowners, along with public forest agencies, that is looking at resource wide threats. This research is, "using an operationally relevant silvicultural systems project across Michigan to help identify successful alternations to current management practices" (Walters, M.B, 2020). Efforts such as this are key to advancing northern hardwood silviculture in the face of many challenges facing foresters today.

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 become 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 sites, such as unintentionally focusing on tree removal of smaller stems. 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.

2.2 Study Components and Background

This effort utilized the 2016 study that included sample data from an area 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 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. WCFA members have a comparable multiple use management policy, with a focus on 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 methods of the 2016 study can be referenced in that report. However, specifics of the Order of Removal Analysis are important as background and context of this study. This section summarizes the methods of the previous study relevant to the baseline data used in this study.

2.2.1 Previous Study: 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 overseen by WDNR silvicultural principles. As outlined earlier in this section, forestlands designated within timber production units on state and county forests, as well as private lands enrolled in the MFL program, generally 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.

2.2.2 Site Selection Process

Stands on state, county, and private MFL lands were sampled and analyzed. 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.

Private MFL
The private MFL ownership was broken up into two distinct groups. For the purpose of the study, 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. The study included 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.

2.2.3 Data Collection

The extended study utilized the northern hardwood data from the 2015 selected timber sales on state, county, and private MFL forestlands. The 2015 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 that included a $1/5^{th}$ acre sawtimber only plot, a nested $1/10^{th}$ acre all-merchantable timber plot, and nested $1/100^{th}$ 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. Data from both inventory datasets were utilized in this study.

All merchantable tree data was recorded in the $1/10^{th}$ acre plot, while only trees 11.6 inches DBH and larger were recorded in the $1/5^{th}$ acre plot. Refer to state, county, and private MFL fieldwork scope for more details (Exhibit 1).

2.3 Forest Plot Data Processing

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.

2.4 Alternative Harvest Modeling

2.4.1 Alternative Marketing Scenarios

This study used data from nine 1-acre plots (three plots per landowner class: county, private, and state) captured in 2015 as the baseline data, using the alternative harvest model previously developed. Using the 1-acre plots provides a total sample size of 1,752 trees (trees 5 inches and larger), which provided a robust sample for the comparative modeling.

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 $ft.^2$ per acre
- Scenario 2: Maximum tree size =19 inches DBH. Residual BA of 82 $ft.^2$. per acre

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 growing stock (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.

Details on sensitivity testing and final scenario testing is summarized in the original report.

2.5 Future Stand Modeling

Future stand conditions were modeled forward to project future stand conditions and test the viability of the alternative harvest scenarios developed in the 2016 study. This research effort evaluated the following scenarios:

- Scenario 0 (Existing Marking Scenario, or base case) – Existing marking condition modeled forward using FVS single-tree selection harvest treatment, following the Q-factor method
- Scenario 1 – applied Scenario 1 alternative tree selection model for harvests and FVS between treatments
- Scenario 2 – applied Scenario 2 alternative tree selection model for harvests and FVS between treatments

The merchantable trees dataset (trees 5 inches and larger) originates from the 1-acre plots while the trees less than 5 inches are estimated using the variable radius plot data.

Tree seedlings were not sampled in the 2015 study (trees less than 1-inch – regeneration). Tree regeneration following harvest treatments were estimated from research. Seedling density of hard maple was found to dominate the understory of northern hardwood forests following single-tree selection treatments, comprising about 82 percent of the understory (Knapp, Webster, Kern, 2009). These stocking levels are very close to that observed within the 1- to 4-inch diameter classes within the study BAF plots.

FVS regeneration requires custom settings in many cases. Considering challenges throughout the Lake States with northern hardwood regeneration due to deer herbivory, gap success, and invasive competition, among other constraints, we chose to control how FVS established regeneration following silvicultural treatments. We chose intentional natural "planting" keywords in FVS to trigger tree regeneration using assumptions derived from northern hardwood research (Knapp, Webster, Kern, 2009) coupled with dominant tree stocking from the plot data. Exhibit 2 provides additional detail on the stand projection methods and FVS regeneration settings.

For the Existing Marking Scenario, or Scenario 0, tree growth and harvest prescriptions are completed in FVS. Following the initial cut in 2015, the residual tree list was grown in FVS through 2075. There were three cuts performed in 2035, 2055, and 2075. Seedling regeneration was introduced five years following harvests in 2020, 2040, and 2060. Five years after regeneration seedlings were introduced, the model included adjusted mortality settings in FVS to introduce 99 percent mortality for white ash and 65 percent for sugar maple, which was focused in the 1 to 4-inch diameter classes. Mortality was added to the model in 2025, 2045, and 2065.

For Scenarios 1 and 2, growth was performed in FVS, and cutting was performed in the Alternative Harvest Model. Trees from the original tree list were grown forward with the same regeneration and mortality settings used in Scenario 0. In addition to trees from the original tree list, as trees grew into the 5-inch diameter class and larger, they were included in the Alternative Harvest Model to apply cut and leave statuses to each tree record. When trees were designated a cut or leave status, the cut trees were removed from the next tree list to perform another 20-year growth simulation in FVS. Trees were then grown for another period with the same regeneration and mortality settings. Cuttings happened again in 2055 and 2075, with the final growth between 2055 and 2075. Lists of residual trees and harvested trees were created for years 2015, 2035, 2055, and 2075.

2.6 Economic Analysis

We compared pre- and post-harvest timber value for the existing and alternative harvest scenarios from the beginning of the project and for each of the three projected harvests (35, 55, and 75). Timber value was set using the winning bid and contracted product rates by species and product through 2020, with future pricing projected forward at an annual rate of 0.5 percent. Bid results were averaged from the following counties: Forest, Iron, Langlade, Lincoln, Marathon, Oneida, Price, Sawyer, Taylor, and Vilas. Boltwood and veneer volumes used the poletimber and sawtimber rates, respectively.

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).

The present value (PV) of all modeled harvests, beginning with the 2015 existing marking, was calculated and compared. PV calculations report findings in 2015 dollars, using a discount rate of 7 percent. Stumpage values are projected forward beginning in 2020, using the average stumpage (weight average of winning bids) from the fall of 2019 and spring of 2020, at a rate of 0.5 percent.

3. Results

The initial 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. The 2015 initial state and modeled alternative scenarios are considered the starting point of this study.

3.1 Review of Previous Results and Modeling Starting Point

Stand maps for the initial data set, including plot locations, are provided in Exhibit 3 for all state and county stands. Private forest information is kept confidential.

This section of the report summarizes the initial analysis and the starting point of the model period (2015), which is defined as 2015 through 2075.

3.1.1 Alternative Harvest Settings and Initial Analysis

We compared the existing marking for plots in the OOR analysis to alternative scenarios using the nine 1-acre plots.

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

- 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 is 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.

Table 1 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, and 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 1 – OOR Analysis: Alternative Selection Indices' Percent of Basal Area Harvested

Percent BA Removal by Index				
		Index 1	**Index 2**	**Index 3**
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

Alternative harvest results for the project starting point (2015) are summarized in Exhibit 4. These comparative products report cut and leave stocking by owner from the initial project (2015).

In 2015, harvest levels were greater in larger size classes (Figures 1 and 2). 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 1 and 2).

Figure 1 –2015 Model Output: Basal Area Comparison of Alternative Harvests by Ownership

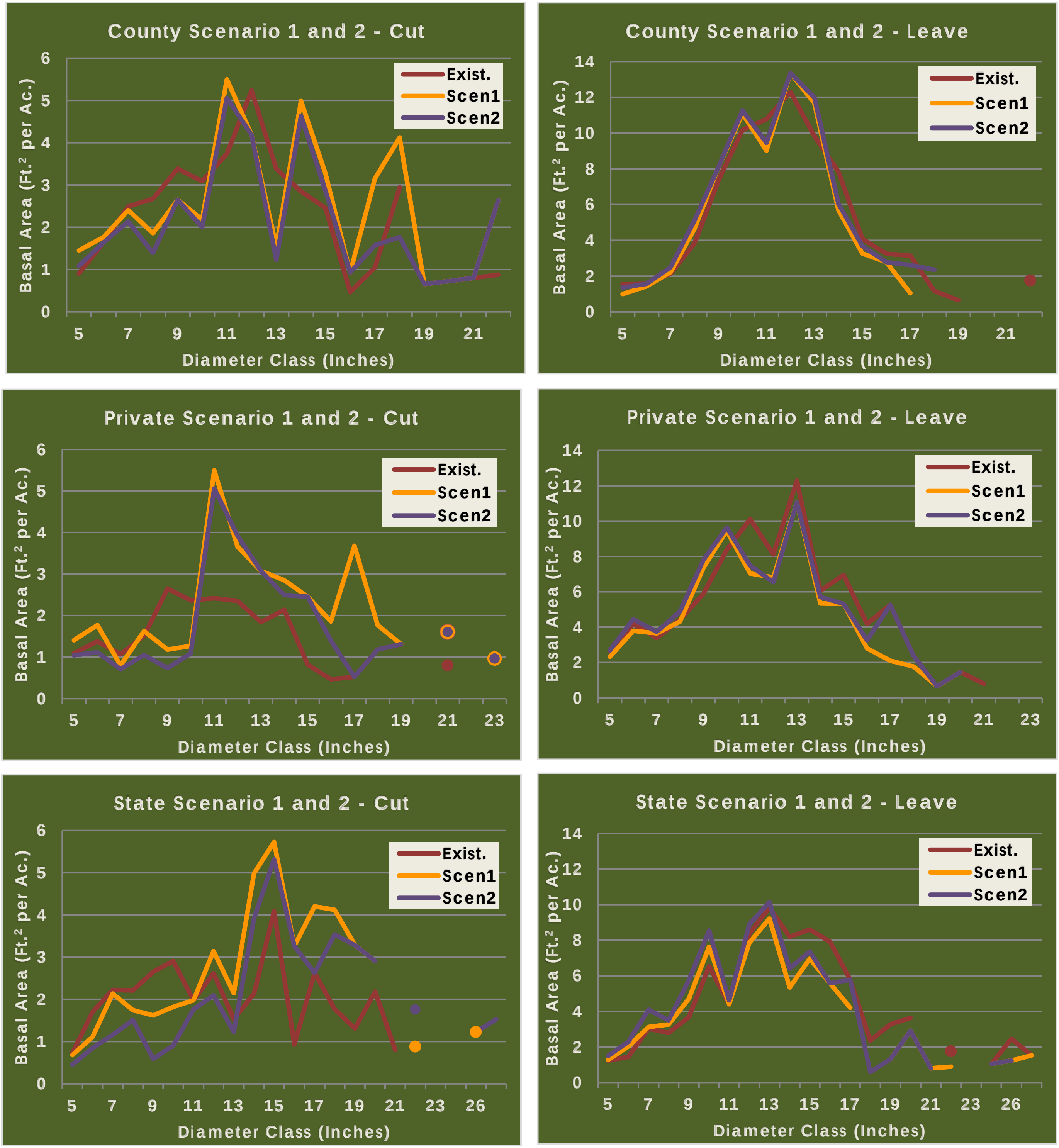


Figure 2 – 2015 Model Output: Trees per Acre Comparison of Alternative Selection by Ownership

3.1.2 Initial Analysis Economic Findings: 2015 Model Results

Tables 2, 3, and 4 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 2 – 2015 Model Output: 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 3 – 2015 Model Output: 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 4 – 2015 Model Output: 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	-

The RVG assumptions applied to hard maple trees are summarized in Table 5. The average RVG for hard maple sawtimber trees 11 inches and larger are depicted by harvest scenario and ownership in Table 6.

Table 5 –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	**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 6 –2015 Model Output: 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

The existing marking modestly improved RVG in 2015 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. 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 6).

3.2 Projected Model Results – 2035 through 2075

This section summarizes the extended study results, projecting the sample data using FVS and the alternative harvest model scenarios. The following approaches were used to project the stand conditions forward, grouped by owner.

- Scenario 0 (Existing Marking): The existing marking condition of each owner was projected forward using FVS growth projections and the single-tree section treatment options. Projected harvests in 2035, 2055, and 2075 relied on FVS to estimate tree removal, strictly following Q-factor removal, based on removal patterns of each owner.

- Scenarios 1 and 2: The post-harvest trees from the 2015 study were grown forward using FVS, but projected harvests were completed using the alternative model applied in the previous report. After each cut, the residual forest trees were input into FVS once again for growth project. This process, where tree data is moved in and out of FVS, was conducted for each harvest period (2035, 2055, and 2075).

The original marking observed in the inventory for each owner is considered Scenario 0 in this portion of the report.

3.2.1 Modeled Stand Conditions – 2035 through 2075

Diameter distributions of the cut and leave stocking by owner and harvest period are summarized in Exhibit 5. These products suggest that allowing various harvest prescriptions to occur over a 60-year growth period creates a range of outcomes.

Scenario 0, utilizing the actual leave trees on the inventory plots, was applied the FVS single-tree removal settings outlined in the methods previously in the report. The settings were based on the Q-factor conditions and residual stocking observed in the data. As a result, the future harvest was cut explicitly in FVS using those conditions. There are pros and cons to this approach, but in an effort to model similar marking conditions over time, it was determined to be the most appropriate method. Since, Scenario 0 would be directly compared to the Scenarios 1 and 2 modeled, it was decided to keep the harvest applications for each scenario for the entire model period.

Most of the modeled harvests in Scenario 0 occurred in trees 10-inches DBH and larger. The state forest consistently harvested more trees less than 10 inches, especially in 2035 and 2075. Each ownership had unique residual forest conditions in 2015 that were entered into FVS for future growth and harvest projects. The impacts of the Q-factor harvest prescriptions and FVS growth and yield are unique to the residual forest condition of each ownership (Exhibit 5).

The regeneration and ingrowth of trees in the 5-inch class is one area to closely watch. The model settings introduced seedling and sapling-sized trees in the FVS projections, resulting in significant ingrowth in the 2055 projection for Scenario 0. Ingrowth in Scenarios 1 and 2 generally lags until the 2075 model output in many cases (Exhibit 5).

The following figures display the cut and leave forest structure reported in basal area per acre. These figures allow for a more direct comparison of the FVS modeled harvests (Scenario 0) to the custom Scenario 1 and 2 alternative scenarios. Some areas of difference in Scenario 0 include a lack of harvest in diameter classes less than 10 inches in 2035 (Exhibit 5), increased harvest in smaller sawtimber-size classes (11 to 15 inches), fewer large diameter trees harvested, and no harvest above the 20-inch class until 2035 (Figures 3, 4, and 5).

In the county forest, the Scenario 1 and 2 alternative harvests removed larger diameter trees and left greater stocking in the 9- to 10-inch classes and the small sawtimber class, especially early in the model period. Notably, more trees were removed in Scenarios 1 and 2 in the sawtimber size classes (11 inches and greater), including the larger sawtimber size classes (16 inches and greater). In 2075, the Scenario 0 harvest produced more sawtimber removal than any other time during model period, and actually harvested trees greater than 21 inches in size classes not cut in either Scenario 1 or 2. The residual stand conditions for the county forest in 2075 differed among the tree projections. Scenarios 1 and 2 left significantly more stocking in trees 15 to 20 inches, while Scenario 0 had greater stocking in the 10- to 14-inch and 21-inch and greater diameter classes. Scenario 2 had the greatest stocking in trees less than 9 inches (Figures, 3, 4, and 5).

Harvest projections in the state forest were most similar across the scenarios when compared to the other owners. Harvest ratios in 2035 were comparable across the scenarios. Notably, more stocking was removed in Scenarios 1 and 2 for the 2055 and 2075 periods. Residual stocking was projected quite close to the model settings in Scenarios 1 and 2 at 75 and 80 square feet per acre, respectively. This compares to residual stocking on state forest ranging from 86 in 2015 to 90.8 square feet per acre in 2075. Residual stocking in 2017 remains similar across the scenarios, except Scenario 1, which has less stocking in trees 19 inches and smaller and generally more stocking in trees 23 inches and larger (Figures 3, 4, and 5).

Private forest harvests for Scenario 0 removed more trees in the center of the distribution (13 to 16 inches) and less stocking below 10 inches in 2035. As the model period progressed, Scenario 0 cut more trees in the larger diameter classes (greater than 21 inches). Residual forest conditions in state forest showed many similarities across the scenarios, but generally found Scenarios 1 and 2 to carry more trees in the 15- to 20-inch classes. By 2075, Scenario 0 the residual stand conditions include more trees in the 10- to 16-inch classes and reported trees out to the 29-inch class. At the end of the period, Scenarios 1 and 2 did carry more larger sawtimber trees in the residual forest, but may result in some understocked conditions in the small sawtimber diameter classes (11- to 15-inch classes) (Figures 3, 4, and 5).

