Growth, lumber yields, and financial maturity of archetype, isolated eastern white pine crop trees

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Retaining isolated white pine trees as reserves at the time of the final harvest of other shade-tolerant conifers (mainly red spruce, balsam fir, and eastern hemlock) in the Acadian forest results in significant growth response and can be financially lucrative, especially if the reserve trees are relatively small (under 12 inches dbh) and have vigorous crowns when released. Assuming such trees have a knotty core defined by their diameters at release and subsequently form clear wood outside this core, on average, trees reached a peak net present value 52 years after the final harvest of the shade-tolerant species, with significant variation in both directions depending on size at release and post-harvest growth response.

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Project Summary

The ability of eastern white pine (*Pinus strobus* L.) to persist as emergent trees makes this species well suited to silvicultural systems in which they are retained as isolated reserves after a regeneration harvest. While such systems are implemented throughout the Acadian spruce-fir region of Maine, little is known about the growth response and financial performance of eastern white pine following complete release from competition. We measured bole and crown dimensions of 77 sample trees from 8 sites throughout the Acadian spruce-fir region; increment cores were extracted at breast height, as well as from the top of the valuable first 16 foot log. A subsample of 9 trees climbed to measure basal diameter and vertical location of each branch to develop allometric leaf area equations and to examine influence of site productivity and age on growth efficiency. Leaf area-volume increment relationships were modeled with a nonlinear power function with a random effect for site, and employed to forecast future growth. A sawmill simulator was used to estimate post-release standing tree values and financial analysis was performed to assess performance of completely released trees for an unpruned and a hypothetical pruned scenario.

Volume growth was examined prior to and following release, and overall response to release was favorable. Unpruned trees, on average, peaked in net present value 52 years post-release. Pruned trees declined in net present value following release, due to high initial values. The net benefit of pruning reached its maximum 30 years after pruning, and stayed positive for 101 years, suggesting that pruning is a viable practice for eastern white pine that will be released and retained as reserve trees. The retention of eastern white pine reserve trees appears to be both biologically and financially sound, but forest managers should be careful to select vigorous younger trees as reserves to maximize financial performance.
Background and Justification

- White pine is potentially a high-value species, owing to a large market premium for clear lumber.
- Most “woods-run” pine is not of high value, however, owing to:
  - Poor natural branch shedding
  - Weevil (*Pissodes strobi*) deformation
- Financial performance thus depends heavily on management designed to develop high-quality butt logs.
Background and Justification

- In old-field monocultures, value depends on early pruning.
- In mixed-species, stratified stands, competition from tolerant conifers often promotes rapid branch shedding and minimizes weevil attack, thereby creating high-quality logs naturally without pruning.
Background and Justification

- White pine responds well to release, and unlike its common tolerant associates, remains windfirm
- Emergent pine may have a positive effect on stand productivity when grown in association with shade-tolerant conifers
Background and Justification

- Many spruce budworm-era (1975-90) salvage harvests retained immature white pine reserve trees

- Overall goal:
  - Examine the growth of isolated reserve white pines
  - Determine financial maturity
Objectives (ecological)

- Examine the growth response of completely released mature pine trees
- Model relationships between tree characteristics and projected leaf area (PLA)
- Model relationships between PLA and volume increment (VINC)
- Examine growth efficiency (GE) of large trees grown in isolation
Objectives (financial)

- Assess the post-release financial performance of eastern white pine reserve trees that were previously pruned or unpruned
- Assess the financial viability of pruning white pine that will at some point be completely released and retained as a reserve tree
Study Sites

- 8 stands throughout the spruce-fir region of Maine
- Each stand was two-aged
  - Mixed conifer regeneration stratum
  - Sparse canopy of heavily released pine
- Regeneration harvests occurred between 1980 and 1994
Methods: Data Collection

- Reserve tree survey
- Stratified sample of suitable trees (n=77)
- Measured diameters at breast height and top of first 16 ft. log, tree height, height to live crown base, and crown radii in 6 directions
- Extracted two increment cores at breast height, and one at the top of the first log
Data Collection (continued)

- A subset of the sampled trees were climbed (n=9), and every branch was measured for basal diameter and vertical location.
- Three branches in random azimuth direction and varying vertical positions were removed for detailed analysis.
Growth Response Analysis

- Tree ring data was used to reconstruct diameters
- Site index equations were used to estimate previous heights
- Honer’s equation was used to estimate pre- and post-release volume increment, as well as average volume increment over the last five years
Leaf Area Analysis

- Branch summation method
- ~100 field frozen needles from each sample branch were scanned to measure PLA, then oven dried and massed to determine specific leaf area (SLA)
- Remaining foliage dried and massed
- SLA was then used to estimate branch leaf area (BLA)
Leaf Area Analysis

- Relationship between BLA and branch diameter (BD) modeled with:

\[ e^{BLA} = \beta_0 + \beta_1 * e^{BD} \]

- Predictions made for all measured branches
- BLA was back-transformed and corrected for log bias\(^4\), then BLA was summed for each tree
Leaf Area Prediction Equations

