## APPENDICES

<table>
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<th>Page</th>
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<tbody>
<tr>
<td>2.</td>
<td>Accomplishments 2013, Greg Ettl,  Appendix A</td>
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<td>18.</td>
<td>Field Measurements SMC Field Crew,  Appendix B</td>
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<td>21.</td>
<td>Sun setting protocol Eini Lowell,  Appendix C</td>
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### Technical Reports

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<tr>
<td>21.</td>
<td>Wood Quality TAC Report-Eini Lowell, Wood Quality Project Leader, New CAFS proposal to augment Type V wood quality sampling,  Appendix D</td>
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<td>Nutrition TAC Report-Rob Harrison, Nutrition Project Leader,  Appendix E</td>
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<td>Kim Littke, Comparison of fertilizer response in the RFNRP and Type V paired-tree installations,  Appendix F</td>
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<td>Stephani Michelsen-Correa, Completed project 15N,  Appendix G</td>
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<td>Jason James, Deep soils pits, additional plots, members interested,  Appendix H</td>
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<td>Marcella Leite De Campos Menegale, Fall River / New LTSP study,  Appendix I</td>
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<td>Silviculture TAC Report –Eric Turnblom, Silviculture Project Leader,  Appendix J</td>
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<td>Connie Harrington, (PNW Research Station), Winter Temperature Matters!” (aka Winter dormancy requirements for Pacific Northwest tree species),  Appendix K</td>
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<td>145.</td>
<td>Doug Maguire, (CIPS), Response of foliage mass to N fertilization on SMC Type I installations: Preliminary results, (Maguire, Mainwaring, Bluhm, Harrison, Turnblom),  Appendix L</td>
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<td>Director’s Introductory Preface: SMC budget and research, discussion on RFP proposals, hiring needs,  Appendix A</td>
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SMC Spring Meeting

May 23, 2014
Gregory J. Ettl
Budget

• Carried over $54,229 (~8% of budget)
• 10% increase in dues increases revenue, but...
  – ODF dues won’t increase until 2015
  – WADNR back to 100% but no 10% increase (2015?)
  – With increased expenses anticipated $95K ($65K?) available for 2014
• We have opportunity to expand research
SMC Updates since 9/2013

• The measurements are nearly completed for 2013-2014 measuring season
• Data will likely be available for distribution July 1 but maybe as late as August 1 (recall ½ time database manager)
• We initiated funding for PCT analysis in fall 2013 (underway)
• Joint TAC meeting in November 2013
  – Designed analyses to use Regional Forest Nutrition Research Project plots with Kim Littke’s predictive models
  – Installation Review Committee: protocol for Type I sunsetting
• Policy Advisory Committee: briefed on CAFS and Research opportunities
• Kim Littke working as a Post-doctoral Research Associate
SMC Recent Updates (Cont.)

- Wood quality TAC: proposal to augment wood quality paired tree study (Eini Lowell TAC report)
- Update on fate of labeled $^{15}$N study (NSF/CAFS)
- Deep soil carbon and forest production
- Update on Silvicultural Manipulations Consequences at Stand Management Cooperative Sites
- Progress on genetic gain trial (Type IV) study
Measurement Highlights

- Type I’s
  - 8 Full measurements
  - 19 RD checks
  - 5 plots marked for thinning

- Type III’s
  - 8 Full Measurements
  - 1 plot measured and marked for thinning

- Type IV’s
  - 3 Full Measurements

- Type V’s
  - 34 Full Measurements
  - 73 Weather stations data collected and maintained
  - 18 Weather stations dismantled
Center for Advanced Forestry Systems

- (CAFS) Phase II proposal submitted March
  - $65,000/y, down $5k from Phase I
  - You are all members (you can vote)
  - Indirect cost rate may be temporarily lowered

- Burkhart, Weiskittel, Turnblom: NSF proposal: Understanding and Modeling Competition Effects on Tree Growth and Stand Development Across Varying Forest Types and Management Intensities

- Annual meeting May 19-21, Coeur D’Alene
Growth and yield modeling

Wood quality

Paired tree fertilizer study

Fertilizer predicted response

SMC Spacing Trials

SMC Fertilization Trials

CAFS Phase I

Analysis of Genetic Gain and Wood quality, w/ Oregon St.

Competition effects on growth and stand development

$^{15}$N to trace N fertilizer Efficiency

Predictive models to guide fertilizer application

CAFS Phase II
## Morning Schedule

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<td>✓ Plot based paired tree studies&lt;br&gt;✓ Completed project 15N&lt;br&gt;✓ Deep soils pits, additional plots, members interested&lt;br&gt;✓ Student updates</td>
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<td>Silviculture TAC Report –Eric Turnblom, Silviculture Project Leader</td>
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<td>✓ (SMC)^2 report&lt;br&gt;✓ GGTIV update (five installations)&lt;br&gt;✓ Student updates</td>
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<td>Break</td>
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<td>Doug Maguire, (CHIPS, Oregon State University), Response of foliage mass to N fertilization on SMC Type I installations: Preliminary results, (Maguire, Mainwaring, Bluhm, Harrison, Turnblom)</td>
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<td>Kim Littke, (SEFS Post Doc)</td>
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<td>3) 2014 Plans</td>
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<td>✓ Working toward SMC products</td>
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<td>✓ Contracting out field measurements</td>
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<td>✓ We need to review the database and compile a full and then a “cleaned database”</td>
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<td>- Set location, date, structure</td>
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<td>- Any interests in a half day hands-on workshop-using the Type I, II, III models web interface or database usage? Other?</td>
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<td>✓ Separate TAC Meetings for Nutrition and Silviculture June/July 2014</td>
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Taking the next steps

SMC RESEARCH PLANS
CAFS and Indirect Costs

• SMC Indirect costs are 26%
• NSF/CAFS Phase II would only allow us to charge 10% indirect
  – We don’t know if we will get the funds
• This doesn’t change available funds
  – Accounting difficulties (would we give a refund?)
  – Could we keep the funds for more research?
Approach to Expanding Research

• We can use the request for proposal process we have established?

