Modelling Forest Thinning Effects by Reduction of Leaf Area Index in JULES LSM

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Outline

• Forest Management in Land Surface Model

• Thinning-induced changes of microenvironmental conditions

• The effects of thinning on stand transpiration and productivity

• Modelling thinning effects by modifying leaf area index
**LMC Vs. LCC**

- Impacts on surface temperature
  - Land Management Change (LMC) ≡ Land Cover Change (LCC) [Luyssaert et al. 2014]

Biophysical effects of land management change, or land cover change.
Forest Management Effects

- Biogeochemical changes
  - Carbon sink strength
  - Direct carbon uptake capacity
  - GHGs emissions

- Biophysical changes
  - Forest structural changes
  - Albedo, Energy partitioning to sensible heat flux
  - Water and Energy fluxes
Consequence of Forest Management

![Pie charts and table]

### Contribution to changes since 1750

<table>
<thead>
<tr>
<th></th>
<th>ΔRF due to GHGs (W m⁻²)</th>
<th>ΔRF due to surface change (W m⁻²)</th>
<th>ΔTₐ, summer (K)</th>
<th>ΔPrecipitation, summer (mm per season)</th>
<th>ΔAtmospheric carbon (Pg C)†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenhouse gas emissions</td>
<td>2.98*‡</td>
<td>0.00</td>
<td>1.71*‡</td>
<td>-6</td>
<td>247§</td>
</tr>
<tr>
<td><strong>European</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land-use change</td>
<td>0.01*</td>
<td></td>
<td></td>
<td>0.11*¶</td>
<td>0.12*#</td>
</tr>
<tr>
<td>Land-cover change</td>
<td>-0.01</td>
<td>0.12*¶</td>
<td>0.02*¶</td>
<td>0</td>
<td>-0.7**</td>
</tr>
<tr>
<td>Forest management</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.10*#</td>
<td>-3*‡</td>
<td>1.9</td>
</tr>
<tr>
<td>Species conversion</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.08*#</td>
<td>-4*‡</td>
<td>-0.6‡</td>
</tr>
<tr>
<td>Wood extraction</td>
<td>0.03</td>
<td>-0.01</td>
<td>0.02*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Naudts et al. 2016]
Thinning?

- Partial removal of trees from forest plantations

- Objects
  - Reduce competition intensity among trees
  - Produce more valuable trees
  - Reduce natural fire risk
  - Promote the forest health
Schematic Representation of Thinning

Before

After
# Changes of Environmental and Physiological Conditions by Thinning

<table>
<thead>
<tr>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil Water Content</strong></td>
<td><strong>Leaf Area</strong></td>
</tr>
<tr>
<td>(Lagergren et al., 2008; Simonin et al., 2007)</td>
<td>[Harrington and Reukema, 1983]</td>
</tr>
<tr>
<td><strong>Competition</strong></td>
<td><strong>Basal Area</strong></td>
</tr>
<tr>
<td><strong>Hydrological Conductivity</strong></td>
<td></td>
</tr>
<tr>
<td>(Shinozaki et al., 1964a; b)</td>
<td>[Harrington and Reukema, 1983]</td>
</tr>
<tr>
<td><strong>Fertilization effect</strong></td>
<td></td>
</tr>
<tr>
<td>(Wollem and Schubert, 1975)</td>
<td></td>
</tr>
</tbody>
</table>
Thinning Effects on Productivity

[Mäkinen and Isomäki, 2004] [Franklin et al., 2009]
The Objectives

- Quantify the effects of thinning on stand transpiration and productivity
- Modelling thinning effects with JULES land surface model
Part 1.
Quantification of Thinning Effects on Stand Transpiration and Productivity
### Study Site

**Mt. Taehwa**  
**Gyounggi-Do, Korea**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thinning area (ha)</td>
<td>0.54</td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>129~219</td>
</tr>
<tr>
<td>Aspect</td>
<td>NE 50~60</td>
</tr>
<tr>
<td>Annual precipitation (mm)</td>
<td>1329.2</td>
</tr>
<tr>
<td>Annual mean air temperature (°C)</td>
<td>10.3</td>
</tr>
<tr>
<td>Tree height (m)</td>
<td>19.1</td>
</tr>
<tr>
<td>Mean DBH (cm)</td>
<td>27.9</td>
</tr>
<tr>
<td>Stand density (no./ha)</td>
<td>440</td>
</tr>
</tbody>
</table>
Thinning Treatments

20%

40%

75m

50m

13/30
Stand Transpiration - Sapflux Density

- Thermal dissipation probe methods (Granier, 1985)

\[ \Delta T = T_H - T_R \]
Stand Productivity

- Allometric equation
  \[ Y = 0.2849 \times (DBH)^{2.0553} \]  
  [Ryu et al. 2014]