Figure 3 – 2035 Modeled Harvests: Basal Area Comparison by Scenario and Owner

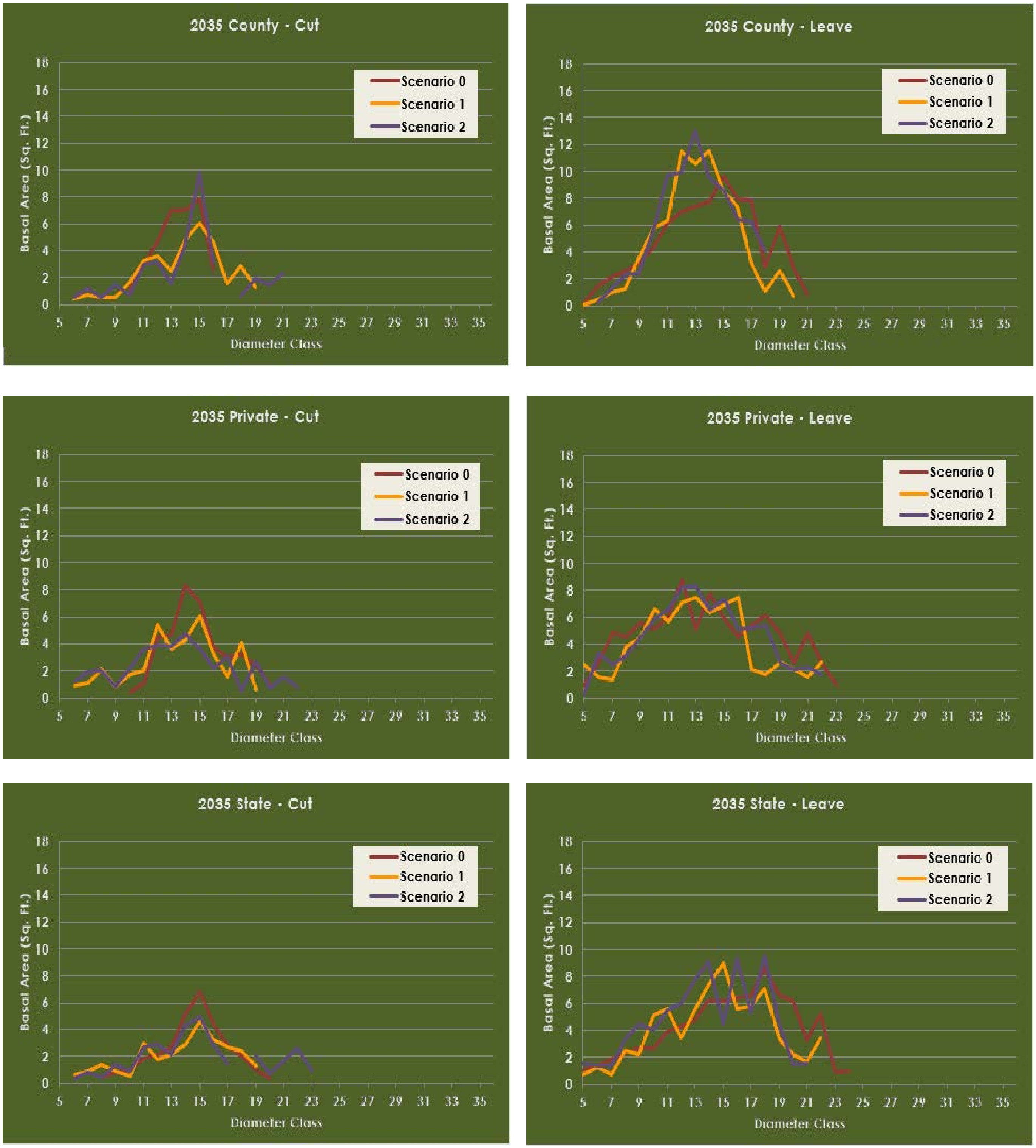


Figure 4 – 2055 Modeled Harvests: Basal Area Comparison by Scenario and Owner

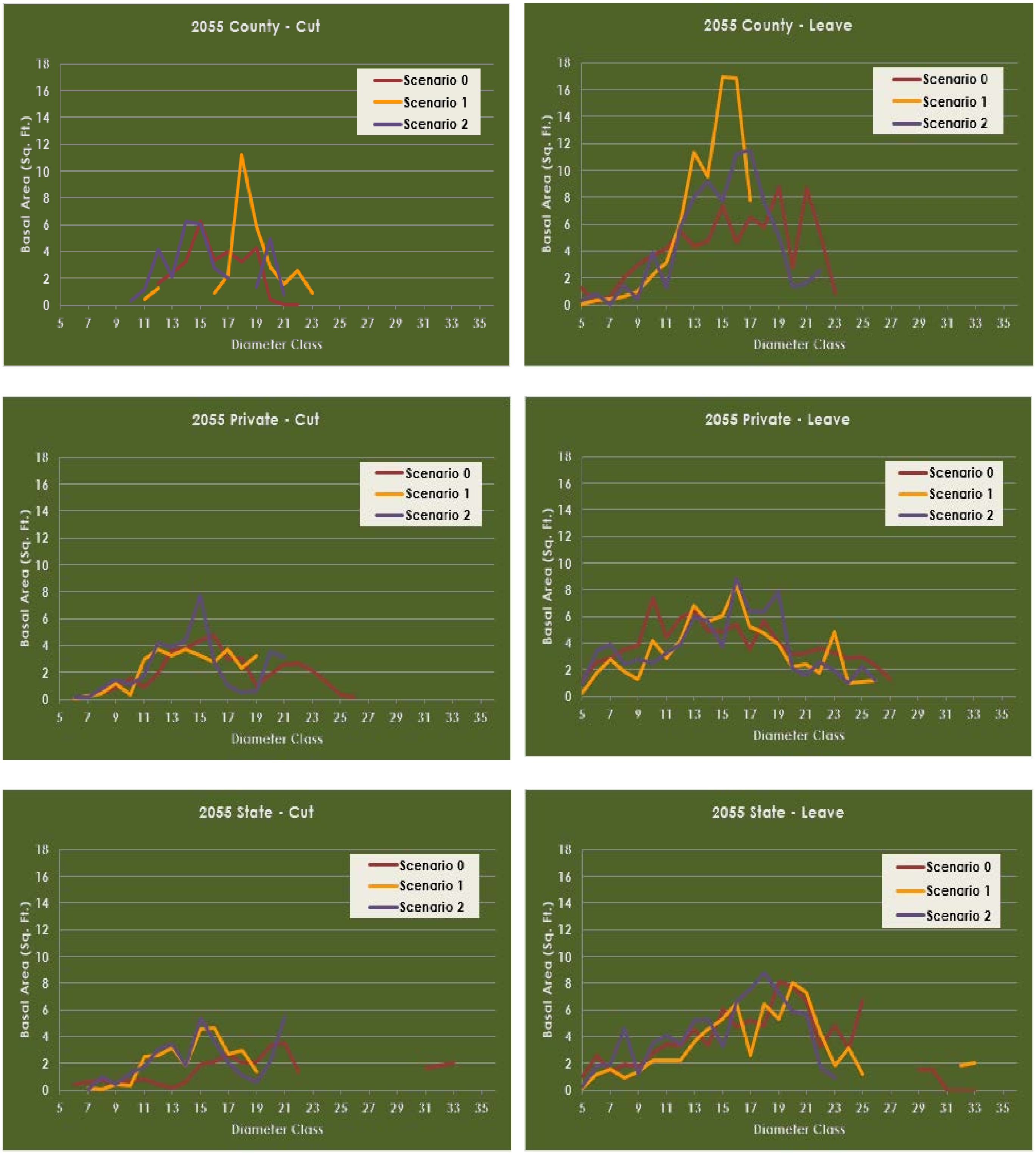
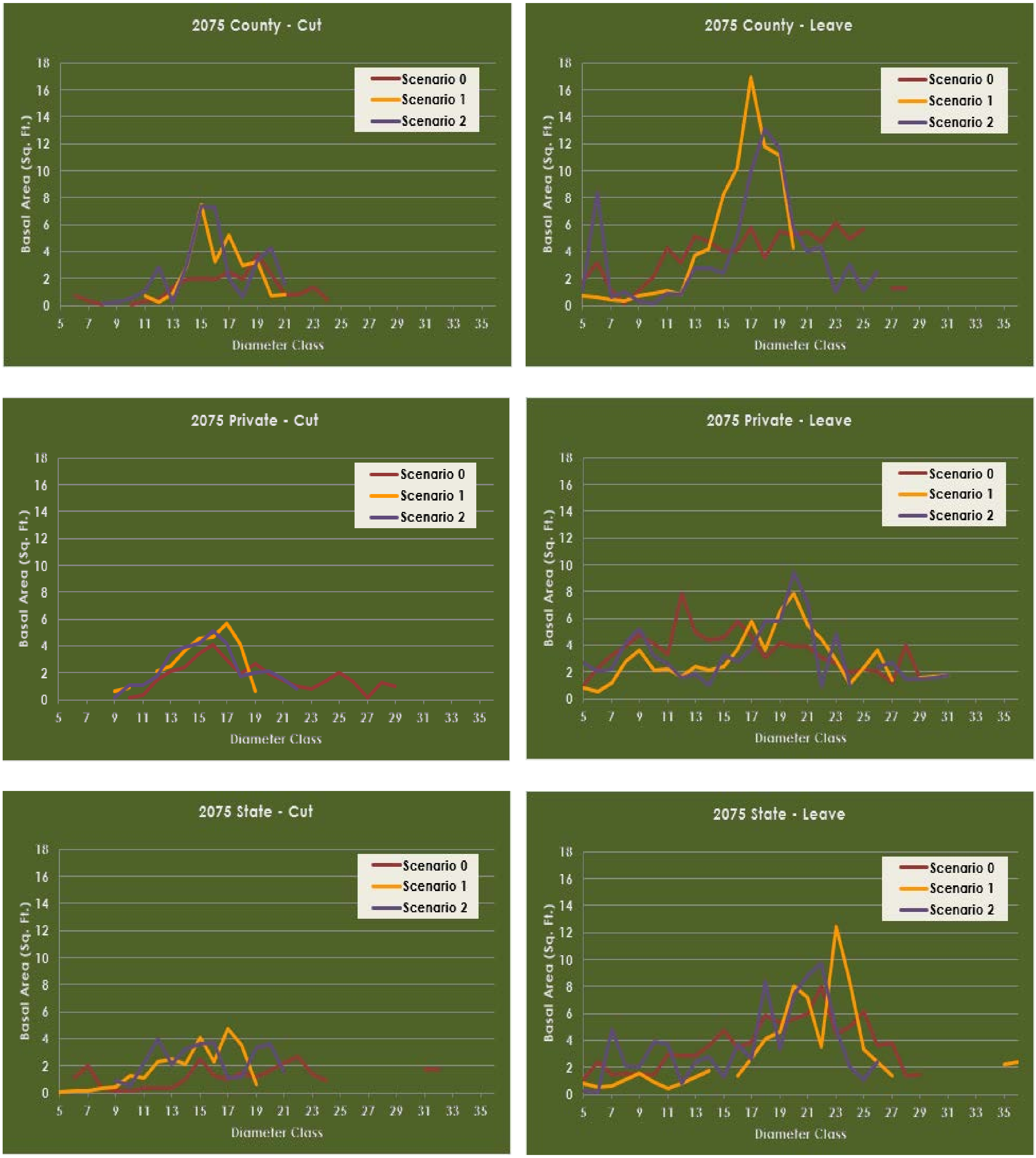


Figure 5 – 2075 Modeled Harvests: Basal Area Comparison by Scenario and Owner



The following figures display cut and leave basal area stocking by growing stock classification and owner for the last period of the model, 2075. These results are only available for Scenarios 1 and 2 as individual trees were not tracked throughout the period for Scenario 0. As found in the initial model period in 2015, the focus on lower quality growing stock occurred through the end of the model in year 2075.

For all owners, the harvest in 2075 focused on removing the lower potential trees, with all harvest occurring in acceptable and lower-classed trees. Harvest, as a ratio of total stocking in each class, was highest in the unacceptable and undesirable classes (Figures, 6, 7, and 8).

Figure 6 – Cut and Leave by Growing Stock Classification for Scenarios 1 and 2 – 2075 Projected Harvest: Private

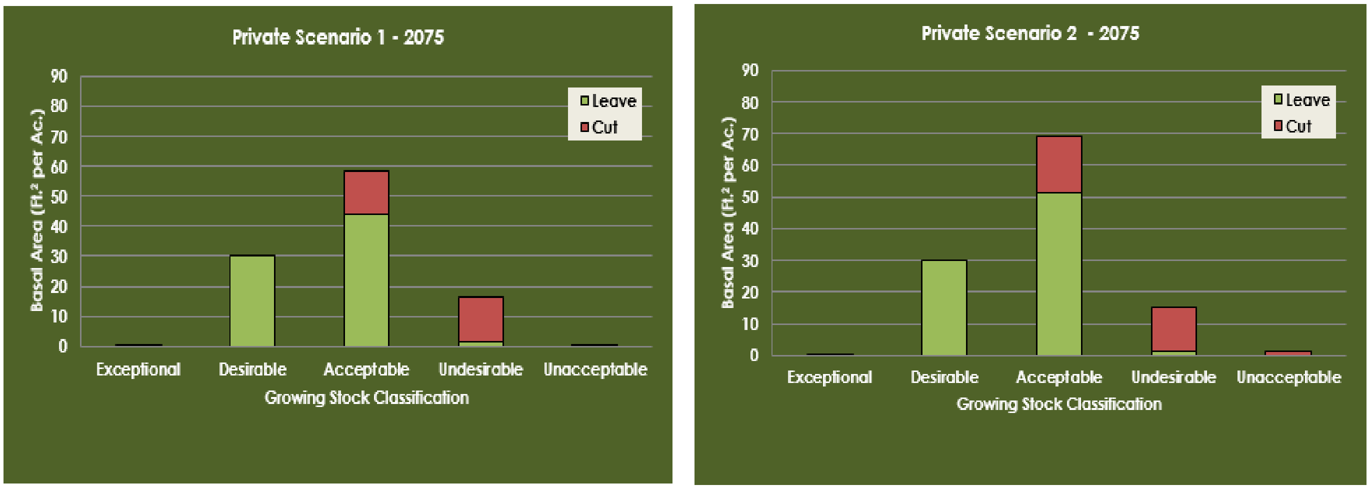


Figure 7 – Cut and Leave by Growing Stock Classification for Scenarios 1 and 2 – 2075 Projected Harvest: State

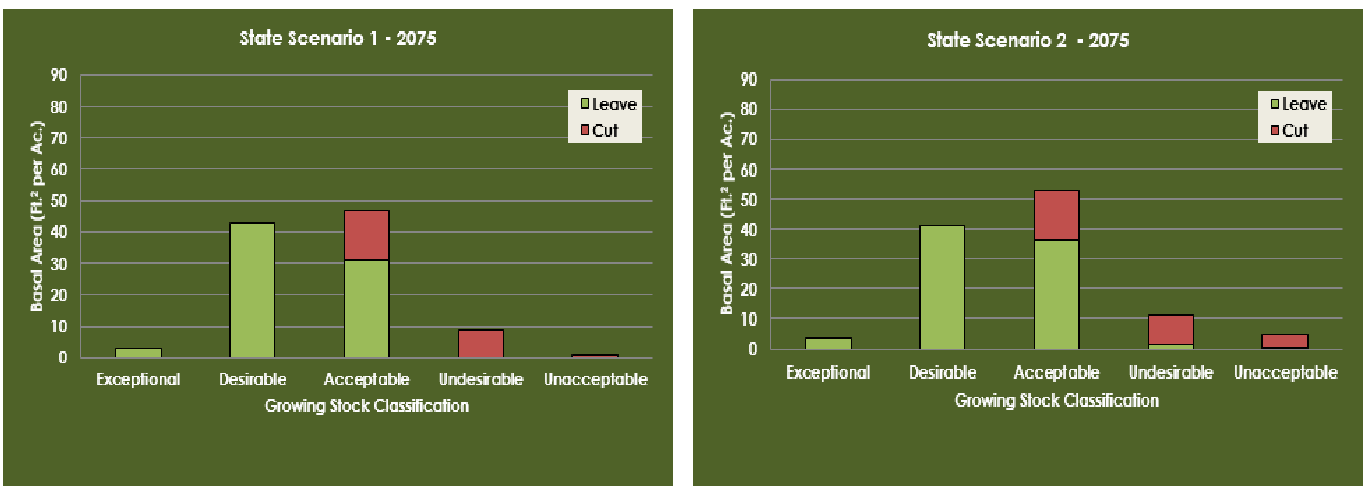
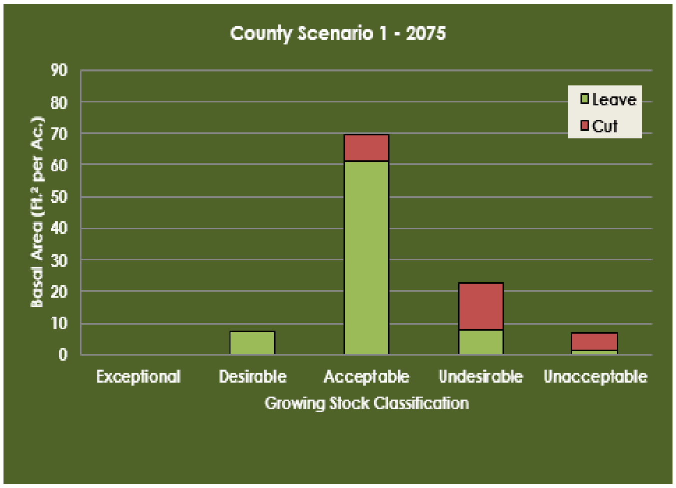
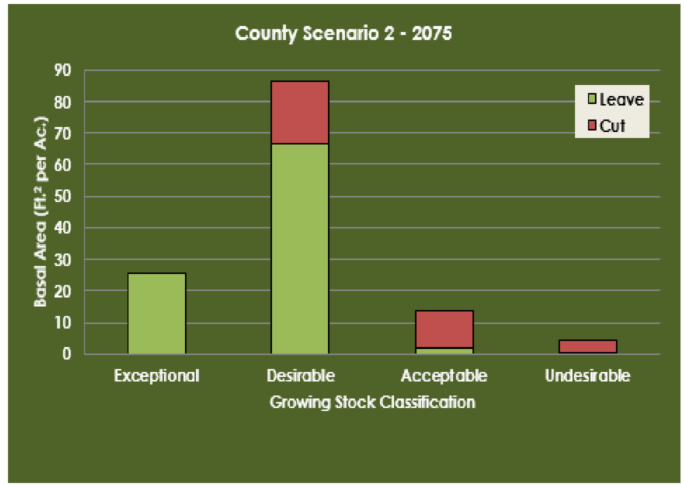


Figure 8 – Cut and Leave by Growing Stock Classification for Scenarios 1 and 2 – 2075 Projected Harvest: County





3.2.2 Economic Findings – 2035 through 2075

Timber volume and value of the harvest approaches are compared in the following tables. The comparisons are summarized by ownership and report the percent difference from Scenario 0.

County forest statistics report that Scenarios 1 and 2 harvests result in more harvest (cut) and residual (leave) stand value per acre in 2075 when compared to Scenario 0. In 2075, Scenario 0 results in a forest with more total stocking than Scenario 1, but has less sawtimber stocking (both cut and leave) when compared to both Scenarios 1 and 2. Harvest value is highest in Scenario 2, and is 44.4 percent higher than Scenario 0 (Table 7).

Table 7 – County Forest Timber Value Analysis: 2075 Harvest

2075 County Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$614.90	$839.02	36.4%	$887.75	44.4%
Leave	$1,736.16	$2,112.48	21.7%	$1,873.40	7.9%
Total	$2,351.06	$2,951.50	-	$2,761.15	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	10.3	9.9	-4.1%	13.4	29.7%
Leave	39.8	26.3	-33.8%	31.9	-19.7%
Total	50.1	36.2	-	45.3	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	1,288.6	1,914.3	48.6%	1,806.1	40.2%
Leave	3,223.4	5,047.6	56.6%	4,550.5	41.2%
Total	4,512.0	6,961.9	-	6,356.7	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Ft.^{2})	% Dif.
Cut	25.3	28.6	12.8%	34.7	37.1%
Leave	84.7	76.0	-10.2%	83.1	-1.9%
Total	110.1	104.6	-	117.8	-

Total value of the harvest in Scenarios 0 and 1 are less than 1 percent different for the state analysis. Total residual forest value of Scenario 0 is higher than both alternative harvest scenarios in 2075. Total state forest residual basal area stocking is ±17 and ±9 square feet higher in Scenario 0 when compared to Scenarios 1 and 2, respectively. Harvest value is highest in Scenario 2, followed by Scenario 1 and 0 (Table 8).

Table 8 – State Forest Timber Value Analysis: 2075 Harvest

2075 State Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$703.67	$708.50	0.7%	$905.83	28.7%
Leave	$2,355.38	$2,086.59	-11.4%	$2,007.27	-14.8%
Total	$3,059.05	$2,795.09	-	$2,913.10	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	12.7	13.0	2.8%	14.9	17.2%
Leave	48.1	38.6	-19.8%	43.8	-8.9%
Total	60.8	51.6	-	58.7	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	1,340.9	1,331.8	-0.7%	1,785.2	33.1%
Leave	4,305.4	4,121.0	-4.3%	3,740.4	-13.1%
Total	5,646.2	5,452.7	-	5,525.6	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area ($Ft.^2$)	% Dif.
Cut	25.4	25.9	2.2%	31.1	22.5%
Leave	90.8	75.3	-17.0%	82.5	-9.2%
Total	116.2	101.3	-	113.6	-

The value of the 2075 harvest on private forest is ±17 and ±4 percent less in Scenarios 1 and 2 when compared to Scenario 0 for private lands. Additionally, the residual forest value is higher in Scenario 0 following the 2075 harvest at the end of the model. Sawtimber harvest is also lower in Scenarios 1 and 2, but residual sawtimber volume is higher when compared to Scenario 0 (Table 9).

Table 9 – Private Forest Timber Value Analysis: 2075 Harvest

2075 Private Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$1,089.85	$910.05	-16.5%	$1,051.07	-3.6%
Leave	$2,217.11	$2,096.80	-5.4%	$2,161.00	-2.5%
Total	$3,306.96	$3,006.85	-	$3,212.07	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	17.6	14.2	-19.4%	15.6	-11.1%
Leave	49.9	32.3	-35.3%	38.9	-22.1%
Total	67.5	46.4	-	54.5	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	2,467.6	1,900.3	-23.0%	2,306.9	-6.5%
Leave	4,435.2	5,819.3	31.2%	5,749.4	29.6%
Total	6,902.8	7,719.6	-	8,056.3	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Ft.^{2})	% Dif.
Cut	35.9	29.5	-17.7%	33.3	-7.3%
Leave	88.8	75.4	-15.1%	82.8	-6.7%
Total	124.6	104.9	-	116.1	-

The residual forest conditions created in 2015 in Scenario 0 resulted in forest conditions that grew more pulpwood than sawtimber when compared to the alternative scenarios (Scenarios 1 and 2). The selection of different combinations of trees, coupled with modeling constraints, show that a range of forest stand conditions are likely to occur over time. Residual stocking in 2075 was higher in Scenario 0 in all cases except the county forest. As expected, Scenario 1 had the lowest final residual forest stocking since the model was set to a residual forest condition of no less than 75 square feet of basal area (Tables 7, 8, and 9).

Economic summaries comparing the cut and leave conditions for the 2035 and 2055 harvests are summarized in Exhibit 6. The county forest was found to have the greatest harvest value in 2075 for Scenarios 1 and 2 when compared to Scenario 0, which peaked in 2055. State results found the greatest harvest value to occur in 2055 for Scenarios 2 and 0, while Scenario 1 peaked in 2035. All scenarios had the highest harvest value occurring in 2075 for private (Exhibit 6).

The following table displays the original RVG from 2015 (also shown in Table 6), along with the residual forest conditions following future harvests in Scenarios 1 and 2. The future tree conditions in Scenario 0 could not be tracked over time since FVS was allowed to move the trees unconstrained in a way that did not allow for individual tree tracking. For comparative purposes, we have included the original RVG to show how future harvests impact forest conditions. As suggested earlier in the report, the potential value growth of a stand may not increase continually over time. One of the main constraints of a tree's potential to increase value over time is tree size. As a tree increases in size, growth rates decrease, and the opportunity for product jumps declines. As trees increase in size, the RVG of a stand can decrease, even if high quality trees are retained during harvest treatments. The modeled alternative harvest scenarios resulted in an RVG decrease in Scenario 1 of 42 percent for county, 46 percent for private, and 61 percent for state. This compares to Scenario 2 where county, private, and state decreased by 41, 44, and 50 percent, respectively (Table 10).

Table 10 – Average Hard Maple Rate of Value Growth Comparison – All Harvest Periods

County RVG of Residual Trees				
	2015	2035	2055	2075
Before Harvest	0.022	-	-	-
Scenario 0	0.028	-	-	-
Scenario 1	0.033	0.030	0.024	0.019
Scenario 2	0.032	0.026	0.028	0.019
Private RVG of Residual Trees				
	2015	2035	2055	2075
Before Harvest	0.013	-	-	-
Scenario 0	0.018	-	-	-
Scenario 1	0.028	0.024	0.023	0.015
Scenario 2	0.027	0.025	0.022	0.015
State RVG of Residual Trees				
	2015	2035	2055	2075
Before Harvest	0.020	-	-	-
Scenario 0	0.024	-	-	-
Scenario 1	0.031	0.026	0.019	0.012
Scenario 2	0.030	0.025	0.023	0.015

Alternative harvest Scenarios 1 and 2 removed the lowest quality stems during harvest treatments, as evidenced in Figures 6, 7, and 8, suggesting that as stands age and trees increase in size, the average RVG potential may decrease for a period of time as younger trees or smaller cohorts are developing in the stand. Further, our model period extended 60 years into the future, allowing the dominant and codominant stems existing in 2015 to mature well beyond economic rotation age, and likely beyond biologic rotation in many cases (Table 10).

The present value, in 2015 dollars, of the four modeled harvests is show in Table 11 by ownership. Scenario 1 has the highest present value of the future harvests when compared to the other two scenarios. For the county forest, Scenario 0 exceeds the Scenario 2 present value by about 7 percent; however, Scenario 2 exceeds that of Scenario 0 on both private and state forest (Table 11).

Table 11 – Present Value for All Modeled Harvests

Present Value – 2015, 2035, 2055, and 2075 Cuts	
	All Cuts (2015 Dollars)
County	Value Per Acre
Scenario 0 - Cut	$ 988.89
Scenario 1 - Cut	$ 1,145.61
Scenario 2 - Cut	$ 919.25
Private	Value Per Acre
Scenario 0 - Cut	$ 780.52
Scenario 1 - Cut	$ 1,029.15
Scenario 2 - Cut	$ 797.26
State	Value Per Acre
Scenario 0 - Cut	$ 981.81
Scenario 1 - Cut	$ 1,340.87
Scenario 2 - Cut	$ 1,207.64

The economic value of the future forest condition is further examined by calculating the present value of the residual forest stumpage value in year 2075. In 2015 dollars, the present value of the forests in the final model period is highest in Scenario 1 for the county, but for both private and state forest, it is highest in Scenario 0. This coincides with the highest residual stocking in year 2075, where Scenario 0 had the highest residual stocking for private and state forest, but not county (Table 12).