• Do we want to start another installation or expand the Paired-tree studies?
  – In 3 years the existing paired tree study will be done

• Do we want to limit new installations so we will have increased resources for analyses.
Expanding Research

• Expand research
  – Hire an analyst?
  – Wood quality?
  – Expand paired tree to paired plots?
  – A pool to ask for other proposals?
• Develop transition options for measurements
  – Test contract work
  – Train a 3rd person to measure
Outside Crew Cost Test Run

• Outside Crew Measurement Costs (e.g. from 2013 measurement stands)
  – $2 to $6/tree
  – Silvercreek ($2850-$8550)
  – Prather Creek ($1210-$3630)
  – Boxcar ($5250-$15,570)
  – Total Contract Crew Cost Estimate ($9310- $27,750)
    • $19,650 best guess at what our crew would cost if we did it
  – SMC Check Crew Estimate: $6640 (10% check)
  – Estimated Funds Required: $26,290
An example plan for $65,000

- $15,000 to test contract crew approach to measuring plots
- $5000-$15,000 for analyst
- $25,000-$35,000 for sunsetting measurements? More Type V?
- Or priority to contract “data cleaning”?
Next Steps

• Schedule TAC meetings (June-July)
• Installation Review Committee Meeting
• Fall meeting date? 9/9 to 9/11?
## 2013-2014 SMC Field Season
### Field Measurements

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## 2013-2014 SMC Field Season
### Field Measurements

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### 2013-2014 SMC Field Season
#### Field Measurements

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<td>874</td>
<td>Morgan Creek</td>
<td>Full Measurement</td>
<td>9/24/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>875</td>
<td>Old River Road</td>
<td>Full Measurement</td>
<td>11/5/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>876</td>
<td>Tilton River East</td>
<td>Full Measurement</td>
<td>10/10/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>877</td>
<td>Wood Road</td>
<td>Full Measurement</td>
<td>1/8/2012</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>878</td>
<td>Les Smith</td>
<td>Full Measurement</td>
<td>1/8/2014</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>879</td>
<td>Black Rock 2</td>
<td>Full Measurement</td>
<td>12/5/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>880</td>
<td>Mitchell Creek</td>
<td>Full Measurement</td>
<td>12/9/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>881</td>
<td>East Humptulips 2</td>
<td>Full Measurement</td>
<td>10/24/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
<tr>
<td>882</td>
<td>Upper Rock Creek</td>
<td>Full Measurement</td>
<td>9/24/2013</td>
<td>Finished</td>
<td>Download weather data</td>
</tr>
</tbody>
</table>
SMC Spring Meeting
April 23, 2013
Vancouver, WA
Sunsetting of Type 1 Installations

Now you see it........

Now you don’t........
Sunsetting Type I Installations

A measurement protocol
The Effects of Soil Parent Material and Fertilization Treatment on the Wood Quality of Douglas-fir in the Pacific Northwest

- Luyi Li
- Faculty Advisor: Dr. Eric C. Turnblom
- School of Environmental and Forest Sciences, College of the Environment
- University of Washington, Seattle, WA
Examine wood properties:
  • acoustic velocity
  • ring width
  • earlywood/latewood proportion
  • wood density

In response to:
  • soil parent material
  • fertilization treatments
<table>
<thead>
<tr>
<th>Site</th>
<th>Type</th>
<th>SPM</th>
<th>Elevation (ft)</th>
<th>Slope (%)</th>
<th>TPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Home</td>
<td>Sedimentary &amp; Igneous</td>
<td>1450</td>
<td>15</td>
<td>390</td>
<td></td>
</tr>
<tr>
<td>Vernonia</td>
<td>Sedimentary</td>
<td>800</td>
<td>5</td>
<td>290</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>QMD (in)</th>
<th>Ht (ft)</th>
<th>CR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Home</td>
<td>12.8</td>
<td>92.9</td>
<td>51</td>
</tr>
<tr>
<td>Vernonia</td>
<td>12.6</td>
<td>90.5</td>
<td>50.5</td>
</tr>
</tbody>
</table>
- Base of live crown (LCB)
- Top of first 16 ft log (TF16)
- Breast height (BH)
- Stump height
Disk and specimens
Specific Gravity

SPM_S Treated Period SG

SPM_SI Treated Period SG

= control

= fertilized
• Nitrogen Fertilization Treatment
  – Mixture - upon stiffness (Hitman)
  – Negative - on specific gravity
  – Positive - on growth rate

• Soil Parent Material
  – Unclear in stiffness and specific gravity
  – Productivity: Sedimentary & Igneous > Sedimentary
Wood Property Assessment of Trees from mid-rotation Coastal U.S. Douglas-fir Plantations on sites with varying Soil Parent Material that have undergone Fertilization using a paired-tree approach
To test for effects of fertilization with nitrogen and soil parent material, both singly and in combination on:

(1) tree and log acoustic velocity, ring width, latewood/earlywood proportion, and latewood and earlywood density

(2) to quantify those significant treatment effects on the key wood quality attributes of density and stiffness, as derived from specific gravity and acoustic velocity

(3) to examine potential effects of soil type and other soil properties on these attributes.
Data collection, analysis and modeling fit within the framework of a 2-year program for a Master of Science degree.

- Year 1 (2015): data from four SMC sites (40 trees) collected and processed, preliminary analysis completed and reported at 2015 CAFS meeting.

- Year 2 (2016): data from two SMC sites (20 trees) collected and processed, penultimate analysis completed and reported at 2016 CAFS meeting with final report and MS Thesis completed by end of summer quarter 2016.
• Leverages ongoing research and provides additional information that aids CAFS members in making land management decisions

• Understanding the effects of silvicultural activities, particularly fertilization, and how the effects of different soil parent materials play into quality attributes is key to obtaining wood with desired properties

• Informs decision making in understanding the impacts for merchandising stands along the value chain used to match trees with different/desirable attributes to end product needs


Northwest Advanced Renewables Alliance

SMC NARA members:
  - Doug Maguire and Greg Johnson, Feedstock
  - Rob Harrison, Feedstock, Sustainability Measurement
  - Eini Lowell, Outreach Team
SMC Nutrition Report

Spring, 2014 meeting,
Marshall Community Center, Vancouver, WA

http://www.forestsoils.org/publications

(note: page advance arrow at bottom right hand corner)
1) **Paired-Tree & Paired/Plot studies – Kim Littke will present**

2) 15N – Stephani Michelsen-Correa (Ph.D.)

3) Deep soils – Jason James (M.S.)

4) Fall River/ new LTSP studies (Marcella Menegale)

5) Student/funding updates
SMC Type V
paired-tree study sites

Soil origin:
Red = glacial
Blue = volcanic
Green = sedimentary
SMC Type V
paired-tree study sites
Soil origin:
Red = glacial
Blue = volcanic
Green = sedimentary
SMC Nutrition Report,
Spring, 2014
Rob Harrison

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Paired Tree Study and 15N

• Objectives:
  – Quantify amount of fertilizer N distributed to each ecosystem component and compare among four different types of N fertilizers (3 controlled release) over a 1 year period
  – Determine the effectiveness of three controlled-release urea fertilizers in minimizing volatilization loss

Sites selected from subset of SMC Paired Tree Study
Paired Tree Study and 15N

Objectives:
– Quantify amount of fertilizer N distributed to each ecosystem component and compare among four different types of N fertilizers (3 controlled release) over a 1 year period
– Determine the effectiveness of three controlled-release urea fertilizers in minimizing volatilization loss

Sites selected from subset of SMC Paired Tree Study
**MILESTONES:**

1) Establishment of 10 installations in PNW, 9 in the Midwest and 21 in the South completed over a two-year period.  
2) Completed of sampling for installations established in 2011.  
3) Beginning sampling of installations installed in 2012.  
4) Purchase of Isotope Ratio Mass Spectrophotometer at Virginia Tech for $^{15}$N analysis.  
5) Sample analysis of tree, understory vegetation, forest floor and soil samples for $^{15}$N is in progress.  
6) Graduate student theses and publications are being prepared.
EXPECTED DELIVERABLES:

- The project will provide the members of CAFS with data on the N uptake efficiency following fertilization with conventional urea and how that can be improved if enhanced efficiency fertilizers are used instead of urea. The study will also provide information on the environmental fate of the applied urea, including losses from volatilization, which is needed to demonstrate that forest fertilization is an environmentally sound forestry practice.

