Regeneration Modelling in a Changing Environment

Dick Dempster

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Foothills Growth and Yield Association
Introduction and Presentation Outline

Outline

• The Foothills Growth and Yield Association (FGYA)
  • What’s changing in the Foothills forest environment?
  • What have we done so far?
  • What are we going to do now?
What’s Changing in the Foothills Forest Environment?
Alberta’s Historical Temperature Trends


Average Temperature:
- Feb (+0.75°C/decade)
- Mar (+0.39°C/decade)
- Apr (+0.26°C/decade)

Mean Monthly Temperature (°C)

Year

Predicted Warming in the Foothills
Predicted Warming in the Foothills
The Silviculturist’s View: Deciduous Encroachment
The Wake-up Call: Mountain Pine Beetle
The Insidious: Other Pathogens
More Upsets: What the Hail?
Juvenile Mortality Trend with Temperature
The Juvenile Mortality Risk
The Good News: Ingress
More Good News (or Wishful Thinking?): Growth

• Height growth increases in managed versus fire-origin stands
  – Udell and Dempster 1986
  – Huang, Monserud et al 2004
  – FGYA 2008

• Height growth increases with climate warming
  – Monserud and Huang 2002
  – Monserud, Yang et al 2008
  – Cortini, Comeau et al 2011
  – FGYA (unpublished)

• Negative impact of climate change on radial growth
  – Chinn et al 2008
Operations: for Better or for Worse?

• Harvest versus fire
• 2nd pass alternate clear-cutting
• Roadside versus stump-side processing
• Planting versus natural regeneration
• Brushing
• Thinning and fertilization
The Future is Friendly: Predicted Yields (GYPSY)
The End is Near: Predicted Habitat Suitability
Are Predictive Models Reducing Uncertainty about the Future?

Are They Supporting Wise Decision Making?

• The forester’s view:
  – *Growth and yield models are witchcraft, whimsy or wishful thinking*

• The lawyer’s view:
  – *Growth and yield models are hearsay*
Change in a Nutshell

- Climate warming
- Increased stand height growth and pathogen occurrence (both climate and management implicated)
- Increasing juvenile mortality likely, directly and indirectly linked to climate
- Yields forecast to increase, but ....
- .... most of Foothills forecast to become unsuitable for lodgepole pine within one rotation
- Major uncertainty and apparent inconsistencies in long-term predictions and interpretation of research results
- Some current reforestation practices may be ineffectual or counter-productive
What Have We Done So Far?
Regenerated Lodgepole Pine Trial

- Monitoring stand development of harvest-origin lodgepole pine in relation to site, planting density, and vegetation management
- Split-plot design with replication
- 102 one-hectare plot clusters established throughout the Foothills, 2000 – 2002

Lodgepole Pine Regeneration Trial
Design of a Plot Cluster

Treatments:
W = weed
T = thin

= 0.1 ha assessment plot
WT = 0.25 ha treatment plot

(102 clusters installed across 5 site types at 6 planting densities, with replication)
Analytical Approach

• Main models
  – Height and diameter distributions
  – Ingress
  – Mortality

• Auxiliary models and derived variables

• Applications
  – Plantation
  – Natural regeneration
  – Consolidated

• Testing
  – Preliminary validation and cautious extrapolation
  – Experimental data
  – Operational block history data
Height and Diameter Distributions

\[ F(x) = 1 - \exp\left(-\frac{x}{B}\right)^C \]
$P = (1+\exp(a+b\times \text{YSD}^{1/2}))^{-1}$
Mortality

Mean annual temperature (°C)

Average annual mortality (%)

Overall trend
Class 1
Classes 2 & 5
Classes 3 & 4
Auxiliary Models and Derived Variables

- **Density:**
  - Trees per stocked plot (natural regeneration)
  - Planting density less mortality (planted stock)

- **Species composition**

- **Variables derived directly from Weibull distributions (average heights, densities, diameters, basal areas at various measurement thresholds)**

- **Crop tree height**

- **Top height**

- **Stump and breast-height conversions**

- **Stocking adjustment algorithm**
## Growth and Yield Association

### Regenerated Lodgepole Pine Project Forecast

#### Options (select ecological site class, vegetation treatment and mortality calculation method)

<table>
<thead>
<tr>
<th>Ecological Site Class (moisture / nutrient regime)</th>
<th>Vegetation Treatment</th>
<th>Mortality Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: dry / medium - poor</td>
<td>Weed</td>
<td>Default</td>
</tr>
<tr>
<td>2: mesic / poor (Lab. tea)</td>
<td>Leave</td>
<td>User-defined</td>
</tr>
<tr>
<td>3: mesic / medium</td>
<td></td>
<td>Climatic</td>
</tr>
<tr>
<td>4: moist / rich</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5: wet / poor (Lab. tea)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Inputs (fill white cells)