Table 12 – Residual Forest Value and Present Value of 2075 Condition

Present Value - Residual in 2075		
	2015 Value	2075
County	Value Per Acre	Value Per Acre
Scenario 0	$ 29.96	$ 1,736.16
Scenario 1	$ 36.46	$ 2,112.48
Scenario 2	$ 32.33	$ 1,873.40
Private	Value Per Acre	Value Per Acre
Scenario 0	$ 38.26	$ 2,217.11
Scenario 1	$ 36.19	$ 2,096.80
Scenario 2	$ 37.29	$ 2,161.00
State	Value Per Acre	Value Per Acre
Scenario 0	$ 40.65	$ 2,355.38
Scenario 1	$ 36.01	$ 2,086.59
Scenario 2	$ 34.64	$ 2,007.27

4. Summary

4.1 Project Overview

This research expanded on the single-tree selection order of removal research completed in 2016 and evaluated the future forest conditions in a 60-year projection. The future stand condition and economic performance of multiple single-tree selection treatments were projected over time using FVS and our custom alternative harvest scenarios model. FVS settings were adjusted to provide reasonable tree regeneration response and utilized research to best estimate stand development under the all-aged system following multiple partial harvest entries.

These results are not intended to compare future outcomes between the ownerships evaluated in this study, or to suggest that one type of forest management is superior to other treatments or systems. In addition, the initial conditions derived from the inventory plots may not be indicative of the average forest conditions on these ownerships.

4.2 Conclusions

This study projected future harvest conditions using an individual tree model (FVS) and the custom alternative tree selection model developed in the original study. The developed scenarios estimated three different cutting prescriptions, outlined below:

- Scenario 0 – Existing marking condition modeled forward using FVS single-tree selection treatment. The residual stocking and Q-factor of the 2015 marketed harvest condition was modeled forward using a 20-year cutting cycle
- Scenario 1- Using Scenario 1 alternative tree selection model and FVS between treatments, individual tree data was moved in and out of the FVS for growth modeling
- Scenario 2 – Using Scenario 2 alternative tree selection model and FVS between treatments, individual tree data was moved in and out of the FVS for growth modeling

The initial forest conditions (2015) were found to support the following.

- Forest structure was quite variable in northern hardwood stands, as evidenced by the varying diameter distribution in the 2015 “leave” forest condition
- Of the existing marking, 63 to 77 percent were 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”
- 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 diameter distributions of the projected stands appear to have varied amongst the scenarios over time. The three harvest prescriptions removed different trees in each entry, so as the stands developed and responded to the harvests over the 60-year period, the resulting structures in 2075 tell different stories. The distributions for Scenarios 0, 1, and 2 for state produced the most similar structure in the 2075 leave condition. On private and county, Scenario 0 generally resulted in more stocking in the 10- to 14-inch size classes. Since Scenarios 1 and 2 removed larger trees in the 2015, 2035, and 2055 entries, the stands developed differently and typically left more small-sawtimber in each entry.

Modeled outcomes for Scenario 0 suggest.

- Total sawtimber harvest (volume per acre) for Scenario 0 peaked in 2055 for county and in 2035 for private and state

- Pulpwood harvest peaked in 2055 for state and private and in 2035 for county
- Stocking in the 5- to 9-inch classes are similar to that of Scenarios 1 and 2 in 2075, suggesting that the alternative scenarios likely produce similar stand conditions to that of current practices on the sampled lands into the future

Scenario 1 and 2 support of the following conclusions.

- Sawtimber harvest for Scenarios 1 and 2 commonly peaked in 2035 for private, state, and county, with the exception of Scenario 2 peaking in 2075 for private
- Similarly, pulpwood harvest for Scenarios 1 and 2 peaked in 2035 for all owners, except for Scenario 2, which peaked in 2055 for state
- The projected harvests focused tree removal on poor quality trees, focusing harvest on unacceptable, undesirable growing stock

Projected harvest economic outcomes report the following.

- Harvest value was highest in 2075 for private and county, while the state model projection found the harvest peak to occur in 2055 for Scenario 2 and 2035 for Scenario 1
- In 2075, harvest value was highest in Scenario 2 in all cases except private forest, where Scenario 0 was the highest
- Residual stand value was highest in Scenario 1 for county and Scenario 0 for state and private
- RVG decreased over time in the alternative scenarios as trees increased in size
- The present value of all modeled harvests is greatest for Scenario 1, followed by Scenario 2, except for on county, where Scenario 0 was higher than Scenario 2

The RVG generally decreased by 40 to 50 percent across the ownerships from 2015 to 2075. This compares to an increase in average stand diameter (in sugar maple 5 inches and greater) of 41 and 19 percent in Scenarios 1 and 2, respectively. The model period also saw an increase in the average size of sugar maple, which increased from ±10-inches in 2015 to ±12- to 14 inches in 2075. These results show that as tree size increases, the potential for product and grade jumps also decreases.

A key investigation area in this project was to test the viability of the alternative harvest scenarios over time. The residual stand value in 2075 was found to be higher in Scenarios 1 and 2 when compared to Scenario 0 for county, which reported an increase of 22 to 8 percent, respectively. Residual forest value was found to be higher in Scenario 0 for private and state, but by no more than 5 and 15 percent, respectively. No statistical tests were completed on the residual forest value in 2075, but the outcomes clearly show that the alternative harvest approaches do not result in a meaningful difference from that modeled in Scenario 0. Furthermore, Scenario 1 produced 15 to 36 percent more present value (2015 dollars) from the modeled harvests when compared to Scenario 0.

Harvest volumes of both poletimber and sawtimber varied across the model period. However, harvest value was found to generally increase with time (nominal values, using projected stumpage rates). While the alternative harvest scenarios focused on removing larger trees, the model suggests that the approach can be sustained over time without compromising future harvest opportunities.

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. Of course, these concepts work well in the vacuum of a model where regeneration and growth are modeled under FVS assumptions. Our regeneration and mortality settings were quite aggressive in an effort to constrain FVS from allowing unrealistic ingrowth over time (Exhibit 2). FVS can be quite sensitive to regeneration settings, and since there is little science to reference, is an area where future studies could improve upon individual tree modeling in this forest type.

It is extremely difficult to model all of the stand dynamics at play in the northern hardwood forests of Wisconsin, as our forests are faced with invasive species, deer herbivory, large scale species-level mortality (ash), and many other constraints. Our results, which utilize the widely-accepted growth equations of the FVS - Lake States Variant, suggest that sustainable marking approaches that focus on tree quality and economics, and less focus on stand structure, can produce long-term sustainable forest conditions that do not jeopardize future harvest potential.

Submitted by:

STEIGERWALDT LAND SERVICES, INC.

Forrest Gibeault, ACF
Analysis and Technology Solutions Director
Steigerwaldt Land Services, Inc.

Martha J. Sebald
Forest Analyst
Steigerwaldt Land Services, Inc.

Richard W. Congdon
Assistant Analyst/Real Estate Specialist
Steigerwaldt Land Services, Inc.

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

Richard W. Congdon
Assistant Analyst/Real Estate Specialist
Steigerwaldt Land Services, Inc.

Martha Sebald
Forest Analyst
Steigerwaldt Land Services, Inc.

Exhibit 1

Inventory Manuals

Exhibit 1
Inventory Manual

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.

Exhibit 1
Inventory Manual

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:
    A. Suppressed/Unacceptable Growing Stock - stock that are heavily browsed, multi-stemmed, in an area with poor availability of light and nutrients, or are not likely to respond to release.
    B. Acceptable Stock – stock that could respond to release, are not heavily browsed, and have good form
    C. Exceptional Stock – stock that are in an area of open canopy with availability to light and nutrients

Exhibit 1
Inventory Manual

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).

Exhibit 1
Inventory Manual

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.

Exhibit 1
Inventory Manual

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 Sivicultural 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, and 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.**

Exhibit 1
Inventory Manual

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.
Hardwood 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.

Exhibit 1
Inventory Manual

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

Exhibit 1
Inventory Manual

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.

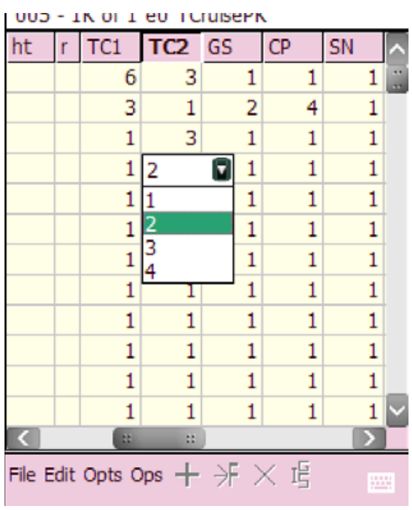
3. *Optional Step* - Folder: create a "tce document" folder on your SD Card (TCruise field will use the My Documents folder on the handhelds main memory as a default – create a new folder on your SD Card to redirect the file location).
4. Type: leave as (*.tce)
5. Location: SD Card
6. Select **Save**.

Exhibit 1
Inventory Manual

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

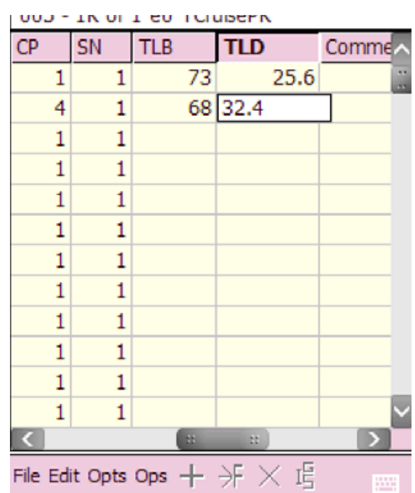


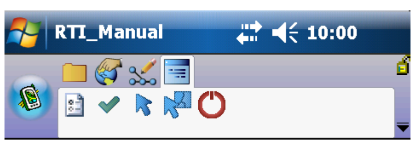
Exhibit 1
Inventory Manual

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

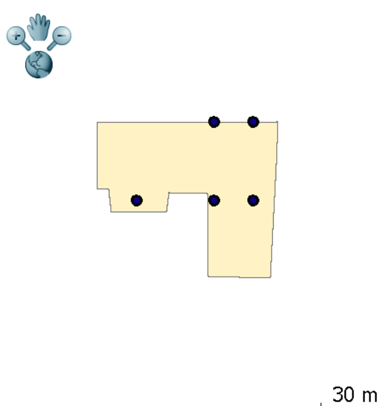
1. **Merchantable Trees** = trees 5 inches in diameter (DBH) and larger on a BAF plot
   a. Enter Species (SPP), (DBH), Product (Prod), and Number (N=) if applicable, in the tree data screen.
2. **Sub-Merchantable and Pre-Merchantable Trees** = established trees on a 1/100th acre plot that are 0 to 4.99 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 **<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

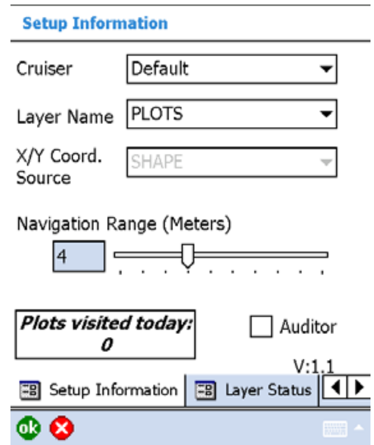
Navigate To Plot

Clear Navigation Target

Close and Save Map

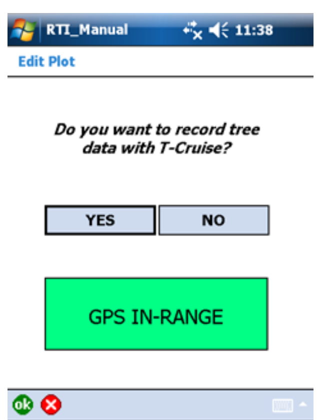
Exhibit 1
Inventory Manual

c. Before you begin to navigate to a point and begin cruising, you must first set the 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

Stand Projection Methods and FVS Settings

Exhibit 2 - Stand Projection Methods and FVS Settings Modeling Summary

Small trees and regeneration in each scenario were addressed similarly in FVS. In addition to the original tree list that included stems 5-inches and larger, we added small trees one to four-inches in diameter. Stocking of these trees was adopted from the studies BAF plots, where saplings were measured in 2015. Stocking by ownership and diameter class was added to the model dataset using the existing fixed plot species distributions.

Additionally, five years after each harvest treatment regeneration was introduced to the stands assuming 10,000 one-foot tall seedlings per acre, which again followed the observed species distributions from the fixed plot inventory. This total stocking figure was adopted from single-tree selection research, which suggested sugar maple seedling stocking from ±7,400 to ±15,300 stems per acre (stems less than or equate to 50 centimeters tall) (Knapp, Webster, Kern, 2009). We gave these seedlings a 20% survival rate. Five years after the regeneration was introduced, we modeled sugar maple and white ash mortality. Ninety-nine and sixty-five percent of the white ash and sugar maple seedlings between one and four inches in diameter, respectively, were killed. Throughout the growth simulation, natural regeneration was introduced in 2020, 2040, and 2060, and mortality was introduced in 2025, 2045, and 2065. Within the FVS settings, sprouting of cut trees was turned off.

Scenario 0 - Timeline and Notes

Year	Event
2015	Original tree list
2020	Seedling regeneration
2025	WA and SM mort
2035	Thin to Q factor
2040	Seedling regeneration
2045	WA and SM mort
2055	Thin to Q factor
2060	Seedling regeneration
2065	WA and SM mort
2075	Thin to Q factor
2080	Seedling regeneration

1"-4" Small Trees – Understory trees added to start of modeling period – 2015

Tree stocking derived from BAF plot data on 1"-4" trees.
Broken down by ownership, diameter, and species.

County	Tree Size (in.)	Stocking (TPA)		Private	Tree Size (in.)	Stocking (TPA)		State	Tree Size (in.)	Stocking (TPA)
Hard Maple	1	1040		**Hard Maple**	1	346		**Hard Maple**	1	511
	2	25			2	68			2	23
	3	9			3	18			3	5
	4	1			4	14			4	8
Red Oak	1 2	61 1		**Soft Maple**	1 2	6 8		**Soft Maple**	1 2	10 10
Yellow Birch	1	33			4	1			3	3
	2	14		**Hemlock**	1	15		**Basswood**	1	5
Soft Maple	1	21			2	8			2	6
					3	3			3	5
					4	4			4	1
				Yellow Birch	1	8		**Yellow Birch**	1	14
					2	5			4	1

Tree Regeneration added after Modeling Events

Plant/natural regeneration:

- Implemented after treatment events - 2020, 2040, 2060, 2080.
- Stocking of Sugar maple: 8,231 seedlings, basswood: 120 seedlings, red maple: 235 seedlings, white ash: 1,414 seedlings.
    - Comes from distribution of 1"- 4" trees from BAF plots data across ownerships.
    - A total of 10,000 seedlings per acre were allocated in FVS to replicate regeneration. Applied regeneration is summarized below:

Species	Distribution from BAF Plots	BAF stocking Ratio (%)	FVS Seedlings Applied (TPA)
Hard Maple	2,066	82	8,231
Basswood	30	1	120
Soft Maple	59	2	235
White Ash	355	14	1,414

- Assumed 20% survival for all species
- 1-foot height
- Natural regeneration settings applied in FVS

Adjusted mortality after planting events to replicate realistic regeneration performance in FVS:

- Mortality applied in years - 2025, 2045, 2065
- Species - White ash and sugar maple
- Diameters mortality applied to included, 1 to 4-inch trees
- 99% of white ash killed
- 65% of sugar maple killed

FVS KEYWORDS

Thin to Q factor:

- 2035, 2055, 2075
- County, residual BA of 82, 1-factor of 1.2
- Private, residual BA of 87, q-factor of 1.4
- State, residual BA of 88, q-factor of 1.1
- 5"- 30" DBH considered for removal

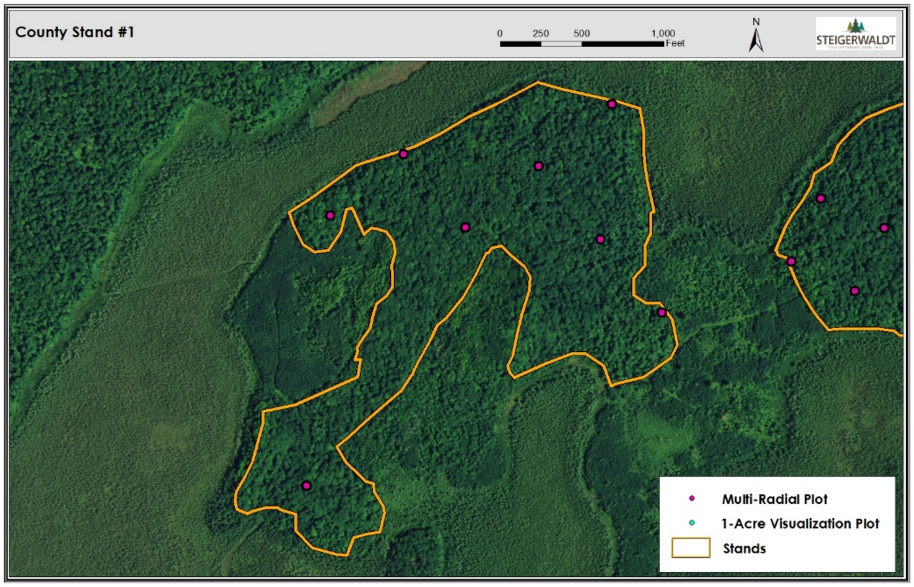
Turn off sprouting

No triple

Exhibit 3

County and State Timber Sale Map

Exhibit 3
Order of Removal Case Study Timber Sale Maps



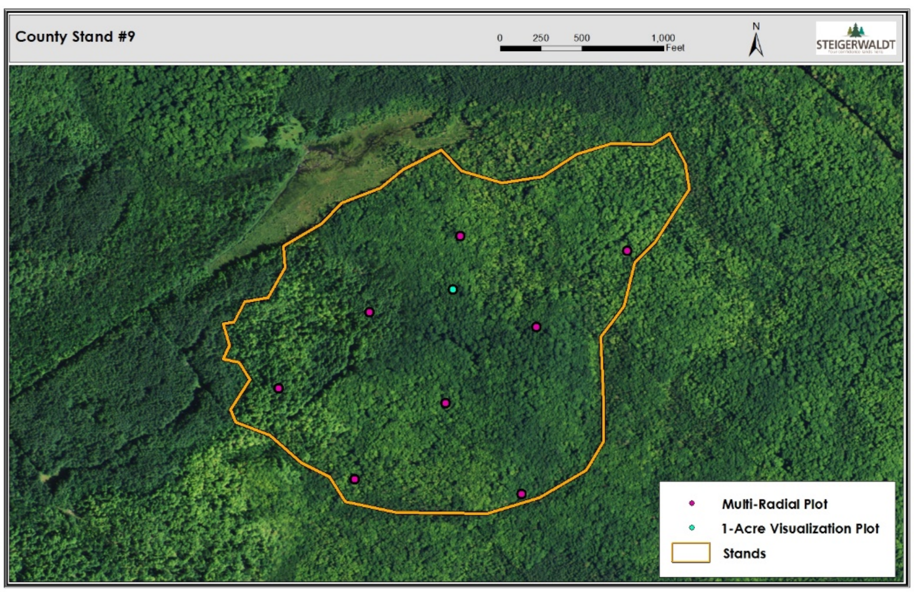
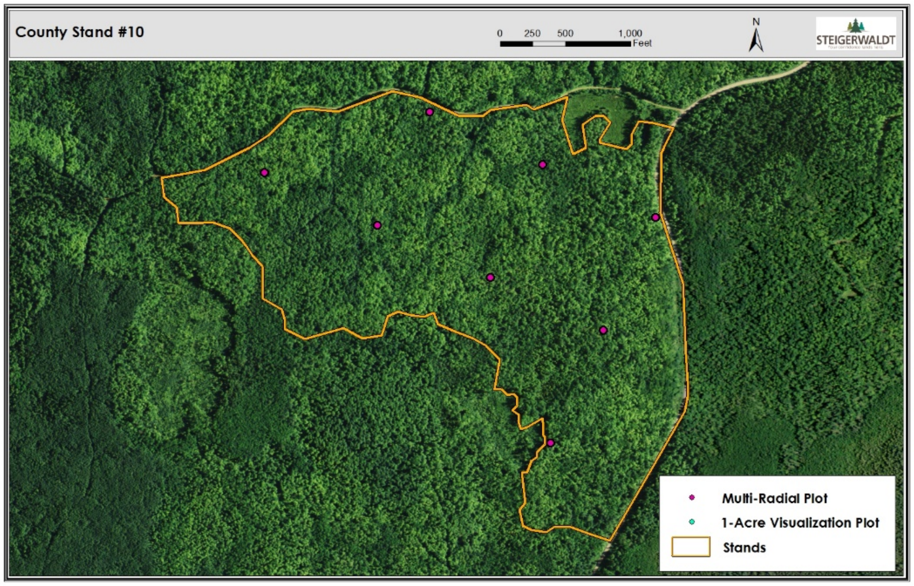


