

**Development of Natural Regeneration and Juvenile Height Growth
Models for Complex Stands
of Southeastern and Central British Columbia**

Final Report for Activities from April 1, 2001 through March 31, 2002

By Valerie LeMay, Ph.D., RPF, (Principal investigator),
Peter Marshall, Ph.D., RPF, H. Temesgen, Ph.D., RPF (Co-investigators),
Abdul Azim Zumrawi, Ph.D., RPF (Partner),
Badre Hassini (M.Sc. candidate), Katrina Froese, (M.Sc. candidate),
Cornel Lencar (M.F. candidate), and Rene Martin, M.Sc. (Research Associate)

Forest Resources Management Department,
2045 2424 Main Mall, University of BC,
Vancouver, BC V6T 1Z4

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Abstract

Mixed-species and/or uneven-aged stands (complex stands) are common in southeast and central British Columbia. Management using some form of partial cutting generally increases the structural complexity of such stands, complicating predictions of future development. Prognosis^{BC} is a growth and yield model adapted from the original Prognosis model that was developed for the northern Rocky Mountain region of the United States to assist in predicting the dynamics of complex stands. The model can be used to simulate almost any form of harvesting, from clearcutting to partial cutting, and can also be linked to other models to simulate the impacts of various disease and insect vectors.

To date, Prognosis^{BC} has been calibrated by the Ministry of Forests, for use in a number of Biogeoclimatic Ecosystem Classification (BEC) subzone variants in the Nelson, Kamloops and Cariboo forest regions. Permanent sample plot data from these regions have been used to calibrate the large tree growth and mortality components of the model. However, lack of natural regeneration and small tree data has limited the full calibration of the model to a few subzone variants, where regeneration and sapling layer data were collected in 1998 and 1999. This lack of data also limits the utility of the model for making long-term projections following disturbances.

This research addresses the natural regeneration and small tree growth components of Prognosis^{BC}. The three-year study from 2001 through 2004 was designed to complement the large tree component of the Prognosis^{BC} modelling effort, part of the Ministry of Forests research program. Only the first year of funding was made available, however.

For the first year (2001/02 fiscal year), the specific objectives were to:

1. Collect regeneration and small tree height growth data in the IDFdm2 (Interior Douglas fir dry moist 2) subzone variant in the vicinity of Invermere;
2. Complete the development of imputation techniques for predicting regeneration and seedling development in complex stands;
3. Use the imputation technique(s) to predict regeneration and seedling development in the subzones variants where data were previously gathered, specifically, ICHmw2 (Interior Cedar Hemlock moist warm 2) variant, and IDFdk1, IDFdk2, IDFdk3 (Interior Douglas-fir dry cool 1, 2, and 3) variants combined; and
4. Disseminate this work through an effective extension plan.

The current year built upon the natural regeneration and small tree modelling effort that was conducted by the project team over the previous two years, expanding and enhancing the modelling of these components for complex stands in IDFdk1, dk2, and dk3 variants and ICHmw2 variants in the Nelson, Kamloops, and Cariboo Forest Regions. Existing regeneration data already collected by the project team, Ministry of Forests, and industry were used for ICHmw2, and IDFdk1, dk2 and dk3. In this year, data were also gathered in IDFdm2 variant and preliminary analyses were completed. In addition, imputation

methods were selected and compared to traditional regression approaches for modeling regeneration.

In the short term, the regeneration results for IDFdk1, dk2, and dk3, and for ICHdm2 will be distributed to all collaborators and partners. If funding is obtained, results will also be posted on the UBC Prognosis web site for access. This will allow practitioners to use the data as inputs to Prognosis^{BC} for these variants. Other related Prognosis reports will also be posted, as funding becomes available for this extension work.

The results have been extended to the collaborators, and also to an international audience of researchers, through meetings and conferences. Further analysis is planned for the IDFdm2 data collected last year, as part of Katrina Froese' M.Sc thesis funded, in part, by the National Science and Engineering Research Council via a scholarship won by Ms. Froese. Research by Badre Hassani, M.Sc. candidate and by Cornel Lencar, M.Sc. candidate is part of their theses work. They are expected to defend their work within three months, although there is no funding for the final thesis writing phase. At this time, there is no funding to extend the work into the MS (Montane Spruce) zone, as was originally planned.

Keywords: Regeneration estimation, nearest neighbour, imputation

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List of Species Names

Local Name	Scientific Name	Code
Douglas-fir	<i>Pseudotsuga menziesii</i> var. <i>glauca</i> (Mirb.) Franco	Fd
Hybrid spruce	<i>Picea glauca</i> (Moench) Voss x <i>Engelmannii</i> Parry	Sxw or Sx
Lodgepole pine	<i>Pinus contorta</i> var. <i>latifolia</i> Dougl.	Pl
Paper birch	<i>Betula papyrifera</i> Marsh.	Ep
Ponderosa pine	<i>Pinus ponderosa</i> Laws.	Py
Rocky Mountain Juniper	<i>Juniperus scopulorum</i> Sarg.	Rj
Subalpine fir	<i>Abies lasiocarpa</i> (Doug.) Lindl	Bl
Trembling aspen	<i>Populus tremuloides</i> Michx.	At
Western larch	<i>Larix occidentalis</i> Nutt.	Lw
Western redcedar	<i>Thuja plicata</i> Donn	Cw
Black cottonwood	<i>Populus trichocarpa</i> Torr. & Gray	Act
Grand fir	<i>Abies grandis</i> (Doug.) Lindl.	Bg
Water birch	<i>Betula occidentalis</i> Hook.	Ew
Willow	<i>Salix</i> sp.	W
Western hemlock	<i>Tsuga heterophylla</i> (Raf.) Sarg.	Hw
Western white pine	<i>Pinus monticola</i> Dougl.	Pw
Western yew	<i>Taxus brevifolia</i> Nutt.	Tw

Introduction

Mixed-species and/or uneven-aged stands (complex stands) are common in southeast and central British Columbia. Management using some form of partial cutting generally increases the structural complexity of such stands, complicating predictions of future development. Natural regeneration and the subsequent development of sapling layers are key components in the dynamics of such stands. Accurate predictions of these components are essential for good projections of stand structure following some form of partial cutting or other disturbance.

The ability to forecast stand structure for a wide range of silvicultural treatments in complex stands, and to incorporate natural and managed disturbance regimes in ecosystem management and restoration, were listed as high priorities in all regions by Forest Renewal BC (FRBC). Also, predicting the effect of initial density, thinning and partial harvesting on stand structure, and suitability and capability of habitat is defined as a high priority in the Cariboo-Chilcotin and the Kootenay-Boundary regions. This recognises the need for better information about the growth and yield of complex forest stands in order to predict response to silvicultural treatment and to support more informed silviculture investment decisions.

Prognosis^{BC} is a growth and yield model adapted from the original Prognosis model (Stage 1973) that was developed for the northern Rocky Mountain region of the United States to assist in predicting the dynamics of mixed-species and/or multi-aged stands (complex stands). The model forecasts future stand conditions based on the expected growth and mortality of individual trees within a stand. It is best used for projecting an existing stand from a ground-based inventory. The model's strengths include its ability to simulate almost any form of harvesting, from clearcutting to partial cutting, and to link to other models to simulate the impacts of various disease and insect vectors.

