Proceedings of the Post-harvest Stand Development Conference

Edmonton, Alberta
31 January – 1 February
2006

Sponsored by:

Foothills Model Forest
Foothills Growth and Yield Association
Alberta Forest Genetic Resources Council, and
Forest Resources Improvement Association of Alberta

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Post-Harvest Stand Development Conference
Edmonton, Alberta

1. OVERVIEW

With funding support from the Open Funds program of the Forest Resource Improvement Association of Alberta, three cooperators (Foothills Model Forest, the Foothills Growth and Yield Association, and the Alberta Forest Genetic Resources Council) hosted a conference focused on the integration of genetics, silviculture, and forest health into the forecasting of stand development, growth, and yield following harvest. To ensure appropriate discussion of the theme of the conference, the organizing committee sought a good mix of employment, expertise, and experience in the delegates and was pleased at the response.

The Post-Harvest Stand Development Conference was held on January 31 and February 1, 2006 in Edmonton. The objectives and desired outcomes were:

1. To share and integrate information relevant to the effective management of forest stands regenerated after harvesting in Alberta;
2. To identify delivery options for the integration of genetic, growth and yield, silvicultural, and forest health information;
3. To achieve understanding by forest managers of how this information can be applied in policy and practice;
4. To identify information gaps and associated research requirements.

The assembly explored ideas that could inform Alberta forest policy as well as suggest action plans appropriate for the Foothills Growth and Yield Association, the Alberta Forest Genetic Resources Council, their corporate members and, potentially, other participating agencies.

To help frame the conference, the organizers interviewed a number of opinion leaders before the conference and used the results of these interviews to establish seven major themes under which improvements in policy and practice would be valuable. The results of the interviews were then used in a pre-registration process to gather input and expressions of interest from the delegates under the major theme areas.

The conference had over 150 registered delegates, representing a broad cross-section of practitioners and policy-makers, and experts from the different disciplines from across North

America and offshore. The delegates shared information and ideas and listened to 25 speakers in plenary and concurrent sessions. The speakers provided valuable insights into the disciplines of the conference and integration experiences from other areas. The speakers then participated with the delegates in nine breakout groups focused on the fourth objective of the conference. The breakout groups met and reported back to the plenary session the morning of the second day. Forty-one issues were identified and 44 recommendations presented for consideration.

A final panel of seven experts reflected on the outcomes of the breakout groups as well as their own perspectives on the major themes of the conference.

2. CONFERENCE SPONSORS

The Forest Resources Improvement Association of Alberta is a Designated Administrative Authority that collects a portion of stumpage from timber cut and applies it to approved projects that enhance the value of the forest resources of Alberta, and improves their management on public lands. Each year for the past few, it has issued a call for proposals under its Open Funds initiative and, in 2004, FRIAA selected the proposal for this conference as one of the projects it would support.

The Foothills Model Forest, established in 1992, is one of the 11 model forests in Canada. In its 13-year history it has earned a reputation as a “can do” organization that is focused on developing practical and important tools that advance the theory and practice of sustainable forest management.

The Foothills Growth and Yield Association, established in 2000, has 11 members working together to advance knowledge in the growth and yield of lodgepole pine – both natural and regenerated. The work of the Association clearly shows that there are opportunities arising from the enhanced growth performance of regenerated lodgepole pine stands, but these opportunities come with uncertainties that need attention. Such stands are substantially different from their fire-origin predecessors, and the integration of knowledge from genetics, silviculture, and forest health disciplines into management planning and growth and yield forecasting is a challenge to all involved in developing and approving forest management plans in Alberta and elsewhere.

The Alberta Forest Genetic Resources Council was also formed in 2000 with a mandate to provide advice to the provincial government on policy issues and opportunities involving genetic conservation and tree improvement. In the spring of 2004, the Council identified the apparent

lack of integration of forest genetics into growth and yield forecasting and established a strategic objective to address this deficiency.

3. ORGANIZING COMMITTEE

The organizing committee was co-chaired by Dick Dempster of the Foothills Growth and Yield Association and Cliff Smith of the Alberta Forest Genetics Resource Council. Lisa Jones managed all logistics for the conference. Beginning in January 2005, the committee members worked together throughout the year in pulling the conference together, refining the themes, and selecting the major speakers and panellists.

Committee members were:

Victor Lieffers	Silviculture	University of Alberta
Barb Thomas	Forest Genetics	Alberta Forest Genetic Resources Council (AFGRC)
Sally John	Forest Genetics	Alberta Forest Genetic Resources Council (AFGRC)
Cliff Smith	Forest Genetics	Alberta Forest Genetic Resources Council (AFGRC)
Ken Greenway	Forest Genetics, Silviculture	Alberta Sustainable Resource Development and Alberta Forest Genetic Resources Council (AFGRC)
Dick Dempster	Growth & Yield	Foothills Growth and Yield Association
Bruce MacMillan	Silviculture	Mixedwood Management Association
Jan Volney	Forest Health	Canadian Forest Service
Bob Udell		Moderator
Lisa Jones	Conference Coordination	Foothills Model Forest

4. PRE-CONFERENCE ASSESSMENT

A structured pre-conference assessment process helped focus the conference and its proceedings and discussions.

In October 2005, Equus Consulting Group was selected to conduct telephone interviews of 11 opinion leaders and experts representing science, policy, management, and education. The experts gave their views on eight questions developed by the organizing committee with the intent of refining the conference themes, guiding the content of the presentations, and framing the breakout group themes and discussion.

From these initial interviews, the organizers developed the themes for the breakout groups and a refined set of questions for delegates in a second pre-conference, on-line, assessment process. Of the 160 registered delegates, 88 submitted their responses before the cutoff date for this process; the responses were very helpful in refining the breakout group process and participants.

Interviews with Opinion Leaders

The committee identified 11 opinion leaders for the interviews on the basis of three criteria, in order of importance:

1. Interviewees would be of senior stature and capable of speaking on behalf of their discipline/sector/industry.
2. At least one interviewee would be chosen from each discipline of growth and yield, forest genetics, silviculture, and forest health.
3. Interviewees would represent the areas of policy, planning, and operations.

The following leaders were interviewed:

Marty Alexander (Forest Health, Fire)	Canadian Forest Service
Thom Erdle (Management Planning)	University of New Brunswick
Sam Foster (Genetics)	US Department of Agriculture
Jim Goudie (Growth and Yield)	British Columbia Ministry of Forests
Greg Johnson (Growth and Yield)	Weyerhaeuser Canada Ltd.
Steve Knowe (Genetics)	American Forest Management Ltd.
Clem Lambeth (Genetics)	Weyerhaeuser Canada Ltd.
Doug Sklar (Gov’t Regulator)	Alberta Sustainable Resource Development
John Spence (Forest Health, Insects & Disease)	University of Alberta
Tom Terry (Silviculture)	Weyerhaeuser Canada Ltd.
Jim Thower (Growth and Yield)	J.S. Thrower & Associates

Questions focused on barriers – technical or institutional/cultural – to integration of the four disciplines. Highlights of the interviews follow:

Q.1. Are you aware of any attempts or successes in integrating forest genetics, forest health, and silviculture into growth and yield models?