Exhibit 3
Order of Removal Case Study Timber Sale Maps



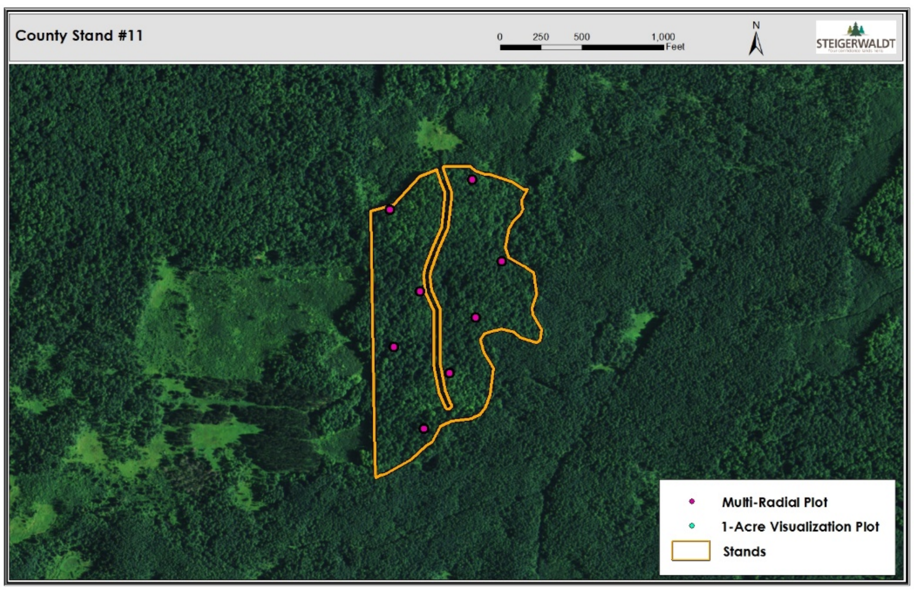
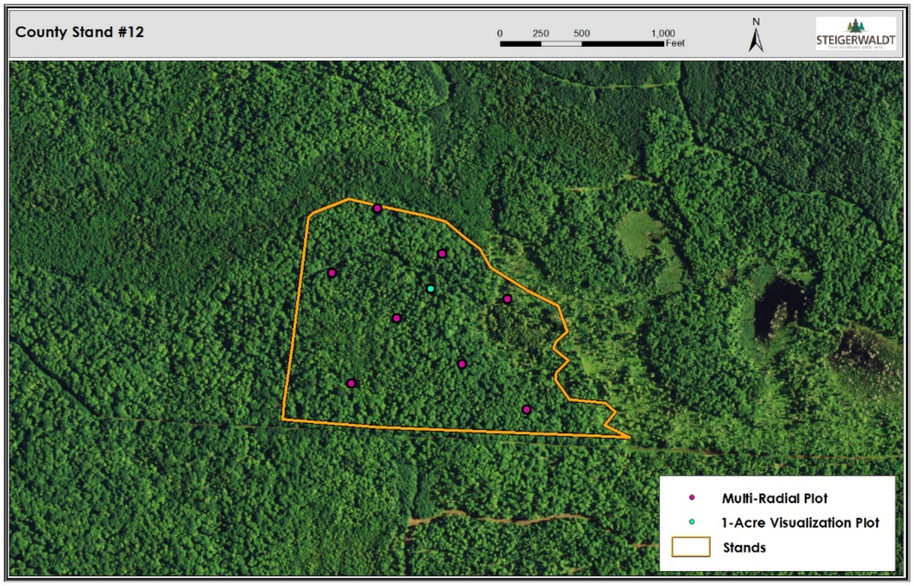


Exhibit 3
Order of Removal Case Study Timber Sale Maps



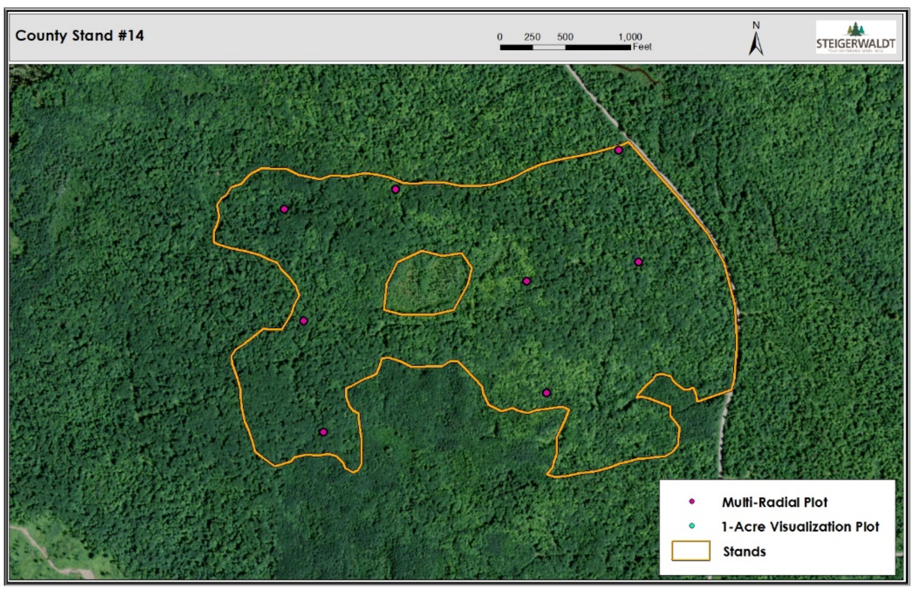
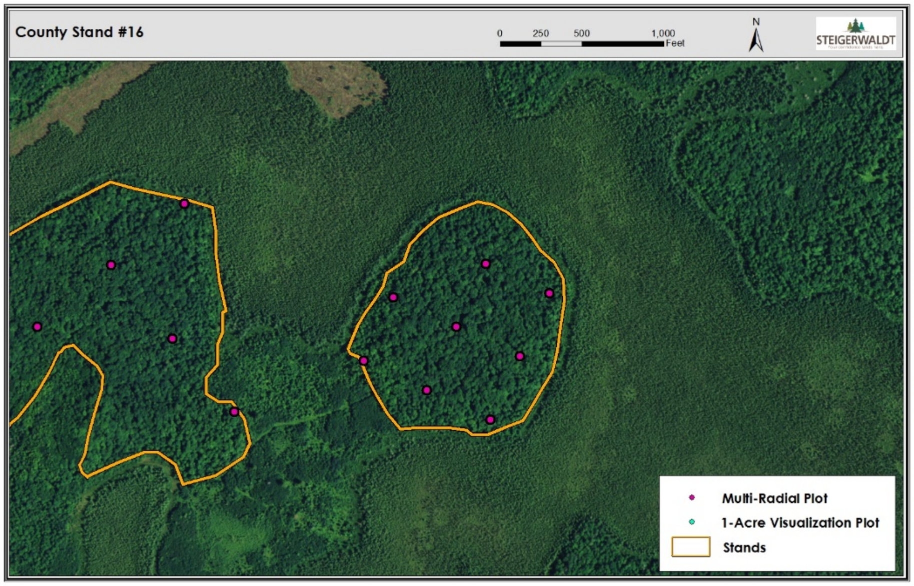


Exhibit 3
Order of Removal Case Study Timber Sale Maps



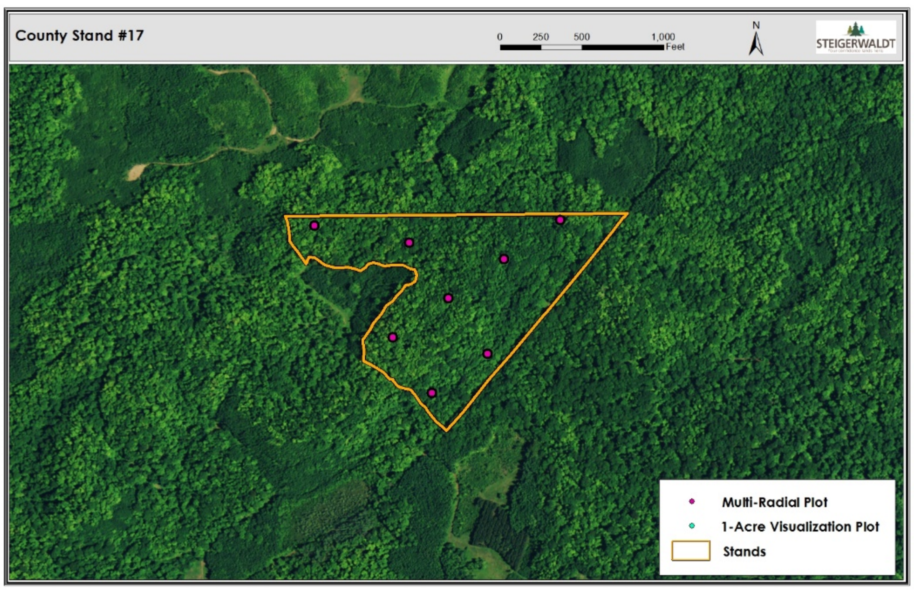
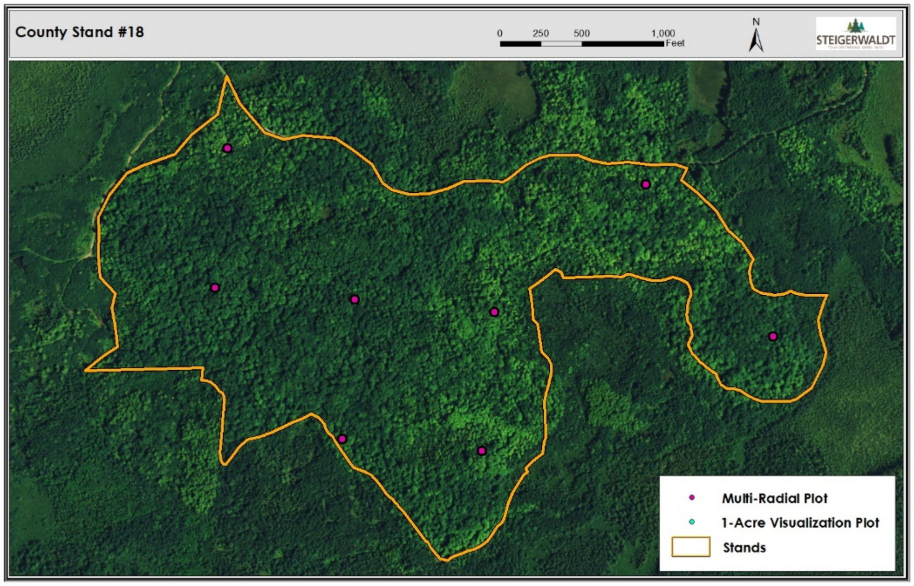


Exhibit 3
Order of Removal Case Study Timber Sale Maps



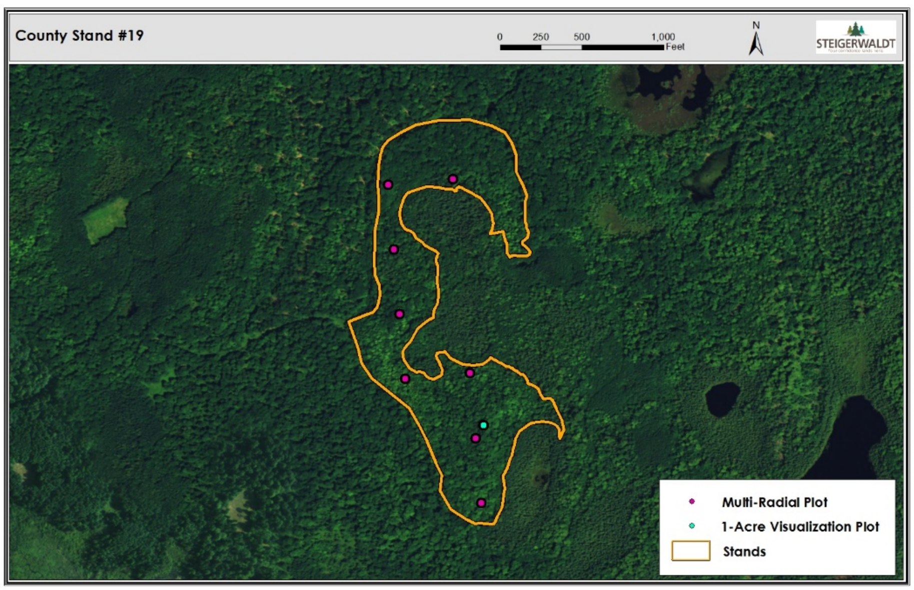
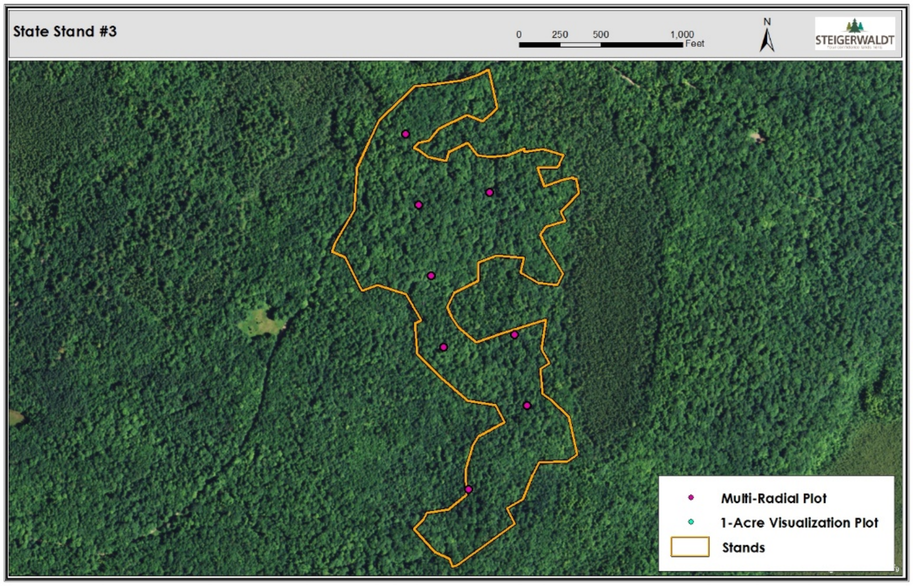


Exhibit 3
Order of Removal Case Study Timber Sale Maps



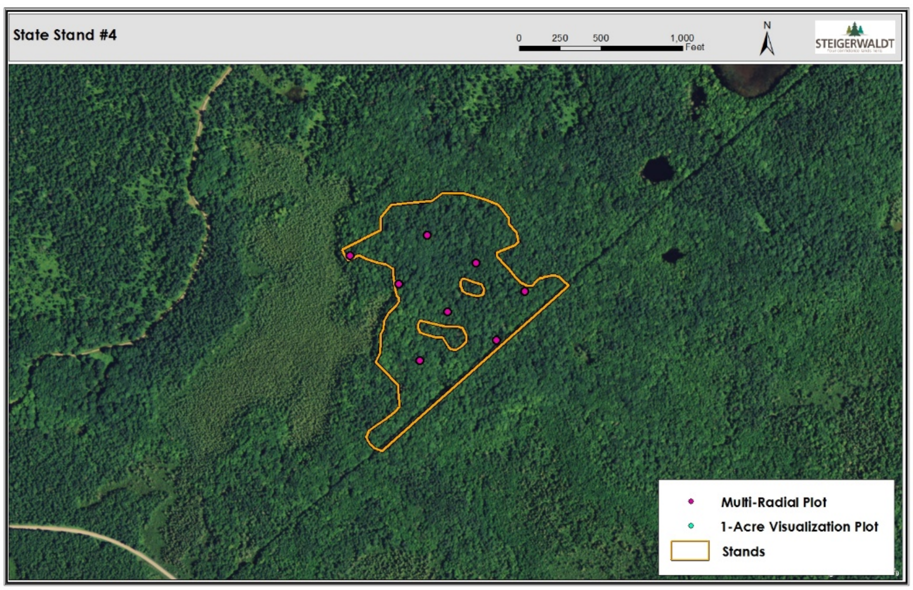
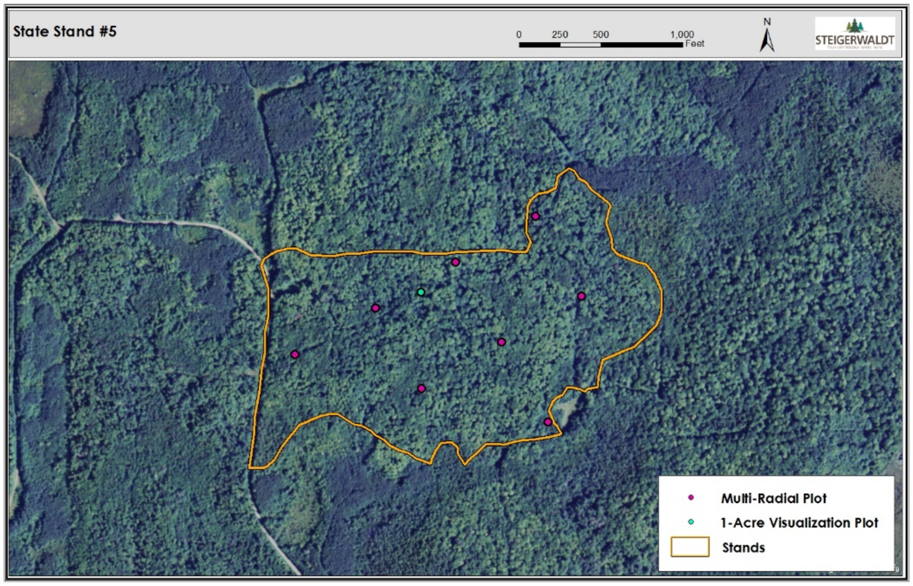


Exhibit 3
Order of Removal Case Study Timber Sale Maps



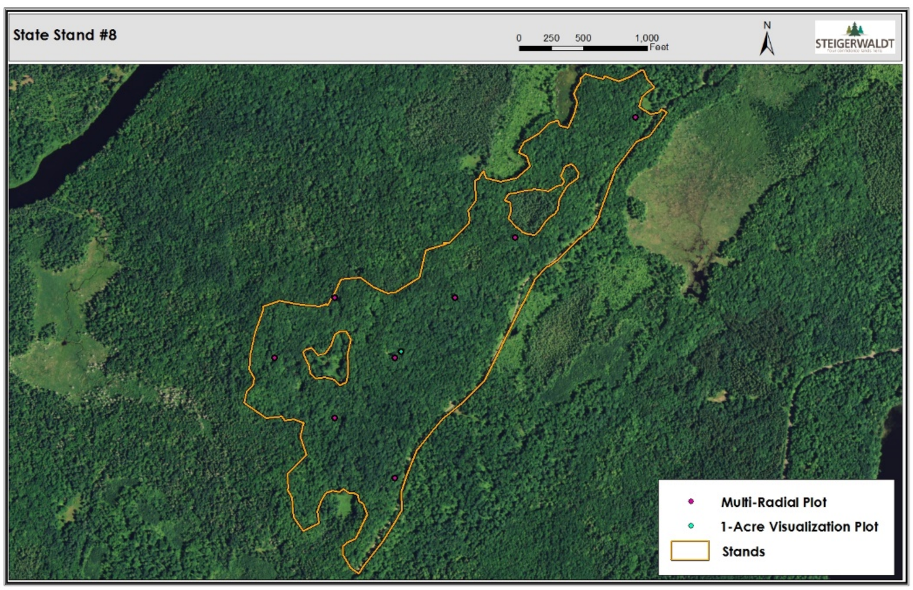
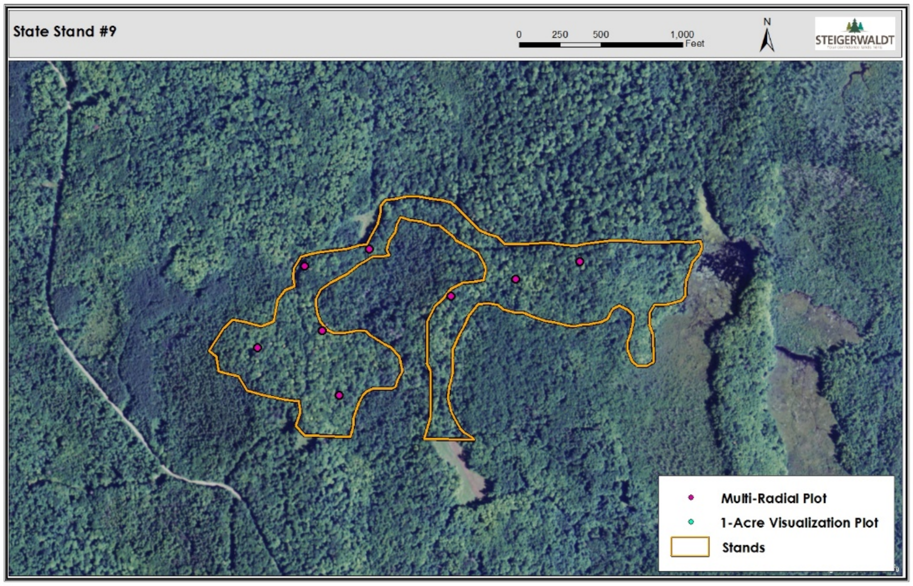