To date, Prognosis^{BC} has been calibrated by the Ministry of Forests, for use in a number of Biogeoclimatic Ecosystem Classification (BEC) subzone variants in the Nelson, Kamloops and Cariboo forest regions. Permanent sample plot data from these regions have been used to calibrate the large tree growth and mortality components of the model (Robinson 1997; Temesgen and LeMay 2000; Zumrawi *et al.* (in press)). However, lack of natural regeneration and small tree data has limited the full calibration of the model to a few subzone variants, where regeneration and sapling layer data were collected in 1998 and 1999 (Boisvenue and Marshall 1999; Lencar and Marshall 2000). This lack of data also limits the utility of the model for making long-term projections following disturbances. The current Prognosis^{BC} user policy limits the number of stand entries and the duration of projections following a disturbance. The "regeneration" component is turned off on public releases and users must supply their own regeneration data in order to incorporate this component into projections of stand development. This precludes using Prognosis^{BC} to readily explore the silvicultural impact of various partial cutting strategies.

This research addresses the natural regeneration and small tree growth components of Prognosis^{BC}. The three-year study from 2001 through 2004 was designed to complement the large tree component of the Prognosis^{BC} modelling effort, part of the Ministry of Forests research program.

The data and models from this study will allow the Prognosis^{BC} to be used in long-term projections, thus allowing the user to:

- evaluate the impact of different silvicultural treatments and partial cutting scenarios;
- make more informed silvicultural investment decisions;
- evaluate natural and managed disturbance regimes (e.g. root disease and partial cutting) in ecosystem management and restoration; and
- generate long-term yield curves for partially cut complex stands for use in timber supply analyses.

For the first year (2001/02 fiscal year), the specific objectives were to:

1. Collect regeneration and small tree height growth data in the IDFdm2 (Interior Douglas fir dry moist 2) subzone variant in the vicinity of Invermere;
2. Complete the development of imputation techniques for predicting regeneration and seedling development in complex stands;
3. Use the imputation technique(s) to predict regeneration and seedling development in the subzones variants where data were previously gathered, specifically, ICHmw2 (Interior Cedar Hemlock moist warm 2) variant, and IDFdk1, IDFdk2, IDFdk3 (Interior Douglas-fir dry cool 1, 2, and 3) variants combined; and
4. Disseminate this work through an effective extension plan.

The current year built upon the natural regeneration and small tree modelling effort that was conducted by the project team over the previous two years, expanding and enhancing the modelling of these components for complex stands in IDFdk1, dk2, and dk3 variants and ICHmw2 variants in the Nelson, Kamloops, and Cariboo Forest Regions. Existing regeneration data already collected by the project team, Ministry of Forests, and industry were used for ICHmw2, and IDFdk1, dk2 and dk3. In this year, data were also gathered in IDFdm2 variant and preliminary analyses were completed. In addition, imputation methods were selected and compared to traditional regression approaches for modeling regeneration.

Despite a number of studies on regeneration (e.g., McCaughey *et al.* 1991; Shearer and Schmidt 1991, 1999; Cobb *et al.* 1993), and juvenile height growth (e.g., Minore 1979; Wang *et al.* 1994; Chen *et al.* 1996; Klinka *et al.* 1998; Williams *et al.* 1999) in forest types similar to those found in southeastern and central British Columbia, prediction remains problematic. Some success has been achieved using traditional regression techniques to predict small tree height growth in complex stands in southeastern British Columbia (e.g., Froese and Marshall 1998; Boisvenue 1999; Froese 2000). The system of equations embedded in the original Prognosis model for predicting regeneration has not yet proven to be a good predictor for some conditions in southeastern British Columbia, because of too little data and high inherent variability (Boisvenue 1999).

Imputation techniques were therefore developed and tested for the ICHmw2, and IDFdk1, dk2, and dk3 variants.

This report summarizes the research completed on modeling regeneration and height growth for these subzone variants in the 2001/2002 fiscal year. As the research results are quite extensive, separate reports were prepared for IDF dk1, dk2, and dk3, combined, ICHmw2, and IDFdm2, and are included with this overview report. Each of the documents includes an executive summary, which is repeated in this overview report. The extension of the research is reported in this overview report following the executive summaries. Finally, concluding remarks are given.

Report Summaries

Report 1. Prognosis^{BC} Calibration in the IDFdm2, Invermere Forest District: Field Sampling and Preliminary Results (Froese *et al.* 2002)

This report summarizes the collection of field data in the Kootenay Dry Mild Interior Douglas-fir variant (IDFdm2) within the Invermere Forest District. Sampling for the calibration of the Prognosis^{BC} model followed the methods used in previous research in southeastern British Columbia. Additional measurement for substrate and spatial attributes was based on research by LePage *et al.* (2000). Field sampling was completed during the 2001 (May to August) field season.

A total of 111 plots were sampled from 37 polygons. On 25 of these plots additional measures of substrate and spatial attributes were obtained. The target of sampling 80 percent in partial cut areas, 10 percent in clearcuts, and 10 percent in undisturbed stands was achieved. The plots provide a good range of aspects, elevations, geographic locations, and site series. Since the IDFdm2 sites occur on mid- to low- slope areas, the range for slope is restricted.

Preliminary analyses indicate that residual basal area has some effect on both five-year height growth of small trees and average height growth of regeneration. Site series does not appear to have a clear effect, but may be interacting with other site factors. Regeneration abundance does not show a relationship with residual basal area. Modal site series may have higher overall abundances of regeneration. In all cases, Douglas-fir is the dominant species, while other species contribute a minor component. Lodgepole pine is prevalent in planted sites, which correlates with low residual basal area values.

A meeting in November 2001 in Invermere, BC provided the opportunity for extension of early results to Ministry and industry stakeholders. Feedback is being incorporated into analysis. A poster, entitled "PrognosisBC Modelling at the University of British Columbia", was presented at the Second Forest Vegetation Simulator (FVS) Conference, Fort Collins, Colorado, February 12-14, 2002 and at the University of British Columbia

Forestry Research Evening, March 5, 2002. A web site has also been created for extension purposes.

Calibration of the small tree height growth model is underway. Imputation methods will be used to predict regeneration rather than calibration of the regeneration establishment component of the Prognosis^{BC} model.

Report 2. Development of Regeneration Imputation Models for the IDFdk1, dk2 and dk3 in the Kamloops and Cariboo Forest Regions (Martin *et al.* 2002)

Many models have been developed that attempt to predict future forest resource conditions based on information from current stand characteristics. In order to do so, all aspects of forest succession must be included in the model, including the regeneration component, which is often overlooked in growth and yield modelling. Estimations of post-harvest conditions and regeneration require a substantial amount of data be collected over vast forested landscapes. Because of this, stand level information that is available over the forested landscape is often supplemented with more detailed information on sampled areas. Imputation modelling objectively links detailed ground samples to the stand level information available for a larger portion of the entire landscape.

Accuracy of prediction of regeneration for Interior Douglas-fir dry cool subvariants (IDFdk1, dk2, and dk3) in the Kamloops and Cariboo Forest Regions was tested using two imputation methods: tabular and Most Similar Neighbour (MSN). For the tabular imputation, tables of average number of seedlings per ha were calculated using sample data by species and height class for a specified time since disturbance, site series class, and overstory basal area. MSN used reference plots containing complete information about stand overstory and site characteristics and regeneration variables to estimate the regeneration values for target plots that only contained information about stand overstory and site characteristics.

Data from 335 plots were collected in the summer of 1999. The sampling and measurement protocols employed were based on methods developed for the small tree and regeneration components of Prognosis, a single tree growth and yield model developed in Idaho. More than 70% of the plots experienced some disturbance in the previous 12 years. More regenerated trees were found in open sites (< 30.0 m²/hectare residual basal area) than in dense sites (> 30.0 m²/hectare residual basal area). The most common regenerating species found was Douglas-fir. The majority of regeneration in dense stands occurred in wet areas, and in mesic sites in open stands. In dense stands, regeneration was highest within 6-10 years-since-disturbance, and in open stands, 1-5 years-since-disturbance.