1. Nitrogen uptake efficiency
2. Changes in nitrogen uptake efficiency following fertilization with enhanced efficiency fertilizers Data will allow CAFS members to determine whether the use of enhanced efficiency fertilizers are a viable economic alternative to traditional fertilization techniques with untreated urea.
3. The amount of nitrogen lost to volatilization following fertilization with urea and enhanced efficiency fertilizers
4. The amount of nitrogen lost below the rooting zone via leaching will be accounted for. This will aid CAFS members in determining the environmental fate of applied fertilizer and the potential for off-site environmental movement of nitrogen following fertilization.
SMC Nutrition Report, Spring, 2014
Rob Harrison

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Objectives:

Quantify soil C and N to depth in as many Type V sites as possible, and use this as a tool, similar to what Steinbrenner did earlier, to predict impact on productivity and potential for response to treatments, including N fertilization.
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SMC Nutrition Report,  
Spring, 2014 
Rob Harrison 

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Bole-only harvest

Whole-tree + ff
1) Paired-Tree & Paired/Plot studies – Kim Littke will present
2) 15N – Stephani Michelsen-Correa
3) Deep soils – Jason James
4) Fall River/ new LTSP studies (Marcella Menegale)
5) Student/funding updates
Funding, new initiatives

- $20K NCASI additional through 2014 ($640K total)
- Approx $300K/y equiv. TA/Gessel fellowships
- Partial salary buyback by UW Extension for Rob 3 months per year, about $30K to spend on SMC work
- Funding of $195,000 for 15N work finishing
- Bioenergy grant from USDA, $321K to SMC (2011-2015), also funding to OSU and Weyerhaeuser for biomass work, new Springfield OR site located and work is underway
People/Graduate Students

- Three graduate students added 2012 continuing 2014
  - Jason James (MS, Spring 2014), continuing PhD
  - Stephani Michelsen-Correa (PhD)
  - Marcella Menegale (PhD)
- Three started Fall 2013
  - Christiana Dietzgen (PhD)
  - Erin Burke (MS)
  - Matt Norton (MS)
- Kim Littke postdoc.
- Tom Terry consulting as he can
- all salaries currently funded with external funding
COMPARISON OF FERTILIZER RESPONSE IN THE RFNRP AND TYPE V PAIRED-TREE INSTALLATIONS

Kim Littke
Post-doc
University of Washington
Introduction

• The Regional Forest Nutrition Research Project (RFNRP) was the first widespread plot-based fertilization study in the coastal Pacific Northwest
  • 1969-1980

• The SMC Type I installations were installed as plots on younger plantation stands that were also thinned
  • 1987-1992

• The Paired-tree study differed from previous studies because fertilization was centered around a plot-tree
  • 2008-2011
RFNRP and Paired-tree Installations

- 92 RFNRP installations
  - Plantation and natural stands
  - 3-47 breast height age
- 9 Type I installations
  - Thinned to half of the initial stands per acre
  - 3-9 breast height age
- 71 Paired-tree installations
  - 7-27 breast height age
Histograms of Site Conditions
Methods

- 4-year basal area (BA) plot growth and percent response was the difference between fertilized and control plot BA growth.
- 4-year BA growth per tree was determined for the largest diameter trees.
  - Equivalent to 200 trees per acre for each plot.
  - Tree growth and percent response to fertilization were determined for each installation.
- Boosted regression tree models were used in R.
  - Paired-tree BA percent response.
  - RFNRP tree and plot growth and percent response.
- Tree and plot responsiveness was determined using a Chi-square test.
  - Yes/No response using the confidence interval from a paired t-test.
- Significant differences in response were assessed using an independent-samples t-test.
### Relationship between Tree and Plot Responsiveness

- Tree and plot responsiveness within the RFNRP and Type I installations
- 44% of the installations responded in both tree and plot response
- A quarter of the installations did not respond at all
- 31% of the installations disagreed in tree or plot response

<table>
<thead>
<tr>
<th>Tree Responsiveness</th>
<th>Plot Responsiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Response</td>
<td>Response</td>
</tr>
<tr>
<td>26%</td>
<td>14%</td>
</tr>
<tr>
<td>17%</td>
<td>44%</td>
</tr>
</tbody>
</table>
## Paired-tree Basal Area Response BRT Models

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Mapped Model</th>
<th>Combined Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Water Supply</td>
<td>&lt; 6 in</td>
<td>&lt; 0.025 ft²/yr&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Slope</td>
<td>&gt; 25%</td>
<td>Forest Floor C:N Ratio &gt; 40</td>
</tr>
<tr>
<td>April Temperature</td>
<td>&lt; 47.3 °F</td>
<td>February Precipitation &gt; 9 in</td>
</tr>
<tr>
<td>Latitude</td>
<td>&lt; 46°</td>
<td>April Temperature &lt; 48.2 °F</td>
</tr>
<tr>
<td>February Precipitation</td>
<td>&gt; 9 in</td>
<td>Slope &gt; 25%</td>
</tr>
<tr>
<td>August Precipitation</td>
<td>&lt; 1.3 in</td>
<td>August Precipitation &lt; 1.4 in</td>
</tr>
</tbody>
</table>

RI: Relative Importance
## Predicting Responsiveness

<table>
<thead>
<tr>
<th>Mapped Model</th>
<th>Tree Responsiveness (#)</th>
<th>Plot Responsiveness (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Response</td>
<td>Response</td>
</tr>
<tr>
<td>Predicted No Response</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Predicted Response</td>
<td>38%</td>
<td>62%</td>
</tr>
<tr>
<td>Combined Model</td>
<td>No Response</td>
<td>Response</td>
</tr>
<tr>
<td>Predicted No Response</td>
<td>53%</td>
<td>47%</td>
</tr>
<tr>
<td>Predicted Response</td>
<td>27%</td>
<td>73%</td>
</tr>
</tbody>
</table>