Exhibit 3
Order of Removal Case Study Timber Sale Maps



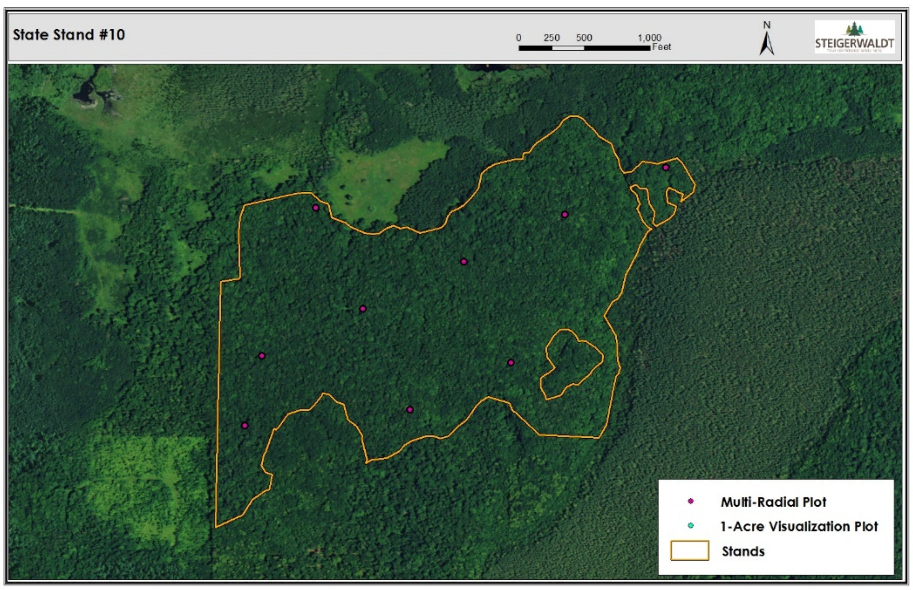
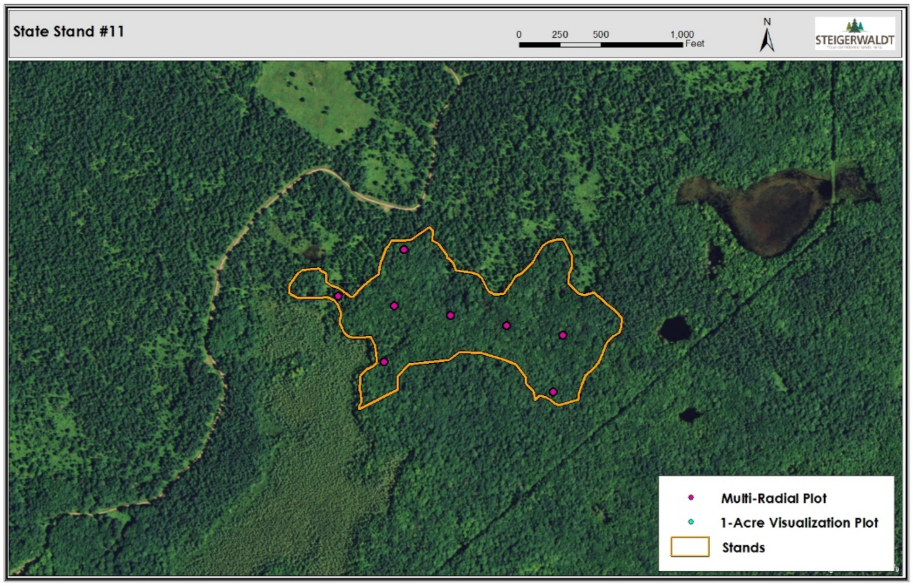


Exhibit 3
Order of Removal Case Study Timber Sale Maps



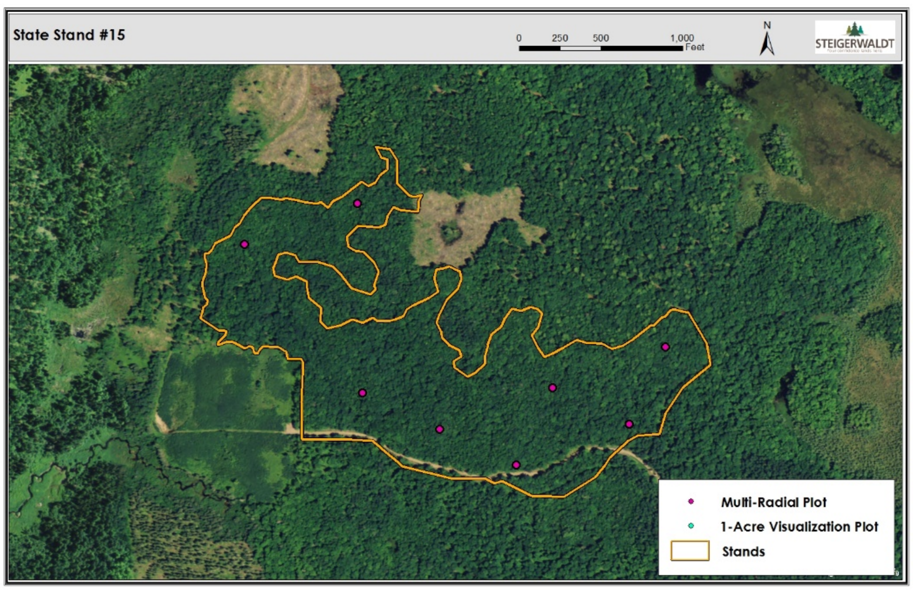
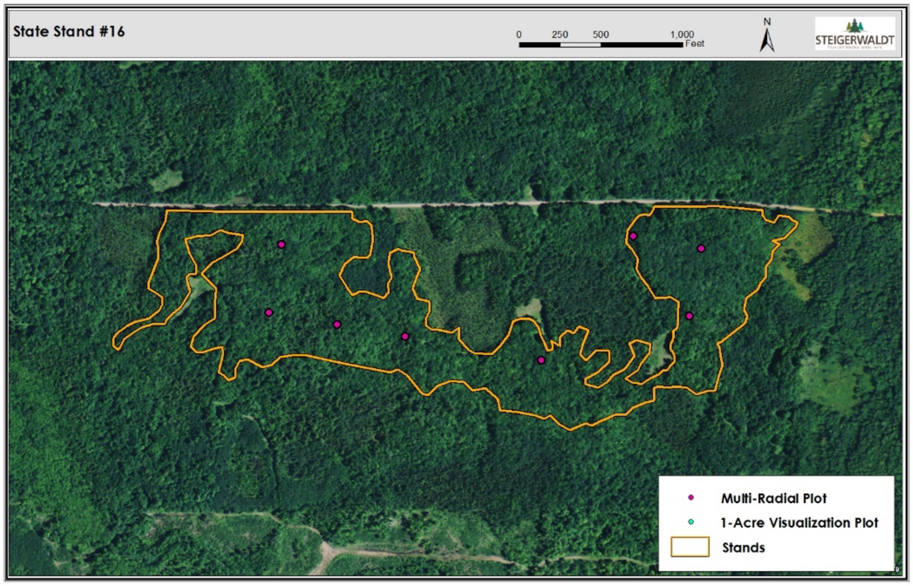


Exhibit 3
Order of Removal Case Study Timber Sale Maps



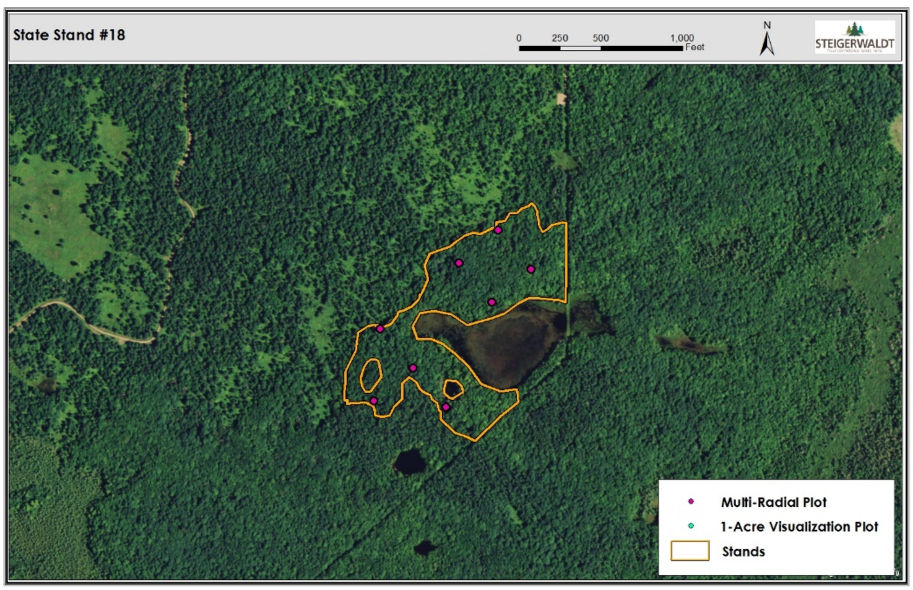


Exhibit 4

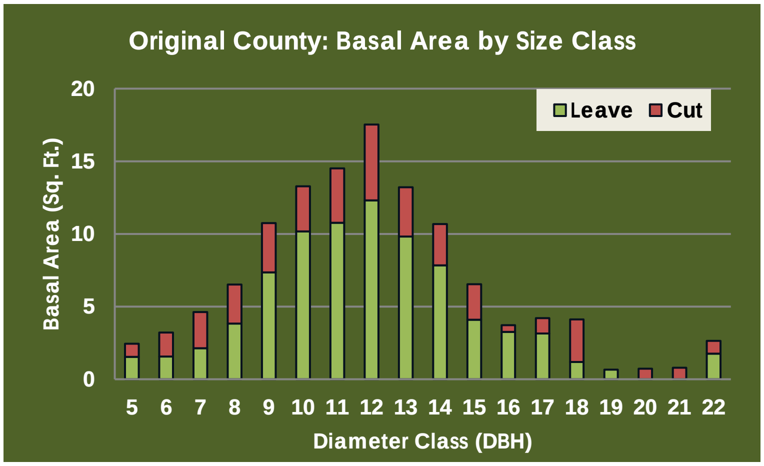
2015 Starting Point Harvest Treatments by Owner

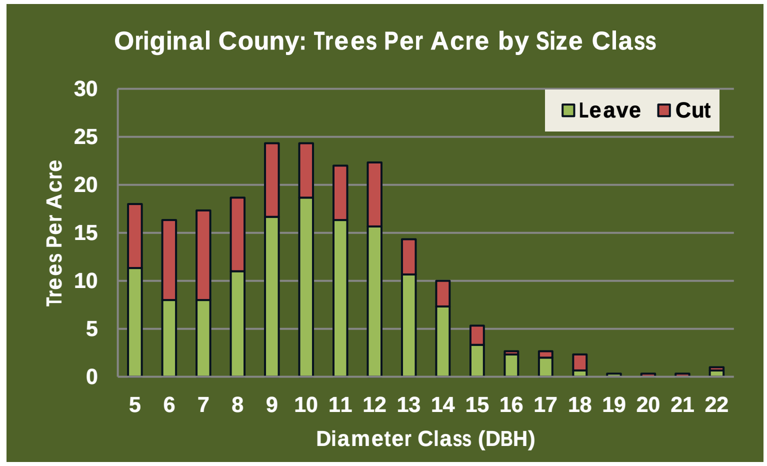
Exhibit 4
2015 Starting Point Harvest Treatments by Owner

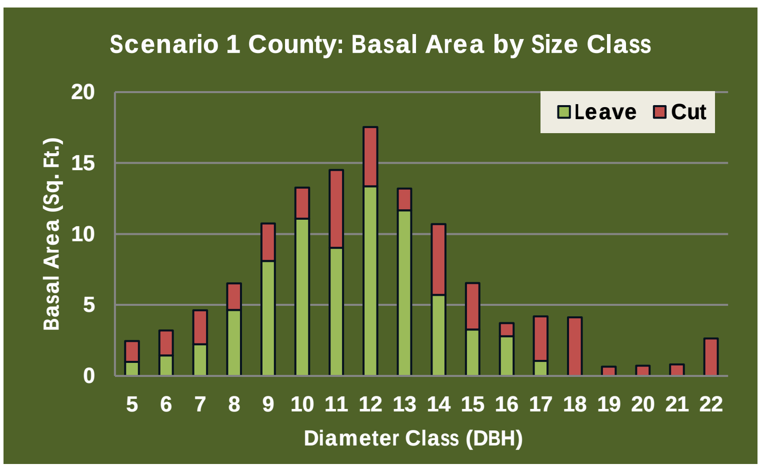
County

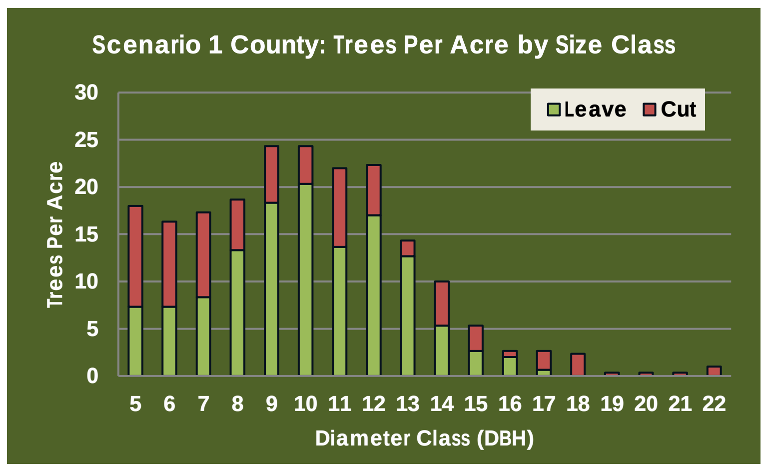
Basal Area

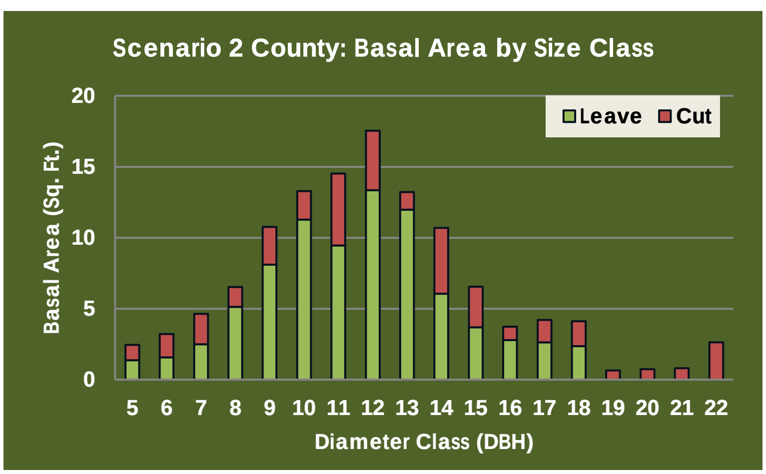
Trees per Acre











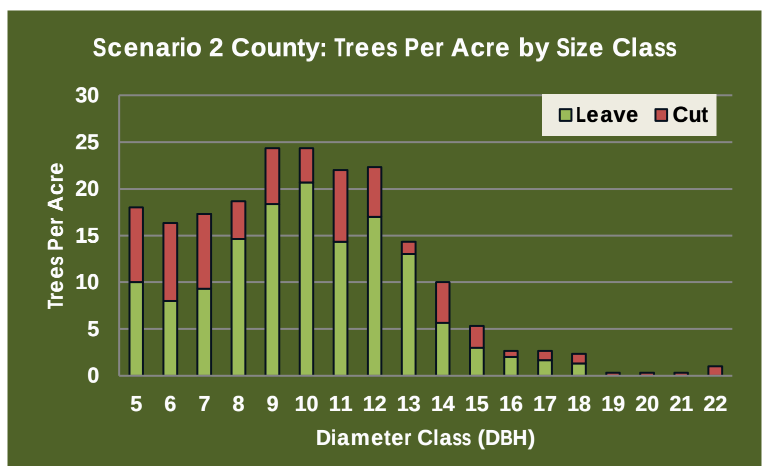
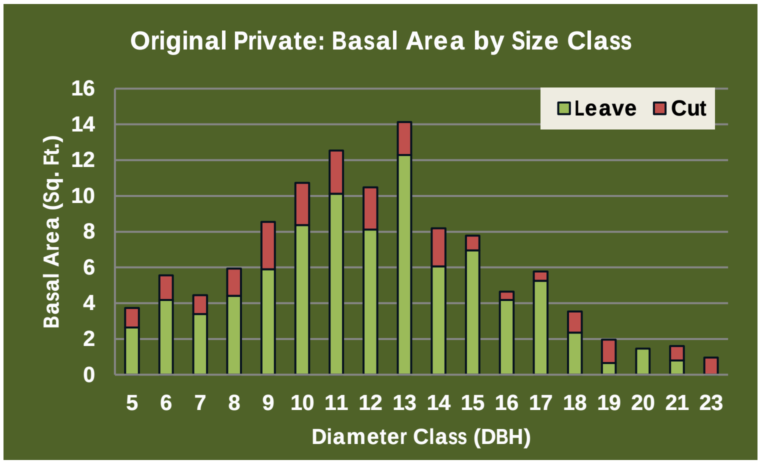


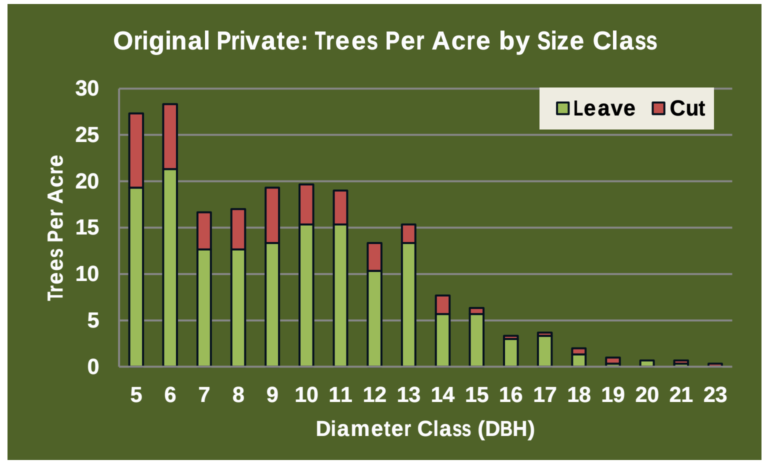
Exhibit 4
2015 Starting Point Harvest Treatments by Owner

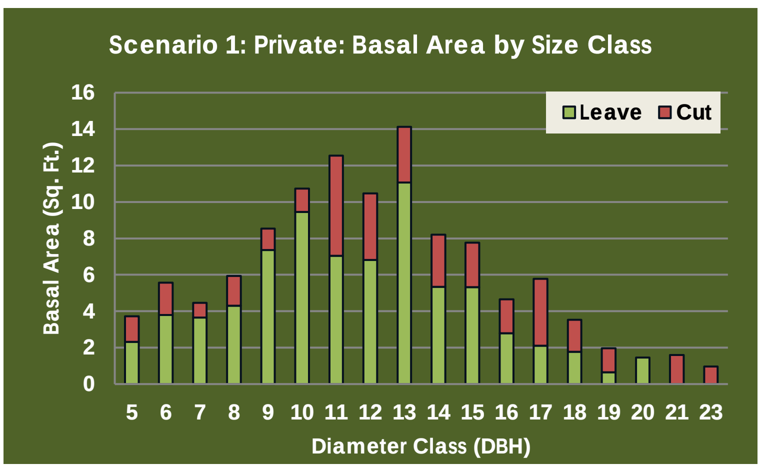
Private

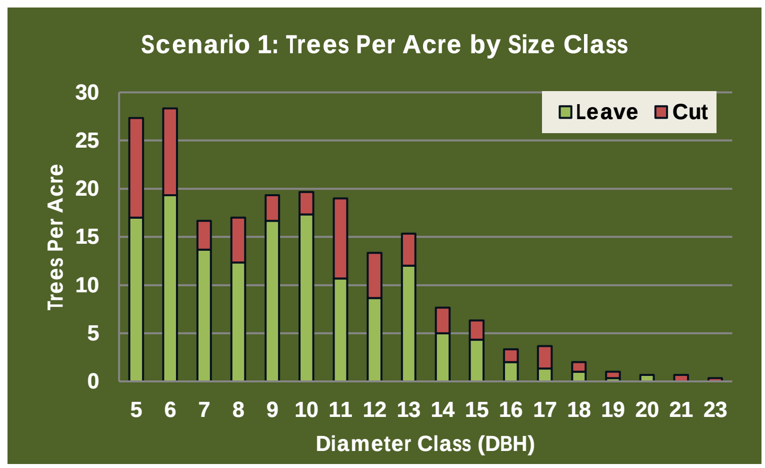
Basal Area

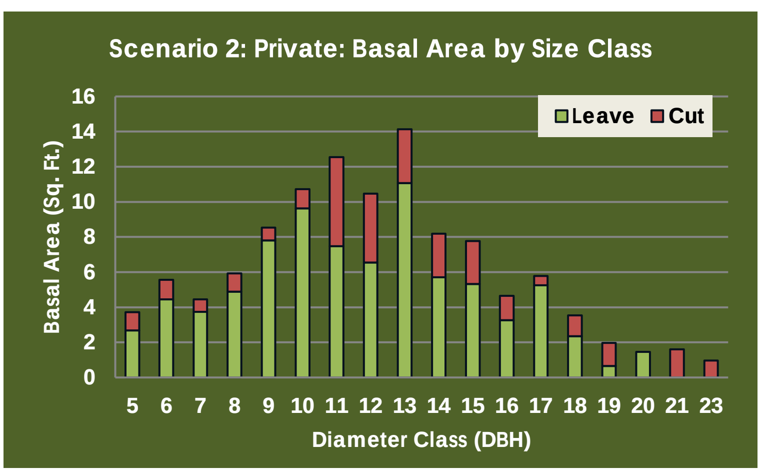
Trees per Acre











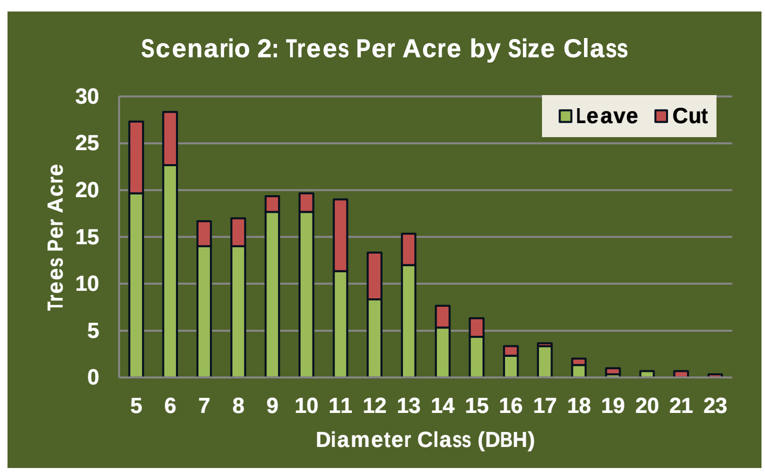
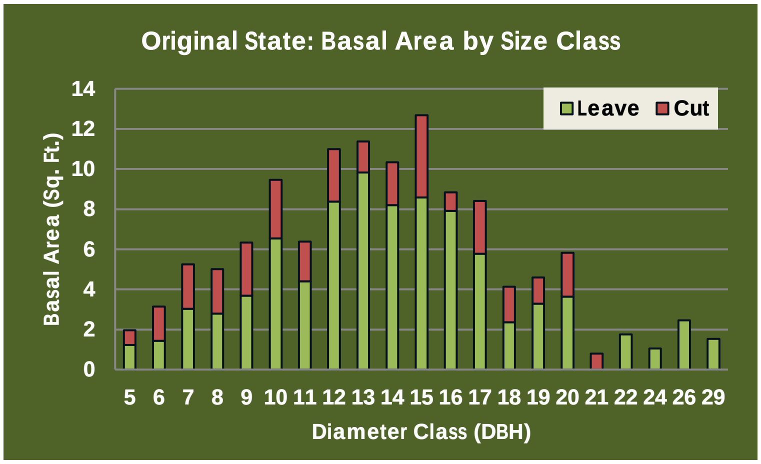


