Optimization of the Steering Treatment of Hardwood Stands under the Selection System

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Broad-leaved Volume
Volume de feuillus
Most hardwood & mixedwood stands in Eastern Canada are uneven-aged and heterogeneous in structure.
Management of Hardwoods in the Province of Quebec (Canada)

Source: Bedard & Meunier 2006 IUFRO Conference Rouyn-Noranda
SELECTED CUTTING METHOD IN
EASTERN CANADA

- Management of cutting cycle and residual stocking
- Continuous stand improvement
  
  "Cut the worse, leave the best"

- Size-structure management
- Tighter control through tree marking
- Growth monitoring
SELECTION CUTTING BASED ON STAND IMPROVEMENT IS OFTEN NOT PROFITABLE

1. Stand improvement cuttings produce large amounts of pulpwood.

2. In average, supply costs for pulpwood exceeds market price.

3. The supply of low grade hardwood exceeds the demand in many regions.

4. Negative impact on high quality lumber supply.

Typical market prices and costs of low-grade hardwood (mill gate):

- Market prices
- Planning & Management
- Harvest & Bucking
- Loading & Deloading
- Transportation
- Roads & camps

Supply costs for different mills:

- Norampac-Cabano
- Groupe Savoie-St-Quentin
- Domtar-Windsor
- Fortress- Thurso

Supply cost vs. Market prices Planning & Management Harvest & Bucking Loading & Deloading Transportation Roads & camps

$/m³
Can we optimize tree selection to achieve a more profitable and sustainable production?
Conduct Treatments

Current State

« Distance » from ideal

Ideal State

Time

YR 25

YR 50

YR 75

YR 100
BIOLLEY IS...

... an Excel Sheet Program

... a stand-level decision support tool

... for the application of the selection silviculture system

... designed to determine the number of trees to be marked

... to maximize net revenues of periodic harvest

... in a sustainable way
24 TREE CLASSES

2 SPECIES GROUPS
- **HW**
  Hardwoods (Sugar maple, yellow birch, ...)
- **SW**
  Softwoods (Balsam fir, spruces, pines, ...)

4 DBH CLASSES
- **PO**
  Poles (9cm<dbh<25cm)
- **ST**
  Small Timber (25cm<dbh<41cm)
- **LT**
  Large Timber (41cm<dbh<49cm)
- **XLT**
  X-Large Timber (dbh>51cm)

3 QUALITY/RISK CLASSES
- **C1**
  Sawlog quality + Low Risk
- **C2**
  Sawlog quality + High Risk
- **C3**
  Pulpwood Quality
Markov Size-Class Model applied to partial harvests

**Density independent Transition Matrix**

**Initial Stage**

**Harvest**

**Final Stage**
**INGROWTH FUNCTION**

- **Ingrowth** = number of saplings reaching 9cm in dbh per year

- Linear function of the number of trees/ha per tree class
  - Proportional to # Poles
  - Inversely proportional to # ST, LT and XLT

- Data from predictions from ARTEMIS growth model *(Fortin & Langevin 2009)*
Current and expected future stumpage value per tree

- **Hardwoods**
  - **Poles 10-22cm**: Current $3, Expected $3
  - **Small Timber 24-38cm**: Current $24, Expected $25
  - **Large Timber 40-48cm**: Current $52, Expected $53
  - **X-Large Timber 50cm+**: Current $70, Expected $76

- **Graph**
  - **Y-axis**: $/tree
  - **X-axis**: Hardwoods
  - **Legend**:
    - Orange: Current
    - Red: Expected average in 25 yrs
FIXED COSTS

Management: 440$/ha
Tree Marking: 100$/ha
Roads: 320$/ha
Camps: 40$/ha
TOTAL: 900$/ha
Mechanical Selection Cutting System with Permanent Trails

Zone of tree selection
75% Area

Permanent Trail
25% Area

25m

5m
What would be the optimal steady state?
Managing the roof frame

- Too closed
  - No sprinters
  - Sparse waiting room

- Too opened
  - No control on sprinters
  - Empty waiting room
Optimizing the Steady State (without trails)

**Objective Function**

Periodic Net Stumpage Value

**Constraints**
- Residual Structure at YEAR 0 = YEAR 25
- Basal Area between 18 and 27 m²/ha
- Harvest < Initial

**Decision Variables**

- Residual Structure at YEAR 0 = YEAR 25
- Basal Area between 18 and 27 m²/ha
- Harvest < Initial
RESULTS Optimal Steady State with trails

- **Initial Basal Area** (m²/ha): 24
- **Acceptable Growing Stock (C1)**: 33%
- **Hardwoods**: 84%
- **Increment (m²/ha/yr)**: 0.23
- **Harvest (m³/ha)**: 41
- **Revenues**: 2 005 $
- **Harvest Costs**: (762 $)
- **Fixed Costs**: (900 $)
- **TOTAL**: 343 $
RESULTS How does it compare with other selection cutting guides?

![Graph showing basal area (m²/ha) across different diameter classes for various selection cutting guides.]

