Simplified Models for Linking Regeneration Standards to Desired Future Forest Condition

Contract report to
Canadian Forest Products Ltd.
Fort St. John BC
March, 2008

Completed by:
Craig Farnden RPF
PhD Candidate
University of British Columbia

craigfarnden@telus.net
Contents

Introduction ........................................................................................................................................... 1
  Simplified Models ............................................................................................................................ 1
Analysis Framework ........................................................................................................................... 2
Case Studies – Context ....................................................................................................................... 2
Case Studies – Methods ...................................................................................................................... 3
  Growth Modeling – MGM .................................................................................................................. 4
  Growth Modeling – SortieND ........................................................................................................... 4
  Surveys – Stocked Quadrats ............................................................................................................. 4
  Surveys – UofA Mixedwood ............................................................................................................ 5
  Surveys – Mixedwood Well Spaced ............................................................................................... 5
  Construction of Simplified Models ................................................................................................. 5
Case Studies – Results ....................................................................................................................... 6
Discussion ........................................................................................................................................... 8
  Model Properties ............................................................................................................................. 8
  Survey Summaries as Predictive Parameters ............................................................................... 9
  Growth Models as Reflections of Reality ....................................................................................... 10
  Further Work .................................................................................................................................. 11
Conclusions ....................................................................................................................................... 14
References .......................................................................................................................................... 14
Figures
1. Use of most existing growth models for individual cutblock assessments requires a large amount of expensive data collection, specialized knowledge to run the models, and a considerable amount of time. .............................................................................................................. 1
2. There are advantages and disadvantages to a set of simplified models, including small losses in reliability and transparency, and possibly small increases in consistency ................................. 1
3. Simplified models are developed based on the parallel processes of projecting future attributes of a large number of computer generated stands and simulating silviculture surveys on the same stands ................................................................................................................. 2
4. Comparison of actual (MGM) versus predicted values for simplified models based on 10 m³ quadrat surveys ........................................................................................................................................ 6

Tables
1. Model formats used to construct predictive models based on summary statistics from stocked quadrat surveys .............................................................................................................................. 7
2. Parameters estimates and fit statistics for the predictive models based on summary statistics from stocked quadrat surveys ........................................................................................................... 7
3. Model forms, parameters estimates and fit statistics for the predictive models based on summary statistics from UofA Mixedwood surveys ........................................................................... 8
4. Model forms, parameters estimates and fit statistics for the predictive models based on summary statistics from Mixedwood WS surveys ........................................................................... 8
Introduction
Contrary to the current paradigm of forest administration where we hope the sum of our actions in various stands adds up to a desirable outcome at the larger scale, Sustainable Forest Management (SFM) requires that we actively plan for future forest conditions. As part of the move to SFM, we need regeneration standards that assess not only stocking but also the contribution to our desired future forest. In this manner, regeneration standards will move from simply playing a role in maintaining adherence to contractual or policy based reforestation requirements to one where they are also a key component in the forest steward’s toolbox.

Simplified Models
We currently have the ability to predict future outcomes using a wide range of computer-based models. Such models are more and more being used by managers to formulate a working estimate of future “realities”, upon which they make management decisions. However, these models are often perceived as impractical for widespread use due to the expense of collecting appropriate input data or the requirements for specialized knowledge to properly run them. Such hurdles can be overcome, however, using a parallel system of simplified models using readily available and cheap inputs such as silviculture survey summaries. A contrast of these approaches is illustrated in Figures 1 and 2.

**Figure 1.** Use of most existing growth models for individual cutblock assessments (the “Hard Way”) requires a large amount of expensive data collection, specialized knowledge to run the models, and a considerable amount of time. The “Easy Way” uses data from operational silviculture surveys, and can readily be added to silviculture survey compilation software.