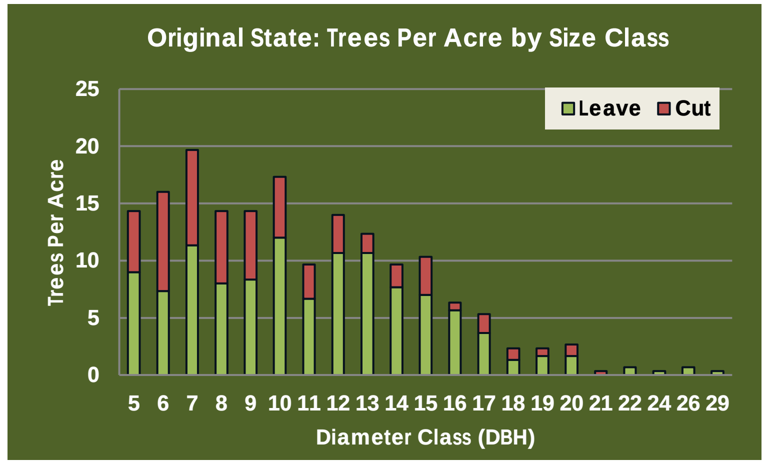
Exhibit 4
2015 Starting Point Harvest Treatments by Owner

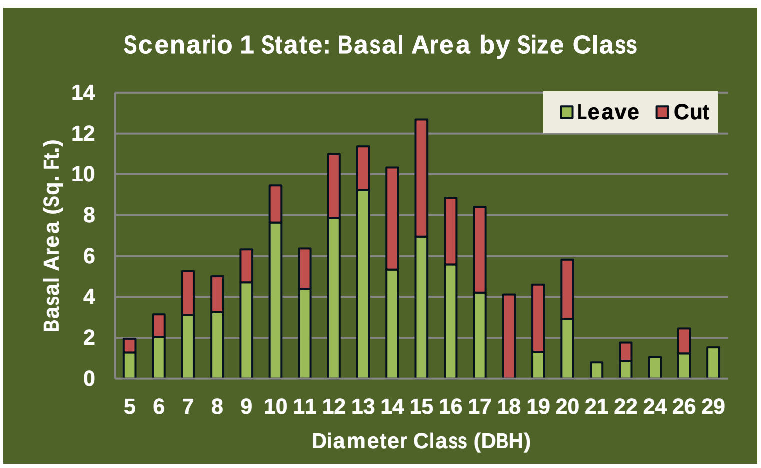
State

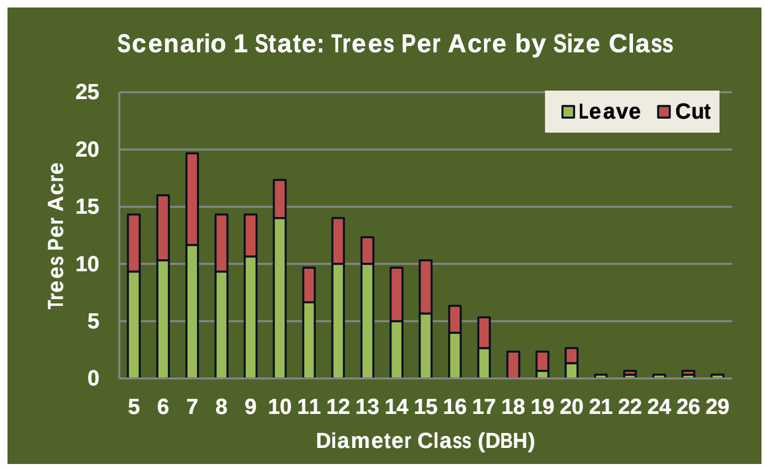
Basal Area

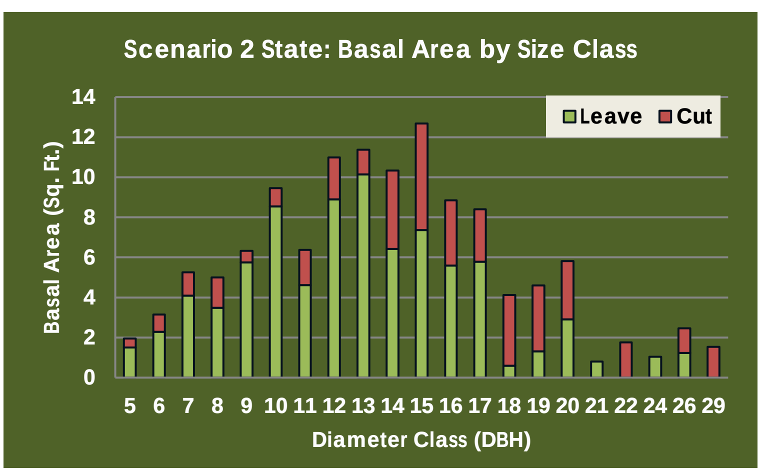
Trees per Acre











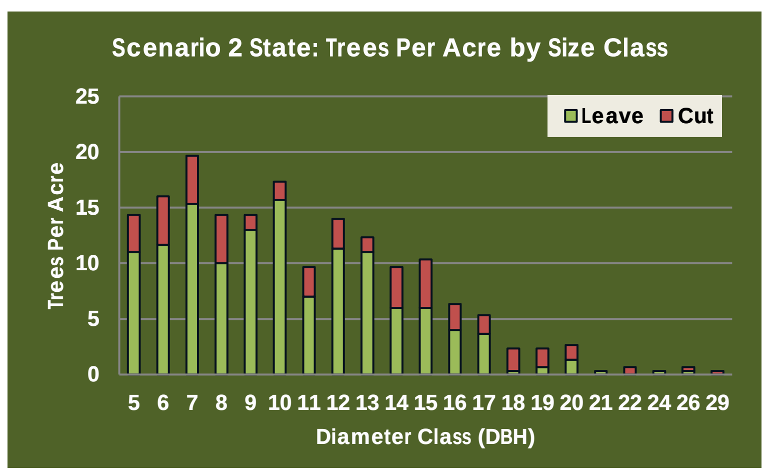
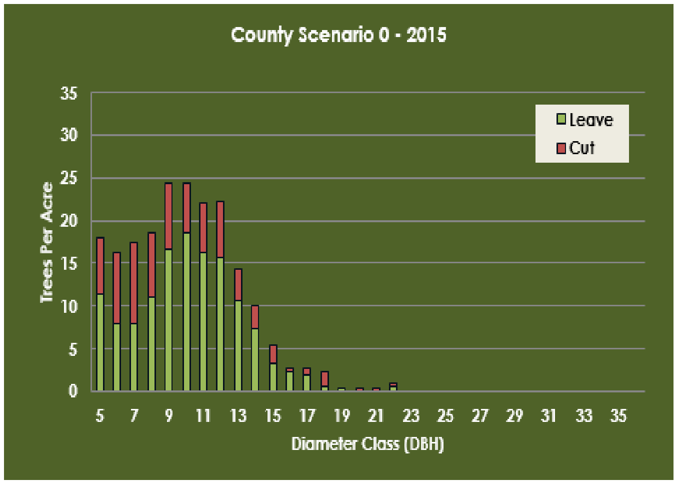


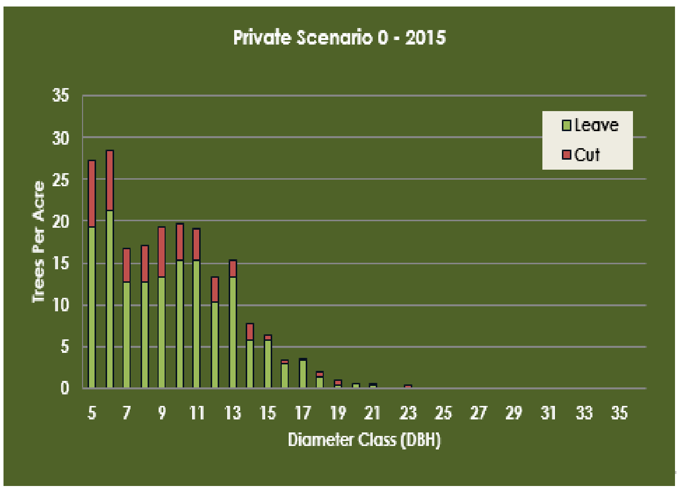
Exhibit 5

Diameter Distribution Summary by Scenario and Owners

Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 0 – Cut and Leave Distribution, 2015





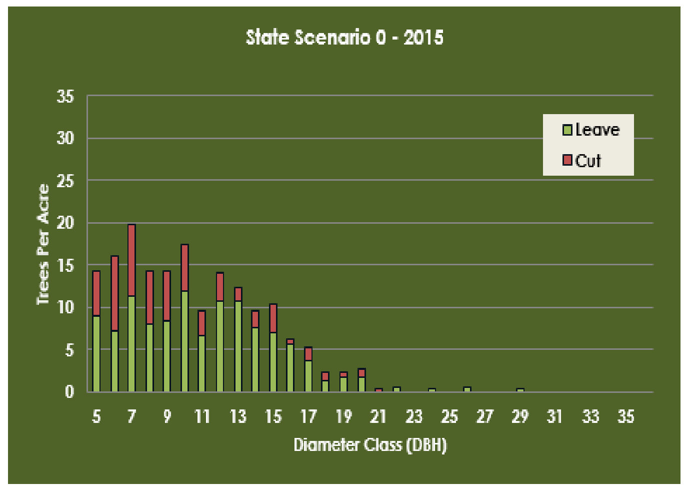
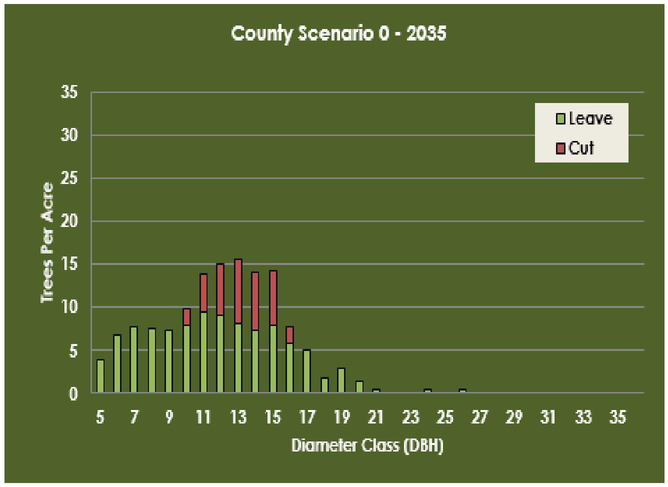
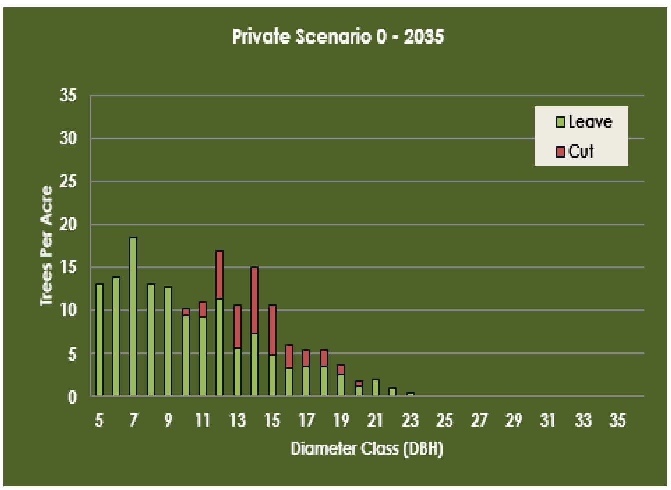


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 0 – Cut and Leave Distribution, 2035





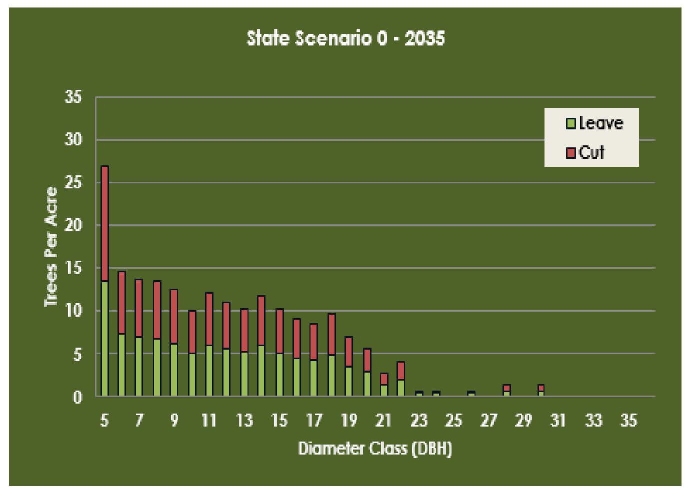
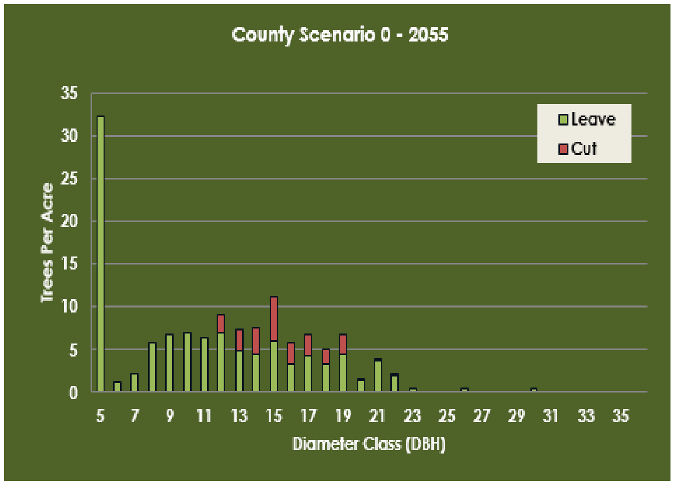
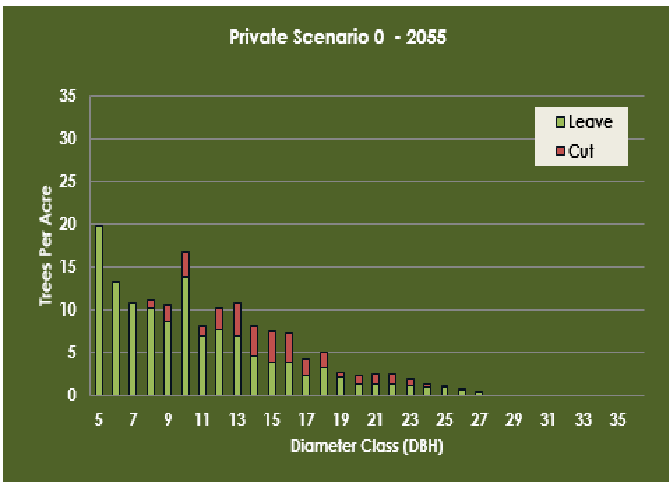


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 0 – Cut and Leave Distribution, 2055





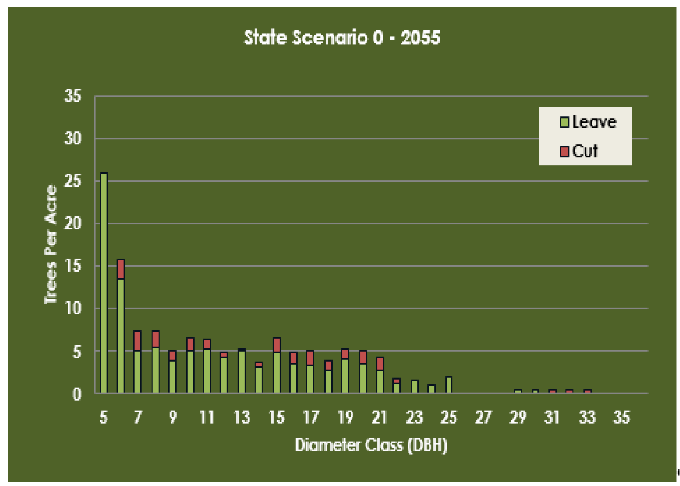
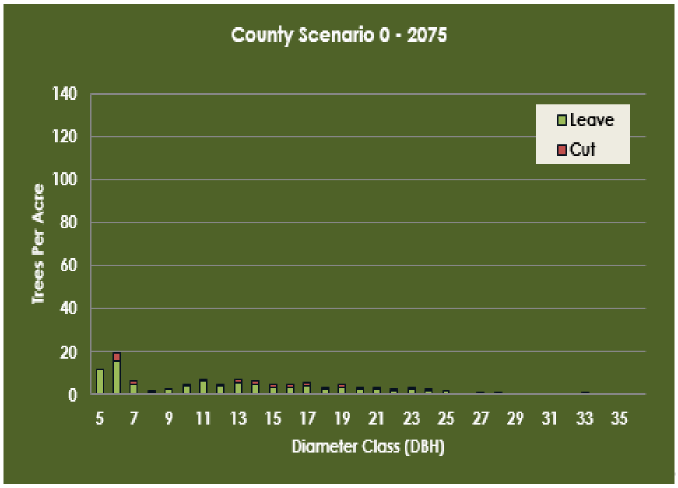
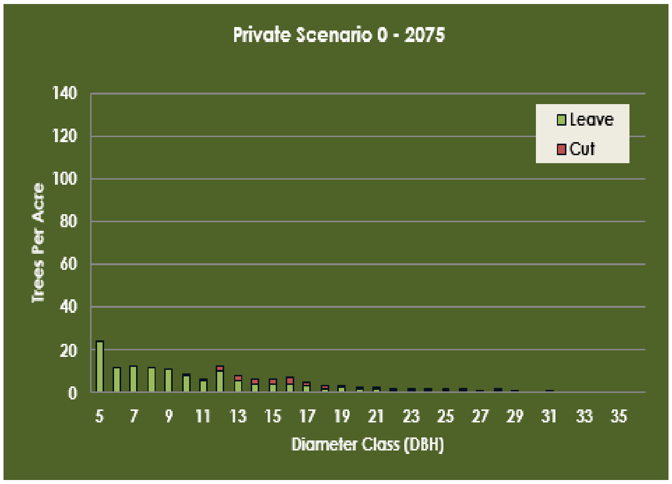


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 0 – Cut and Leave Distribution, 2075





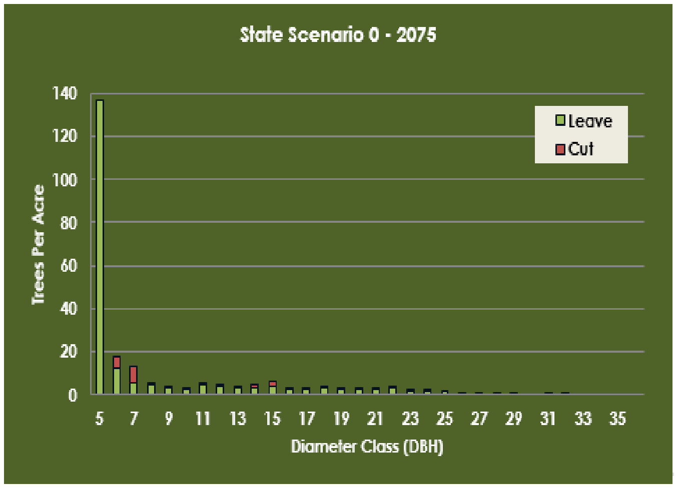
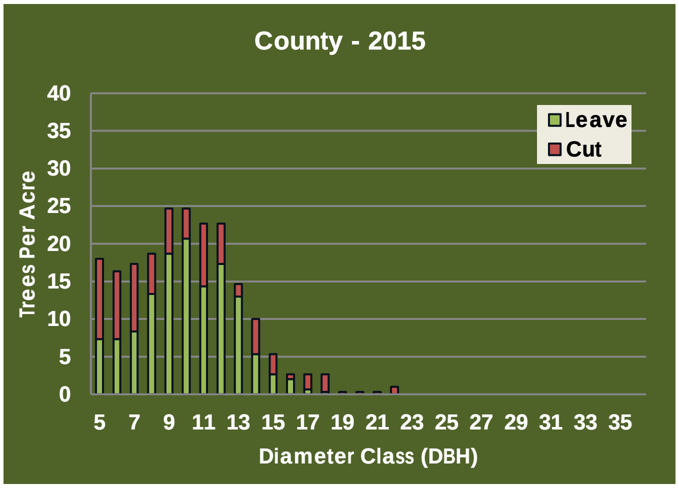
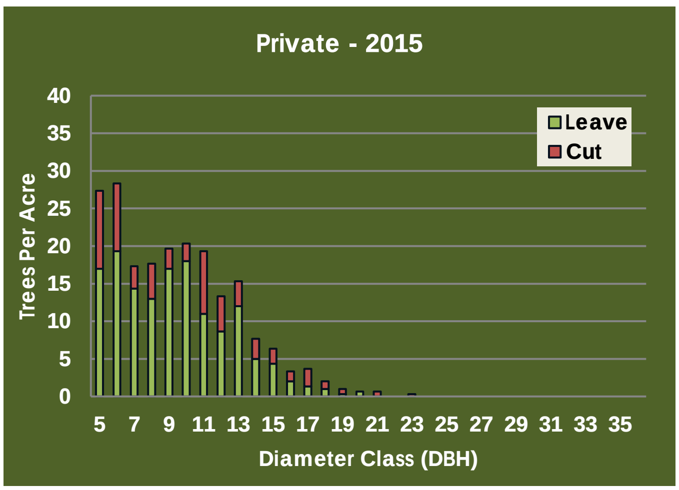