Both the tabular and the MSN methods performed well. Each had relatively low bias and RMSE; however, the tabular method had slightly lower error than MSN. Many of the plots contained a large number of zeros, representing no regeneration of a particular species, which may explain the low bias and RMSE found in the tabular method. For MSN, a large percentage of the overall plots (80%) were used as reference plots. Such

high sampling intensity may explain the low bias and RMSE found for this method. The tabular results can be used to estimate regeneration in non-sampled areas, by selecting a table based on stand and site variables, and substituting the average regeneration values.

Report 3. Development of Regeneration Imputation Models for the ICHmw2 in the Vicinity of Nelson (Hassani *et al.* 2002)

Forests are dynamic systems and are seldom in equilibrium. This is due, in part, to anthropogenic disturbances such as harvesting. Understanding the dynamics of complex stands has become a management priority and is the subject of a number of studies in northwestern North America. Understanding regeneration patterns in these stands is crucial, since future stands are determined by the way the regeneration is managed. The objective of this work is to explore and test the applicability of using imputation techniques rather than more traditional regression techniques for predicting regeneration in the complex mixed-species stands prevalent in the ICHmw2 subzone variant in the vicinity of Nelson, BC (Interior Cedar-Hemlock most warm variant 2). Two approaches were used: tabular imputation and Most Similar Neighbour (MSN) imputation.

This report describes the sampling regime employed to collect regeneration and small tree data in the ICHmw2. The regeneration data collected during the 2000 field season and that collected during the 1998 field season are summarized. A series of tabular imputation and MSN imputation approaches are developed and their performances in predicting the regeneration are compared. The tabular approach depicted average regeneration by five site groups, two residual density classes, five years-since-disturbance classes, species, and height class. The MSN approach made use of regeneration data of some plots (called reference plots) and a complete coverage of selected easy-to measure attributes for the entire data set (called reference and target plots) for its development. MSN imputation provided regeneration for the assumed missing regeneration data (target plots) by choosing a most similar plot from the reference plots to act as its surrogate. The most similar plot selection was based on a similarity measure that took into consideration the multivariate relationships between the two different sets of data.

The full MSN imputation model (four height classes) was the best predictor for regeneration. Stand density indicators (basal area (BA), number of residual trees per hectare (TPH), and crown coefficient factor (CCF)) were the driving variables in the most similar neighbour selection process. When the number of match categories and the root mean square error (RMSE) were used as comparison criteria, about 97.5% of the target plots imputations were classified as being moderate to good. Perfect matches with high precision corresponded to those plots that had high number of cells with no regeneration (zero). However, the use of the number of matched categories and the ratio of the RMSE to the observed regeneration of target plots provided better results by decreasing the number of unsatisfactory predictions from 2.4% to 0.3%. The mismatch of BA, TPH, CCF, and seemingly, the presence/absence of advance regeneration were considered as a major cause of poor predictions.

A sensitivity analysis showed that PrognosisBC was mostly insensitive to regeneration predictions from both imputation models during the first 50 years of the projection. However, regeneration estimates were generally quite good. Also, with longer periods of simulation, it is likely that the model would be more sensitive, particularly to tabular predictions.

As PrognosisBC grows stands based on the interaction among trees, the user can provide data either by randomly selecting a single plot from those having the same variables, or by using the means from the table that has the desired characteristics. As more data become available, these tables can be easily updated and the reliability of tables based on small sample size can be improved. There were not a lot of obvious trends apparent in the tabulated data. This may be due to the dominance of advance regeneration among the regeneration present. Advance regeneration would be more affected by the conditions that existed prior to the most recent disturbance than the conditions that exist today. Designing a sampling that separates advance from subsequent regeneration will without doubt improve the results.

Extension

Meetings with Collaborators

Prior to meeting the collaborators, the sampling plan for the IDFdm2 subzone variant was discussed by the team of investigators, partners, and graduate students. Sampling protocol used for previous zones (IDFdk1 and dk2, and ICH) were adopted for use for the IDFdm2 sites. However, the research team felt that spatial and substrate information were needed to better examine regeneration. These data were not available in previous studies. A draft of how this spatial and substrate data might be obtained was made, along with a plan to discuss this at the meeting with collaborators in Invermere.

The meeting with collaborators on May 16, 2001 included several members of the team (Appendix I). Collaborators gave feedback on difficulties that might be faced in doing the research including skid roads, advanced regeneration, and blowdown. Access was not considered a problem, and ISIS (Integrated Silviculture Information System) records were made available to the field crew for site selection. During the field tour, preliminary decisions were made on how to obtain the spatial and substrate information on a subsample of plots.

The field crew maintained contact with the collaborators throughout the summer, via informal meetings in Invermere, and kept contact with the research team via e-mail. Abdul-Azim Zumrawi joined the field crew for a few days in June, Peter Marshall, Valerie LeMay, and a visiting scientist from China, Dr. Feng Zhang joined the field crew in July, and Temesgen joined the field crew in August. Each field visit by the UBC researchers helped in defining the spatial sampling, and also in illustrating the issues with modelling regeneration in IDFdm2.

In November, 2001, Katrina Froese and Dr. Peter Marshall met with the collaborators in Invermere, BC, to present the results of summer field work, including preliminary data analysis (Appendix II). Present at the meeting were: Barry Snowdon (BC Ministry of Forests, Victoria), representatives from the Invermere District Ministry of Forests, and interested parties from both industry and consulting. Ideas were exchanged on how to improve the regeneration modeling. Collaborators had a particular interest in the effect of residual stand basal area on Douglas-fir height growth, which has been informally recognized in the District but not measured quantitatively. Reports on the preliminary results for IDFdm2 and on ICHdm2 were distributed to all persons at the meeting.

Design of Web Site

A web site summarizing the work at the University of British Columbia on Prognosis^{BC} was initially released January 31, 2002. Some revisions were implemented on March 8, 2002. The web site contains preliminary summaries of work done at UBC by the project team of researchers and graduate students. A list of extension products (reports, presentations, posters, and theses), including links to some products available online is also provided. Future plans for the site include providing more reports and detailed results online, plus periodic progress updates.

The website is currently available at <http://www.forestry.ubc.ca/prognosis>

Conference Presentations

The research results were extended via several conference posters and presentations. Abstracts for the posters and presentations are given in Appendix III.

Posters:

Badre Hassani presented regeneration results at the IUFRO forest modelling international conference in Vancouver, August 12 to 17, 2001. Also, a poster titled “Prognosis^{BC} Modelling at the University of British Columbia” was presented at the Second FVS Conference, Fort Collins, Colorado, February 12-14, 2002. This poster was also presented at the University of British Columbia Forestry Research Evening, March 5, 2002. The poster summarizes the work done by UBC staff, research assistants and graduate students on the Prognosis^{BC} model, and is available on the web site: (<http://www.forestry.ubc.ca/prognosis/documents/poster.jpg> [1.5 MB]).

Presentations:

Results of modelling regeneration for IDFdk1 and dk2 were presented at the Western Mensurationists meeting in Klamath Falls, Oregon, in June, 2001 by Cornel Lencar. The use of Prognosis^{BC} for timber supply modeling was presented at the FVS conference, Fort Collins, CO, February, 2002.