**Figure 2.** There are advantages and disadvantages to a set of simplified models (the “Easy Way”), including small losses in reliability and transparency, and possibly small increases in consistency (everyone gets the same answer). The big differences relate to flexibility and practicality: the simplified models are tied to a specific set of site and stand conditions and are poorly transferable, but are very inexpensive and easy to apply.
Analysis Framework

An analysis framework has been developed (Farnden 2007, 2008) to facilitate development of simple and reliable predictive relationships between silviculture survey outcomes and long-term achievement of management objectives. A large number of simulated stem maps at the scale of operational cutblocks are generated, with yields simulated using existing growth models. The same cutblocks are then sampled using simulated silviculture surveys, and the summaries correlated to growth model outcomes to become predictive parameters (Figure 3). Where strong correlations exist, these simplified models can form the basis of useful and defensible regeneration standards.

Figure 3. Simplified models are developed based on the parallel processes of projecting future attributes of a large number of computer generated stands and simulating silviculture surveys on the same stands. The growth simulations are assumed to be the manager’s version of “reality”, and the survey summary statistics are used as predictive parameters to mimic that reality. (Photos: Apple Inc., Cameron Farnden)

Case Studies – Context

In a Sustainable Forest Management Plan (SFMP) for the Fort St. John Timber Supply Area (Fort St. John Pilot Project 2004), licensees made commitments to design a forest management system that recognizes the natural variability of ecosystems and attempts to emulate patterns of natural disturbance and resulting stand types. Part of this process is a provision to evaluate
reforestation success at the landscape level for activities undertaken at the stand level. Major Forest Types based on species composition have been identified, with targets for each based on historic occurrence by Landscape Unit. Following this strategy, conifer and deciduous species are managed separately in discrete patches at scales ranging from “macro” (cutblock level) through meso (stratum level) and micro (small group or strip) patches, with a minor component of cutblocks (10%) being managed to intimate (tree level) mixtures on a trial basis.

In order to monitor achievement of these objectives, a system of operational measurements is needed to assess the contribution of each regenerated unit to the landscape target. Ideally, a system of simple field assessments analogous to current silviculture surveys could be used to assess both minimum stocking requirements and the contribution of each unit to future conifer and deciduous yields (or species composition for habitat or biodiversity requirements). For this purpose, we need to be able to forecast future stand outcomes from a relatively simple and inexpensive set of predictor variables in the form of silviculture survey summaries.

**Case Studies - Methods**

A set of 108 stands were generated representing 3 levels of planted spruce stocking (1400 trees/ha with 10%, 40% and 70% random mortality), 9 levels of area coverage by aspen clones (10 to 90% coverage, in coverage increments of 10%, with 10,000 trees/ha in clumps), and 4 levels of aspen density for areas not covered by clonal clumps (0, 50, 200 and 800 trees/ha randomly distributed). Each stand covered 9 ha, and site index was assumed to be 20 m (BHage 50) for both species. Size distributions were developed for spruce and aspen based on 13-year-old stands generated using the MGM growth model tempered with observations from a mixedwood field experiment (Kabzems et al. 2007):

- Aspen heights were assumed to follow a normal distribution with a mean of 3.0 m and a variance of 0.6 m.
- Spruce heights before adjustments for suppression followed a normal distribution with a mean of 1.2 m and a variance of 0.2 m. Based on overtopping aspen densities (N as trees/ha) within the same 5 m pixel cell, a height adjustment factor was developed as:

  \[
  AdjustmentFactor = \frac{10^{(-0.000035 \times N + 1.285)}}{20}
  \]

- DBH for each tree was calculated as a function of height, maximum tree height within 5 m and local density (M) within 5 m:

  \[
  DBH = \frac{Height}{(0.000022 \times M + 0.98) \times \left(\frac{MaxHt}{Height} \times 0.2 + 0.9\right)}
  \]

  Within the denominator, the first set of brackets generates a height/diameter ratio based on density, and the second set generates an adjustment factor ranging between 0.9 and 1.1 based on relative tree height.

Simplified models were developed to predict whole stand merchantable volume at 80 years and the percentage of that volume comprised of spruce (species composition) based on two model-based realities (MGM and SortieND) and six different silviculture survey methods as a source of predictor variables.
**Growth Modeling - MGM**

MGM is an individual tree, distance independent growth model developed at the University of Alberta by Dr. Steve Titus and colleagues (University of Alberta 2007). It is primarily intended for use in boreal mixedwoods. The model is initiated with a representative sample of trees from the stand (a treelist), which are grown in a competitive environment where competition is specified based on social status (size rank) and stand level measures of crowding. The spatial positions of trees are not known, so spatial pattern (clumpiness) has no effect on an individual run of the model. Problems related to spatial pattern were dealt with in this project by generating thirty six different treelists using 100 m$^2$ plots on a 50 m grid with a random starting point. Each treelist in a stand was simulated separately, with the results combined to form a composite yield table.