- The combined model was able to predict RFNRP tree responsiveness (yes/no), but not plot responsiveness.
- The mapped BRT could not predict responsiveness of tree or plot data.
## Predicting Response

<table>
<thead>
<tr>
<th>Mapped Model</th>
<th>4-yr Tree Growth Response (ft²)</th>
<th>SD</th>
<th>4-yr Tree Percent Response (%)</th>
<th>SD</th>
<th>4-yr Plot Growth Response (ft² ac⁻¹)</th>
<th>SD</th>
<th>4-yr Plot Percent Response (%)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted No Response</td>
<td>0.017</td>
<td>0.025</td>
<td>27</td>
<td>41</td>
<td>4.6</td>
<td>8.0</td>
<td>32</td>
<td>55</td>
</tr>
<tr>
<td>Predicted Response</td>
<td>0.022</td>
<td>0.022</td>
<td>25</td>
<td>30</td>
<td>5.0</td>
<td>9.3</td>
<td>39</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Combined Model</th>
<th>4-yr Tree Growth Response (ft²)</th>
<th>SD</th>
<th>4-yr Tree Percent Response (%)</th>
<th>SD</th>
<th>4-yr Plot Growth Response (ft² ac⁻¹)</th>
<th>SD</th>
<th>4-yr Plot Percent Response (%)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted No Response</td>
<td>0.012 a</td>
<td>0.025</td>
<td>19 a</td>
<td>41</td>
<td>2.8 a</td>
<td>7.5</td>
<td>24</td>
<td>61</td>
</tr>
<tr>
<td>Predicted Response</td>
<td>0.025 b</td>
<td>0.021</td>
<td>34 b</td>
<td>34</td>
<td>6.6 b</td>
<td>8.7</td>
<td>43</td>
<td>71</td>
</tr>
</tbody>
</table>

- The combined model was able to find a significant difference in response for tree and plot growth and tree percent response.
- The mapped model was not able to determine tree or plot response.
RFNRP BRT Models

- BRT models were formed from the RFNRP and Type I data only to compare to the Paired-tree models.

- Shared predictors between the models were colder spring temperatures and low annual basal area growth.

- Many of the predictors in these models are out of the range of installations in the Paired-tree study.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Predictor</th>
<th>Tree Models Range</th>
<th>RI</th>
<th>Predictor</th>
<th>Plot Models Range</th>
<th>RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>May Precipitation</td>
<td>&gt; 4.5 in</td>
<td>32%</td>
<td></td>
<td>Douglas-fir Stand Density</td>
<td>&gt; 1,000 trees per acre</td>
<td>27%</td>
</tr>
<tr>
<td>All Species Stand Density</td>
<td>&gt; 1,250 trees per acre</td>
<td>28%</td>
<td></td>
<td>Basal Area Mean Annual Increment</td>
<td>&lt;0.015 ft²/year</td>
<td>18%</td>
</tr>
<tr>
<td>Site Index</td>
<td>&lt; 110 ft at 50 years</td>
<td>16%</td>
<td></td>
<td>June Precipitation</td>
<td>&gt; 3.5 in</td>
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</tr>
<tr>
<td>Basal Area</td>
<td>&lt; 175 ft²/acre</td>
<td>11%</td>
<td></td>
<td>Relative Density</td>
<td>&lt; 70</td>
<td>15%</td>
</tr>
<tr>
<td>December Temperature</td>
<td>&gt; 40 F</td>
<td>7%</td>
<td></td>
<td>Site Index</td>
<td>&lt; 125 ft at 50 years</td>
<td>11%</td>
</tr>
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<td></td>
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</tr>
<tr>
<td>Breast Height Age</td>
<td>&gt; 38 years</td>
<td>3%</td>
<td></td>
<td>Relative Density</td>
<td>&lt; 70</td>
<td>12%</td>
</tr>
<tr>
<td>Clay Content</td>
<td>&lt; 10% or &gt; 30%</td>
<td>3%</td>
<td></td>
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</table>
Comparing Response Predictors

• The improvement in the combined model was due to the addition of the BA mean annual increment predictor
  • No strong correlations, but a negative trend with response
• Forest floor C:N ratio was not indicative of RFNRP BA response
  • Has been linked to RFNRP volume response in the past
Using RFNRP Models to Predict Paired-tree Response

- The RFNRP plot models were able to separate 2-year BA response in the Paired-tree study
  - RFNRP tree models predicted no response in almost all models
- Paired-tree percent volume response was correlated with previous response models from the RFNRP study
  - R²=0.26 - Edmonds and Hsiang 1987
  - R²=0.24 - Miller et al. 1989
  - Forest floor and soil C:N ratios, slope, site index, age, relative density
Comparing Tree Growth Response

- Still waiting for 4-year response from 11 Paired-tree installations
- Responding installations in the RFNRP study had slightly greater response
- On average, the RFNRP installations responded much more than the Paired-tree installations
Conclusions

• The combined BRT model was able to predict tree responsiveness and response
  • Also found differences in plot response
• Low BA mean annual increment was a predictor in both studies
  • Strongly affected by summer soil water (and nitrogen) availability through earlywood growth
• Colder spring temperatures were also a shared predictor
  • Inhibits soil fauna and microbe activity in the summer
  • Decreases N cycling, which is then boosted by fertilization
• Stand variables differ significantly between the studies
  • Affects the use of stand variables for predicting fertilizer response
Questions going forward

• Are there any other angles that should be investigated between the RFNRP, Type Is, and Paired-tree studies?

• Because of older stand characteristics, does fertilizer response in the RFNRP studies reflect fertilizer response in current plantations?

• Are the cooperators interested in new fixed-area plot fertilization studies on current plantations?
Paired Tree Study and 15N
Stephani Michelsen-Correa, PhD

Spring, 2014 meeting,
Marshall Community Center,
Vancouver, WA
Paired Tree Study and 15N

- Objectives:
  - Quantify amount of fertilizer N distributed to each ecosystem component and compare among four different types of N fertilizers (3 controlled release) over a 1 year period
  - Determine the effectiveness of three controlled-release urea fertilizers in minimizing volatilization loss

Sites selected from subset of SMC Paired Tree Study
Paired Tree Study and 15N

• Objectives:
  – Quantify amount of fertilizer N distributed to each ecosystem component and compare among four different types of N fertilizers (3 controlled release) over a 1 year period
  – Determine the effectiveness of three controlled-release urea fertilizers in minimizing volatilization loss

Sites selected from subset of SMC Paired Tree Study
• **MILESTONES:**

• 1) Establishment of 10 installations in PNW, 9 in the Midwest and 21 in the South completed over a two-year period. 2) Completed of sampling for installations established in 2011. 3) Beginning sampling of installations installed in 2012. 4) Purchase of Isotope Ratio Mass Spectrophotometer at Virginia Tech for \(^{15}\text{N}\) analysis. 5) Sample analysis of tree, understory vegetation, forest floor and soil samples for \(^{15}\text{N}\) is in progress. 6) Graduate student theses and publications are being prepared.
• **EXPECTED DELIVERABLES:**
  
  The project will provide the members of CAFS with data on the N uptake efficiency following fertilization with conventional urea and how that can be improved if enhanced efficiency fertilizers are used instead of urea. The study will also provide information on the environmental fate of the applied urea, including losses from volatilization, which is needed to demonstrate that forest fertilization is an environmentally sound forestry practice.

