Long term effects of alternative group selection harvesting designs on stand production

C. Halpin, C.G. Lorimer, J.J. Hanson, B. Palik
Objectives

- To assess group selection’s impact on
  - Stand-level volume production
  - Stand-level growing space efficiency
  - Tree-level volume production
  - Tree-level growing space efficiency
Approach

- Use CANOPY to simulate
  - A range of group selection alternatives
  - Standard silvicultural benchmarks
Height/Diameter Growth

Large trees (>17m tall) grow in diameter
Small trees (<17m tall) grow in height

Sugar maple on AOCa
Crown growth

Crown radii can grow N, S, E, W

1. Exposed and facing gap
2. Exposed and not facing gap
3. Shaded
4. Touching

![Diagram of tree growth]

- Exposed and facing gap
- Exposed and not facing gap
- Shaded (150% stocking)

[Graph showing crown growth vs. tree diameter]
Mortality

Mortality is stochastic

Annual probabilities of mortality given by a Logistic function of diameter and stocking

Function follows a U-shaped trend with diameter, and predicts higher mortality at higher stocking

- Observed mortality
- Predicted mortality
Recruitment

The number of 2-6 cm trees expected in each 100m² area is predicted

- 100m² stocking
- 800m² stocking

New saplings are added if there is a deficit

Species of new saplings is influenced by overstory composition
Validation

Comparing CANOPY simulations of standard single-tree selection against NH-25 field data for the same treatment:

<table>
<thead>
<tr>
<th></th>
<th>CANOPY Prediction</th>
<th>NH-25 Measurement</th>
<th>%Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survivor Growth (m²/ha/yr)</td>
<td>0.35</td>
<td>0.32</td>
<td>9.3%</td>
</tr>
<tr>
<td>Mortality (m²/ha/yr)</td>
<td>0.11</td>
<td>0.10</td>
<td>10.0%</td>
</tr>
<tr>
<td>Harvest Rate (m³/ha/yr)</td>
<td>4.58</td>
<td>4.42</td>
<td>3.6%</td>
</tr>
</tbody>
</table>
**Treatments**

a) Standard STS
b) GS+STS
   800m², 3%
c) Clearcutting
   w/ Thinning
d) GS 800m², 120yr
Methods

- Simulated 10 reps of each treatment
- Used last 150 years of simulation to compute annualized volumetric yield and mortality
- Life-cycle inventory for individual trees
  - A cohort of trees is tracked from birth to death
  - 5-year volume increments are used to compute yield and efficiency averaged by size class
Hypotheses

• H1: Group size and the percentage of the stand occupied by groups will not affect net production rate

• H2: Under group selection alone, net production will decline as rotation age increases

• H3: Increases in sapling/pole GSE will not increase stand-level production markedly because the sapling/pole component produces only a small fraction of the total
Stand-level Production

<table>
<thead>
<tr>
<th>Method</th>
<th>Net Production</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial STS</td>
<td>5.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Heavy STS</td>
<td>5.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Standard STS</td>
<td>4.5</td>
<td>1.5</td>
</tr>
<tr>
<td>GS+STS 800m2, 3%</td>
<td>4.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Clearcutting w/ Thinning</td>
<td>3.5</td>
<td>2.5</td>
</tr>
<tr>
<td>GS 800m2, 120yr</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Clearcutting</td>
<td>2.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Volume Production (m³/ha/yr)
Group Selection with Single-tree Cutting between groups

Net Production (m$^3$/ha/yr) vs Opening Size (m$^2$)

- 1%
- 3%
- 5%
- 9%
Group Selection Alone

Net Production (m³/ha/yr) vs Opening Size (m²)

- 100yr
- 120yr
- 135yr
Relative volume produced by trees in each size class

- **Standard STS**
- **GS+STS 800m2, 3%**
- **Heavy STS**
- **Clearcutting w/ Thinning**
- **GS 800m2, 120yr**
- **Clearcutting**
- **Industrial STS**

The graph shows the percentage of total production for different tree size classes and treatments, with four size classes: Large, Mature, Pole, and Sapling.
Lifetime Average $GSE_{ECA}$

- Large
- Mature
- Pole
- Sapling

- Standard STS
- GS+STS 800m2, 3%
- Heavy STS
- Industrial STS
- GS 800m2, 120yr
- Clearcutting w/ Thinning
- Clearcutting

$GSE_{ECA}$ (dm$^3$/m$^2$/yr)
Production and Stand-level GSE$^\text{TCA}$
Relative Production of Clearcutting and Standard STS
Evaluation of Hypotheses

• H1: Group sized/extent does not affect net production
  – Supported by data
• H2: Under group selection alone, net production will decline as rotation age increases
  – Supported by data
• H3: Increases in sapling/pole GSE will not increase stand-level production markedly because the sapling/pole component produces only a small fraction of the total
  – NOT supported by data
Concluding Remarks

• Paradox of efficiency vs yield
  – Clearcutting without thinning is less productive than STS because of unsalvaged mortality
  – Clearcutting with thinning is very similar in production to STS despite clear GSE advantages
    • GSE advantage is mitigated by lower site occupancy
Questions ?
GSE_{ECA} within a size class

- GS 800m2, 120yr
- Heavy STS
- Industrial STS
- GS+STS 800m2, 3%
- Standard STS
- Clearcutting w/ Thinning
- Clearcutting

GSE_{ECA} (dm³/m²/yr)
Relative volume harvested from each size class

- Standard STS
- GS+STS 800m², 3%
- Clearcutting w/ Thinning
- Heavy STS
- Industrial STS
- GS 800m², 120yr
- Clearcutting

% Total Production
Diameter growth equations
Canopy and non-gap trees

For each habitat type:

\[ \ln(\Delta \text{ Diameter}) = A + B \ln(\text{Diameter}) - C \text{ Diameter} - D \text{ Stocking} \]

1. Calibrate equation using 2/3 of data (Sugar maple example)

\[ \ln(\Delta D) = -0.245 + 0.904 \ln(D) - 0.028 \text{(D)} - 0.008 \text{Stocking} \quad R^2 = 0.403 \]

2. Evaluate equation using reserved 1/3 data

Compare predicted to observed growth using the “Simultaneous F-test”:

Do predicted = observed?

Not significantly different
\[ p = 0.305 \]
Ecological benchmarks

Diameter distribution
year 1700

Trees / ha

Tree diameter (cm)

Basal area (m²/ha)

Time (years)

Saplings (trees / ha)

Time (years)

>50cm trees (trees/ha)

Time (years)
Building a database

Variety of stand conditions

Over 13,000 trees

- Porcupine Mountains: 1981-2004
  Unmanaged late successional / old growth
- Dukes Experimental Forest: 1952-2002
  Selection harvests in old forest
- Sylvania Wilderness
  Unmanaged late successional / old growth
- NHAL: 1983-1996
  Single-tree selection
- Argonne Exp. Forest: 1951-2001
  Selection harvests in young forest
- Chequamegon/Nicolet National Forest
  Selection harvests
- Menominee Reservation: 1979-1999
  Selection harvest with big trees