**Growth Modeling – SortieND**

SortieND is an individual tree model in which tree growth is based on spatially explicit measures of the competitive environment, and growth of young trees is mediated by light availability through the use of a ray tracing sub-model. SortieND was originally developed in the eastern United States (Pacala et al. 1993) and later adapted for use in British Columbia (Coates et al. 2003, Astrup 2007). Strengths of this model for the current project include its spatially explicit nature, its ability to simulate a relatively large stand in a single run (a few of the 9 ha stands with higher stand densities had to be split into quarters and recombined after simulations were completed) and the use of the light model for assessing small tree competitive environments. Weaknesses included a poor height model for large trees based on a fixed allometric relationship to diameter, and for the currently available version an optimistic growth rate for spruce.

**Surveys - Stocked Quadrats**

Stocked quadrat$^1$ surveys assess stocking based on the presence or absence of desirable trees in each plot. In the case of mixedwoods, plots are placed into one of four classes:

- 0: Plot is unstocked
- 1: Plot contains at least one deciduous tree but no conifers
- 2: Plot contains at least one conifer, but no deciduous trees
- 3: Plot contains both conifer and deciduous trees

Summary statistics for the survey are based on the proportion of plots in each class ($C_0$, $C_1$, $C_2$ and $C_3$). This system typically needs a large number of plots in order to generate reliable statistics, but they are very quick to install and very cost effective. One hundred and forty four plots were used in each stand for this project. Six variants of this system were employed, each using a different plot size: 5, 7.5, 10, 12.5, 15 and 20 m$^2$.

---

$^1$ Quadrats are fixed area plots, typically quite small, used as a measure of habitat in which individuals in a population are tallied to assess local distribution. The word quadrat originally (and frequently still) referred to a rigid square frame used to define the limits of the plot, which in turn is derived from the squarish shape of the quadrate bone in the skulls of birds or reptiles. In practice quadrats may be any shape but are most commonly square or circular (Oxford University Press 2005).


**Surveys - UofA Mixedwood**

The UofA Mixedwood Survey uses a 50 m$^2$ circular plot (3.99 m radius) that is divided along the cardinal axes into quadrants. Stocking in each quadrant is classified similarly to a quadrat in the stocked quadrat survey, with one important difference. In order for a spruce (or other conifer) to be tallied in a quadrant, it must be free of overtopping competition according to strict criteria. An acceptable or “well growing” spruce is assessed based on its own tree-centered sub-plot. The distance to the nearest deciduous tree is tallied in each of 4 quadrants up to a maximum of 6 m. For a spruce tree to be accepted, all of the measured distances must exceed 2m, and the sum of the distances must exceed 14 m (or some other arbitrary threshold). The orientation of the quadrants can be adjusted to maximize the sum of the distances.

Summary statistics for the survey are simply the proportion of plots in each class ($C_0$, $C_1$, $C_2$ and $C_3$). This system typically needs one quarter of the number of plots as in a stocked quadrat survey in order to generate comparable statistics. Thirty six plots were used in each stand for this project.

**Surveys - Mixedwood Well Spaced**

A new variation on the BC Ministry of Forests well spaced survey system is proposed for use in spruce-aspen mixedwoods. This system uses a standard 50 m$^2$ plot (3.99 m radius). Well spaced trees are counted in the plot based on a minimum inter-tree distance of 2 m. Where the standard survey employs a single tally of well spaced trees, the mixedwood variant uses three:

1: Conifer trees are tallied ignoring the presence or absence of deciduous trees
2: Deciduous tree are tallied ignoring the presence or absence of conifers
3: Total well spaced trees are tallied with no species preference – note that tree selection for this tally is independent of the other two tallies (different trees may be selected)