There appears to be limited knowledge even among opinion leaders of such attempts, and more particularly of successes arising from these attempts. Eight were aware of some attempts, three knew of none. Among the notable attempts cited were:

- A fire/dwarf mistletoe interaction (*Forestry Chronicle* May/June 2005).
- B.C. Ministry of Forests was said to incorporate all these factors in planning models.
- Sue Carson's work in radiata pine in New Zealand (Carson was subsequently invited and spoke at the conference).
- Barry Shriver and Steve Logan's work in loblolly pine, and a new model developed by Shrivers, available from the University of Georgia.
- Work on short-rotation eucalyptus species in South Africa and Brazil.
- Genetic improvement work in the southern United States building disease resistance and frost hardiness into successive generations.
- Brian Stanton's work with fast-growing cottonwoods (Vancouver, Washington).
- Weyerhaueser's work (Howard Duzan) on incorporating genetics into growth and yield forecasting.

One respondent noted that some models are available to address these issues but may not have been used effectively, and noted that forecasting errors do not appear to have much improved in 20 years.

Another respondent noted previous attempts to address this through meetings such as the joint meeting between the Western Forest Genetic Association and Western Mensurationists (1994) and a think-tank organized by the Stand Management Cooperative in Washington State.

Q.2 Do you think integration of forest genetics, forest health, and silviculture into growth and yield models is an important issue at this time?

Again, a wide range of opinion was expressed, with some major uncertainties identified and some stressing the need to prioritize these uncertainties. While all respondents recognized the role these factors played in growth and yield, opinions were mixed about their relative significance and how their impacts should be integrated.

The challenge of sorting out the interactions between factors in a growing stand was noted by some, with a call for a more systems-like approach to growth and yield forecasting.

Another respondent noted the growing importance of quantifying these interactions and their impacts on growth, yield, and value in the southern U.S. as former industrial forest lands are transitioning to private ownership, many with significant retirement fund investments. These lands are increasingly managed by TMOs (Timber Management Organizations) and the importance of value reporting is paramount. Land – through an arbitrary assignment of value – can be undervalued if the appraiser does not have the knowledge or tools to produce reasonable and defensible estimates of juvenile stand development.

Work is underway between the B.C. Ministry of Forests and the Canadian Forest service in modelling the various elements and their linkages to yield projections.

The importance of developing a strong strategic database for stand modelling and yield forecasting was noted. Development of that database calls for a committed R&D program, in order to properly experiment, measure, report, and model various stand management/ forest health/ genetics interactions.

One respondent noted that while reflecting forest health and genetics in growth and yield modelling is important, there are larger uncertainties that are not well addressed in current forecasting that have even greater impacts on growth and yield, for example, density control, competition, stocking.

Q.3 Have you observed undesirable consequences resulting from lack of integration of these disciplines?

Several respondents noted this as an issue, in a wide range of answers. Several noted the uncertainty around decision-making that results.

The impact of the mountain pine beetle was foremost in many responses, for example the importance of second growth stands as the replacement for forests being decimated by the beetle and therefore the need to develop improved and reliable estimates of their development.

One noted the undesirable effects of certain silviculture practices (some mandated by regulation) that increase the risk, or exacerbate the effects of forest health factors. Thinning of second growth stands, thereby increasing their susceptibility to mountain pine beetle attack, was a timely and dramatic example of this interaction.

One noted that inflated estimates of timber supply arising from over-optimistic forecasts for post-harvest stand development can lead to unsustainable operations with major impacts on communities – an over-riding economic scale concern.

Another pointed out that the removal of fire from the landscape, along with the failure to manage the resulting buildup of highly flammable forest stands through the lack of public support for such interventions, is turning some public lands in the USA into a huge tinder-box.

The need to develop improved forecasting tools was again noted, along with the observation that pest impact forecasts have been unreliable. The uncertainty surrounding the forecasting of such things as pest impacts and genetics in forest management planning not only impacts the reliability of the exercise, but also has major impacts on the willingness of managers to invest money in implementing such measures. Similar uncertainties in forecasting have negative consequences for investments in competition and control of stand density.

Q.4 What benefits would result from improved integration?

This question elicited a number of significant and revealing responses. Most responses were related to the preceding question, but there was consensus among the group that better integration would lead to better forecasting of growth, better management of risk, better investment and management decisions, and better forest management plans.

Value return to the investor and the province are important; therefore the dollars spent on stand development must be carefully invested, with foresters as portfolio managers allocating funds towards areas that optimize return on investment. Lower costs and more realistic plans that avoid catastrophic changes to forests, to industry, and to forest-based communities were noted.

Increasing confidence about treatment effects on growth and yield lead to improvements in designing management strategies. Further, they could increase the level of confidence in discussions between the disposition holder and the public land management agency. Current disagreements between these parties about benefits of such measures relative to their costs often arise because of the uncertainty surrounding benefit forecasts. Removal of this uncertainty would streamline the discussion by focusing on the costs necessary to get agreed-upon benefits.

Q.5 What are the barriers to improved integration?

This question was very important to this conference and there were some very interesting answers. Responses clearly showed that there are two major categories of barrier that should be examined: cultural/institutional vs. technical.

Respondents noted the (institutional) tradition of working in silos. This is promoted through the competitive and single-issue research system favoured by most agencies that fund research, which is also attractive to the researchers themselves who are usually rewarded for their individual contributions, not as members of a team.

The current system fails to reflect or encourage the teamwork approach that must be put in place to address the multiple and interactive factors that impact stand growth and yield. Respondents noted that current research is based on business plans that do not stress interactive teams and collaborative approaches, and this institutional template must be opened up to a new vision of integrative research. This new template would encourage and reward scientists for their contribution to the new team approach to integrated research.

Further, current funding favours short-term timelines and deliverables, and as a result, the researchers need complete control over every input factor. This is incompatible with big, multi-faceted projects that require a systems approach, with several disciplines involved working on integrated issues and forecasting over longer time periods.

Questions of trust between members of different disciplines were raised, along with the challenges of communications between them – a cultural challenge. One respondent noted malaise (i.e., the unwillingness of individuals to try a different approach) as an issue. He reported that he had been trying to get people to break out of this mould for 10 years with no success.

Some respondents noted the lack of long-term vision that attends institutional cycles – quarterly returns for industry, four-year political cycles, etc. Also, funding cutbacks resulting from this short-term focus have led to a shortage of qualified modellers to do the work.

Technical issues surrounding the design of databases suitable for integrative modelling were noted. Some respondents pointed to the need for pilot studies and realized gain trials, but one reported that in some cases the trials were in place but forgotten with the measurements as yet unexamined.

Some respondents noted the need for companies and the province to collaborate in developing a strategy, designing a database, and implementing research/data collection to support the integrative program. They noted the importance of shared decision-making, and the willingness to collaborate in implementation as critical to success in this area. There were mixed views on whether tenure would present an impediment to such cooperation.

Q.6 What changes would you suggest to improve integration among these disciplines?

A wide range of views offered some very interesting responses, ranging from the high-level policy arena to specifics at the operational level.

One respondent suggested that private land tenure could help resolve this by removing the political cycle and providing a more stable business environment.

Another called for a task force to be struck after the conference with a three-month mandate to examine possibilities for integration and likely studies that would be needed to support this work. More than one respondent noted the value of interdisciplinary meetings and discussions leading to action plans.

Partnership and trust was the theme of several responses. The value of good inventory and good data was stressed, along with a call for a stronger partnership approach between industry and regulator. Failure to do so leads to a growing gap in trust.