  1) Nitrogen uptake efficiency
  2) Changes in nitrogen uptake efficiency following fertilization with enhanced efficiency fertilizers Data will allow CAFS members to determine whether the use of enhanced efficiency fertilizers are a viable economic alternative to traditional fertilization techniques with untreated urea.
  3) The amount of nitrogen lost to volatilization following fertilization with urea and enhanced efficiency fertilizers
  4) The amount of nitrogen lost below the rooting zone via leaching will be accounted for. This will aid CAFS members in determining the environmental fate of applied fertilizer and the potential for off-site environmental movement of nitrogen following fertilization.
Interactions of Carbon, Nitrogen, and Base Cation Cycles in Deep Forest Soils

Jason James
Rob Harrison
University of Washington
Why Deep Soils?

- Effective soil depth one of the important predictors of productivity
- Douglas-fir maximum rooting depths can be over 3 meters
- Substantial storage of C, N, and base cations in deep soil
- Ecologically active
- Hydraulic redistribution

Longleaf pine root system, *P. palustris*
Sample Sites

[Map showing locations labeled with abbreviations such as Hk, Ol, Bn2, Tk, R, Ov, L, K, etc., with markers indicating sample sites in Oregon and Washington.]
Methods
Methods
Soil Nitrogen

Soil Series

Depth Interval (m)
- O Horizon
- 0-0.1
- 0.1-0.5
- 0.5-1.0
- 1.0-1.5
- 1.5-2.0
- 2.0-2.5

Soil N (kg ha⁻¹)

A B Bl Bn1 Bn2 C Hg HK Ho J K L M Ob Ol Ov R Sh Sm Tk Tv V W
Soil Potassium

Depth Interval (m)
- 0-0.1
- 0.1-0.5
- 0.5-1.0
- 1.0-1.5
- 1.5-2.0
- 2.0-2.5
- 2.5-3.0

Exchangeable K (keq/ha)

Soil Series
Soil Magnesium

Exchangeable Mg (keq/ha)

Depth Interval (m)
- 0-0.1
- 0.1-0.5
- 0.5-1.0
- 1.0-1.5
- 1.5-2.0
- 2.0-2.5
- 2.5-3.0

Soil Series: A, Bl, Bn1, Bn2, C, Hg, Hk, Ho, J, K, L, M, Ob, OI, Ov, R, Sh, Sm, Tk, Tv, V, W
## Soil Totals & Distribution

<table>
<thead>
<tr>
<th></th>
<th>Average Soil Total</th>
<th>% Below 1.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon</strong></td>
<td>131.1 Mg ha(^{-1})</td>
<td>21%</td>
</tr>
<tr>
<td><strong>Nitrogen</strong></td>
<td>8645 kg ha(^{-1})</td>
<td>31%</td>
</tr>
<tr>
<td><strong>Ex. Calcium</strong></td>
<td>761 keq ha(^{-1})</td>
<td>66%</td>
</tr>
<tr>
<td><strong>Ex. Potassium</strong></td>
<td>47.7 keq ha(^{-1})</td>
<td>57%</td>
</tr>
<tr>
<td><strong>Ex. Magnesium</strong></td>
<td>496 keq ha(^{-1})</td>
<td>69%</td>
</tr>
</tbody>
</table>
Nitrogen Interactions

**Calcium**

- Total Exchangeable Ca (keq ha\(^{-1}\)) vs. Total Soil N (kg/ha)
- \(R^2 = 0.3132\)

**Magnesium**

- Total Exchangeable Mg (keq ha\(^{-1}\)) vs. Total Soil N (kg/ha)
- \(R^2 = 0.2155\)
Carbon Interactions

Calcium

Total Exchangeable Ca (keq ha\(^{-1}\))

R\(^2\) = 0.2344

Magnesium

Total Exchangeable Mg (keq ha\(^{-1}\))

R\(^2\) = 0.2185
Conclusions

- Substantial stores of C, N and other nutrients in deep soil
- Significant under-estimation based upon shallow sampling
- C & N interact with cation cycles through leaching
- Other nutrients may be necessary for fertilization & management
Timeline & Milestones

- Manuscript on deep soil carbon published in Soil Science Society of America Journal
- Deep soil nitrogen manuscript will be submitted summer 2014
- New deep soil sampling pits – Summer 2014
- Manuscript on base cation cycling in preparation
Questions?

Acknowledgements

- Kim Littke, Erika Knight, Vitor Gamba, Thiago Bonassi
- Rob Harrison, Bob Gonyea, Bert Hasselberg
- Funding Sources:
LTSP Lysimeters Study

Research Group:
Marcella Menegale – University of Washington
Rob Harrison – University of Washington
AB Adams – University of Washington
Scott Holub – Weyerhaeuser Co.
Nathan Meehan – Weyerhaeuser Co.
Study Objective

Look at the fate of the influence of organic matter removal during timber harvest – how does the presence/absence of harvest debris (such as chips, branches) in the area influences the accumulation of nutrients in the soil and, consequently, the final productivity of Douglas-fir forest.
Hypothesis

- **H-1**: Nutrient mobilization is not related to increasing intensity of organic matter removal.
- **H-2**: Nutrient loss is not related to increasing intensity of organic matter removal.
- **H-3**: Nitrogen movement into soil horizons is not related to increasing intensity of organic matter removal.
- **H-4**: Carbon movement into deep soil horizons is not related to increasing intensity of organic matter removal.
Experimental Design

Site Location – New LTSP Site (Springfield/OR)

5 treatments, with 4 replications:

A: Bole-only harvest, no compacted soil
B: Total-tree harvest, no compacted soil
C: Bole-only harvest, compacted soil
D: Total-tree harvest, compacted soil
E: Total-tree harvest + forest floor removal

Experimental Design – plots according to the different treatments.
Experimental Design

Lysimeters installation:

4 lysimeters per plot:

- 2 lysimeters at 20-cm depth and
- 2 lysimeters at 100-cm depth.

Total of 80 lysimeters.

Figure 1. 100-cm depth lysimeter.