Four summary statistics are generated from this survey: the mean number of well spaced trees from each of the three tallies ($WS_C$, $WS_D$, $WS_T$), and the mean number of deciduous well spaced trees found in the same plot as each well spaced spruce tree ($WS_R$):

$$WS_R = \sum_{i=1}^{n} C_iD_i + \sum_{i=1}^{n} C_i$$

Where:  
- $n = \text{number of plots}$
- $C_i = \text{number of well spaced conifers in the } i^{th} \text{ plot}$
- $D_i = \text{number of well spaced deciduous trees in the } i^{th} \text{ plot}$

Thirty-six such plots were used in each stand to generate these summary statistics.

**Construction of Simplified Models**

Separate linear models were developed for each combination of two growth models, six survey methods and two “real” stand attributes. Each set of survey summary statistics were then contrasted with a corresponding set of “real” stand attributes to evaluate their value as predictor variables.
A set of multiple linear regression models was developed using least squares procedures in JMP version 5.1 (Sall et al. 2005) to predict whole stand merchantable yield and species composition at 80 years. In many cases, either or both of the x and y variables had to be transformed in order to linearize the relationships.

**Case Studies – Results**

Model forms, coefficients and fit statistics are provided in Tables 1 to 4, and a sample comparison of actual versus predicted values in Figure 4. Except where otherwise noted, the models satisfy the assumptions of normally distributed, independent and homoschedastic residuals.

![Figure 4. Comparison of actual (MGM) versus predicted values for simplified models based on 10 m² quadrat surveys. For a perfect fit, all of the points would fall on diagonal line from the lower left to the top right of each chart.](image-url)
Simplified Models for Linking Regeneration Standards to Desired Future Forest Condition

Table 1. Model formats used to construct predictive models based on summary statistics from stocked quadrat surveys.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameter Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGM-Based “Reality”</td>
<td>MerchVol = a + b_1 C_0 + b_2 C_1 + b_3 C_2</td>
</tr>
<tr>
<td></td>
<td>%Conifer = a + b_1 C_0 + b_2 C_1 + b_3 C_2</td>
</tr>
<tr>
<td>SortieND-Based “Reality”</td>
<td>MerchVol = a + b_1 C_0 + b_2 C_1 + b_3 C_2</td>
</tr>
<tr>
<td></td>
<td>%Conifer = a + b_1 C_0 + b_2 C_1 + b_3 C_2 + b_4 C_2^2</td>
</tr>
</tbody>
</table>

Table 2. Parameter estimates and fit statistics for the predictive models based on summary statistics from stocked quadrat surveys.

<table>
<thead>
<tr>
<th>Model</th>
<th>Quadrat Size (m²)</th>
<th>Parameter Estimates</th>
<th>Parameter Estimates</th>
<th>R²_adj</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a</td>
<td>b_1</td>
<td>b_2</td>
<td>b_3</td>
</tr>
<tr>
<td>MGM – Merchantable Volume</td>
<td>5</td>
<td>492.3</td>
<td>-435.7</td>
<td>-146.5</td>
<td>-98.8</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>435.3</td>
<td>-386.4</td>
<td>-100.45</td>
<td>-149.1</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>411.1</td>
<td>-399.8</td>
<td>-97.1</td>
<td>-143.1</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td>400.4</td>
<td>-409.13</td>
<td>-103.5</td>
<td>-150.8</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>392.7</td>
<td>-401.7</td>
<td>-123.8</td>
<td>-152.9</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>381.9</td>
<td>-458.85</td>
<td>-148.5</td>
<td>-147.8</td>
</tr>
<tr>
<td>MGM - % Conifer</td>
<td>5</td>
<td>0.4482</td>
<td>0.2785</td>
<td>-0.5653</td>
<td>0.5363</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>0.3224</td>
<td>0.4209</td>
<td>-0.4037</td>
<td>0.6101</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.2991</td>
<td>0.4324</td>
<td>-0.3528</td>
<td>0.6233</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td>0.2995</td>
<td>0.4110</td>
<td>-0.346</td>
<td>0.619</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.3130</td>
<td>0.3320</td>
<td>-0.3476</td>
<td>0.6123</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.3379</td>
<td>0.3968</td>
<td>-0.4562</td>
<td>0.5705</td>
</tr>
<tr>
<td>SortieND – Merchantable Volume</td>
<td>5</td>
<td>215.0</td>
<td>227.8</td>
<td>-21.7</td>
<td>471.0</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>233.1</td>
<td>211.1</td>
<td>-23.6</td>
<td>395.4</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>250.5</td>
<td>174.1</td>
<td>-29.2</td>
<td>362.0</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td>260.8</td>
<td>143.1</td>
<td>-27.2</td>
<td>342.2</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>271.2</td>
<td>89.7</td>
<td>-30.0</td>
<td>338.2</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>288.4</td>
<td>84.6</td>
<td>-67.2</td>
<td>308.9</td>
</tr>
<tr>
<td>SortieND - % Conifer</td>
<td>5</td>
<td>0.1192</td>
<td>0.5501</td>
<td>-0.3867</td>
<td>2.0622</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>0.0566</td>
<td>0.5787</td>
<td>-0.2807</td>
<td>1.9487</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.0685</td>
<td>0.4948</td>
<td>-0.2605</td>
<td>1.8998</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td>0.1091</td>
<td>0.4352</td>
<td>-0.2957</td>
<td>1.7630</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.1523</td>
<td>0.2808</td>
<td>-0.3107</td>
<td>1.6817</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.2258</td>
<td>0.4119</td>
<td>-0.5222</td>
<td>1.4526</td>
</tr>
</tbody>
</table>