The issue of single-focused regional research cooperatives by universities was raised. Breaking down these barriers for a more collaborative approach presents some challenges, not only because the researchers themselves resist this collaborative approach, but also because the large funding agencies do not support this type of inter-university collaboration and continue to maintain a single focus. There was a call to set aside professional jealousy and suspicion in the interest of learning from each other.

The need for controlled experiments using known populations planted at different densities was suggested. Realized gain trials were noted, along with the suggestion that federal work on such agents as armillaria root rot be linked to growth and yield work.

The bottom line represented by forest management plans, the process by which they are developed, and the information needed to support them was a key factor in some responses.

This need for dialogue was extended to cross-specialist discussions and the call for more involvement of geneticists and other specialist input into forest management planning. The priority of the forest management planning process should lead to less theorizing and more focus and applied discussion around these issues.

Establishing the linkages between growth and yield forecasts of future stand development and the actual development that ensues suggested the need for an early warning system to determine if forecasts are wrong, and why. The quantification of the factors that impact growth and yield are critical for confidence in forecasting. At the same time, if models require sophisticated data that are difficult to acquire and not generally available to forest management planners, they will not be used. The focus of researchers on highly detailed models with very detailed input produces results that management planners cannot use.

Q.7 What other weaknesses in our ability to predict post-harvest stand development should the conference address?

Several items were noted including climate change, non-timber values, etc. This points to the issue of prioritizing those issues where actions can make a significant difference. The Province has highlighted the need to develop knowledge and tools that can be used in management planning.

A number of factors were listed with suggestions as to their relative importance. One respondent suggested that climate change may impact the reliability of forecasting tools that use past development as a foundation for forecasts of future development.

The need for a common site classification system as the basis for information gathering and forecasting was noted, as well as the need to improve our understanding of site productivity.

Again the need for integration and collaboration was emphasized relative to data standards, funding agencies, and academic philosophies. Sometimes these are greater barriers than the science itself.

The need to categorize and define impacts on growth and yield in terms of their impacts on forest management planning and AAC was again noted. Also the need to consider wildlife, water, and soil impacts as part of the integration process was brought up.

The three elements suggested for the conference were deemed sufficient for the considerations of this meeting, and respondents further noted some silvicultural and genetic elements requiring more detailed examination, among them:

- Variable retention systems
- Partial harvesting
- Site preparation methods
- Weeding
- Spacing
- Ingress
- Deployment strategies.

A number of other factors were listed that need better definition, but outside the original terms of this conference:

- Climate change
- Wind firmness in post-harvest stands
- Habitat implications
- Tree and wood quality
- Full tree logging impacts on nutrient budgets.

Q.8 If you were setting the program for the conference, what topics or issues would you ask people to address?

Responses showed more diversity in views, but there was a definite split between issues that are technical vs. those that are cultural/ institutional.

A focus on case studies of successful integration was suggested, along with the underlying human or organizational factors that led to their success. Examples of barriers to this success included the fundamental drivers for different organizational groups – university/government focus on publication, industry focus on fiscal and business plan goals, etc. The problem of language and jargon differences between disciplines was noted as a problem in understanding and collaboration.

Picking up this theme, another respondent suggested an examination of the whole research process and how to get the funding agencies together with the researchers and scientists to talk about how to move towards better integration instead of just splitting up the research funding pie. Linked to this was a call to work together to define the need for and elements of a strategic database that would serve the needs of all players.

Also, the need to take great research projects such as the Hubbard Brook Experimental Forest and use the results to inform and change practice was noted as something that is not happening, but should.

Further, there was a call to look at the bigger picture of how research trials contribute to the need for a suite of data necessary to generate models and systems for growth and yield. Many trials exist, but they are not coordinated and there are gaps between them. This falls in part from the funding system we work under, and perhaps a longer-term process of funding overseen by a board of some kind would be useful.

The challenge of addressing serious forest health issues, such as mountain pine beetle, in growth and yield projections was noted. These often run as side models and are not embedded in the growth and yield model. More importantly, can we learn from these health models and use the information to better manage the system to avoid or minimize catastrophic mortality through such things as managing stand density and age classes?

The quality of information available from remote sensing appears to be growing faster than our ability or interest in using it to improve our stand-monitoring programs and methods. This should be considered in developing new studies, databases, and models.

A discussion around how growth and yield models would be useful, built on the basis of considerable intergenotypic competition, could be adapted to effectively reflect uniform clonal stands.

The application of all these principles and models to forest management planning was again stressed.

Online Survey of Conference Registrants

To ensure appropriate discussion of the theme of the conference, the organizing committee sought a good mix of employment, expertise, and experience in the delegates and was pleased at the response. The delegates represented a broad cross-section of expertise and employment. They were skewed somewhat towards office-based responsibilities, reflective of today's forestry reality where much of the fieldwork is the responsibility of entry-level or contract employees.

Eighty-nine delegates responded to the survey by the deadline, listing their primary employment as follows:

Forest industry	31
Provincial/state government	23
Consultant	14
University	10
Federal government	7
Other	4

Of these, the 89 respondents were further categorized by their involvement in forest management:

Researcher or educator/researcher	24
Silviculturist	17
Management forester	13
Administrator/manager	8
Forest geneticist	7
Timber supply analyst	4
Inventory specialist	3
Educator	3

Growth & yield specialist	2
Other	8

Twenty-four delegates listed themselves as researchers, and 20 indicated they were also involved in research, although it was not their primary focus:

Growth & yield	14
Silviculture	12
Forest genetics	6
Forest health	2
Other:	8

- Long-term site productivity
- Forest management planning
- Using science to improve practice
- Policy analysis
- Integrated silviculture, growth & yield and forest genetics
- Forestry and forest products
- Forest pathology
- Forest industry

Finally, respondents were asked where they do most of their work:

In office more than the field	43
In offices, mainly	35
Equally in field and office	9
In the field more than the office	2
Mainly in the field	0

Conference registrants were also asked to provide their input by answering multiple-choice questions on opportunities and barriers to integration of the four disciplines. Their answers gave the organizers a further perspective on topics for the conference, as well as supporting a first cut at slotting delegates into appropriate breakout groups, based on their interest in the various themes.

The responses to these survey questions provided some insight into the recommendations that attended the breakout groups, as well as those priority recommendations emphasized by the organizers of the conference.

Q1. What factors most limit the reliability of any growth and yield models you have used or might use in forecasting post-harvest stand development?

52 Amount or quality of data used in model development.
33 Failure to integrate silvicultural/genetic/forest health/climate change/ other factors.
26 Predictions not checked against results.
24 Lack of common standards for data collection (i.e., incompatible databases).
18 Inappropriate approaches to model formation.
18 Expertise and awareness of users.
12 Analytical expertise.
9 Don't know.
8 Other.

Some comments were invited. Some respondents noted models that were too complex and impractical for application, and there is a view that workable growth and yield models for practical use by silviculturists are not available in Alberta. Further, lack of agreement on the appropriate drivers that influence growth by species and should be measured is a problem. Some noted the inappropriate dependence on models developed from unmanaged stands as the basis for managed stand forecasting. Challenges with mixedwood modelling were noted as more of a problem than those associated with single-species and even-aged stands. Another noted the need to continually revisit and recalibrate the models with a continuous improvement approach to data collection and remodelling.

Respondents noted the challenges of incorporating probabilistic events (fire, insect, extreme weather, climate change), as well as the capturing tree improvement responses in modelling.