Meeting with Experts

Drs. LeMay and Temesgen met with Dr. Albert Stage and Dr. Nicholas Crookston of the USDA Forest Service while attending the Forest Vegetation Conference (core model is Prognosis) in Fort Collins, CO in February, 2002. We had originally planned to invite Dr. Stage to UBC as an outside expert; however, the trip to Fort Collins allowed us to meet with both Drs. Stage and Crookston, as well as a variety of FVS researchers, working on various aspects of FVS, including visualization, model components, use of FVS for landscape analysis, and public perceptions of graphics outputs. Also, this allowed us to extend the research results. We discussed the issues with imputation methods and regeneration with Drs. Stage and Crookston. Future collaborations on these models were also discussed.

Conclusions

The results from this study are expected to be implemented by the Ministry of Forests, and used in connection with the Prognosis^{BC} growth and yield model. This will enhance the model's capabilities for predicting the development of the complex (uneven-aged and/or mixed-species) stands in southeastern British Columbia.

Benefits to practitioners once the results are implemented include:

- reliable regeneration and sapling layer projections from the Prognosis^{BC} model;
- the ability to more accurately evaluate alternative silvicultural regimes and their impact on the long-term development of stand structure;
- allowing evaluation of alternative partial-cutting regimes on non-timber resources (e.g., in the IDF dk subzone, the study will provide the tools needed to more effectively use the Prognosis^{BC} system to model mule deer winter range (MDWR) selection harvesting); and
- allowing more reliable use of the Prognosis^{BC} system in making long-term projections to generate yield curves for timber supply analysis.

Benefits to policy makers include:

- providing tools to assist in formulating policies for selection harvesting to satisfy requirements for non-timber resources (e.g., specifying criteria for stands to be eligible for selection harvesting and developing guidelines for selection harvesting); and
- providing tools that will enhance long-term projections of the inventory, and provide data for the purpose of AAC determination in areas under uneven-aged management.

In the short term, the regeneration results for IDFdk1, dk2, and dk3, and for ICHdm2 will be made available to all collaborators and partners. This information will also be posted on the UBC Prognosis web site for access, if funding becomes available. This will allow practitioners to use the data as inputs to Prognosis^{BC} for these variants. Other related

Prognosis reports will also be posted, as funding becomes available for this extension work.

The results have been extended to the collaborators, and also to an international audience of researchers. Additional research is planned for the IDFdm2 data collected last year, as part of Katrina Froese' M.Sc. thesis, funded, in part, by the National Science and Engineering Research Council via a scholarship won by Ms. Froese. Research by Badre Hassani, M.Sc. candidate and by Cornel Lencar, M.Sc. candidate is part of their thesis work. They are expected to defend their work within three months, although there is no funding for the final thesis writing. At this time, there is no funding to extend the work into the MS zone, as was originally planned.

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Appendix I. Presentation to Collaborators, May 14, 2001 in Invermere

Attending:

Investigators:

Valerie LeMay, Ph.D., RPF, UBC, Vancouver

Peter Marshall, Ph.D., RPF, UBC, Vancouver

Abdel-Azim Zumrawi, Ph.D., RPF, Ministry of Forests, Research Branch, Vancouver

Katrina Froese, M.Sc. (candidate), UBC, Vancouver

Karl Froese, B.S.F. (candidate), UNBC, Prince George

Badre Hassani, M.Sc. (candidate), UBC, Vancouver

Partners:

Barry Snowdon, RPF

Collaborators:

Darrell Regimbald, RPF, Ministry of Forests, Invermere Forest District

Richard Dominy, RPF, Ministry of Forests, Invermere Forest District

Douglas Braybrook, RPF, Tembec, Canal Flats

Vivian Jablanczy, RPF, Slocan, Radium Hot Springs

Agenda:

1. Presentation by research team to collaborators. Questions and suggestions noted.
2. Field tour arranged by MOF to IDF and MS sites with variations in silvicultural/harvest regimes.

A copy of the presentation by the research team follows.

Prognosis^{BC}

- Adapted from Stage (1973) model for US Rocky Mountains
- predict the dynamics of mixed-species and/or multi-aged (complex stands)



Prognosis^{BC}

- Adapted from Stage (1973) model for US Rocky Mountains
- predict the dynamics of mixed-species and/or multi-aged (complex stands)
- forecasts future stand conditions based on the expected growth and mortality of individual trees within a stand
- can be used to simulate almost any form of harvesting, from clearcutting to partial cutting
- can add on component models for insect/disease impacts

Progress on Model Adaptation

- Prognosis^{BC} has been calibrated by the MoF for use in a number of BEC subzone variants in the Nelson, Kamloops and Cariboo forest regions
- PSP data used to calibrate large tree height and mortality
- small tree height and regeneration-- lack of data noted, which limits the utility of the model for making long-term projections following disturbances

Prognosis^{BC} Use Policy

- Limited number of stand entries and the duration of projections following a disturbance
- "Regeneration" component is turned off on public releases
- Users must supply their own regeneration data to incorporate this component into projections of stand development
- Precludes using Prognosis^{BC} to readily explore the silvicultural impact of various partial cutting strategies

Small tree height and regeneration modelling

- complements the large tree component of the Prognosis^{BC} modelling effort
- Data on regeneration and small tree height growth:
 - already available for: (list subzones here)
 - will be collected over the next two years for: (list subzones here)
- Models
 - already developed for: (list subzones here)
 - will be developed for: (list subzones here)

Field Methods



- Use sampling methods suggested by Stage for consistency
- This year-- add variables to describe spatial positions of trees and regen, measured on a some of the plots

Analysis Methods

- Relate regen to overstory trees
- A variety of modelling methods
 - equation fitting
 - tabular imputation i.e. tables of regen by height and species for each type of stand (density, site series, etc.)
 - nearest neighbour methods-- i.e. find a similar stand to substitute for the stand with no regen data (new method)
- New this year-- add spatial position to improve regen estimates

Appendix II. Summary Minutes of the Presentation to Research Partners and Other Interested Parties

Presentation Title: PrognosisBC Calibration in the IDFdm2, Invermere Forest District
Location: Invermere Forest District Office
Date: November 26, 2001
Presentors: Ms. Katrina Froese, M.Sc. Candidate, and Dr. Peter Marshall, Professor, Dept. of Forest Resources Management, UBC

There were 11 local foresters in attendance at the meeting, along with Barry Snowden, from the Forest Practices Branch of the Ministry of Forests, Victoria. Most of the attendees were Ministry of Forests employees from the district office, but there were at least three consulting/industrial foresters present. Bound reports on some regeneration and small tree height growth results from other parts of the province were distributed to interested individuals.

The more formal part of the meeting began about 8:40 a.m. with Dr. Marshall providing a brief synopsis of the project and introducing Ms. Froese. Ms. Froese then gave the bulk of the presentation, speaking to a series of PowerPoint slides. The presentation given by Ms. Froese was divided into two parts: (1) background and sampling design, and (2) preliminary data analysis and interpretation. A five-minute break was provided between the two parts. Attendees were encouraged to ask questions and comment on possible interpretations of the results. Considerable discussion took place, particularly during the second part of the presentation. Dr. Marshall concluded the presentation by thanking the attendees for their interest and contributions. He promised that further results would be available by the late spring or early summer. The meeting concluded at 10:15.

Special thanks are extended to Richard Dominy of the Inveremere District Office who capably handled the local coordination for this meeting.

