Short-term growth and soil biological responses to post-thinning biomass removal and complementary soil amendments

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Does removal of thinning residues for bioenergy decrease site quality?

- Thinning produces abundant small-diameter wood
- Improves resource availability and stand quality
- Biomass removal extracts organic matter (N, C)
- Know more about whole-tree vs. bole-only impacts
- Few report effects of thinning residue removal, especially in small-diameter stands
Can soil amendments mitigate any negative impacts of biomass removal?

• Maintaining soil quality involves retention of soil organic matter
• Forest stands respond to N fertilizer
• Biochar amendments replenish organic matter
Pitwood
MAT 6.6 °C, MAP 106 cm

UIEF
MAT 7.8 °C, MAP 74 cm
Experimental design

<table>
<thead>
<tr>
<th>Unthinned control</th>
<th>0X, No biomass retention</th>
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<tbody>
<tr>
<td>untreated</td>
<td>fertilizer</td>
</tr>
<tr>
<td>biochar</td>
<td>fertilizer &amp; biochar</td>
</tr>
<tr>
<td>1X, All biomass retained</td>
<td>2x biomass retained</td>
</tr>
<tr>
<td>untreated</td>
<td>fertilizer</td>
</tr>
<tr>
<td>biochar</td>
<td>fertilizer &amp; biochar</td>
</tr>
</tbody>
</table>

- 4 biomass treatments: Con, 0x, 1x, 2x
- 4 amendment treatments: Con, Fert, BChar, FxBC
- Replicated 4x: 2 at Pitwood, 2 at UIEF
4 biomass treatments
4 amendment treatments
Replicated 4x
Slash distribution

UIEF
## Initial and post thinning stand conditions

<table>
<thead>
<tr>
<th></th>
<th>TPH (trees ha⁻¹)</th>
<th>QMD (cm)</th>
<th>BA (m² ha⁻¹)</th>
<th>SDI (trees ha⁻¹)</th>
<th>RD (Curtis)</th>
<th>Species distribution (% BA)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DF</td>
</tr>
<tr>
<td><strong>Pitwood</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pre-thin</td>
<td>2625</td>
<td>9</td>
<td>17</td>
<td>481</td>
<td>40</td>
<td>42</td>
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<tr>
<td>Post-thin</td>
<td>467</td>
<td>17</td>
<td>10</td>
<td>237</td>
<td>17</td>
<td>59</td>
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<tr>
<td><strong>UIEF</strong></td>
<td></td>
<td></td>
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<tr>
<td>Pre-thin</td>
<td>1563</td>
<td>12</td>
<td>16</td>
<td>440</td>
<td>33</td>
<td>10</td>
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<tr>
<td>Post-thin</td>
<td>373</td>
<td>14</td>
<td>6</td>
<td>136</td>
<td>11</td>
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Biomass and N added

<table>
<thead>
<tr>
<th></th>
<th>Pitwood</th>
<th></th>
<th>UIEF</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1x</td>
<td>2x</td>
<td>1x</td>
<td>2x</td>
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<tr>
<td>DWD (Mg ha(^{-1}))</td>
<td>76±9</td>
<td>158±12</td>
<td>27±2</td>
<td>72±4</td>
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<tr>
<td>Nitrogen content (kg ha(^{-1}))</td>
<td>44±4</td>
<td>258±5</td>
<td>44±1</td>
<td>118±2</td>
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</tbody>
</table>

- No other study reports more than 70 t ha\(^{-1}\)
Biochar application

$2.5 \text{ Mg ha}^{-1}$

No impact on soil carbon concentration

![Graph showing no impact on soil carbon concentration between control and biochar treatments. The y-axis represents soil organic matter, LOI (%), and the x-axis represents locations (UIEF and Pitwood). The bars for both UIEF and Pitwood show similar values for both control and biochar treatments, indicating no significant difference.]
Fertilizer application

224 kg ha$^{-1}$
BA growth depended on location

- Growth at Pitwood was twice that at UIEF
- Response to initial basal area depended on location
Biomass treatment response
3-yr periodic annual increment

- Best growth at 1x slash retention
- Slowest growth when not thinned or when 2x biomass is retained
Growth decline at high slash is consistent between locations

• PAI basal area growth response to downed woody debris by location with fitted quadratic curve.

• What’s causing the growth decline with high slash?
Soil temperature and moisture not different among biomass treatments.
N limitation probably not causing Growth decline

- No statistical differences among treatments or locations
- 2x tends to have improved nutrition
Amendment treatment response
3-yr periodic annual increment

- Growth responded to fertilizer, not biochar
- Potential to mitigate nutrient loss through fertilization
- Biochar increases soil carbon with no detrimental effects
Leaf N responded to fertilizer

- Stronger response at UIEF than Pitwood
- Can say fertilized trees took up more N than non-fertilized
Soil biology measurements

Field measurements of soil respiration

Lab assays of exoenzyme activity
Soil respiration

- Season largely controls soil respiration
- Seasonal patterns differed between locations
- No biomass or amendment treatment effects
Soil exoenzyme activities

• Nutrient release depends on carbon release
• Seasonal patterns differed between locations
• No biomass or amendment treatment effects
Conclusion

• Removal of thinning residues for bioenergy is not harmful for tree growth
• Retaining excessive slash does lower tree growth
• Fertilizer, not biochar, can mitigate detrimental effects
• Observed responses are short term.
• Assessing thinning impacts yields results quicker than harvest-impact studies
Conclusion cont.

• Expected 10- or 20-year responses
  • Thinned trees will be superior size and quality
  • 2x biomass will no longer be detrimental
  • Fertilizer will no longer affect growth or foliar nutrients, but total volume (yield) will be greater
  • Biochar may show positive response, at least it won’t be detrimental
Idaho forest growth response to post-thinning energy biomass removal and complementary soil amendments

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\textsuperscript{2}United States Department of Agriculture Forest Service, Rocky Mountain Research Station, Moscow, ID, 83843, USA
### Soil Biology analysis of variance results

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<tr>
<td>Location (L)</td>
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<tr>
<td>ln (BG)</td>
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<tr>
<td>ln (MC)</td>
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<tr>
<td>ln (LOI)</td>
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<tr>
<td>Temperature</td>
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<tr>
<td>pH</td>
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*P<0.10, **P<0.05, ***P<0.01, ns=not significant