Others cited too much duplication and overlap in research efforts, and the failure of various specialists to work together on these issues – along with the failure of senior policy-makers to enforce this collaboration.

Several noted the lack of good data for analysis, especially in regenerated stands and the lack of long-term monitoring plots to track regenerated stand performance, as well as the relative early stage of development of most regenerated stands. The gap in information on stands aged 25–70 years was noted, a gap that will be closed only if we continue to support juvenile PSP sampling programs, and an expansion of PSPs in this age class.

Some noted the short history of aspen plantation history in Alberta and the problems associated with attempting to use natural aspen clonal development – so heavily influenced by local environments - as the basis for a regenerated aspen establishment and growth. This led to a call for aspen provenance trials with clonal structure.

Others noted the decline in the expertise and practical background of field workers collecting data, the heavy reliance on data collectors without consideration whether the data makes sense or is being collected correctly.

Similarly, there appears to be a decline in the number of biometricians, and those available are being spread too thin.

Q2. What growth and yield information do we REALLY need for forest management planning?

This question elicited a wide range of responses, some of which were already noted in the responses to the first question, such as gathering information on forest health and incorporation of non-timber values.

Three issues led the responses to this question. First, the linkage between silviculture treatment and subsequent development of various forest types was repeatedly noted, and the need to relate silviculture performance and modelling to forest site classification. The need to track this through to rotation was emphasized.

Second, and related to the first issue, there were many calls for repeat measurements to track performance, especially through the use of permanent sample plots.

Third, many called for robust models informed by strong and compatible databases including growth and yield models linked to silviculture/ genetic practices. The relevance of assumptions built into, and over-reliance on the output resulting from models was noted as a problem, especially where such forecasts are not validated by field observations and data collection.

The challenges of mixedwood management and forecasting were also brought up several times.

Q3. What would you change to reduce barriers to the integration of genetics, silviculture, and growth and yield modelling?

28 Forest management planning requirements.
29 Research funding levels.
26 Institutional arrangements for conducting research.
25 Institutional arrangements for prioritizing research.
24 University teaching of growth & yield/ genetics/ silviculture/ forest management.
23 Policy formulation.
22 Other (specified).

Responses to “other” included a call for industry and government to cooperate in addressing these barriers through seeking common ground on the need for research and development of information and models to support this integrative need. There was a suggestion to get key interested people together and develop the action plan and resources to make it happen. Field trips with industry, government, and specialists to look at the issue were recommended.

Some called for reforms in policy to move this integration forward, including a review of FMA size and yield expectations. One noted that much of the technical information is already available but is not being used to its potential due to the lack of “integrated” research and policy development.

Meanwhile, others recognized that any policy review should recognize the need for a return to forest managers for investing in this integration. The need for – and the lack of incentive for installing – the plots necessary for model development was noted. By the same token, without this information and the ability to capture that investment through AAC increases, there are no incentives to invest in improving silviculture. There was a concern over the Province’s seeming reluctance to provide the incentive for industry to invest in this improved silviculture.

Another offered a contrary view, noting that changes to policy and management planning requirements are like changing the problem to fit the solution. This response called for a return to research on growth and yield as the foundation for examining all aspects of stand development in response to treatments and other influences. The remarkable growth and yield programs of the CFS in the mid-20th century were cited, along with a call for the CFS to consider placing this research back at the top of its agenda.

There was a call for universities to return to teaching the basics of forestry and in particular to review their curricula to reinforce the training and development of more biometricians, noting that you cannot manage what you cannot measure. A respondent noted this problem in the USA also, where universities are only successful in seeking and finding funds for research in restoration ecology. There is little emphasis on growth and yield, productivity, and silviculture in an atmosphere where these words – along with "timber" – are rarely spoken and actively avoided.

There was a call for mid-career training programs for mid-career managers, noting the most serious impediment to forest management planning was the lack of communication and common knowledge between growth and yield specialists, silviculturists, and wildlife biologists.

Q4. Which of the following areas would be of most interest to you at the conference?

57	Improving yield forecasting in forest management planning.
42	Data collection, data management and research design.
38	Barriers to, and opportunities for integration of research – technical, institutional.
38	Priority-setting in integrated research and growth and yield forecasting (e.g., what to integrate?).
27	Implications of climate change in growth and yield forecasting, forest health.
16	Research funding – stability, structure, levels and commitment.
16	The human factor – training and availability of biometricians, foresters and technologists.
5	Other (specified).

Under "other," there was an interest in case studies and examples of areas where such work is underway and successful. Again there were suggestions to have some discussion around policy reform that might support this integration.

The need for increased and stable research funding support to cover the whole continuum of forest types was noted, along with the need to develop better knowledge around plantation management, growth, and yield.

5. KEYNOTE SPEAKERS

A GROWTH AND YIELD PERSPECTIVE

Harold E. Burkhart
Department of Forestry
Virginia Polytechnic Institute and State University

Harold Burkhart has been a faculty member in the Department of Forestry at Virginia Polytechnic Institute and State University (Virginia Tech) since 1969. He presently serves as professor and head of the department, and as director of the Loblolly Pine Growth and Yield Research Cooperative, a consortium of industry, public agency, and university partners. Active in publishing and professional organizations, he is a past editor of *Forest Science* and co-author of the textbook, "Forest Measurements."

Speech Purpose: This session provided an overview of developing growth and yield models for managed stands. The emphasis was on installing and maintaining long-term field studies and on incorporating data from a host of sources for calibrating reliable stand simulators that allow for a wide range of silvicultural and utilization options.

Well, it's great to be back in Alberta. I've been here a number of times, so when I was asked to participate in this conference, I immediately said yes. I am pleased to be here and present a perspective on growth and yield modelling.

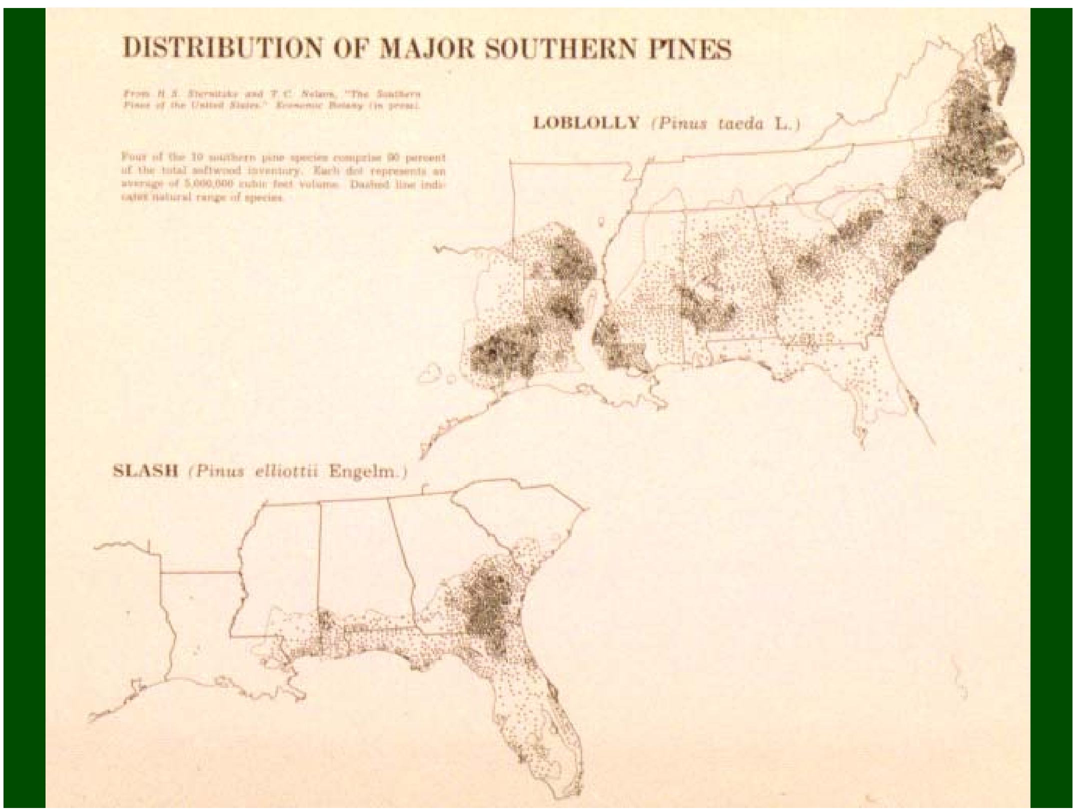
I will use modelling of southern pines to illustrate this talk – not because we have reached perfection in developing these models, but because we have faced a lot of problems in growth and yield modelling due to changes in our management practices and changes in information needs. It is my hope that our experience can be used in your own situation and that you will be able to build on what's been done in other parts of the world and to improve on it.