A copy of the presentation follows

PROGNOSIS^{BC} CALIBRATION IN THE IDFdm2, INVERMERE FOREST DISTRICT: FIELD SAMPLING

Katrina Froese, M.Sc. (candidate), Valerie LeMay, Ph.D., RPF,
Peter Marshall, Ph.D., RPF, and Abdel-Azim Zumrawi, Ph.D., RPF

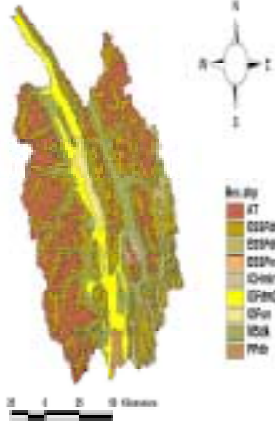
Forest Resources Management Department
University of British Columbia

PROGNOSIS^{BC} REVIEW

- ▣ Adapted from Stage's (1973) model for the Rocky Mountains
- ▣ Predicts the dynamics of mixed species and/or multi-aged (complex) stands
- ▣ Forecasts future stand conditions based on the expected growth and mortality of individual trees
- ▣ Can be used to simulate almost any form of harvesting, clearcut to partial cut stands
- ▣ Can add-on components such as insect or disease impacts
- ▣ Has been calibrated in a number of BEC subzones
- ▣ Small tree height and regeneration data lacking
- ▣ Limits utility of the model for making long-term projections following disturbances
- ▣ Regeneration component turned off in public releases
- ▣ Users must supply their own regeneration data

PROJECT OBJECTIVES

- ▣ MAIN OBJECTIVE: Calibrate the small tree and regeneration components of the PROGNOSIS model for the IDFdm2
- ▣ Examine relationship between substrate information and regeneration
- ▣ Examine spatial patterning and relationship to regeneration and/or small tree growth



Map of biogeoclimatic variants within the Invermere Forest District

SAMPLING FRAME

- AREA**
- ▣ All areas within the IDFdm2, Invermere Forest District
 - ▣ Within 2 hour driving radius
 - ▣ Based upon accessibility
 - ▣ Disturbance within the last 5-25 years
- TARGET COVERAGE**
- ▣ 10% undisturbed
 - ▣ 10% clearcut
 - ▣ 80% partial cut
 - ▣ 1/3 shelterwood
 - ▣ 1/3 seed tree
 - ▣ 1/3 selection

SAMPLING FRAME CONT'D

- ▣ 333 Openings identified using ISIS
- ▣ Removed from list if:
 - ▣ Missing BEC site series, disturbance type, elevation
 - ▣ Less than 0.4 ha in size
 - ▣ Marked as "burned" or wildfire"
- ▣ 232 Openings remained as potential sites
- ▣ Categorized into sampling matrix based on:
 - ▣ Number of years since disturbance
 - ▣ Silvicultural system
 - ▣ BEC site series
 - ▣ Elevation

SAMPLING FRAME CONT'D

- ▣ 75 matrix categories out of a potential 256 were filled
- ▣ To maximize coverage across matrix, maximum of one site per matrix category was selected
- ▣ Selection was also made such that a good geographic range of sites was obtained
 - ▣ North to south along trench
 - ▣ East to west
- ▣ Selection was also oriented towards getting a good range of aspects

SAMPLING FRAME CONT'D

YESSNETS	SILVICULTURE															
	Clearfelled				Skidder				Shelterwood				Seedtree			
Bedrock	10-15	16-20	21-25	26-30	10-15	16-20	21-25	26-30	10-15	16-20	21-25	26-30	10-15	16-20	21-25	26-30
10-15 (10-15)																
16-20 (16-20)																
21-25 (21-25)																
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26-30 (16-20)																
10-15 (21-25)																
16-20 (21-25)																
21-25 (21-25)																
26-30 (21-25)																

SAMPLING FRAME CONT'D

- ▣ Openings were field assessed for suitability
- ▣ If suitable, a single polygon within the opening was selected for sampling based on set criteria
- ▣ If no polygon was suitable, or opening was not suitable, a new site was selected

SAMPLING METHODS

Site Details:

- Mapsheet, opening, polygon, and plot numbers
- Latitude and longitude
- Aspect (degrees)
- Slope angle (percent)
- Elevation
- BEC site series and partial vegetation list
- Site preparation method
- Disturbance information
- Disturbance year
- Other (e.g. cattle grazing intensity)



SAMPLING METHODS CONT'D

Large tree plots:

- 11.28 m radius plot
- All trees greater than 7.5 cm DBH
- Measured for species and DBH
- Two trees for each species randomly selected and measured for height

SAMPLING METHODS CONT'D

Small tree plots:

- 11.28 m radius plot
- Trees 2.0 to 7.5 cm DBH
- Measured for species and DBH
- Five trees of each species were randomly selected and measured for five year height growth and total height

SAMPLING METHODS CONT'D

Regeneration plots:

- 2.07 m radius plot
- Trees at least 15 cm tall and less than 7.5 cm DBH (tolerant) or at least 30 cm tall and less than 7.5 cm DBH (intolerant)
- Measured for height class and noted as subsequent or advance regeneration
- "Best trees" (minimum of four) and random trees (two per species) were measured for height and total age

SAMPLING METHODS CONT'D

Satellite plots:

- Four additional 2.07 m radius plots were established at cardinal directions along the 11.28 m boundary
- Regeneration was tallied by height class and noted as subsequent or advance regeneration
- If the regeneration plot had no regeneration, one of the satellite plots was randomly selected and used to replace the regeneration plot

SAMPLING METHODS CONT'D

Substrate measurements:

- Regeneration plot was divided into quadrants
- Estimate of percent cover by:
 - Mineral soil, Litter, Kinnikinnick, Discontinuous grass, Continuous grass, Moss, Lichen crust, Slash Stump, Coarse woody debris, Shrub, Rock, Tree, Organic, Fine woody debris
- Regeneration was tallied by height class, species, and substrate it occurred on, and classified as advance or subsequent regeneration
- Germinants (less than 15 cm tall for tolerant species and less than 30 cm tall for intolerant species) were tallied by species and substrate of occurrence

SAMPLING METHODS CONT'D

Spatial measurements:

- To qualify to be mapped, the object's centre (stem, clump, etc) had to be within the 11.28 m radius plot
- Distance and bearing was taken for all large trees
- Distance and bearing to the center of regeneration clumps; length and width of regeneration clumps (based on elliptical form), and bearing of long axis
- Tallies for each clump on species, height class, and noted as advance vs. subsequent regeneration
- Distance and bearing for individual small trees
- Definition of small trees and regeneration overlaps; where a small tree occurred within a clump, it was not individually mapped
- Large slash piles, and large clumps of shrubs were measured in a manner similar to regeneration clumps
- Distance and bearing to each stump, plus diameter at 0.15 m
- Distance and bearing to each standing dead, plus DBH
- Windthrow measured for DBH, length, and

DISTRIBUTION AND NUMBER OF PLOTS

37 Polygons were sampled

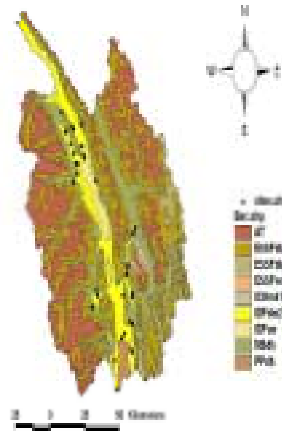
- 32 from disturbed stands
- 5 from undisturbed stands

Total of 111 plots

- Spatial and substrate data were collected for 25 plots -- roughly 1 in 4 plots

SAMPLING ISSUES

- Access was limited in some cases due to ranches
- Some sites did not match the information in ISIS
- In some cases, BEC site series was transitional to either the ICH or MS
- Therefore there were several cases where filled matrix categories had no suitable candidates
- Separation of planted and natural important to analysis; difficult to identify in the field and requires more "file research"