* This model was not completely linear and resulted in patterned residuals. While this situation can be corrected with the addition of transformed variables, it has been left in the same form as for the other quadrat sizes for comparative purposes.

** Models for which the Y variable was transformed have an I² statistic replacing the R², and RMSE statistics have been calculated using back-transformed predicted values. The I² statistic can be compared to the R² statistic, recognizing that the comparison is not perfect.
**Table 3.** Model forms, parameter estimates and fit statistics for the predictive models based on summary statistics from UofA Mixedwood surveys.

<table>
<thead>
<tr>
<th>“Reality” Source</th>
<th>Models</th>
<th>( R^2_{adj} )</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGM</td>
<td>MerchVol = 253.5 - 329.4C_0 + 139.2C_1 + 36.9C_2 &lt;br&gt;%Conifer = 260.1 - 2.420C_0 - 2.456C_1 - 1.625C_2 + 1.350C_0^2 - 0.3741C_1^2</td>
<td>0.933</td>
<td>15.96</td>
</tr>
<tr>
<td>SortieND</td>
<td>MerchVol = 1117.7 - 697.4C_0 - 896.1C_1 + 547.8C_2 &lt;br&gt;%Conifer^2 = 3.3530 - 2.881C_0 - 3.561C_1 - 2.223C_2 - 0.3502C_1^2</td>
<td>0.949</td>
<td>19.34</td>
</tr>
</tbody>
</table>

* Models for which the Y variable was transformed have an I^2 statistic replacing the \( R^2 \), and RMSE statistics have been calculated using back-transformed predicted values. The I^2 statistic can be compared to the \( R^2 \) statistic, recognizing that the comparison is not perfect.

**Table 4.** Model forms, parameter estimates and fit statistics for the predictive models based on summary statistics from Mixedwood WS surveys.

<table>
<thead>
<tr>
<th>“Reality” Source</th>
<th>Models</th>
<th>( R^2_{adj} )</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGM</td>
<td>MerchVol = -131.5 + 106.8WS_D + 62.8ln(WS_C) - 37.89ln(WS_R) + 36.87ln(WS_T) &lt;br&gt;ln(% Conifer) = 0.08015 - 0.1751WS_D + 0.6705ln(WS_C) + 0.0958ln(WS_R) - 0.7354ln(WS_T)</td>
<td>0.951</td>
<td>13.17</td>
</tr>
<tr>
<td>SortieND</td>
<td>MerchVol = 358.4 - 81.7WS_D + 25.3WS_R + 7.395WS_C^2 - 1.151WS_C^3 + 112.2ln(WS_T) &lt;br&gt;%Conifer^2 = 0.6443 - 0.2074WS_D - 0.0314WS_R + 0.2567WS_R^0.5 + 0.2554ln(WS_C)</td>
<td>0.977</td>
<td>13.13</td>
</tr>
</tbody>
</table>

* Models for which the Y variable was transformed have an I^2 statistic replacing the \( R^2 \), and RMSE statistics have been calculated using back-transformed predicted values. The I^2 statistic can be compared to the \( R^2 \) statistic, recognizing that the comparison is not perfect.