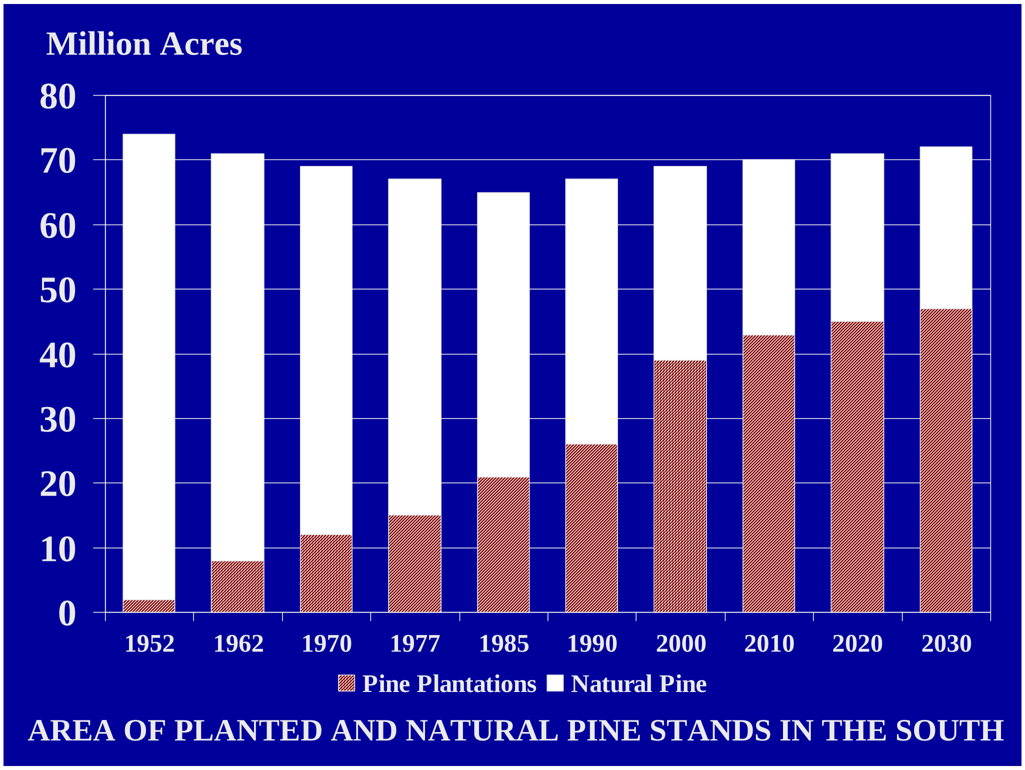
Summary of Presentation

I'm going to first give a review of basic growth and yield components. We need good, reliable, empirical data for empirically-based models. Analyzing that data – that is, distilling that information into just a few simple equations that capture the essence of the system – and computing what's needed for modelling. From there I'll move into field studies because that is, in my view, our biggest challenge and our biggest limitation for developing reliable models. Finally, we'll talk about modelling response to specific kinds of silvicultural practices, we'll talk a little bit about incorporating wood characteristics, because we are going to be affecting not only the amount, but the types of wood that will be produced. I'll briefly touch on accounting for changing environmental conditions, and then I'll offer a summary and hopefully there will be time for some questions.

The Southern Pine Resource – Mainly Plantations

The southern pine resource – loblolly and slash pine primarily – is a major commercial resource, as can be seen on this map. Each dot on the map represents 5 million cubic feet, or about 140 thousand cubic metres of wood, a lot of wood volume and a valued resource.





But this resource is rapidly changing. We've been maintaining an area of around 70 million acres, or approximately 30 million hectares, in the pure pine type. But as the graph illustrates, the area has gone from largely natural stands to mainly planted stands. As a result, over half of the industrial wood supply comes from rapidly grown plantation wood, and this wood is quite different than what we had been dealing with in the past.

Today, virtually all of the seedlings planted are genetically improved. We practice vegetation control, fertilizer applications are common, thinning is normal, and in some instances stands are pruned, depending on the product objective and the degree of thinning. All of these treatments are applied in various combinations. So we need to determine what management treatments we're going to apply, at what particular time, and at what particular levels. This obviously involves models. Plantations are large capital investments, and we need accurate growth and yield models.

Mother Nature will grow pine trees just fine without us and does not need foresters to help her. Natural stands produce beautiful trees with great wood characteristics suitable for many different purposes – in about 80 years. But we can grow trees of similar sizes in a fraction of that time – 30 or so years – using nothing more than simple density control.

By applying not only density control but also additional inputs such as genetic improvement, fertilization, and competition control, we can get greatly enhanced growth.

These three cross-sections represent three timber types. On the left is a natural stand tree, grown under very high stand densities throughout its life. In the middle is a tree from a plantation. You can see where there was initial very rapid growth but then, as the plantation closed up, the growth rings get much closer, and no additional silviculture was applied. And on the right-hand side is a tree from an intensively managed plantation.

A study by Westvaco showed growth rates at around 2 tons per acre per year in natural stands in the 1950s. It is interesting that with simple density control and planted stands we were able to double productivity on a per unit area basis in the 1970s. With additional silviculture we're growing double that again, or four times the natural growth rates, and during this decade the plantations that we're establishing will be growing at eight times that of natural stands.

Basic Components of Growth and Yield Models – Empirical Data, Analytical Methods, Computing Technology

Growth and yield models have three basic components. One is data – good empirical data to go into these models. The second is the analytical methods we need to extract the relevant information from those empirical observations. Finally, we need computing technology, and we use it in all aspects – collecting the basic data in the field, storing it, manipulating it, fitting equations, and then finally in the actual delivery of models to users. Computer technology has had a vast impact on growth and yield modelling, just as it has on all other aspects of science and research.

Computer capacity is still doubling about every 18 months, and it is no longer a constraint. Anything that you can envision or imagine that you might need to do with regard to computing, by the time you can get the modelling done and set about to use it, the computer capacity for implementation is going to be there. We have taken full advantage of this technology because it is no longer a bottleneck on our modelling efforts.