Location of polygons within the IDFdm2

Res@Series	Res@Location	Res@Series			
series02	0	Nat	3	FA	2
series03	5	Sh	47	GA	14
series03D	0	Over	38	Lpr	2
series04	4			NE	2
series04A	25	Res@Location		Low	19
series04	2	OR	4	To	3
		93-100	46	Quon	6
Res@Site		103-110	37		
N	11	113+	21	Res@Site	
NE	6			(Total)	11
E	2	Res@InUse@Site		0D	46
SE	7	Over	11	102	35
S	6	Shdn	38	230	0
SW	8	Shdwed	2	340	6
W	9	Shdlm	30	460	3
NW	11	Unburn	11	360	1

LARGE TREES (dbh >7.5 cm)

Number of Large Trees Sampled by Site Condition

	Dy	SDy	Misc	Sh/W	Wet	Total	
A			3	15	55	75	
B				1	4	5	
Ep				2	11	13	
Fd		55	314	404	488	67	129
Lw			1	45	27	20	93
P			25	54	42	4	125
Py		11	49	2			62
R			1				1
Sw				1	25	30	55
Grand Total	67	332	510	553	188	1710	

SMALL TREES (dbh 2.0-7.5 cm)

Number of Small Trees Sampled by Site Condition

	Dy	SDy	Misc	Sh/W	Wet	Total
A		3	12	36	133	184
B				10	10	
Ep				4	94	98
Fd	159	678	650	578	173	2238
Lw			51	23	2	76
P		48	938	478	104	1538
Py	7	25	2	3		37
R		23	10	6		39
Sw		4	3	48		55
na		1	4	2	2	9
Grand Total	166	781	1681	1188	516	4270

*na is the number of plots with no small trees, and na is including products

REGENERATION (dbh 0.0-7.5 cm, height >15cm)

Number of Regeneration Trees Sampled by Site Condition

	Dy	SDy	Misc	Sh/W	Wet	Total
A		2	8	65	65	140
B				5	5	
Ep				10	49	59
Fd	16	85	106	82	27	326
Lw			25	18	1	45
P		25	20	16	44	45
Py	3	12		2		17
R	1	27	3			31
Sw		1	12	30	30	73
na	5	9	23	12	8	57
Grand Total	30	98	135	118	46	432

*na is the number of plots with no regeneration, and na is including products

SUMMARY

- Target of 80 percent in partial cut areas was achieved (89 plots)
 - 38 plots in selection
 - 21 plots in shelterwood
 - 30 plots in seed tree
- Clearcut and undisturbed stands accounted for 10% each (11 plots each)

PLANNED ANALYSIS

- Data entry has been completed
- First priority for analysis is calibration of the Prognosis^{BC} model for the IDFdm2
- Analysis of spatial and substrate data will follow

PRELIMINARY RESULTS

- Density is based on averages over all plots, including "zeros" – where species did not occur
- Percent composition is based on averages for those plots where the species is found, not including "zeros"
- BEC site series has been converted to a range from Dry (03) to Wet (04)
- Harvest method is used to represent residual BA classes (clearcut = lowest BA; natural = highest)
- Interactions ****

BASAL AREA OF LARGER TREES

Average basal area by harvest method

Harvest Method	Average Basal Area
Clearcut	121
Seed Tree	535
Selection	1520
Shelterwood	1804
Normal	3504

LARGE TREES

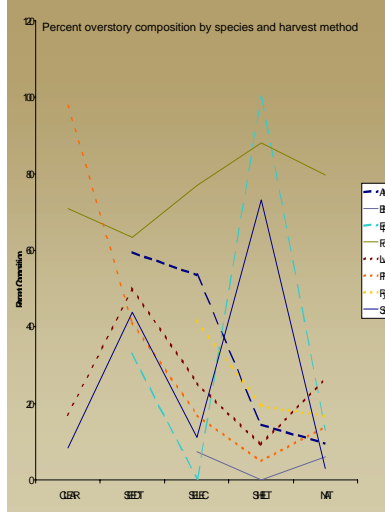
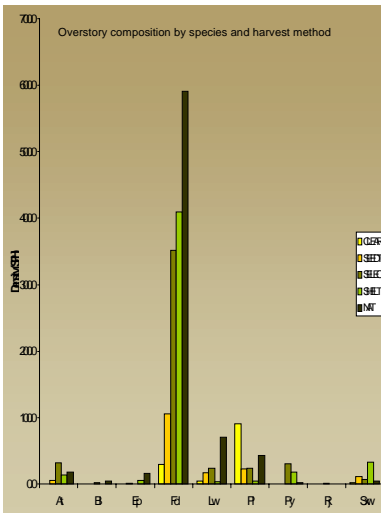
Height (m) of sampled large trees

	Species								
	A	B	Ep	Fd	Lw	P	Py	R	Sw
Max	21.20	22.20	19.40	31.50	31.20	29.80	26.80	4.60	25.70
Min	7.80	5.00	6.40	4.60	4.60	4.30	5.80	4.60	6.40
Mean	15.22	8.80	11.07	14.42	17.76	10.28	14.06	4.60	12.12
StDev	4.55	2.89	3.97	7.00	8.16	5.00	4.82	0.14	5.03

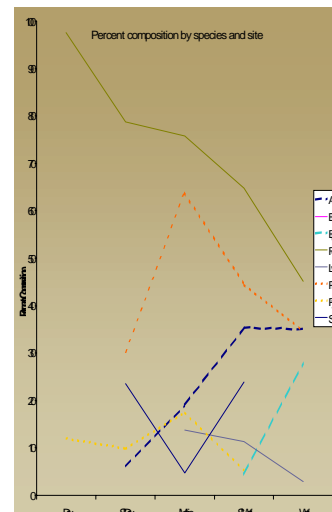
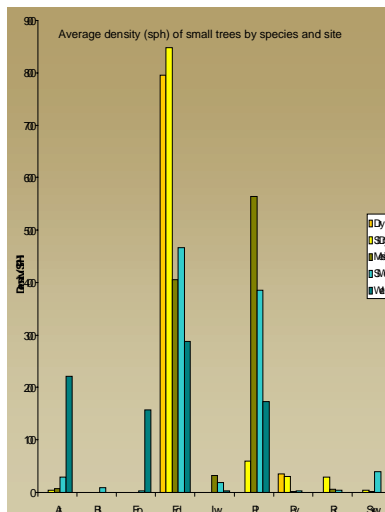
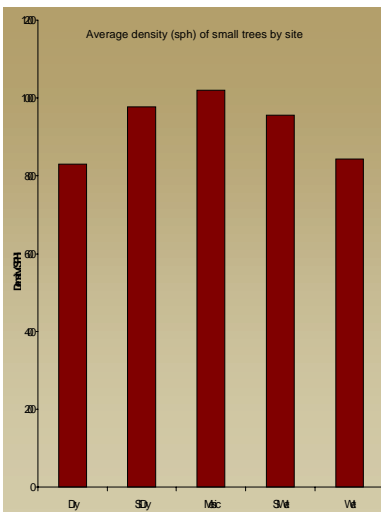
DBH (cm) of sampled large trees