Figure 2. 20-cm depth lysimeter.
Figure 3. New LTSP Site overview

Figure 4. Soil solution sampling process
Figure 5. Bole-only harvest treatment

Figure 6. Total-tree harvest treatment

Figure 7. Total-tree harvest plus forest floor removal treatment
Analysis

• Vegetation and Forest Floor: C and N

• Soil Solution Samples:
  ▪ Dissolved Inorganic Carbon (DIC)
  ▪ Dissolved Organic Carbon (DOC) and Dissolved Organic Nitrogen (DON)
  ▪ NO₃⁻-N, NH₄⁺-N
Work Progress

• Lysimeters installation – July/2013 and September/2013.

• Soil solution samples have been collected monthly (from February/2014).

• Data loggers installed in all plots - soil moisture data.
Figure 8. Soil moisture curve in “Bole only harvest, no compacted soil” treatments (period 10/24/13 to 01/24/14).
Figure 9. Soil moisture curve in “Total tree harvest, no compacted soil” treatments (period 10/24/13 to 01/24/14).
Figure 10. Soil moisture curve in “Total tree harvest plus forest floor removal” treatments (period 10/24/13 to 01/24/14).
Planned Activities and Goals

• Soil solution sampling during the entire season on a monthly basis

• Laboratory chemical analysis

• Annual reports

• Conferences and Meetings Presentations
Thanks

robh@uw.edu
SMC Silviculture Project Report

Eric C. Turnblom
Silviculture Project Leader
Stand Management Co-op (SMC)

SMC Spring Meeting, 23 Apr 2014
Vancouver, WA
Silviculture Project Status

- (SMC)² Report
- GGTIV Updates
- Other Products / Funding
- Student Updates
Objectives

- Summarize into a report how SMC Silviculture Project Type I, II and III installations have performed in terms of yield and increment
- Produce accompanying Fact Sheets
- Produce web(or browser)-based calculator that is useful for practicing forest managers
SMC Performance Report

Modeling Strategy

- Produce yield models using Chapman-Richards
  - BA, QMD, [TPA], CVT, CV4, CV6, BF4, BF6
- Function parameters (asymptote, rate, shape) tested for relationships with initial stand density, site index, other site variables, treatment regimes
- Manipulate fitted models to analyze increment
- Use models to produce yield table summaries
- Produce browser-based ‘Yield Calculator’
SMC Performance Report

- Distributed alpha version of SMC Yield Calculator to Silv.TAC sub-group over summer 2013 through fall
  - Received comments summer / fall 2013

- Distributed draft report to Silviculture TAC sub-group at Fall 2013 meeting
  - Received group comments back fall 2013
SMC Performance Report

SMC Yield Calculator User Requests
- Provide units in ( ) on Yield Tables – done
- Option to view > one species at a time – added
- Option to view both all and crop tree yields – added
- Slider for 50-yr base age SI linked to 30-yr – added
- Option to write out Yield Tables in excel or other file format – difficult, but in progress
SMC Performance Report

- Distributed draft report to Silviculture TAC sub-group at Fall 2013 meeting
  - CV 4” and CV 6” yields (BF similarly) appeared to were too high and crossed depending on density
    - Issue arose from two sources:
      1. log bucking algorithm – fixed
      2. Richards function asymptote formulation – revised
    - Refitted Type I, II, & III models, under final evaluation
    - Models will be incorporated into the Yield Calculator and (SMC)^2 Report in that order
SMC Performance Report

Example (Type III)

Cubic-foot Volume-4" top

Cubic-foot Volume-6" top

Age
SMC Performance Report

Contributors

- Type III analysis
  - Kevin Ceder, Eric Turnblom, SMC Silv. TAC
- Type I, II analysis
  - Kevin Ceder, Jed Bryce, Eric Turnblom, Jeff Comnick, SMC Silv. TAC
- Browser-based calculator
  - Jeff Comnick, Eric Turnblom, SMC Silv. TAC
Silviculture Project Status

- (SMC)^2 Report
- GGTIV Updates
- Other Products / Funding
- Student Updates
GGTIV (Genetic Gain / Type IV joint trials)

Objectives:

- Provide information to guide managers currently applying combinations of genetics, spacing and vegetation control.
- Provide linkages with other studies (such as Genetic Gain Trials, intensive ‘veg’ mgt. trials, spacing trials (like SMC Type III), that will assist modeling.
- Compare realized gains (per unit area basis) with predicted gains (individual tree basis).
- Compare estimates of growth and yield parameters for populations with different expected growth potentials.
GGTIV Installation Locations (apprx.)
Data & Methods

- Measurements
  - Diameter Breast Height on 100% of trees
  - Total height on 50% sample
  - Crown Width, two perpendicular directions on 42 tree sample
  - Height to Live Crown on 42 tree sample
  - Comments where warranted (Ex. BR, browsed; DE, dead; etc.
  - Diameter of Largest Limb in BH whorl, count of branches >1/2 LLDBH w/in whorl, and internode

- Five sites completely measured and loaded into the database
Age 9 Volume - Five Sites (2005 reps, 2-2006 reps)

Volume (cu.ft./ac.)

Spacing (ft)

- 15x
- 10x
- 7x

Woods run
Intermediate
Elite

Policy Meeting, Vancouver, WA
23 Apr 2014
GGTIV Updates

- CAFS Project: WQ Traits in GGTIV
  - One (of two 2006 reps) site nearly complete)
  - Developing relationships between resistance and specific gravity
  - Developing relationships between key wood property measures and tree / stand variables
Contributors

- Dave Briggs, Eric Turnblom, Eini Lowell, Keith Jayawickrama
- CL Huang, Jeff Comnick
- J Brad St Clair, Terrance Ye
- Jed Bryce, Sam Israel, Randy Collier, Armin Farahmandnia
Silviculture Project Status

- (SMC)^2 Report
- GGTIV Updates
- Other Products / Funding
- Student Updates
Other Products / Funding


- CAFS Phase II UW Site Proposal

- CAFS New Project Proposal
  - Wood Property Assessment of Trees from mid-rotation Coastal U.S. Douglas-fir Plantations on sites with varying Soil Parent Material that have undergone Fertilization using a paired-tree approach
Other Products / Funding

- CAFS Supplemental Funding Pursued
  - Burkhart, H.E., E.C. Turnblom, A. Weiskittel
  
  Understanding and Modeling Competition Effects on Tree Growth and Stand Development Across Varying Forest Types and Management Intensities.
Silviculture Project Status

- (SMC)^2 Report
- GGTIV Updates
- Other Products / Funding
- Student Updates
Student Updates

- **Kevin Ceder, Ph.D. Candidate (2014)**
  - Modeling vegetation dynamics in young, managed coastal Douglas-fir forests

- **Luyi Li, pursuing M.S. (2014)**
  - Douglas-fir wood quality properties in response to soil parent material and fertilization
Student Updates

- Armin Farahmandnia (undergraduate)
  - Will pursue his Senior Capstone Project working with the mixed DF/WH Type III
- One new M.S. Student expected AU ‘14
Silviculture Project Report

... Discussion ...