- Dendrometer
Environmental conditions

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ta (°C)</td>
<td>10.7</td>
<td>11.0</td>
<td>11.4</td>
</tr>
<tr>
<td>Q (µmol m⁻² s⁻¹)</td>
<td>293.4</td>
<td>271.1</td>
<td>262.4</td>
</tr>
<tr>
<td>D (kPa)</td>
<td>0.53</td>
<td>0.53</td>
<td>0.52</td>
</tr>
<tr>
<td>PRCP (mm d⁻¹)</td>
<td>1685.6</td>
<td>1366.9</td>
<td>791.5</td>
</tr>
</tbody>
</table>
Thinning - Stand Transpiration

![Graph showing Thinning Stand Transpiration](image)

- **$E_T$ (mm y$^{-1}$)**
- Lines and markers for Con, LT, HT
Thinning - Diameter Growth

- DOY (Days of Year)
- RGR (%) - Relative Growth Rate
- DBH increment (mm)

Graphs show the growth patterns of trees from 2012 to 2014, comparing different treatments (Con, LT, HT) for Relative Growth Rate and DBH increment.

Legend:
- Con: Control
- LT: Low Treatment
- HT: High Treatment
Thinning - Stand Productivity

![Graph showing NPP (gC m$^{-2}$ yr$^{-1}$) from 2012 to 2014. The graph includes lines for Con, LT, and HT treatments.]
Thinning - Water Use Efficiency

![Graph showing water use efficiency (WUE) over time for different treatments: Con, LT, HT.](image)
Part 2.
Modelling Thinning Effects by Reduction of Leaf Area Index
Procedure of Thinning Effects Estimation by JULES LSM

- **Site-specific Optimization of the Model**
  - Sensitivity of canopy radiation transfer model
  - Sensitivity test and modification of plant functional type related parameters
  - Model validation by comparing with EC flux data

- **Estimation of Thinning Effects**
  - Modification of LAI input data by measured thinning induced reduction and recovery of LAI
Sensitivity of Canopy Radiation Modules
Parameter Sensitivity Analysis

Changes in GPP (%)

Changes in LE (%)
Model Validation
- Model estimation Vs. EC-measured flux

\[ r^2 = 0.77 \]

\[ r^2 = 0.46 \]
Leaf Area Reduction by Thinning

![Graph showing LAI (m² m⁻²) over time with different treatments: Con, LT, HT.](image)
LAI Reduction – GPP/NPP

GPP (gC m\(^{-2}\) y\(^{-1}\))

Year

NPP (gC m\(^{-2}\) y\(^{-1}\))

Year
LAI Reduction - LE

![Graph showing LE (M J m⁻² y⁻¹) over years from 2008 to 2014. The graph compares three conditions: Con, LT, and HT.]
Difference b/w Measurement and Modeling Results
Conclusion

- Initial reduction and gradual recovery of stand transpiration and productivity by heavy thinning

- Decrease of GPP, Increase of NPP, little change in LE by model estimation with reduced leaf area

- There is discrepancy between field measured thinning effects and model estimated thinning effects, which reveals thinning related changes are not constraint by leaf area reduction
Thank You

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## Parameter Sensitivity Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Unit</th>
<th>Default</th>
<th>Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>neff_io</td>
<td>Scale factor relating $V_{cmax}$ with leaf nitrogen concentration</td>
<td></td>
<td>0.8e-3</td>
<td>0.8e-3</td>
</tr>
<tr>
<td>nl0_io</td>
<td>Top leaf nitrogen concentration</td>
<td></td>
<td>0.030</td>
<td>0.046</td>
</tr>
<tr>
<td>nmass_io</td>
<td>Top leaf nitrogen content per unit mass</td>
<td>kgN kgLeaf$^{-1}$</td>
<td>0.0210</td>
<td>0.0210</td>
</tr>
<tr>
<td>kn_io</td>
<td>Decay of nitrogen through the canopy</td>
<td></td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>alpha_io</td>
<td>Quantum efficiency</td>
<td>mol CO$_2$ / mol PAR photons</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>co2_mmr</td>
<td>Concentration of atmospheric CO2, expressed as a mass mixing ratio.</td>
<td></td>
<td>5.241e-4</td>
<td>5.83e-4</td>
</tr>
<tr>
<td>canht_ft_io</td>
<td>The height of each PFT</td>
<td></td>
<td>16.38</td>
<td>20</td>
</tr>
</tbody>
</table>
Future Works

If we want to change this to

We need to add/modify these modules (color in red)

[ORCHIDEE]

[ORCHIDEE-CAN]

[Naudts et al. 2015]