The same holds true for analytical methods. When we entered the statistical age, we fitted multiple linear regression equations to various components – yield, trees per acre, height over age, and so on, and then assembled these separately-fitted equations into models. We have evolved from separately fitting multiple linear equations to the point where we are now taking into account cross-equation constraints and correlated error. This is possible because we have repeat observations on the same trees and/or plots, and we can fit linear or non-linear models in various systems of formulation. The analytical methods have advanced right along with the computing. Statistical software for computing will always be a bit behind statistical theory, but not very much. Very quickly the newer methods are available in the statistical computing packages, and we can immediately take advantage of them in our growth and yield modelling.

Growth and Yield Models for Even-Aged Stands – Whole-Stand Models, Individual-Tree Models

There is no perfect classification system for models of even-aged stands, but one involves an initial division into whole-stand and individual-tree models. In whole-stand models, the whole stand values are the basic modelling unit. One might further break whole-stand models down into two types: those that provide only overall values and those where you can obtain size-class information from the whole-stand numbers.

In individual tree models, the individual tree is the basic modelling unit, and there are two basic types of these models, i.e. those that do not rely on spatial information, sometimes called distance-independent, and those that do rely on spatial information, usually referred to as distance-dependent. The thing to keep in mind is that in this suite of models, or model types, everything is considered to be a function of some very basic variables. For even-aged stands, those variables are usually stand age and site quality, almost invariably expressed as site index. Usually there is also a measure of stand density or crowding, perhaps a point density measure in the distance-dependent models. Finally, you must factor in the management treatments. These variables are easily accessible, the type of data that field foresters would have or could collect.

These forest models are used for a wide variety of different purposes. They are used to estimate wood production, to examine alternative silvicultural regimes, to update inventories, to set rotation lengths, to develop harvest schedules, and so on. Obviously, a model that's best for one particular purpose will not necessarily be best for other purposes, and choices between particular modeling architectures always involve trade-offs.

We have studied the compatibility or relationships between models at different levels of resolution. Daniels and Burkhart (1988) developed an aggregation scheme where you go from the most detailed – that is, the individual tree distance-dependent modelling architecture – to the individual tree distance-independent, to a size-class, to a whole-stand architecture. It's more common, however, to use disaggregation. There is a good review paper on disaggregation methods by Ritchie and Hann (1997). The point here is that you can develop not only analytic but numeric compatibility between different levels of resolution if, indeed, that is important to you and you want to operate at different levels of resolution.

Two Types of Field Studies – Operational vs Experimental Plots

I want to emphasize the importance of field studies for growth and yield modelling. Our biggest challenge is that of gaining the financial and other commitments for the long-term field studies that are required. Two basic types of field information are needed.

First, we need plots in operational stands, because we are going to be scheduling these stands for harvest, and we need to be able to update the inventories. The typical approach is to define a population of interest – some particular forest population – and establish plots in it. We have found that there really is no substitute for permanent growth plots. We've tried fitting yield equations with temporary plot data, but that is never entirely satisfactory. Certainly permanent growth plots are going to be required, and we fit equations to data from that particular set of plot observations. That then provides us with a base model with which to manage a particular forest type or a particular forest population.

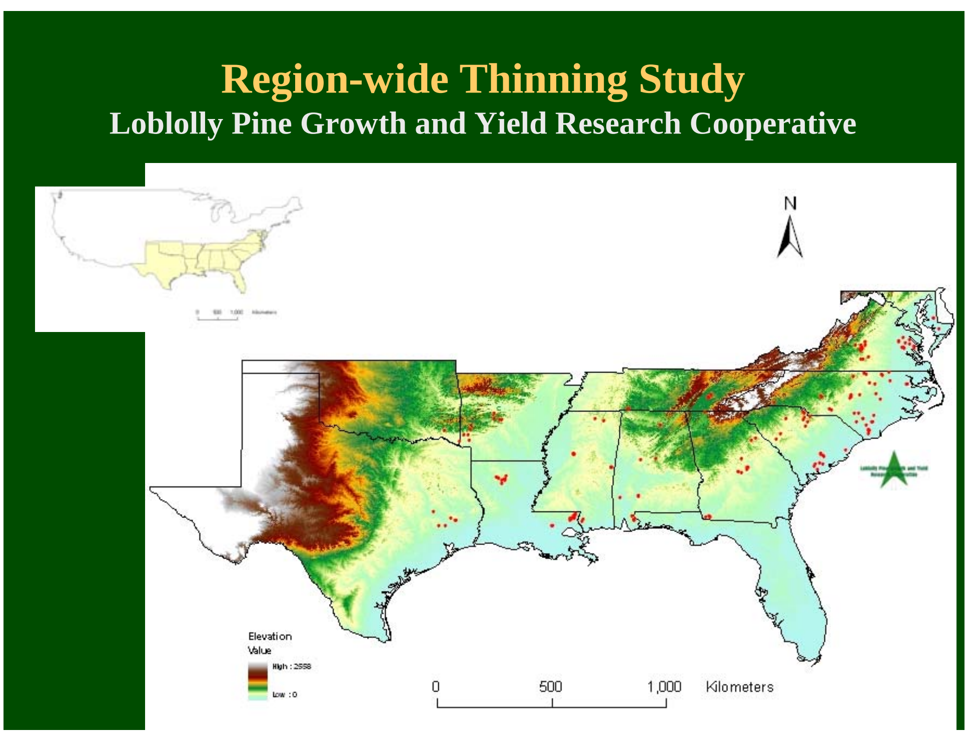
But we're interested also in new methods, new kinds of silviculture, testing new kinds of management regimes. So we establish experimental plots with different kinds of silviculture, push it to the extremes, and then incorporate that data along with our base population data into stand simulators.

Virginia Tech's Loblolly Growth and Yield Research Cooperative

Virginia Tech's loblolly pine growth and research cooperative is a consortium of industry, government agencies, and the university, with two basic thrusts. First, we strive to maintain some long-term field studies. Not all the information we need is available from other sources, so we maintain some of our own field studies. Second, we integrate and synthesize information from a wide variety of sources, including our own studies. There is no way that we could independently undertake all the studies needed to generate the information we need, but fortunately lots of information is available from other silvicultural experiments in genetics, forest fertilization, weed control, and so on. We work with a whole host of different institutions, agencies, universities, and industries to integrate and synthesize this information into models of stand dynamics, growth and yield.

Study One: Thinning Study in Operational Stands

The first study that I'll talk about is a thinning study in operational stands. The original pine plantings in the South were on abandoned agricultural land or old fields, and that particular resource was quickly being eliminated. What was coming on line, and what the industry was going to live on in the future for some period of time, was stands planted on land that was formerly in forest, had been harvested, site prepared, and planted. A region-wide set of plots was established in planted stands on these site-prepared lands.