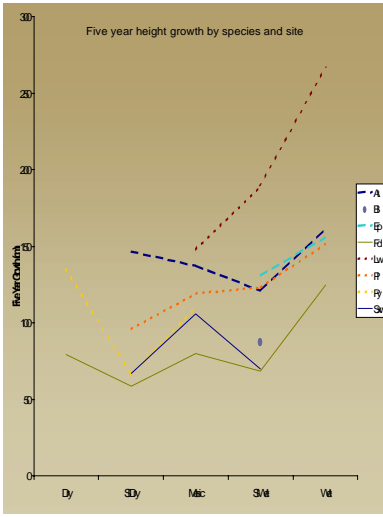
	Species								
	A	B	Ep	Fd	Lw	P	Py	R	Sw
Max	32.30	20.70	21.10	71.00	42.80	24.60	54.40	9.10	31.80
Min	8.20	7.60	8.10	7.50	7.60	7.60	7.70	9.10	7.30
Mean	17.52	11.50	13.42	18.45	21.77	11.91	20.79	9.10	17.23
StDev	5.87	5.44	4.42	9.91	9.68	3.92	8.76	0.14	6.39

LARGE TREES BY HARVEST METHOD



LARGE TREES BY SITE CONDITION





REGENERATION

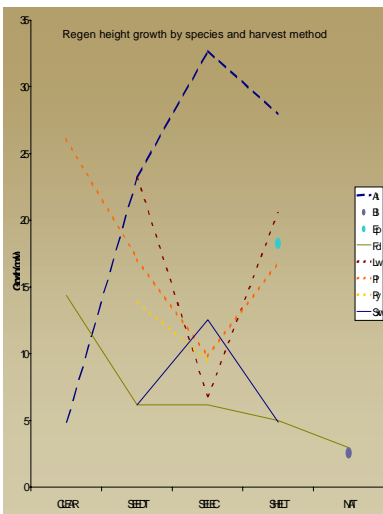
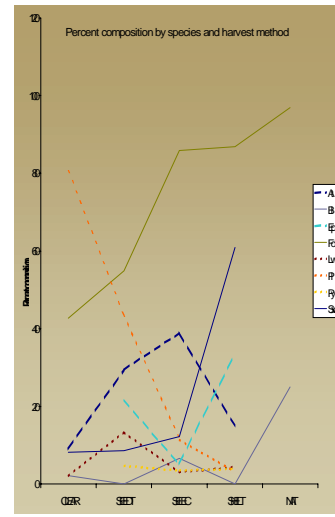
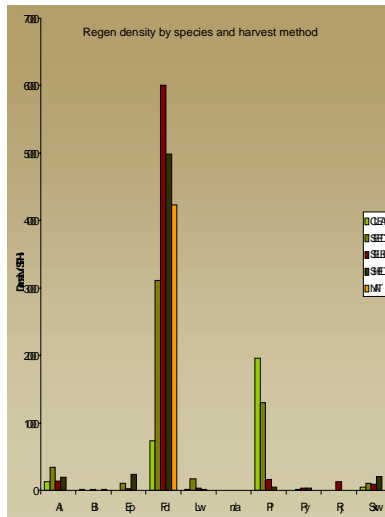
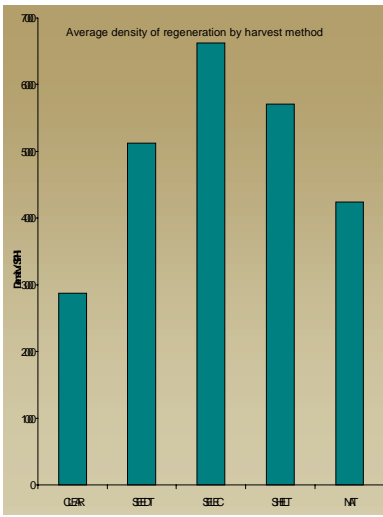
Density of regeneration (sp/ha)

	Species									
	A	B	Ep	Fd	Lw	P	Py	R	Sw	Tot
Nuc	386.0	463	292.0	2099.0	1390	7330	831.0	297.0	2543	21680
Nh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	197.2	69	79.9	432.6	63.4	604.6	22.6	41.5	97.3	5095
SDev	663.4	461	300.8	4639	214.6	13907	126	293	395	44594

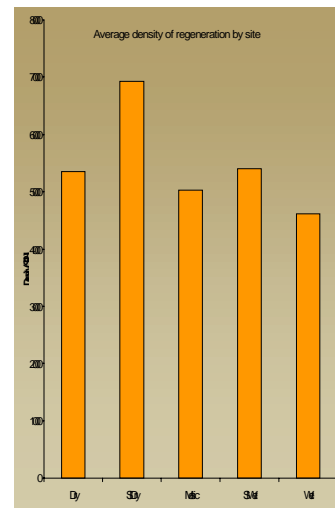
Height growth (m) of early saplings

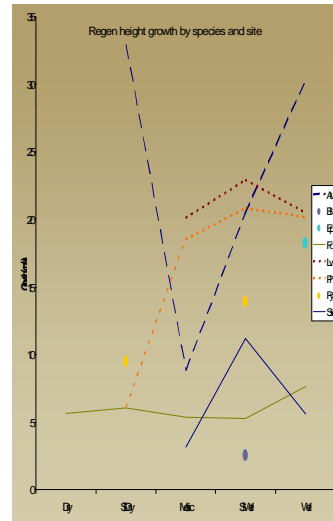
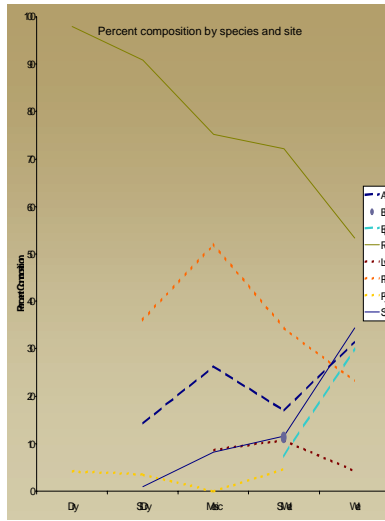
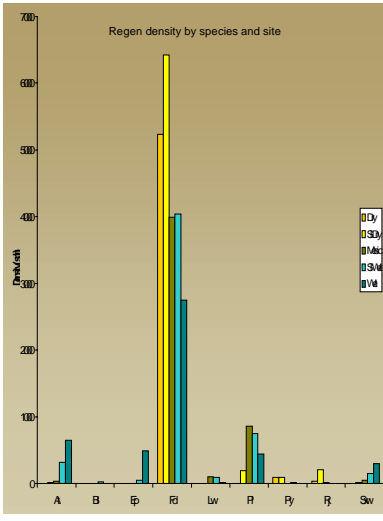
	Species									
	A	B	Ep	Fd	Lw	P	Py	R	Sw	
Nuc	4.92	2.53	13.29	17.0	39.0	36.5	13.9	8.0	23.5	
Nh	4.0	2.53	13.29	1.5	3.78	0.11	9.0	2.2	2.0	
Mean	2.47	2.53	13.29	5.0	13.24	17.5	11.9	5.0	7.9	
SDev	125.9	na	na	3.0	11.3	9.16	3.0	3.0	7.0	

REGENERATION BY HARVEST METHOD



REGENERATION BY SITE CONDITION





RESULTS

Large tree plots:

- Variable patterns in species composition by harvest method
- Generally increase in total height as site moisture increases
- As site moisture increases, percent overstory composition:
 - of Fd, Lw, and Pl decreases
 - of At, Ep and Swx increases

RESULTS

Small tree plots:

- Variable patterns in species composition by harvest method (planted vs. natural, or species tolerances)
- Five year height growth generally better for all species at lower residual basal area (except hardwoods and Pl)
- Five year height growth generally increases as site moisture increases for Fd, Lw, Pl, and hardwoods
- As site moisture increases, percent small tree composition:
 - of Fd, Lw, Pl and Rj decreases
 - of hardwoods increases

RESULTS

Regen plots:

- Variable patterns in species composition by harvest method (planted vs. natural, or species tolerances)
- As basal area increases, percent regen composition:
 - increases for Fd, Swx
 - decreases for Pl
- Height growth of regen decreases with increasing basal area for Fd and Py
- Height growth of regen vs. site conditions shows variable patterns, indicating other interactions
- As site moisture increases, percent regen composition:
 - of Fd decreases
 - of Swx and hardwoods increases

We gratefully acknowledge the cooperation and support provided by the partners and collaborators:

Barry Phillips, Research Branch; Barry Snowden and Ralph Winter, Forest Practices Branch; Jon Vivian, Inventory Branch; Cliff Beliveau, Darrell Regimbald, Richard Dominy, and the staff of the Invermere Forest District; Grant Neville and Douglas Braybrook of Tembec Industries; Vivian Jablanczy of Slocan Forest Products; and Tim Harding of Riverside Forest Products.