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 1 – Cut and Leave Distribution, 2015





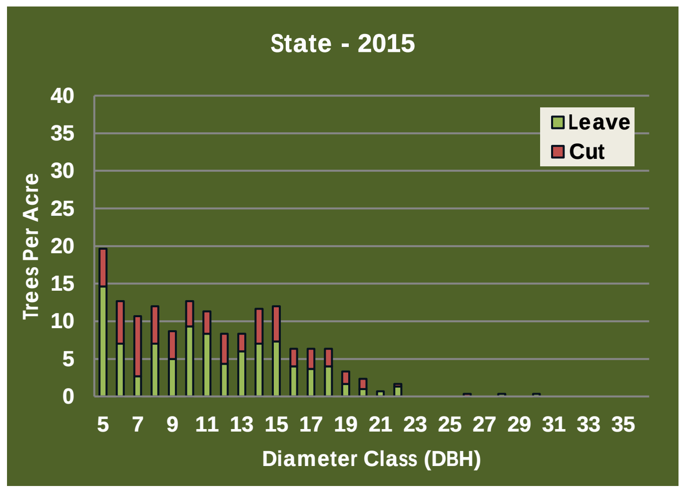
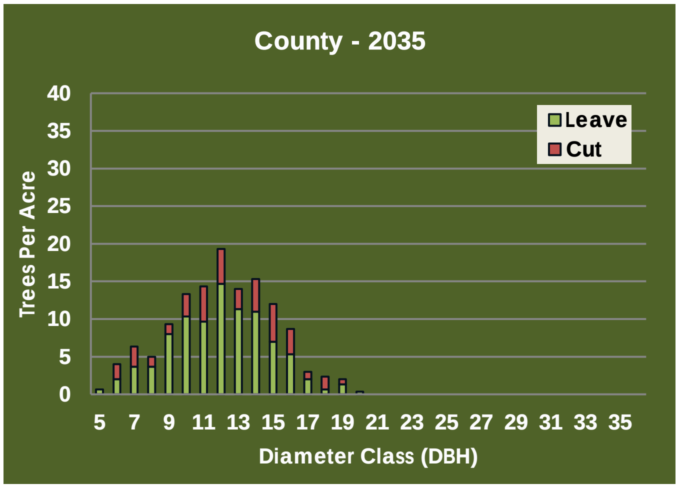
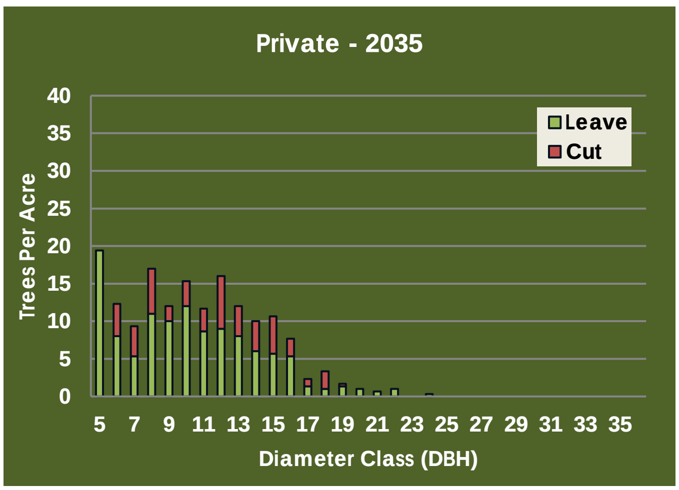


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 1 – Cut and Leave Distribution, 2035





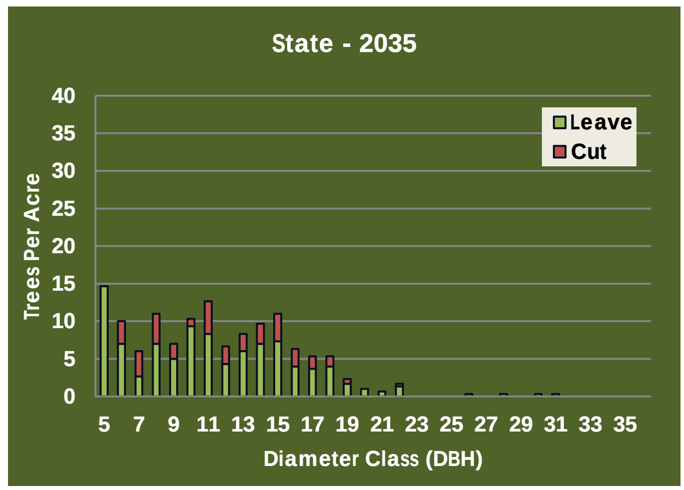
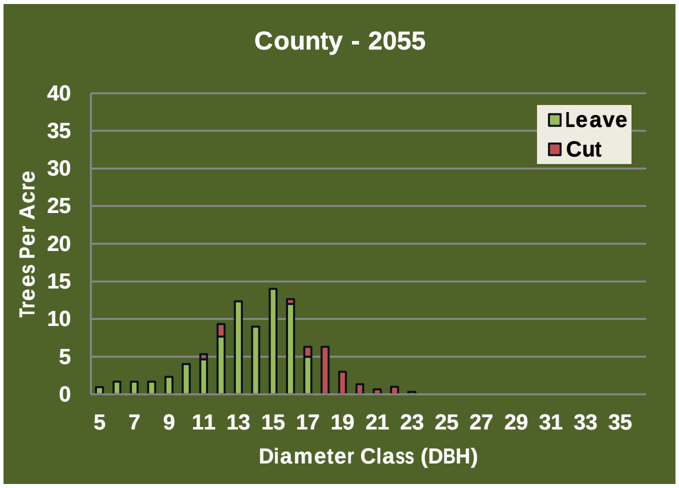
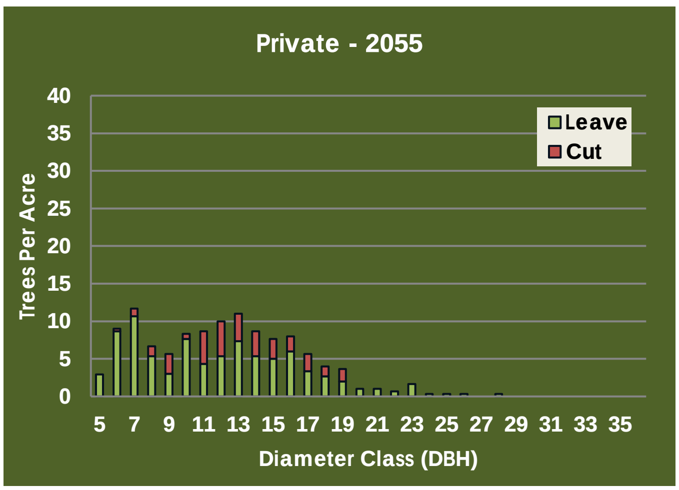


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 1 – Cut and Leave Distribution, 2055





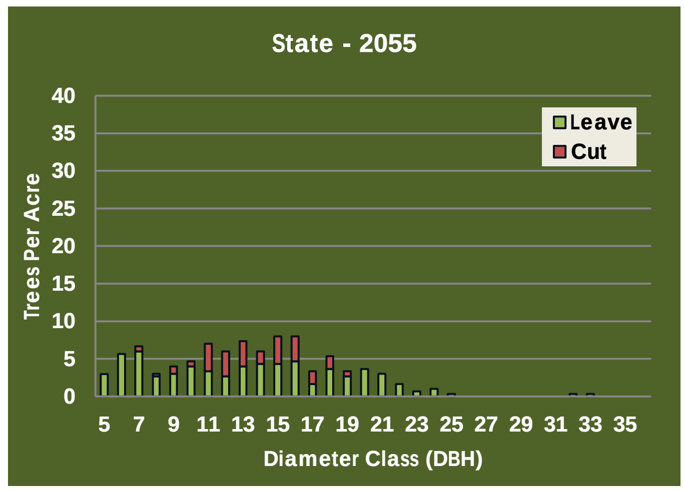
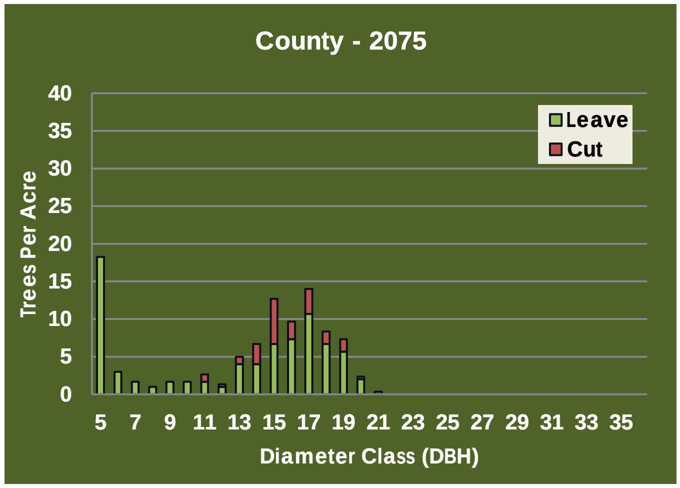
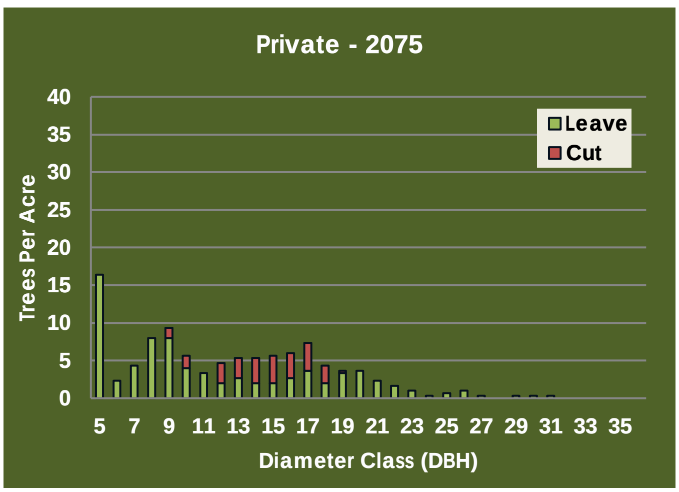


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 1 – Cut and Leave Distribution, 2075





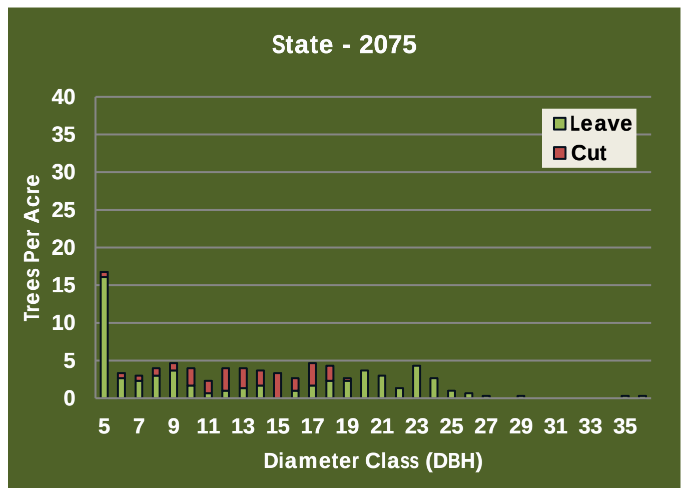
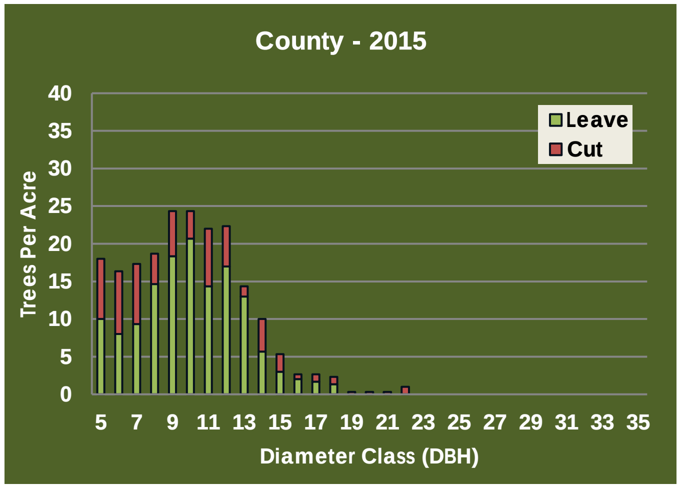
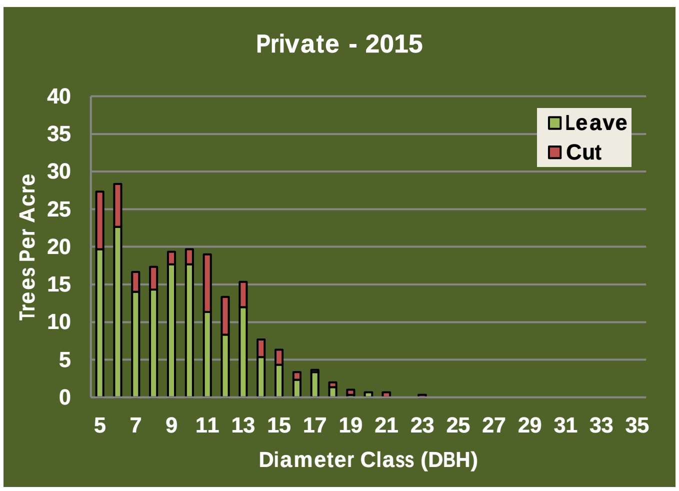


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 2 – Cut and Leave Distribution, 2015





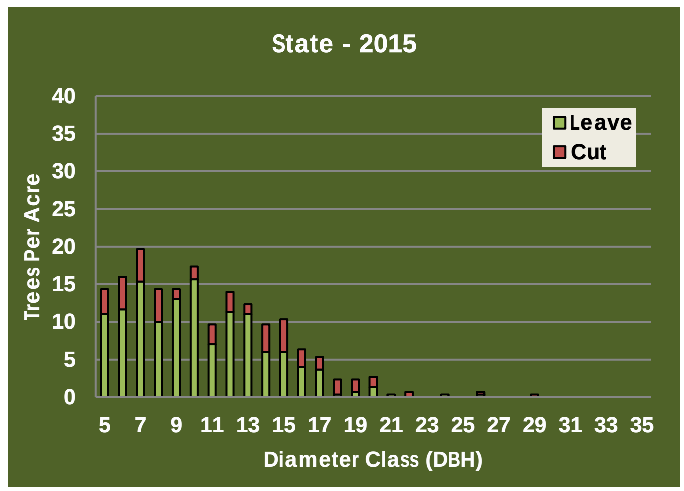
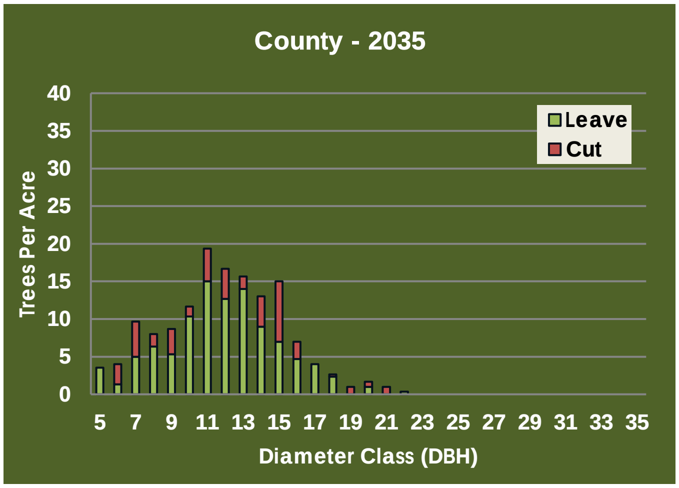
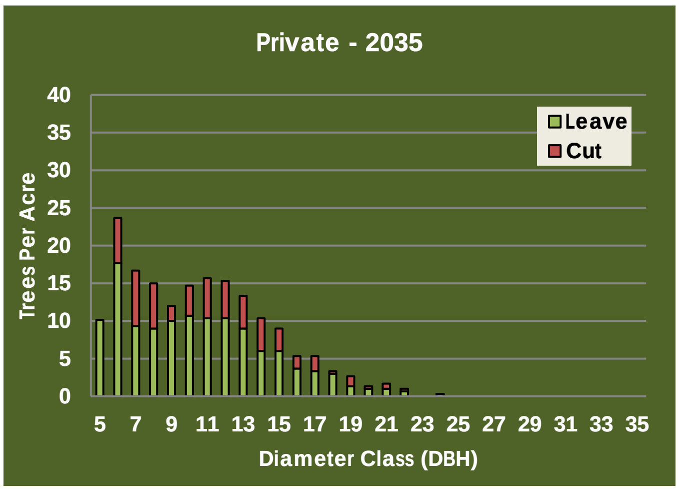


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 2 – Cut and Leave Distribution, 2035





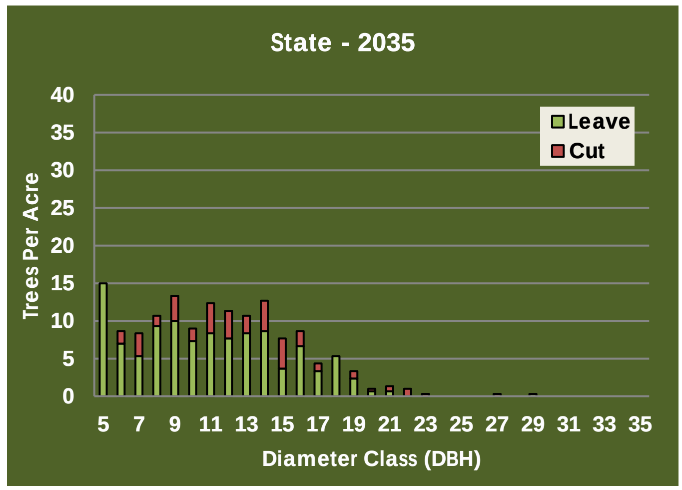
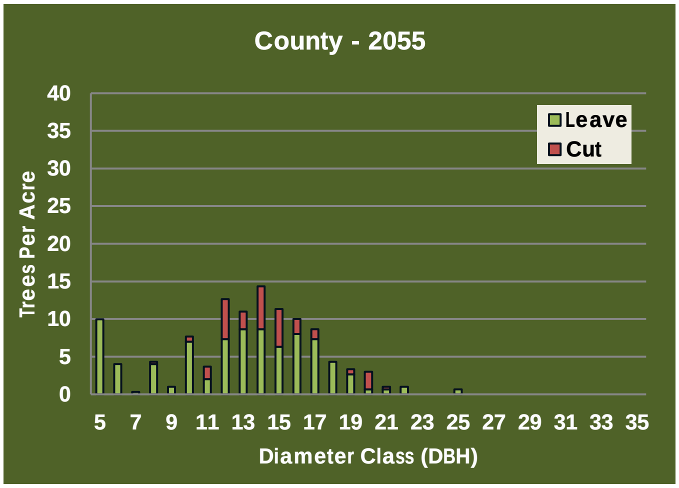
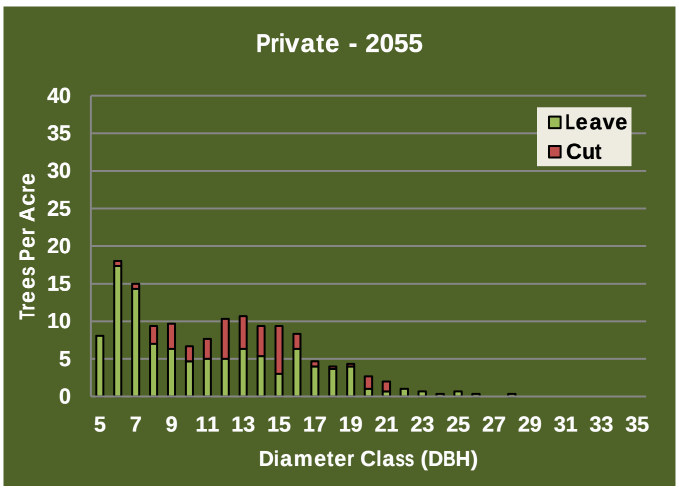


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 2 – Cut and Leave Distribution, 2055





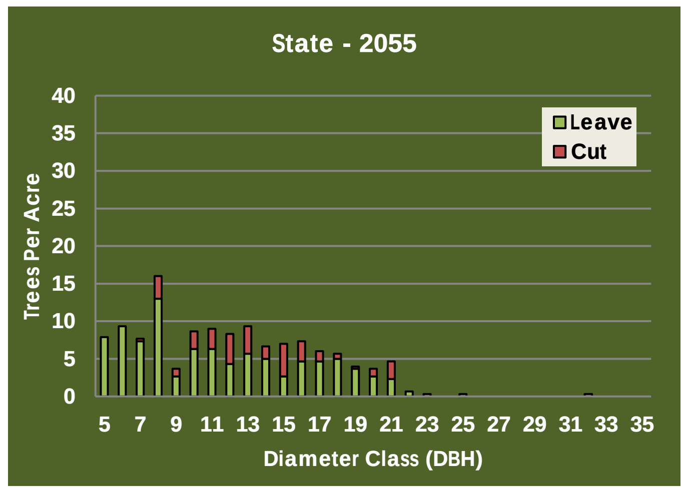
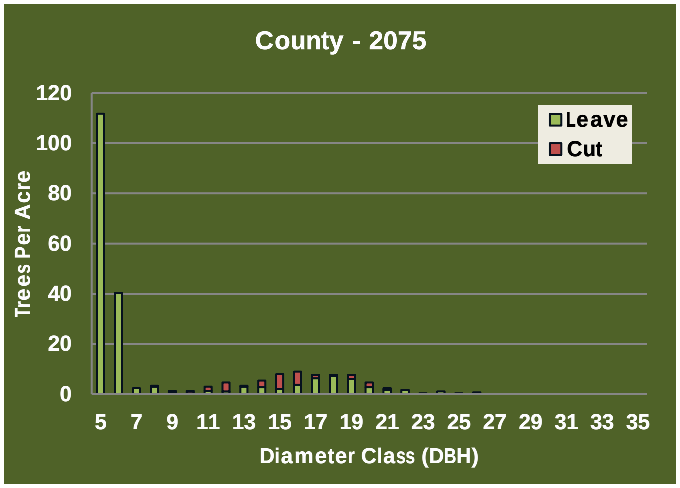
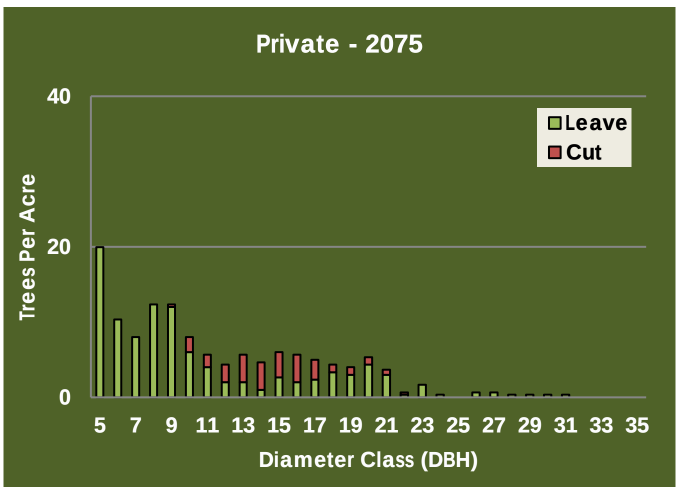