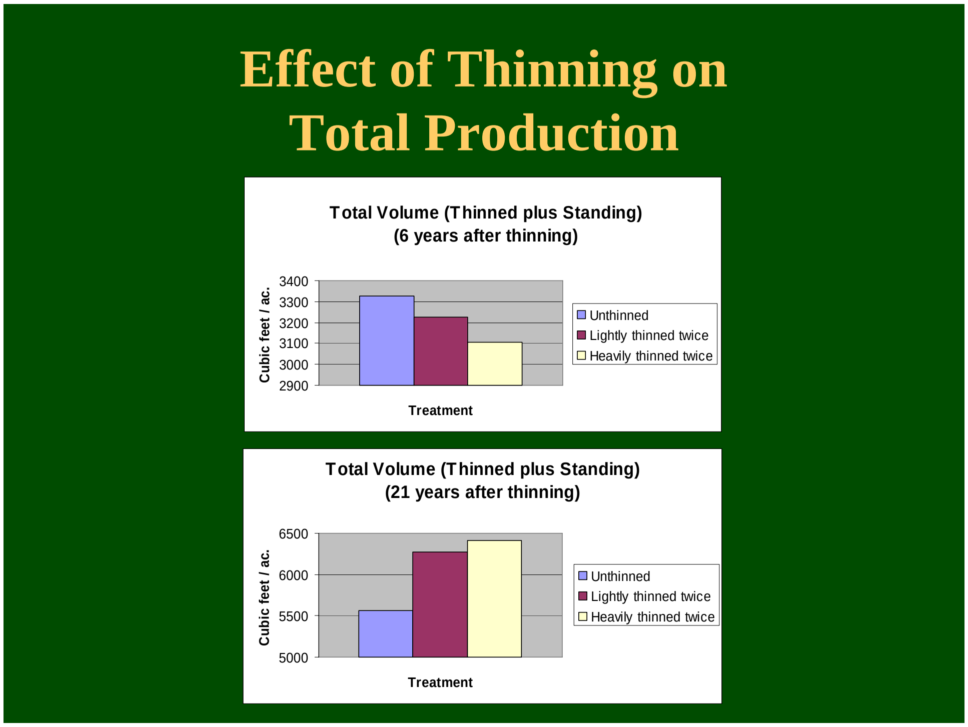


We do all of our measurements during the dormant season; these plots were established in 1980-81 and 1981-82 over two dormant seasons in stands that were from 8 to 25 years old. This was a thinning study, and these stands were all unthinned when we put the plots in. We knew, however, that for stands of this type the optimal time for first thinning would be somewhere around 15 to 17 years. We needed some plots that were younger than that, of course, that we would thin and then some that were older. The mean age of the sample stands was 15 years. Again, these were all site-prepared areas, planted with all woods-run stock. In some of the younger age classes, there were some seed orchard plantings, but we did not sample those nor did we include them. Further, there was no mid-rotation fertilization.

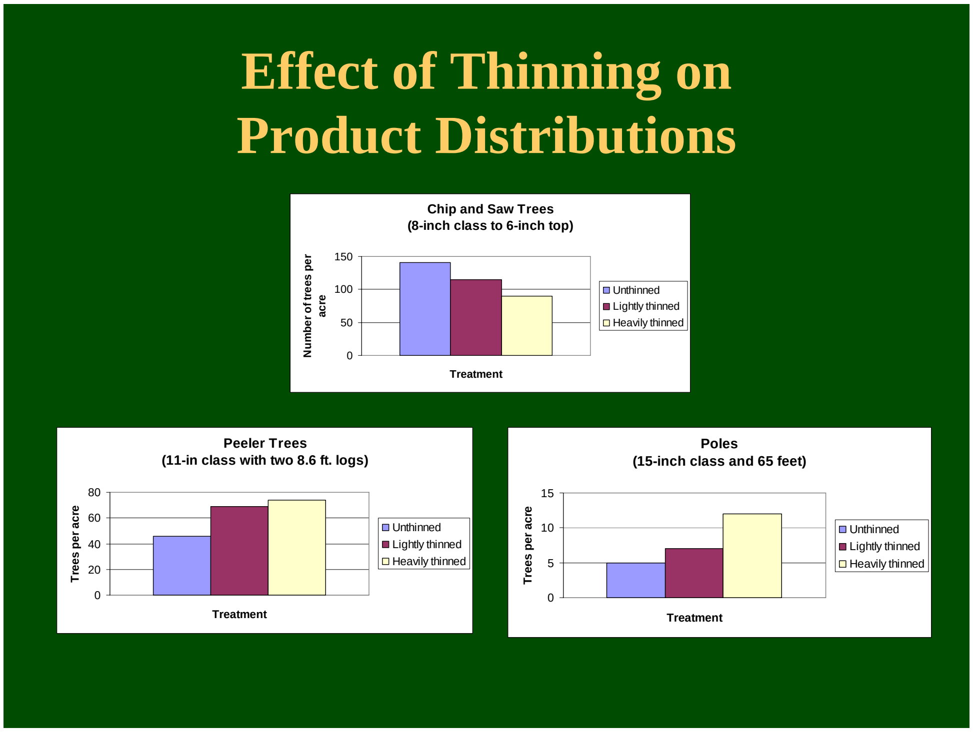
This was a region-wide study with 186 locations. At each place where there is a red dot on the map, a set of plots was installed. This set of plots was distributed across the land ownership pattern of our cooperators. We tried to select as wide a range of soil sites and climate conditions as possible. At each of these locations, there were three plots, selected to be similar in initial condition.

The plots were matched up with regard to basal areas and trees per acre and site index. We established a control, then implemented a light thinning treatment and a heavy thinning treatment. In all cases the thinning was from below, so thinning type was not part of the design. The study was aimed at thinning intensity, based on the concept of thinning for higher value solid wood products.

We measured DBH on every tree (marked, of course), as well as height. We know that the response to thinning and other silviculture treatments depends on the crown characteristics, so we measured crown ratio. We also measured the stem quality at each and every measurement, because it’s not only wood volume but also wood quality that we’re interested in. We measured, or established the spatial location using stem maps, at each and every one of these plots, and I would highly recommend that for any research plot. You only have to stem map on the first measurement occasion. Then, of course, the map has to be updated thereafter, but it just helps immensely to sort out problems that you might have, so – regardless of what kind of modelling you might anticipate – stem mapping research plots, in my view, is well worth the money. We remeasured these plots every three years, always during the dormant season. The seventh and final re-measurement was completed during the dormant season of 2001-02 and 2002-03.



We're interested in a lot of aspects with regard to the effects of thinning on production. At the time of thinning, the total thinned volume and the volume standing is going to be equal for all plots because they were selected to be of similar characteristics – or as close as we could make them. Right after thinning, the thinned plots – because they don't fully occupy the site – are going to have less total volume, but if you follow them over a long enough time period, there is a reversal after 21 years. Twenty-one years after an initial thinning, the total production is highest on the heavily-thinned plots, second highest on the lightly-thinned, and lowest for the unthinned plots, because you don't capture in any of the mortality.



The other aspect of this study was that of quantifying different products and product distributions; this diagram illustrates some of those relationships at 21 years after initial thinning. The *y*-axis shows numbers of trees, not volume, and the graphs show that thinning becomes more and more important as the product specifications become more and more exact. That is, the heavy thinning shows a bigger advantage as you go from chip-n-saw material, to peeler material, to pole material. These are some of relationships we wanted to examine in this study, developing reliable information that wasn't fully available at that time.