**Discussion**

The developed simple models have two distinct applications. The first of these matches the current application of stocking standards for the purpose of administering contractual or regulatory obligations for reforestation. For this purpose, yields predicted for a particular stand using stocked quadrat or UofA surveys could be contrasted with those for a theoretical fully stocked stand with the same species composition simply by removing the unstocked plots. In this scenario, a compliance level would be based on a threshold percentage of potential yield. The second application follows a forest management perspective, where the developed models are intended to assess the contribution of each stand to landscape level objectives. For the landscape unit objectives stated for the Fort St. John Pilot Project, stands can be classified based on species composition so that their area in hectares can be tallied in a ledger system to assess landscape level species composition.

**Model Properties**

The properties of the simplified models can be subjectively assessed against the desired attributes for a predictive model presented earlier, and contrasted to the alternative process of making predictions using the original stand level model (in this case either MGM or SortieND):

**Reliability:** The simplified models were able to explain up to 97% of the variation in MGM and SortieND outcomes. If we assume that projections from either of these models...
Simplified Models for Linking Regeneration Standards to Desired Future Forest Condition

reflect reality, then use of the simplified models in their stead results in a minor degradation of reliability. In a small number of cases, stands will be misclassified by species composition, but these will be predominantly cases where stand composition was close to the class boundary anyway. There is no overt indication that use of the simplified models will result in classification bias.

**Consistency:** The simplified models employ standard survey techniques. Assuming well trained crews, there should be minimal risk of measurement errors. In this regard, the presented techniques should result in a high degree of consistency.

**Transparency:** The simplified models provide either a greater or lesser degree of transparency than a similar process using MGM or SortieND, depending on the user’s perspective and experience. MGM and SortieND provide transparency through quantifying concepts of inter-tree competition, which educated users can conceptualize as the source of successional patterns. The simplified models provide transparency at a different level, whereby the relative abundance of locally dominant stand components (deciduous trees versus conifer trees) has a major influence on stand outcomes, again through the process of succession. Overall, it is difficult to assess whether or not one or the other approach is more transparent, with the “winner” likely varying from individual to individual.

**Flexibility:** The simplified models are constructed using a set of assumptions that fix certain parameters to limit complexity. In the cases presented here, site index was fixed at 20 m for both species, the species composition was limited to two species, and the stands were even-aged with no retention of legacy trees. The models can only be applied under a similar set of conditions. This means that if management objectives are changed, the simplified models may no longer be applicable.

A related issue is the amount of work required to generate simplified models. Limits to flexibility dictate that a range of simplified models may be required to address different stand conditions or management objectives. The feasibility of building simplified models for all such cases will likely depend on the frequency for which such models will be required. If the number of cases is quite small, it will be a far more efficient use of staff resources to complete one-off evaluations using detailed ground sampling coupled with simulations in tree level growth models. The advantages of the simplified models will become more apparent as the number of harvest units with matching conditions grows in number.

**Practicality:** The simplified models are superior to the alternative for practicality. Data requirements are far simpler and can be collected using existing operational processes. Modeled results can be obtained almost immediately after computing very simple summary statistics from survey data.

**Survey Summaries as Predictive Parameters**

Stocked Quadrat surveys, the UofA Mixedwood survey and the Mixedwood Well Spaced survey all produced summary statistics that were useful as predictive parameters. In all three cases, tight correlations could be produced with minimal prediction error. The Mixedwood Well Spaced survey produced slightly better results than the UofA system and the best of the quadrats. Within the quadrat system, smaller plots always produced better results than larger ones.
The Mixedwood WS system likely performed better than the UofA system because it does a better job of using the information on relative species presence and the degree of competition that the conifer component is experiencing. The UofA system makes detailed measurements to assess the competitive condition of individual trees, but discards that information prior to summarization – individual trees are simply recorded as acceptable versus unacceptable\(^2\). In the mixedwood well spaced system, every well spaced conifer is kept in the tally, along with a relative measure of competition (the number of well spaced deciduous trees in the same plot). The quadrat surveys seem to fall in between the other two in this matter – all tallied trees are kept, but less detail is available regarding competitive status.