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

SCENARIO 2 – Cut and Leave Distribution, 2075





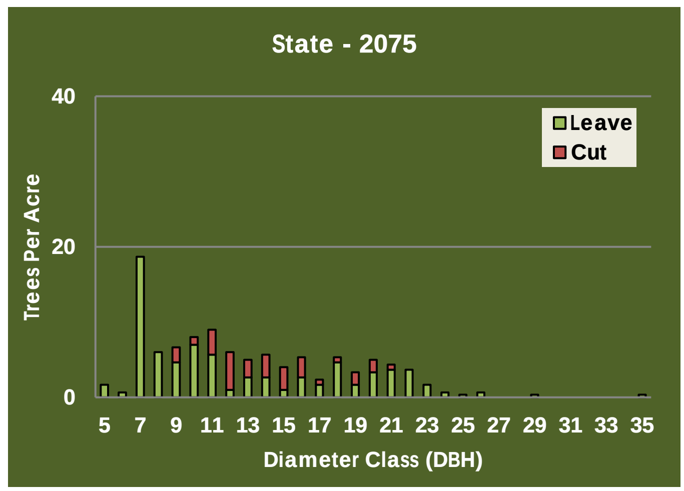
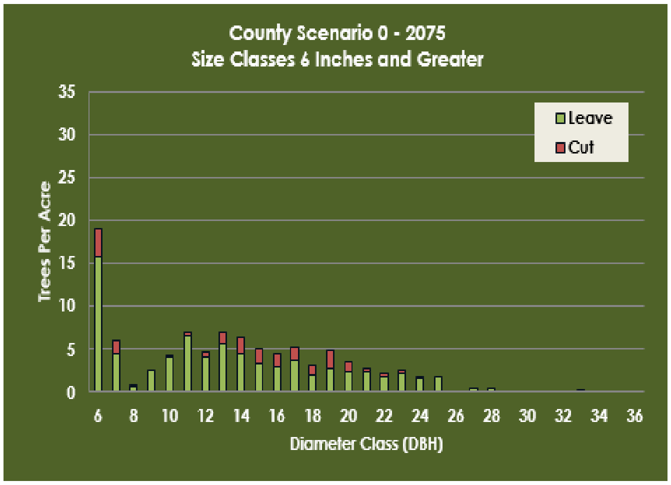
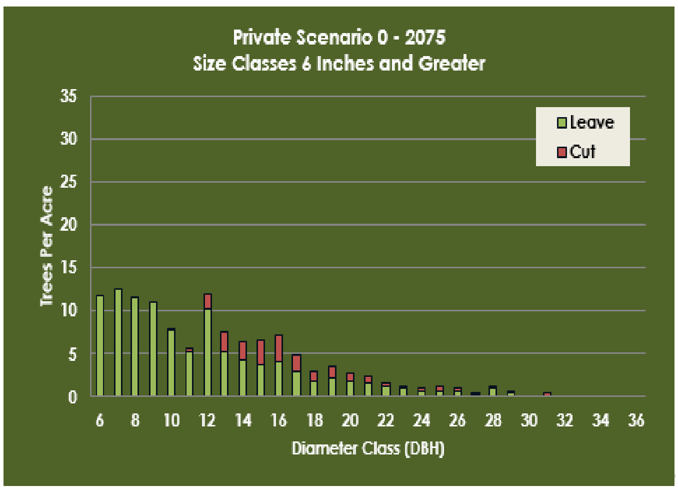


Exhibit 5 - Diameter Distribution Summary by Scenario and Owner

Cut and Leave Distribution, 2075

Size Class 6 inches and Greater





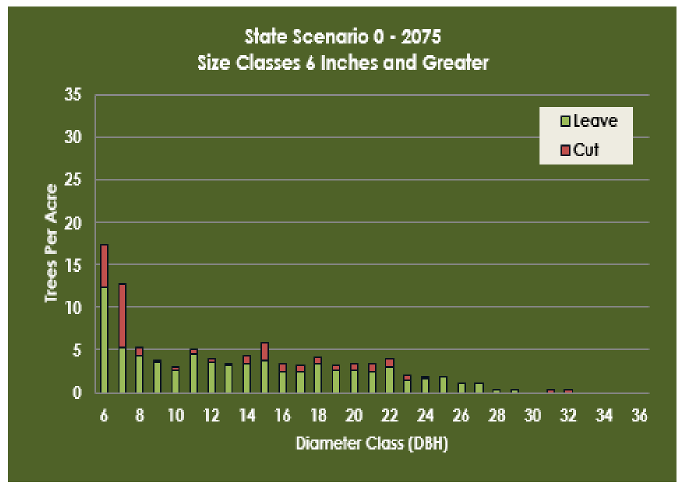


Exhibit 6

Timber Value Analysis for Harvests in 2035 and 2055

Exhibit 6 - Timber Value Analysis for Harvests

SCENARIOS – Harvest Comparison, 2035

2035 County Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$728.52	$737.53	1.2%	$738.89	1.4%
Leave	$1,585.00	$1,481.34	-6.5%	$1,618.39	2.1%
Total	$2,313.52	$2,218.87	-	$2,357.28	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	13.5	13.9	3.1%	14.7	8.6%
Leave	36.2	32.8	-9.3%	36.0	-0.6%
Total	49.7	46.8	-	50.7	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	1,970.6	2,042.9	3.7%	1,985.8	0.8%
Leave	4,254.8	4,321.5	1.6%	4,676.6	9.9%
Total	6,225.4	6,364.4	-	6,662.4	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Sq. Ft.)	% Dif.
Cut	33.2	34.5	4.0%	35.9	8.2%
Leave	82.3	75.6	-8.2%	82.6	0.4%
Total	115.5	110.1	-	118.5	-

2035 Private Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$916.41	$792.23	-13.6%	$852.42	-7.0%
Leave	$1,801.01	$1,473.98	-18.2%	$1,688.10	-6.3%
Total	$2,717.42	$2,266.20	-	$2,540.52	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	17.7	19.2	8.5%	20.8	17.6%
Leave	46.6	37.3	-19.8%	39.6	-14.9%
Total	64.3	56.6	-	60.5	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	2,708.7	2,002.7	-26.1%	2,021.8	-25.4%
Leave	4,685.6	4,314.4	-7.9%	4,978.5	6.2%
Total	7,394.3	6,317.1	-	7,000.3	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Sq. Ft.)	% Dif.
Cut	39.3	37.7	-4.2%	34.5	-12.2%
Leave	89.3	75.4	-15.6%	82.2	-8.0%
Total	128.6	113.0	-	116.7	-

2035 State Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$736.06	$682.34	-7.3%	$761.01	3.4%
Leave	$2,054.83	$1,752.82	-14.7%	$1,791.53	-12.8%
Total	$2,790.89	$2,435.16	-	$2,552.54	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	15.1	15.3	1.1%	16.3	7.8%
Leave	44.9	36.6	-18.6%	40.7	-9.4%
Total	60.0	51.8	-	57.0	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	1,886.9	1,805.8	-4.3%	1,960.6	3.9%
Leave	4,966.9	4,432.9	-10.8%	4,456.5	-10.3%
Total	6,853.8	6,238.7	-	6,417.0	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Sq. Ft.)	% Dif.
Cut	31.4	32.1	2.1%	34.5	9.8%
Leave	89.6	75.6	-15.6%	82.2	-8.3%
Total	121.0	107.7	-	116.7	-

Exhibit 6 - Timber Value Analysis for Harvests

SCENARIOS – Harvest Comparison, 2055

2055 County Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$736.90	$648.99	-11.9%	$718.00	-2.6%
Leave	$1,734.68	$1,897.34	9.4%	$1,886.75	8.8%
Total	$2,471.58	$2,546.33	-	$2,604.75	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	10.1	10.7	5.4%	13.3	31.5%
Leave	37.8	28.9	-23.7%	32.1	-15.1%
Total	48.0	39.6	-	45.5	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	1,999.8	2,040.4	2.0%	1,582.1	-20.9%
Leave	4,037.7	4,897.0	21.3%	5,186.1	28.4%
Total	6,037.5	6,937.4	-	6,768.2	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Sq. Ft.)	% Dif.
Cut	29.2	30.0	2.9%	32.2	10.2%
Leave	83.4	76.3	-8.5%	82.5	-1.1%
Total	112.6	106.3	-	114.6	-

2055 Private Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$1,010.68	$789.67	-21.9%	$903.48	-10.6%
Leave	$2,040.71	$1,886.45	-7.6%	$2,045.64	0.2%
Total	$3,051.39	$2,676.12	-	$2,949.12	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	20.5	15.3	-25.3%	20.5	-0.2%
Leave	47.9	32.9	-31.3%	36.3	-24.3%
Total	68.4	48.2	-	56.8	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	2,529.3	1,900.4	-24.9%	2,001.3	-20.9%
Leave	4,744.6	5,479.6	15.5%	5,876.7	23.9%
Total	7,274.0	7,380.0	-	7,878.0	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Sq. Ft.)	% Dif.
Cut	40.3	31.3	-22.5%	33.5	-16.9%
Leave	89.2	75.7	-15.1%	82.3	-7.8%
Total	129.6	107.0	-	115.8	-

2055 State Harvest Comparison					
	Scenario 0	Scenario 1		Scenario 2	
	Value Per Acre	Value Per Acre	% Dif.	Value Per Acre	% Dif.
Cut	$801.99	$730.92	-8.9%	$858.77	7.1%
Leave	$2,193.18	$1,965.89	-10.4%	$1,941.80	-11.5%
Total	$2,995.17	$2,696.81	-	$2,800.57	-
	Poletimber (Tons)	Poletimber (Tons)	% Dif.	Poletimber (Tons)	% Dif.
Cut	15.1	13.2	-12.5%	17.0	12.8%
Leave	47.2	37.1	-21.4%	41.2	-12.6%
Total	62.2	50.2	-	58.2	-
	Sawtimber (MBF)	Sawtimber (MBF)	% Dif.	Sawtimber (MBF)	% Dif.
Cut	1,766.0	1,738.4	-1.6%	1,840.8	4.2%
Leave	4,590.3	4,434.6	-3.4%	4,315.1	-6.0%
Total	6,356.3	6,172.9	-	6,155.9	-
	Basal Area (Sq. Ft.)	Basal Area (Sq. Ft.)	% Dif.	Basal Area (Sq. Ft.)	% Dif.
Cut	29.9	27.4	-8.1%	33.5	12.2%
Leave	90.6	75.8	-16.4%	82.3	-9.1%
Total	120.5	103.2	-	115.8	-

Exhibit 7

References

Exhibit 7 - References

Arbogast, C., Jr. (1957) Marking Guides for Northern Hardwoods Under the Selection System. Station Paper LS-56. St. Paul, MN USDA Forest Service, Lake States Forest Experiment Station. 20 p.

Crow, T.R., Jacobs, R.D., Oberg, R.R., Tubbs, C.H. Stocking and Structure for Maximum Growth in Sugar Maple Selection Stands. Research Paper NC-199. USDA Forest Service

Ek, A.R., & Brodie, J.D. (1975) A Preliminary Analysis of Short-rotation Aspen Management. *Canadian Journal of Forest Research* **5(2):** 245-258

Eyre, F.H., Zillgitt, W.M. (1953) Partial Cuttings in Northern Hardwoods of the Lake States – Twenty-Year Experimental Results. Technical Bulletin No. Lake States Forest Experiment Station, Forest Services

Franklin, J., Mitchell, F.R., & Palik, B. (2007) Natural Disturbance and Stand Development Principles for Ecological Forestry. U.S.D.A. Forest Service Gen. Tech. Rep. NRS-19. 44 pp.

Gilmore, D.W., & Palik, B.J. (2006) A Revised Manager's Handbook for Red Pine in the North Central Region. General Technical Report NC-264, St. Paul, MN: USDA Forest Service, North Central Research Station. 55 p.

Godman, R.M., Mendel, J.J. (1978) Economic Values for Growth and Grade Changes of Sugar Maple in the Lake States. *USDA Forest Service Research Paper NC-155,* North Central Forest Experiment Station. 16 p.

Hunter, M.L. (1990) Wildlife, Forests, and Forestry. Prentice-Hall, Inc., New Jersey. 370 pp.

Knapp, S.P., Webster, C.R., Kern, C.C., Can group selectin with legacy retention change compositional trajectories in conventionally managed hardwoods? *Forest Ecology and Management.* 488 (2009) 174-186.

Leak, W.B., Yamasaki, M., Holleran, R. (2014) Silvicultural Guide for Northern Hardwoods in the Northeast. General Technical Report NRS-132. Northern Research Station. 9 p.

McDill, M.E., Forest Resources Management (Unpublished). Cited in https://faculty.washington.edu/toths/SEFS540_SyllabusSP2015.pdf

Michigan State University (2014) Michigan State University Extension. http://msue.anr.msu.edu/news/re_thinking_northern_hardwood_management Accessed 15 July 2015

Exhibit 7 - References

Niese, J.N., Strong, T.F., & Erdmann, G.G. (1995) Forty Years of Alternative Management Practices in Second-Growth, Pole Size- Northern Hardwoods. II. Economic Evaluation. *Canadian Journal of Forest Research* **25:** 1180-1188

Orr, B.D., Reed, D.D., & Mroz, G.D. (1994) Three Basal Area Level Harvest Trials in Uneven-Aged Northern Hardwoods. *Northern Journal of Applied Forestry* **11(4):** 117-123

Perala, D.A., (1977) Manager's Handbook for Aspen in the North Central States. General Technical Report NC-36, St. Paul MN USDA Forest Service, North Central Experiment Station. 30 p.

Pond, N.C., Froese, R.E., & Nagel, L. M. (2014) Sustainability of the Selection System in Northern Hardwood Forests. *Forest Science* **60(2):** 374-381

Strong, T.F., (1995) Productivity of Even-Aged, Second-Growth Northern Hardwoods Brought Under Uneven-Aged Management. Unpublished.

Strong, T.F., Erdmann, G.G., & Niese, J.N., (1995) Forty Years of Alternative Management Practices in Second-Growth, Pole-Size Northern Hardwoods. I. Tree Quality Development. *Canadian Journal of Forest Research* **25:** 1183-1179

Walters, M.B., Roloff, G.J., Henry, C.R., Hartman, J.P., Donovan, M.J., Farinosi, E.J., Starking, M.D., (2020) Rethinking Northern Hardwood Forest Management Paradigms with Silvicultural Systems Research: Research- Management Partnerships Ensure Relevance and Application, *Journal of Forestry* **118(3)**: 260-274

Webster, C.E., Reed, D.D., Orr, B.D., Schmierer, J.M., & Pickens, J.B. (2009) Expected Rates of Value Growth for Individual Sugar Maple Crop Trees in the Great Lakes Region. *Northern Journal of Applied Forestry* **26(4):** 133-140

Exhibit 8

Qualifications

Qualifications of
Forrest M. Gibeault
Analysis and Technology
Solutions Director

Education: Michigan Technological University, 2005
Master of Forestry

University of Wisconsin – Green Bay, 2004
Bachelor of Science
Environmental Science, Physical Systems

Employment Period: May 2006 to present

Memberships and Certifications:
Association of Consulting Foresters (2019 and 2020 Wisconsin State Chapter Chair)
Society of American Foresters
Michigan Forest Products Council Board of Directors
Wisconsin Department of Natural Resources (DNR) Silviculture Guidance Team (Co-chair 2018-2020)
American Woodcock Society
Ruffed Grouse Society
Wisconsin DNR Cooperating Forester

Experience:
Forrest serves as our Analysis and Technology Solutions Director at Steigerwaldt. In this role, he leads a team that provides a wide range of forest resource and timber industry analysis services to private, industry, and public agency clients. Forrest works in tandem with Steigerwaldt appraisal, real estate, and forest management departments to support consulting efforts. He manages geospatial services at Steigerwaldt and works to connect clients with GIS solutions that meet their needs, with an eye to enhance and leverage data and processes.

He has extensive experience in designing and implementing varied timber and resource inventories including detailed data acquisition, analysis, reporting, and modeling using state-of-the art hardware and software applications. He oversees cradle-to-grave services on forest carbon projects including project design, inventory, GIS and analysis, and modeling. With a deep knowledge of Lake States silviculture, particularly northern hardwood management, Forrest specializes in forestland real estate due diligence and investment analysis. He has also worked on analysis, inventory, and modeling assignments on projects located across the country from the northeast through the Adirondacks and Appalachia regions, to the western states, including Alaska.

Presentations:
- **"Timber Inventory Processing and Valuation"** – January 2020 – Tree Inventory and Valuation: The Right Approach for the Right Results Workshop in Tomahawk, Wisconsin
- **"Mobile Technology and Forestry: Finding a Tool to Meet your Business Needs"** – April 2019 – 15th Annual Sustainable Forestry Conference in Florence County, Wisconsin
- **"Single-Tree Selection Order of Removal in Northern Hardwood Forests"** – October 2016 – Society of American Foresters National Convention in Madison, Wisconsin
- **"Wood Supply Chain Components Cost Analysis: A Comparison of Wisconsin and U.S. Regional Costs"** – March 2016 – Wisconsin Council on Forestry in Stevens Point, Wisconsin
- **"Lake States Forest Trends and Ruffed Grouse Cover"** – March 2016 – Ruffed Grouse Society, 2016 Minnesota State Workshop in Duluth, Minnesota
- **"Single Tree Selection Order-of-Removal Procedures in Northern Hardwood Forests and Rotation Lengths in Red Pine and Aspen Forests"** – March 2016 – Wisconsin Council on Forestry in Stevens Point, Wisconsin
- **"Lake States Timberland Markets: An Overview of Timberland and Timberland Markets and Trends in Michigan, Minnesota, and Wisconsin"** – September 2015 – Who Will Own the Forest seminar in Portland, Oregon

Qualifications of
Martha J. Sebold
Forest Analyst

Education:

University of Minnesota, 2020
Master of Science
Natural Resources Science and Management

Whitman College, 2014
Bachelor of Arts
Economics, Mathematics minor

Employment Period: April 2020 to present

Memberships and Certifications:
Society of American Foresters

Experience:
Martha supports the Analysis and Technology Solutions department on analysis, valuation, and inventory projects. She specializes in data manipulation, inventory analysis, and modeling. She has experience with survey design, technical report writing, and analytical software (e.g., R Statistical Software, Microsoft Excel).

Prior to her current position, Martha was a graduate research assistant with the Forest Resources Department at the University of Minnesota in St. Paul. She has experience in the financial services industry as an associate investment analyst for a family office in St. Paul, Minnesota. Martha holds a Bachelor of Arts from Whitman College in Economics and a Master of Science in Forestry and Natural Resource Management from the University of Minnesota.

Presentations:

- **"Identifying the Information and Assistance Needs of Private Family Foresters"** – March 2020 – Minnesota Department of Natural Resources Forestry Division Annual Meeting in Cloquet, Minnesota
- **"Identifying the Information and Assistance Needs of a Unique Segment of Minnesota's Private Forest Landowners: A Focus on Landowners Who Sought Professional Information from the Minnesota Department of Natural Resources"** – July 2019 – Small Scale Forestry Conference in Duluth, Minnesota

Qualifications of
Richard W. Congdon
Assistant Analyst/Real Estate Specialist

Education: University of Wisconsin–Stevens Point, 2009
Bachelor of Science, Forest Administration and Utilization; Forest Management
Business Administration Minor

Employment Period: January 2020 to present

Memberships and Certifications:
Society of American Foresters
Wisconsin DNR Cooperating Forester
Wisconsin Managed Forest Law Certified Plan Writer
Michigan Certified Commercial Pesticide Applicator

Experience:
Rich has been a part of the forest products and forest consulting industries since graduating from the University of Wisconsin–Stevens Point with degrees in Forest Administration and Utilization and Forest Management. He has dual responsibilities with the Analysis and Technology Solutions department and Appraisal department. He is responsible for assisting with stumpage valuations, various forest analytics, processing inventory and stumpage volumes and values, appraisal reporting, vacant land valuations, and property inspections.

Rich has extensive experience in land management, specializing in Lake States large-tract timberlands and data analysis. He has a broad skillset and range of knowledge including client relations, contract negotiation and administration, data quality assurance/quality control, design and implementation of timber harvest and inventory programs, short- and long-term harvest planning, timber inventory data processing and tracking, assisting with land acquisitions and dispositions, third-party audits, supervising various levels of personnel, timber sale layout and preparation, timber marking, timber inventory, forest road layout, design, and building, urban hazard tree removal, and heavy equipment operation. He has also represented large landowners on forest management committees.

In his free time, Rich enjoys spending time at his family's cabin in the Upper Peninsula of Michigan.