Funding for this research was provided by Forest Renewal BC.

Funding assistance by Forest Renewal BC does not imply endorsement of any statements or information contained herein.

Appendix III. Abstracts of Presentations at International Meetings

Effects of Regeneration Abundance on Predicted Development of Interior Douglas-fir Stands

Presented by Cornel Lencar, M.Sc. (candidate, UBC)
Western Mensurationists meeting, Kalispell, Oregon, June, 2001

This presentation documents the preliminary analysis done on the effects of regeneration abundance on predicted development of interior Douglas-fir stands. Stand development was predicted using Prognosis^{BC} growth and yield model.

In summer of 1999 data for calibrating the small tree height growth component of Prognosis^{BC} was collected in the vicinity of Kamloops and Williams Lake. A total of 335 plots distributed in three ecological zones and across a range of time since disturbance, site and topographical characteristics.

These data were used to study the relationship between the overstory and the understory in partially cut stands in IDF dk1, IDFdk2 and IDFdk3 [BEC classification system] for a better understanding of the regeneration development in this particular type of stands. Stands were classified using basic criteria as species composition, residual basal area and site type in an effort to rationalize the stand attributes. Average levels of regeneration were calculated for each subzone and grouped by residual basal area and site conditions according to the stand matrix.

Stands disturbed more than 10 years ago were selected from each group of sampled stands defined in the matrix and tree lists were obtained. For each sampled stand, different levels of regeneration were used as input in the Prognosis^{BC} tree list. These stands were then projected for 40 years and compared across regeneration levels.

Little difference was found for the total volumes at different levels of regeneration. There were considerable differences in the stand structures associated with the different regeneration assumptions. Species composition and stand structures varied somewhat among subzones and moisture levels, but the trends were repeated across the subzones.

Comparing Regeneration Imputation Approaches for Mixed-Species, Partially-Cut Stands

By Badre Tameme Hassani, Abdel-Azim Zumrawi,
Peter Marshall, Temesgen Hailemariam, and Valerie LeMay

University of British Columbia, Department of Forest Resources Management
2045-2424 Main Mall, Vancouver, BC, V6T 1Z4, Canada
Tel: (604)- 822-4918, Fax: (604)-822-9106
badre@interchange.ubc.ca

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ABSTRACT

British Columbia (BC) possesses a variety of forest ecosystems and manages about 59 million ha of forestland. Complex stands (multi-species, multi-age) are an important component of these lands. The BC Ministry of Forests is adopting the Forest Vegetation simulator (FVS), developed in the United States, as a forest growth and yield model for use in such stands (called Prognosis^{BC}). The regeneration component of Prognosis^{BC} has been calibrated over last few years using regression approaches with data collected in the southern interior of BC. Previous studies showed difficulties with these approaches due to data shortages and lack of correspondence between the systems of site productivity used in the United States and BC. As result, Prognosis^{BC} is used at present without a regeneration component. Approaches that make efficient use of limited data and avoid the need for correspondence between site productivity systems should result in better regeneration prediction. Imputation techniques meet these requirements

To test the use of imputation approaches in predicting regeneration in complex forests following partial cutting, stands from the Interior Cedar Hemlock moist warm zone variant (ICHmw2) in the vicinity of Nelson, BC were selected. These stands normally are comprised of several tree species, may contain a number of age cohorts, and are commonly harvested using partial cutting techniques. Two imputation approaches were examined: tabular and most similar neighbour (MSN). Comparison of the two approaches showed the MSN approach to provide superior predictions.

Key words and phrases: imputation, most similar neighbour, natural regeneration

Adapting a Mortality Model for Southeast British Columbia

Temesgen H. 1, V. LeMay, and P. L. Marshall

University of British Columbia, Department of Forest Resources Management

2nd Floor, Forest Sciences Centre, 2045-2424 Main Mall

Vancouver, BC, V6T 1Z4, Canada, Tel: (604)- 822-3132, Fax: (604)-822-9106

Email: temesgen@interchange.ubc.ca or lemay@interchange.ubc.ca

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ABSTRACT

Mortality is an essential feature in predicting growth and yield of trees and forests for managing forest resources in perpetuity. One way to model mortality is to predict the probability of death for individual trees while keeping the stand projections within reasonable biological limits. This approach is used in the northern Idaho version of the Forest Vegetation Simulator (FVS), a tree level and distance independent growth model.

The Northern Idaho version of FVS is currently being modified to estimate the growth and yield of forests of southeast interior of British Columbia (Prognosis^{BC}), as these forests are similar to those found in Northern Idaho. Two approaches were assessed to localize and adjust the individual tree mortality models of FVS for use in Prognosis^{BC}. First, ordinary least squares-based multipliers were used to adjust the tree-based mortality model originally developed using a large number of observations. Second, the tree-based mortality model was re-fitted using limited permanent sample plot data from southeast interior of BC. Model validation indicated that the refitting approach better predicted individual tree mortality of both conifer and hardwood tree species. This presentation discusses the results of these approaches to predicting tree mortality by species and bio-geoclimatic zone.

¹The authors are respectively, Research Associate, Associate Professor, and Professor, Department of Forest Resources Management, University of British Columbia, 2045-2424 Main Mall, Vancouver, BC. Email: temesgen@interchange.ubc.ca or lemay@interchange.ubc.ca, or marshall@interchange.ubc.ca.

Linking PrognosisBC to Aerial Attributes for Timber Supply Analysis in British Columbia

Temesgen H. ¹ and V. LeMay

University of British Columbia, Department of Forest Resources Management

2nd Floor, Forest Sciences Centre, 2045-2424 Main Mall

Vancouver, BC, V6T 1Z4, Canada, Tel: (604)- 822-3132, Fax: (604)-822-9106

Email: temesgen@interchange.ubc.ca or lemay@interchange.ubc.ca

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ABSTRACT

In British Columbia, the forestland is divided into various strata based on forest cover types and aerial attributes for forest inventory purposes. To manage forest resources in perpetuity, several growth and yield models have been developed and used in various parts of the province. Among these models, Prognosis^{BC} (adapted from the northern Idaho variant) is used in the southeast interior of the province. However, the estimates from this model has not been linked to aerial attributes nor have they been to update the existing inventory databases.

This presentation discusses how Prognosis^{BC} can be linked to aerial attributes and inventory databases when there are very large and widely varied land bases and insufficient ground data. Differences in observed and estimated species composition, tree and stand attributes are also discussed.

Key words and phrases: Prognosis^{BC}, most similar neighbour, tabular imputation, tree-list.

¹The authors are respectively, Research Associate, and Associate Professor, Department of Forest Resources Management, University of British Columbia, 2045-2424 Main Mall, Vancouver, BC. Email: temesgen@interchange.ubc.ca and lemay@interchange.ubc.ca.