- PLA was then modeled using various tree characteristics

<table>
<thead>
<tr>
<th>Model</th>
<th>Equation</th>
<th>AIC</th>
<th>BIC</th>
<th>RMSE</th>
<th>$R^2$</th>
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</thead>
<tbody>
<tr>
<td>SACL</td>
<td>$PLA = \beta_0 \times SBA^{\beta_1} \times CL^{\beta_2}$</td>
<td>110.76</td>
<td>111.55</td>
<td>72.97</td>
<td>0.77</td>
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<tr>
<td>CLDH</td>
<td>$PLA = \beta_0 \times CL^{\beta_1} \times e^{(\beta_2 \times \frac{DBH}{HT})}$</td>
<td>110.53</td>
<td>111.32</td>
<td>72.04</td>
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<td>mLCR</td>
<td>$PLA = \beta_0 \times DBH^{\beta_1} \times mLCR^{\beta_2}$</td>
<td>108.13</td>
<td>108.93</td>
<td>63.07</td>
<td>0.83</td>
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<tr>
<td>DCL</td>
<td>$PLA = \beta_0 \times DBH^{\beta_1} \times CL^{\beta_2}$</td>
<td>105.88</td>
<td>106.67</td>
<td>55.65</td>
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<tr>
<td>DCPA</td>
<td>$PLA = \beta_0 \times DBH^{\beta_1} \times CPA^{\beta_2}$</td>
<td>103.69</td>
<td>104.48</td>
<td>49.27</td>
<td>0.90</td>
</tr>
</tbody>
</table>

- SBA- sapwood basal area, CL- crown length, HT- tree height, mLCR- modified live crown ratio\(^5\), CPA- crown projection area
Volume Increment Analysis

- Mixed-effects nonlinear modeling with a random effect for site was used to fit:

\[ VINC = \beta_0 PLA^{\beta_1 + b_1} \]

- To assess the influence of age on GE, a second VINC model was fit:

\[ VINC = \beta_0 PLA^{\beta_1} AGE^{\beta_2} \]
Sawmill Simulation

- The CantSim\textsuperscript{[8]} sawmill simulator was used to populate a dataset (n=121) of hypothetical butt logs
  - 5 cm classes
  - Scaling end diameters 30 – 100 cm
  - Knotty core diameters 15 – 70 cm
- Value recovery was maximized using a cant sawing pattern
- When possible, cant width was set to minimum size that would encompass knotty core
Sawmill Simulation

- Products were graded as D select & better if no more than 33% of the best face was within knotty core
- Other products were graded as standard
Value Modeling

- Butt log values were modeled using the simulation results with the two-part polynomial model:

\[
V_{\text{pred}} = \begin{cases} 
(DIA - KC) > 10, & \beta_0 + \beta_1 DIA^2 + \beta_2 KC^2 + \beta_3 DIA + \beta_4 KC \\
(DIA - KC) \leq 10, & \beta_5 + \beta_6 DIA^2 + \beta_7 DIA + \beta_8 KC
\end{cases}
\]

- Butt log volume in board feet was predicted using:

\[
BDFT_{\text{pred}} = \beta_0 + \beta_1 DIA^2 + \beta_2 KC^2 + \beta_3 DIA + \beta_4 KC
\]

- Two scenarios: pruned and unpruned
Value Modeling

- A corrected butt log value was then estimated with:

\[ V_{corr} = V_{pred} \times \left( \frac{BDFT_{intl}}{BDFT_{pred}} \right) \]

- This was needed to account for taper
Value Modeling

- Lumber above the first log was estimated by subtracting estimated butt log volume from whole tree volume
- All lumber above butt log was valued as standard grade
- $363 per Mbf was subtracted from total value to account for costs associated with harvesting, trucking, and milling
Financial Analysis

- Net present value (NPV) at the time of release was calculated for both pruned and unpruned scenarios
- For this analysis, pruning was considered a sunk cost
- To analyze financial viability of pruning, NPV of the increase in value due to pruning, minus pruning costs, was calculated
Growth was significantly greater after release on all but one site.
Tree leaf area was highly related to dbh and crown projection area.
Volume increment was strongly related to projected leaf area, and varied among sites, likely owing to age differences.

\[ VINC = \beta_0 PLA^{\beta_1 + b_1} \]

\[ VINC = \beta_0 PLA^{\beta_1} AGE^{b_1} \]
Growth efficiency varied among sites, and was similar to that of stand-grown trees from other studies.
Growth Efficiency was unrelated to site index, but negatively related to age.
The butt log comprised 45-65% of the entire tree value.
At 4% compound interest, net present value of the average unpruned tree peaks about 50 years after release, at nearly double the value at release.
If pruned at 6 inches dbh, net present value of the average tree is maximum at the time of release, but continues to exceed that of a comparable unpruned tree for at least 50 years.
Key Findings / Management Implications

- Unrestricted crown expansion in completely released trees allows for sustained growth response
- Silviculturally beneficial
  - Seed source
  - Protection
- Reserve tree density: ~30 trees ha\(^{-1}\)
- Select vigorous trees, release early
Key Findings / Management Implications

- Unpruned trees are generally not financially mature at the end of a typical softwood rotation, pruned trees generally are.
- If pruned trees are retained as reserves, the net benefit of pruning is fairly persistent.
- Pruning could be combined with a reserve tree system to maximize profits & provide silvicultural benefits.


List of Products

- **Publications / Manuscripts**

- **Conference presentations and Posters**

- **Master’s thesis**