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) $\equiv$ 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
  - GHG emissions

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

[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

*Image source: [www.qlg.org/pub/act/lnf/lnf1.htm]*
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>Soil Water Content</td>
<td>Leaf Area</td>
</tr>
<tr>
<td>[Lagergren et al., 2008; Simonin et al., 2007]</td>
<td></td>
</tr>
<tr>
<td>Competition</td>
<td>Basal Area</td>
</tr>
<tr>
<td>Hydrological Conductivity</td>
<td>Damage (Stress)</td>
</tr>
<tr>
<td>[Shinozaki et al., 1964a; b]</td>
<td>[Harrington and Reukema, 1983]</td>
</tr>
<tr>
<td>Fertilization effect</td>
<td></td>
</tr>
<tr>
<td>[Wollum and Schubert, 1975]</td>
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</tbody>
</table>
Thinning Effects on Productivity

High site fertility

(A)

Low site fertility

(B)

Early onset

Late onset

[Diameter increment (mm/yr)]

[C L M H]

[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
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</td>
<td>10.7</td>
<td>11.0</td>
<td>11.4</td>
</tr>
<tr>
<td>Q</td>
<td>293.4</td>
<td>271.1</td>
<td>262.4</td>
</tr>
<tr>
<td>D</td>
<td>0.53</td>
<td>0.53</td>
<td>0.52</td>
</tr>
<tr>
<td>PRCP</td>
<td>1685.6</td>
<td>1366.9</td>
<td>791.5</td>
</tr>
</tbody>
</table>
Thinning - Stand Transpiration

\( E_T (\text{mm y}^{-1}) \)

Year

- Con
- LT
- HT
Thinning - Diameter Growth

![Graph showing Thinning - Diameter Growth](image)

- **RGR (%)**
- **DBH increment (mm)**
- **DOY**

The graph compares the growth rate (RGR) and diameter increment (DBH) over the years 2012, 2013, and 2014. The data is categorized into 'Con', 'LT', and 'HT'.
Thinning - Stand Productivity

![Graph showing NPP (gC m\(^{-2}\) yr\(^{-1}\)) from 2012 to 2014 for different treatments: Con, LT, HT.](image-url)
Thinning - Water Use Efficiency

![Graph showing water use efficiency over time for different treatments (Con, LT, HT). The graph plots WUE (gC kg H₂O⁻¹) against years 2012, 2013, and 2014.]
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

The graph plots $GPP_{est}$ (KgC m$^{-2}$ y$^{-1}$) against $GPP_{Obs}$ (KgC m$^{-2}$ y$^{-1}$). The data points for sites R1 to R6 are represented by different symbols. The dashed line indicates a 1:1 ratio.
Parameter Sensitivity Analysis

Changes in GPP (%)

Changes in LE (%)

-30%  -20%  -10%  10%  20%  30%
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 for different treatments: Con, LT, HT.](image)
LAI Reduction – GPP/NPP

![Graph showing GPP and NPP over years with different LAI categories.]

- GPP (gC m⁻² y⁻¹)
- NPP (gC m⁻² y⁻¹)
- LAI categories: Con, LT, HT
LAI Reduction - LE

![Graph showing LAI Reduction - LE](image)

- **LAI (LE)**: LE (M J m⁻² y⁻¹)
- **Year**:
  - 2008
  - 2010
  - 2012
  - 2014
- **Legend**:
  - Con
  - LT
  - HT
Difference b/w Measurement and Modeling Results

![Graph showing NPP (gC m^{-2} yr^{-1}) over years from 2012 to 2014, comparing Con, LT, and HT conditions.]

![Graph showing NPP (gC m^{-2} yr^{-1}) over years from 2008 to 2014, focusing on a specific year range from 2012 to 2014.]

29/30
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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