It appears that suitable simplified models can be built using any of the three survey systems, and likely others as well. The final choice will depend on several factors. The stocked quadrat system is appealing in its simplicity – the simpler the system the less chance for measurement error, variability in surveyor judgment, and misapplication through ignorance. All of these elements are important given that surveyors are often minimally trained contractors. Others factors affecting the choice of a survey system include compatibility with inventory data structures and information needs for other management purposes such as forest health and green-up assessments.

**Growth Models as Reflections of Reality**

In making management decisions, forest managers must have some vision of how the future is likely to unfold. More and more, they are using forest growth models to help define that future “reality”. Two different management realities have been utilized in this project, each with its own strengths and weaknesses.

The currently available versions of MGM and SortieND vary considerably in their stages of development. Neither model has had the extensive development and testing program as models such as TASS in British Columbia or FVS in the United States. Having said this, the MGM model is further along in development than is SortieND, and has been subjected to a higher degree of testing against remeasured plot data. The SortieND model, with the growth parameters currently available for use in this project, is known to overestimate spruce growth (pers. comm. R. Astrup) and is parameterized for only a single set of site conditions.

While MGM is more readily available and suitable for operational use than SortieND at the time of writing, its major drawback for this project is its distance independent nature. This means that stocking issues that are heavily influenced by spatial pattern cannot be explicitly modeled. The workaround for this problem employed in this project was to assume that numerous simulations using localized treelists from 100 m\(^2\) plots could be used to represent spatial variability. The observation that SortieND results had little difference in precision as compared to the MGM results provides some comfort that the MGM results are not biased by the spatial variability issue. Further testing is planned to explore this issue further.

\(^2\) The same argument can be made regarding the use of the “free growing” concept in mixedwood management. There is growing body of opinion that use of the “free growing” concept for assessing conifers in a mixedwood management scenario is inappropriate and misleading.
Further Work

Despite the apparent promise shown by this approach, a considerable amount of development work and testing is still required:

**Treelist Generation:** The treelist generation module in the survey simulator may benefit from better relationships for generating realistic spatial patterns and size class distributions. Data has been collected for this purpose, with calibration planned in the 2008/09 fiscal year.

**Estimates of Actual Outcomes:** The estimates of actual outcomes in this project are based on simulations, introducing the risk that errors or bias in MGM or SortieND will result in similar problems for the simplified models. One way to check for potential problems is to compare the outcomes to other existing models. In such comparisons, one can never know which model is providing the “best” predictions, but the degree of similarity or difference can provide managers with a perspective on model reliability. The other more quantitative solution is a validation approach, whereby outcomes are compared to empirical data from remeasured plots. To a large extent, this is an exercise typically carried out by model developers with the results provided to managers as supporting documentation.

**Variations in Site Quality:** The simulated stands generated in this project assume a site index for both species of 20 m (BHage 50). Total volume will certainly change with site index, and patterns of succession will change if the relative site index between the species is altered by changes in environmental gradients (Green 2004, Green and Hawkins 2005). The importance of the latter factor is primarily of concern for the species composition models.

Conclusions

This paper highlights the potential for moving from stocking standards as simple tools for administering contractual or policy based stocking requirements to regeneration standards that play an active role in forest management. For the case of boreal mixtures of spruce and aspen, it is apparent that simplified predictor models based on silviculture survey outcomes can be used to evaluate both achievement of basic reforestation obligations and cut block level contributions to forest landscape objectives. The overall goal, of course, is good forest management. The starting point is the definition of appropriate objectives and finding practical mechanisms for achieving them. At the end of the day, regeneration standards should be a mechanism for achieving management objectives, and should not become the de facto management objectives on their own.

References