- Interval between harvest and site preparation (years)
- Planting density (trees per ha)
- Stock age at planting (years)
- Interval between harvest and planting (years)
- Survey age (years since harvest)
- Surveyed % coniferous stocking (including under-height)
- Percent periodic mean annual mortality
- Mean annual temperature (degrees C)
Graphic Output

**Graphs**

**Coniferous % Stocking**
- Percent stocking (all conifers including under-height)
- Percent stocking (all conifers 30cm+)

**Pine Basal Area**
- BH basal area per ha of planted stock (m²)
- BH basal area per ha of ingress (m²)
- Combined total BH basal area per ha (m²)

**Pine Density (trees 30cm+)**
- # of planted pine trees per ha ≥30cm
- # of pine ingress trees per ha ≥30cm
- Total # of pine trees per ha ≥30cm

**Pine Density (trees 130cm+)**
- # of planted pine trees per ha ≥130cm
- # of pine ingress trees per ha ≥130cm
- Total # of pine trees per ha ≥130cm

**Pine Height**
- Average height of planted stock (cm)
- Average height of ingress (cm)
- Combined average stand height (cm)
- Top height - based on RSA definition (cm)

**Pine Diameter Breast-height (DBH)**
- Average DBH of planted stock (cm)
- Average DBH of ingress (cm)
- Combined average tree DBH (cm)
## Summary Output (GYPSY Input)

### Forecast Summary

<table>
<thead>
<tr>
<th>Opening age (years since harvest)</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total age (years since germination)</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Top height - based on RSA definition (cm)</td>
<td>92.6</td>
<td>120.9</td>
<td>149.2</td>
<td>187.4</td>
<td>225.6</td>
<td>263.7</td>
<td>301.9</td>
<td>340.0</td>
<td>378.2</td>
</tr>
<tr>
<td>Total # of coniferous trees per ha</td>
<td>1,356</td>
<td>2,902</td>
<td>5,228</td>
<td>7,812</td>
<td>10,056</td>
<td>10,990</td>
<td>10,990</td>
<td>10,990</td>
<td>10,990</td>
</tr>
<tr>
<td># of pine per ha &gt;=30cm</td>
<td>770</td>
<td>1,602</td>
<td>3,838</td>
<td>6,755</td>
<td>9,397</td>
<td>10,606</td>
<td>10,773</td>
<td>10,839</td>
<td>10,857</td>
</tr>
<tr>
<td>Percent stocking (conifers 30cm+)</td>
<td>37.1</td>
<td>58.8</td>
<td>73.0</td>
<td>81.7</td>
<td>84.7</td>
<td>84.7</td>
<td>84.7</td>
<td>84.7</td>
<td>84.7</td>
</tr>
<tr>
<td>Pine BH basal area per ha (m2)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.55</td>
<td>1.01</td>
<td>1.58</td>
<td>2.17</td>
<td>2.91</td>
<td>3.91</td>
</tr>
</tbody>
</table>

### Graph

- **Stand volume (m^3/ha)** vs **Stand age (years)**
- Graph shows the growth of stand volume over time.
- Key lines represent different species or age classes.
What Are We Going To Do Now?
Model Development

- Continued data collection and analysis
- Inclusion of additional species essential to support species selection decisions
- Testing and validation
- Retain as simple stand model or adopt a more sophisticated approach?
- Interdisciplinary discussion and cooperation
Strategic Directions

• Choices:
  – Strive to achieve sustained-yield management objectives?
  – Accept disappearance of the Foothills Forests?

• Directions:
  – Focus on decision support for establishing and restoring healthy stands, and associated opportunities for reduction of silvicultural risks and improvement of operational effectiveness:
    - Increased reliance on natural regeneration
    - Less dependence on planting lodgepole pine
    - Species mixtures and alternatives
    - Hazard assessment and reduction of pathogen threats
    - Adjustments to site and stand survey procedures and prescriptions for site preparation, planting and tending
  – Less emphasis on conventional long-term G&Y prediction, and more emphasis on forecasting regeneration health, performance and risks