Policy Meeting, Vancouver, WA

Stand Management Co-op

23 Apr 2014

Policy Meeting, Vancouver, WA
Winter Temperature Matters!
Or
Winter Dormancy Requirements for Pacific Northwest Tree Species

Constance Harrington, USFS PNW Research Station
Peter Gould, WA Department Natural Resources

Timing is everything!

Chilling and Forcing Requirements

Freezing temps
Warmer temps not very effective
Many combinations can result in spring budburst

Forcing Units

Seed sources respond differently, especially when chilling is low

Seed sources respond differently, especially when chilling is low

WA Coast need 425 more forcing units than CA Sierra

WA Coast need 150 more forcing units than CA Sierra
Predicted date of budburst for Douglas-fir

Predicted date of budburst is earlier after warmer winters

Trend will reverse!!

Warm temps = low chilling effectiveness
Extra warming will change trend

Douglas-fir – Date of Spring Budburst

Based on predictions from ClimateWNA (Forest Genetics, Univ. British Columbia)

Douglas-fir – Predicted Δ in Date of BB by 2080

Red is up to 20 days later
Change in Date of BB by 2080

Western Redcedar  Western Hemlock  Pacific Madrone

Douglas-fir -- very low chilling
Branches from last year have burst bud and are out-growing former terminal

Terminal bud previous year

Grand fir

Low chilling
Mean winter temp 50s °F (10+ °C)

High chilling
Mean winter temp 40s °F (4-9 °C)
Western redcedar

Low chilling

High chilling

Winter temperature matters!
Warmer winters affect tree “futures”
Place matters
Genetics (selection of species, seed source) important

Dendrometer Data: Seasonal Patterns

Growth Initiation
Growth Cessation
Periodic Growth Rate
How is growth related to environment?

![Graph 1: Diameter Growth]

- Diameter Growth from May to September.

![Graph 2: Daily Mean Temp (°C)]

- Daily mean temperature from May to September.

How is growth related to environment?

![Graph 1: Diameter Growth]

- Diameter Growth from May to September.

![Graph 2: Daily Mean Temp (°C)]

- Daily mean temperature from May to September.

How is growth related to environment?

![Graph 1: Diameter Growth]

- Diameter Growth from May to September.

![Graph 2: Daily Mean Temp (°C)]

- Daily mean temperature from May to September.
From Walters and Soos 1963

Growth of WRC started sooner and lasted longer than growth of DF

Seasonal Leader Growth

Douglas-Fir Seed Source Movement Trial

- Established 2009
- 60 populations
- 9 planting locations in diverse environment

Each location has different landowner
Range of test environments

WA High Elevation: coldest site, wet.
2010 Growing Season
mean max T = 16.1°C, Precip = 671 mm
(61°F) (26 in)

WA Low Elevation: warmer, drier.
2010 Growing Season
mean max T = 18.7°C, Precip = 420 mm
(66 °F) (17 in)

OR Low Elevation: warmest, driest site.
2010 Growing Season
mean max T = 24.9°C, Precip = 184 mm
(77°F) (7 in)
Future work 1

Continue DF SSMT projects
More plant types (species as well as genotypes within species)
Reproductive phenology (how does it differ from vegetative? Why do we care? Orchards, naturals, ecology
Diameter growth – Cambial phenology – how “plastic” is it? (electronic dendrometers $$)
Shoot growth (bud set and form)

Future work 2

Implications for management – what do we need to know?

Brain storming – Which time periods in a tree’s life is most important from a biological and economic standpoint?
   Regeneration (planting, veg control)
   Height growth (when is it most important?)
   Density (any changes?)
   Monitoring for forest health

What are the tradeoffs between different growth strategies? (remember video clip)

How important is height growth and upper stem form after 2 logs??

How would answering this question help managers make decisions?
Response of foliage mass to N fertilization on SMC Type I installations

Doug Maguire
Doug Mainwaring
David Hann
Andy Bluhm

(CIPS: Center for Intensive Planted-forest Silviculture)
Rob Harrison
Eric Turnblom

(Stand Management Cooperative)
Response of foliage mass to N fertilization on SMC Type I installations

**Part 1**
*Direct effect of fertilization on crown recession*  
*(Maguire/Hann)*

**Part 2**
*Mechanisms for direct effect of fertilization on crown recession*  
*(Mainwaring)*
Response of foliage mass to N fertilization on SMC Type I installations

Part 1
Direct effect of fertilization on crown recession
(Maguire/Hann))

Part 2
Mechanisms for direct effect of fertilization on crown recession
(Mainwaring)
Implication of static height to crown base models

Fertilization effect on height growth

fertilization effect on crown recession: longer crown

Unfertilized

Fertilized
Fertilization effect on height growth

Unfertilized

Long-term fertilization effect on crown recession?

Denser crown?

Fertilized
1. Correct for respacing effect on crown recession rate:

\[ \Delta HCB_{RS} = (\Delta HCB_C)(MOD_{RS}) \]

where \( \Delta HCB_{RS} \) = Annual crown recession for respaced plots
\( \Delta HCB_C \) = Annual crown recession for untreated plots
\( MOD_{RS} \) = Treatment modifier for the direct effect of respacing

2. Estimate direct effect of fertilization on crown recession rate:

\[ \Delta HCB = (\Delta HCB_{RS})(MOD_F) \]

where \( \Delta HCB \) = Annual crown recession for fertilized plots
\( \Delta HCB_{RS} \) = Annual crown recession for respaced plots
\( MOD_F \) = Treatment modifier for the direct effect of repeated fertilization
Direct effect of fertilization on crown recession rate

\[ \Delta HCB_{RS} = (\Delta HCB_C)(MOD_{RS}) \]
\[ \Delta HCB = (\Delta HCB_{RS})(MOD_F) \]

1. Fit \( \Delta HCB_C \) to trees on unfertilized ISPA plots.
2. Estimated installation-level adjustment factors by regressing observed recession rate on predicted recession rate (through origin) for trees on unfertilized ISPA plots.
3. Apply \( \Delta HCB_C \) equation and installation adjustment to trees on ISPA/2 and ISPA/4 plots.
4. Calculate ratio of average observed crown recession by average predicted crown recession for each plot.
5. Estimate MOD_{RS} from these calculated ratios.
6. Apply predicted \( \Delta HCB_{RS} \) to each tree on fertilized plots.
7. Calculate ratio of average observed crown recession by average predicted crown recession for each fertilized plot.
8. Estimate MOD_{F} from these calculated ratios.
Crown recession rate of Douglas-fir on untreated SMC Type I plots

$$\Delta HCB_c = \frac{(CL+P\Delta H)}{1.0+exp[\alpha_0+\alpha_1 \ln(CR)+\alpha_2 CR+\alpha_3 GEA+\alpha_4 \ln(CCF)]]} + \varepsilon_{\Delta HCB}$$

where

- $\Delta HCB$ = Annual crown recession for fertilized plots
- $\Delta HCBRS$ = Annual crown recession for respaced plots
- $\Delta HCBC$ = Annual crown recession for untreated plots
- $MOD_{RS}$ = Treatment modifier for the direct effect of respacing
- $MOD_F$ = Treatment modifier for the direct effect of repeated fertilization
Respacing modifier

\[ \text{MOD}_{RS} = (1.0 + 0.0563395788 \cdot I_{RS}) \]