- **Lussier et al 2018**: BA 18m²/ha, Dmax 40cm
- **Ontario 2004**: BA 19m²/ha, Dmax 60cm
- **Arbogast 1954**: BA 21m²/ha, Dmax 60cm
- **Hansen 1983**: BA 16m²/ha, Dmax 50cm
What would be the best conduct suite of cuttings?
<table>
<thead>
<tr>
<th>STAND TYPE</th>
<th>Proportion of Basal area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Quality (C3)</td>
</tr>
<tr>
<td>1</td>
<td>52%</td>
</tr>
<tr>
<td>2</td>
<td>25%</td>
</tr>
<tr>
<td>3</td>
<td>27%</td>
</tr>
<tr>
<td>4</td>
<td>32%</td>
</tr>
<tr>
<td>5</td>
<td>21%</td>
</tr>
<tr>
<td>6</td>
<td>21%</td>
</tr>
<tr>
<td>7</td>
<td>30%</td>
</tr>
<tr>
<td>8</td>
<td>14%</td>
</tr>
</tbody>
</table>
STAND TYPE 2

- Most frequent stand type
- Comparison with OSS
  - Higher BA
  - More Large and Xlarge Timber
  - Higher quality

```
OVERSTOCKED
```

### INITIAL STRUCTURE

<table>
<thead>
<tr>
<th>Trees/ha</th>
<th>Stand TYPE 2</th>
<th>Optimal Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poles 10-22cm</td>
<td>red</td>
<td>yellow</td>
</tr>
<tr>
<td>Small Timber 24-38cm</td>
<td>red</td>
<td>yellow</td>
</tr>
<tr>
<td>Large Timber 40-48cm</td>
<td>red</td>
<td>yellow</td>
</tr>
<tr>
<td>Xlarge Timber 50cm+</td>
<td>red</td>
<td>yellow</td>
</tr>
</tbody>
</table>

### Basal Area (m²/ha)

<table>
<thead>
<tr>
<th>Basal Area</th>
<th>Stand Type 2</th>
<th>Optimal Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>46%</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>84%</td>
<td>79%</td>
<td></td>
</tr>
</tbody>
</table>

### Acceptable Growing Stock (C1)

<table>
<thead>
<tr>
<th>Hardwoods</th>
<th>Stand Type 2</th>
<th>Optimal Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td>46%</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>84%</td>
<td>79%</td>
<td></td>
</tr>
</tbody>
</table>
BASE CASE Stumpage Value from Quebec’s 2004 Prescriptions

- Tree selection from a logistic regression based on real operations
- Reference line: Stumpage from the optimal steady-state
- First harvest is profitable
- All other harvests are not
- Stable after 100 yrs
Comparing prescriptions: Quebec 2004 Vs. Optimal Steady State

- Less stock improvement in immature trees
- Less harvest of financially mature trees

Graph showing % Harvest for different categories of trees (Poles 10-22cm, Small Timber 24-38cm, Large Timber 40-48cm, Xlarge Timber 50cm+) over three cycles (C1, C2, C3). The graph compares Quebec 2004 (blue) and Optimal Steady State (red).
CONDUCT OPTION No.1 Cutting the excess from the steady state residual structure

Solution proposed by Buongiorno and Gilless 2003

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>60</td>
<td>40</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>15</td>
<td>25</td>
<td>15</td>
<td>10</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Poles 10-22cm</td>
<td>Small Timber 24-38cm</td>
<td>Large Timber 40-48cm</td>
<td>X-Large Timber 50cm+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- **Stand Type 2**
- **Residual Steady State Structure**
Stumpage Value of Conduct Option No.1

- Very profitable first cutting
- Negative stumpages on the mid-term
- Higher stumpages on the long term
Basal Area from Conduct No.1 (Cutting the excess from OSS)

Too low residual BA may lead to a « shelterwood effect » that will interfere with continuous recruitment
CONDUCT OPTION No.2 Optimizing the Steering toward the Optimal Steady State

GOAL

Target structure

CONSTRATMENTS

- Basal Area between 18 and 27 m²/ha
- Harvest < Initial
- Stumpage ≥ 343 CAD$ starting from Cutting No.2
Stumpage Value of Conduct Option No.2

- Higher stumpages on the short & long terms
- More uniformity among stands
**CONDUCT OPTION No.3** Optimizing the conduct for a non-declining stumpage for 4 cutting cycles

**OBJECTIVE FUNCTION**

Max Sum of Stumpage over 4 cutting cycles

**CONSTRAINTS**
- Basal Area between 16 and 27 m²/ha
- Harvest < Initial
- Non declining Stumpage for 4 cutting cycles

Repeated 3 times (next 300 yrs)
Each time the steering is re-optimized, the stumpage decreases.
Option No.3 Initial Stand Structure from Cutting Cycles 1 to 8 for Stand Type 2

- **Stand Type 2**: Represented by green bars.
- **OSS**: Represented by red bars.

Cycles:
- C1
- C2
- C3

Categories:
- **Pole 10-22cm**
- **Small Timber 24-38cm**
- **Large Timber 40-48cm**
- **Xlarge Timber 50cm+**

The graph shows the change in tree density over cycles, with arrows indicating growth trends.
Conclusions

1. On the long term, the reference selection cutting prescription can lead to a steady revenue, but it is neither the most profitable option, nor the most sustainable on the mid-term.

2. Application of cutting guides can lead to undesirable fluctuations of stumpage and basal area.

3. Determination of optimal steady state provide useful guidelines on the sustainable size structure, quality & species proportions, and stumpage.

4. Maximizing non declining stumpage is not sustainable in unmanaged stands without a proper steady-state target.
HENRY BIOLEY
1858–1939

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