1. Respacing caused about a 5.6% INCREASE in crown recession rate over that predicted for trees on unspaced ISPA plots.

2. Effect of respacing to ISPA/2 was not significantly different from respacing to ISPA/4.

3. Effect of respacing did not diminish or increase over time; i.e., effect was constant and persistent.
$MOD_F = (1.0 + c_1 I_1 + c_2 I_2 + c_3 I_3 + c_4 I_4 + c_5 I_5)$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>P-value</th>
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<tbody>
<tr>
<td>$c_1$</td>
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<td>0.00710</td>
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<td>$c_2$</td>
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<td>$c_5$</td>
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$\Delta HCB_{RS} = (\Delta HCB_C)(MOD_{RS})$

$\Delta HCB = (\Delta HCB_{RS})(MOD_F)$
Direct effect of fertilization on crown recession rate

\[ MOD_F = (1.0 + c_1 I_1 + c_2 I_2 + c_3 I_3 + c_4 I_4 + c_5 I_5) \]
Direct effect of repeated fertilization on crown recession
SMC Type I installations

- Increase in foliar N concentration
- Decrease in light compensation point?
Direct effect of repeated fertilization on crown recession
SMC Type I installations

- Increase in crown density?
- Return to initial light compensation point?
Fertilize

Working hypothesis

crown densification

crown normalization

Yrs 2  6  10  14  18  22

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Response of foliage mass to N fertilization on SMC Type I installations

Part 1
Direct effect of fertilization on crown recession
(Maguire/Hann)

Part 2
Mechanisms for direct effect of fertilization on crown recession
(Mainwaring)
86 trees from 4 SMC type 1 sites

- 86 trees from 4 SMC TYPE 1 installations (East Twin, Ostrander, Roaring River, Toledo)

- Fertilized treatments received 1000 lbs. of N in five 200 pound applications (every 4 years)
  - RR: 1989-2005
  - Toledo: 1990-2006
Questions

• Do the fertilized NARA trees have a greater foliage amount than the unfertilized trees?

• Do the fertilized NARA trees have a different vertical distribution of foliage from unfertilized trees?
Methods, equation fitting

• Estimate foliage mass based on relationship between sample branch size and position and measured mass (branch-level)
  
  – Full model
    log(Foliage mass) = intercept + log(branch diam.) + log(rhacb) + log(dinc) + fert
  
  - Fit separately by site for age classes 1-5, 6+

• Use above equation to fill in non-sampled branches

• Fit separate equations which estimates tree-level foliage mass
  
  – Full model
    Foliage mass = a*Dbh^b * Ht^c * Cl^d * exp(e*fert)
  
  - Fit separately by site
Equation fitting, results

• Branch-level foliage mass
  – Of 24 fits (4 sites, 6 cohorts), fertilization significant in only 2 cases
    • Year 1 foliage at Toledo (positive)
    • Year 4 foliage at Ostrander (negative)
  – Fertilization treatments occurred in the distant past, are likely to be accounted for with branch diameter variable.
    • Live branch weight with fertilization is significantly lower at East Twin and Ostrander after accounting for branch diameter and crown position

• Tree-level foliage mass
  – Fertilization not a significant factor in tree-level equations
    • P-values: East Twin (0.77); Ostrander (0.78); Toledo (0.15); Roaring River (0.52)
Questions

• Do the fertilized NARA trees have a greater foliage amount than the unfertilized trees?

• Do the fertilized NARA trees have a different vertical distribution of foliage from unfertilized trees?
Cumulative relative foliage mass by relative crown position
Cumulative relative foliage mass by relative crown position
Cumulative relative foliage mass by relative crown position
Cumulative relative foliage mass by relative crown position
Test of crown position interactions

- Fit branch-level equations which included interactions of fertilization with Depth into crown (DINC) or Relative Height Above Crown Base (RHACB)

  - Full model
    \[
    \log(\text{Foliage mass}) = \text{int.} + \log(\text{branch diam.}) + \log(\text{rhacb}) + \log(\text{dinc}) + \text{fert} + \text{fert} \times \log(\text{rhacb}) + \text{fert} \times \log(\text{dinc})
    \]

  - Fit separately by site
    - Significant interaction between fertilization and RHACB at RR
    - Significant interaction between fertilization and DINC at ET
Foliage mass by crown position, Roaring River
Foliage mass by crown position, Roaring River

- For a given branch diameter, there is more foliage mass in the lower half of unfertilized crowns.
- For a given foliage mass per branch, lower crown branches of fertilized trees are larger.
Foliage mass by crown position, East Twin
Foliage mass by crown position, East Twin

- For a given branch diameter, there is more foliage mass in the lower half of fertilized crowns, less in the top half

- Difference between RR and ET may be due to needle longevity (ET averages > 9 years of needles, RR <7 yrs)
Thanks!
<table>
<thead>
<tr>
<th>Installation</th>
<th>Name</th>
<th>Year of last fertilization</th>
<th>Year of felled tree sampling</th>
<th>Years since last fertilization</th>
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<tbody>
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<td>704</td>
<td>Ostrander Rd</td>
<td>2003</td>
<td>2011</td>
<td>8</td>
</tr>
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<td>Roaring River</td>
<td>2005</td>
<td>2011</td>
<td>6</td>
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<tr>
<td>726</td>
<td>Toledo</td>
<td>2006</td>
<td>2011</td>
<td>5</td>
</tr>
</tbody>
</table>
Direct fertilization response modifier

\[ \Delta HCB = (\Delta HCB_{RS})(MOD_F) \]

\[ \Delta HCB_{RS} = (\Delta HCB_C)(MOD_{RS}) \]

where

\[ \Delta HCB = \text{Annual crown recession for fertilized plots} \]
\[ \Delta HCB_{RS} = \text{Annual crown recession for respaced plots} \]
\[ \Delta HCB_C = \text{Annual crown recession for untreated plots} \]
\[ MOD_{RS} = \text{Treatment modifier for the direct effect of respacing} \]
\[ MOD_F = \text{Treatment modifier for the direct effect of repeated fertilization} \]