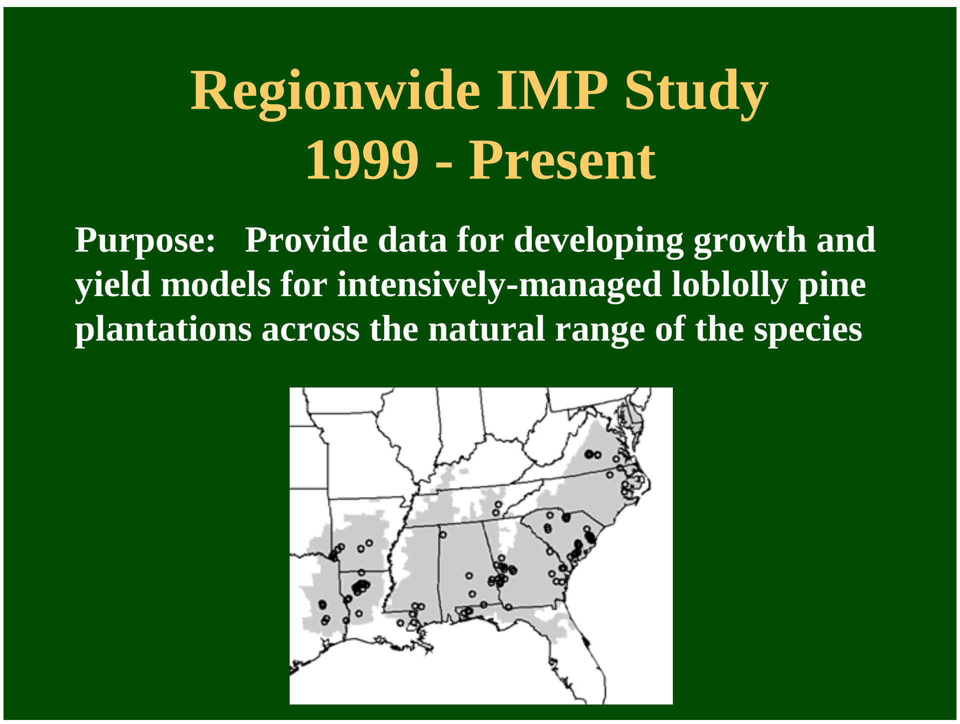
End of Study, and a New Consideration

At the time we terminated this study, we collected information from the dead trees. New questions never anticipated when the study was established have since arisen – questions about carbon sequestration. We could gain additional insight and information into the carbon pool because we had stem maps, and we could go back and find trees that had been dead 3, 6, 9, 15, 20 years, and so on. We took wood samples, brought them into the laboratory, and used that information to better estimate the fate of not only the carbon in the living trees, but where the carbon is actually going and how long it's staying above ground in the dead trees as well. Again, these research plots can be very valuable as the questions being asked are changing over time. These plots are proving valuable for answering questions that we did not even anticipate.

We also gathered additional wood quality data. We had been gathering wood quality data all along, of course, as we did our thinnings, but at the time of study termination, we did additional destructive sampling on the plots, taking the wood in for milling and assessment.

Study Two: the Next Generation of Operational Thinnings

About five years before the termination of that first study, we knew that that particular timber type was soon going to be gone and that we were going to be relying on the next generation of plantations. This newer generation of operational planting is all genetically improved, all from seed orchard stock. Further, the plantations have all received heavy vegetation control and fertilizer as needed. Again we established a region-wide set of plots, called the intensively managed plantation (IMP) study. We started to put in these plots in 1999, with the purpose of providing data for determining the growth and yield of these more intensively managed plantations. The map shows the plot distribution across the region.

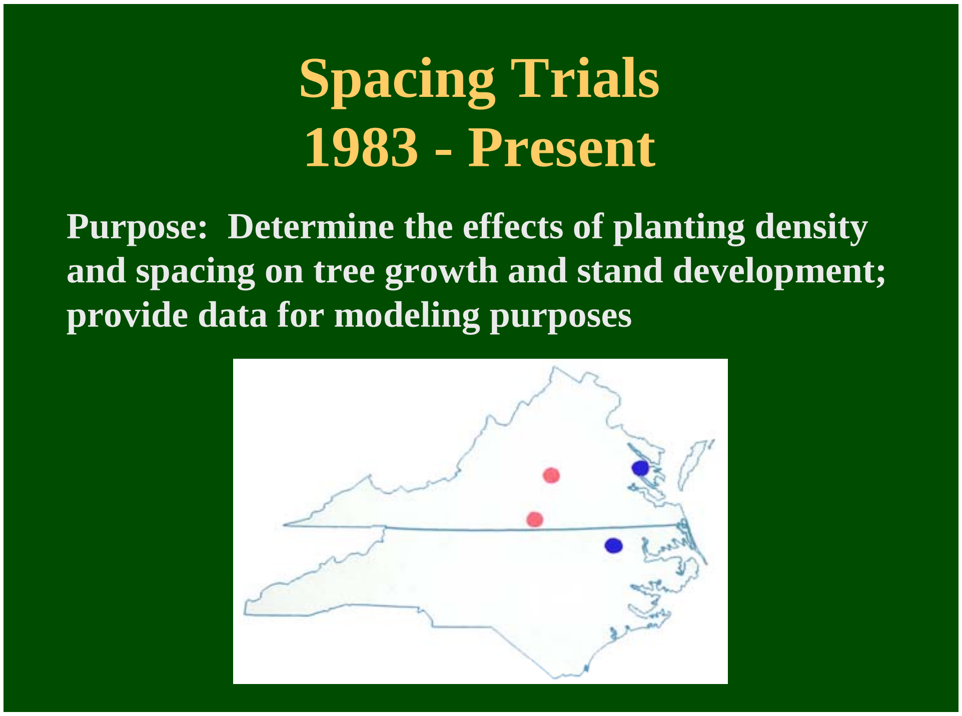


We wanted to start at a younger age, and we wanted to establish the plots before treatment and to have at least a couple of measurements before treatment, so these were established in plantations ranging from 3 years to 8 years of age. The plots were established over a 3-year period, so it's an 8-year window on the technology used in plantation management. But within that window we can say it's a particular type of improved stock, particular kinds of herbicides or other means used for controlling competing vegetation, fertilizer treatments, and so on.

These plots were measured every two years because they're growing rapidly and the rotations are going to be much shorter than in the previous generation. We apply thinning and pruning treatments. In the previous study, we found that we can thin more heavily than we ever thought, but that with very heavy thinning, pruning is required if we want to produce clear wood volume. Thinning and pruning is done at a particular point in stand development, defined as when the dominant height reaches around 45 feet (12 to 14 metres) in height.

We established a control plot – a lightly-thinned plot where we assume that the density is going to be heavy enough to induce self-pruning and still produce good solid wood products. But with the very heavy thinning treatment, we prune the first log.

Study Three – Incorporating Response to Silvicultural Treatments
I turn now to some trials incorporating response to silvicultural treatments, of which we have a wide range. The goal is to incorporate information from many different sources. One primary decision is initial spacing.



In 1983 we established a set of planting spacing trials. There have been many spacing trials established over the years, but a lot of them have not been sufficiently replicated, so we decided to put in a set of our own because of the importance of the decision on spacing at time of planting. We wanted to gather data on initial tree growth, so we started measuring these plots at year one. We have two installations in the Piedmont region, shown in red, and two installations in the Coastal Plain, shown in blue. We wanted to make inference to both Coastal Plain and Piedmont regions.

Initial spacing is so important. Obviously it's going to affect site preparation and planting cost. If you plant more trees, it's going to cost more for seedings, and the site preparation costs may be much greater. When you apply bedding treatments, this is especially important because you want to establish as few beds as possible. To do this, you want the rows as wide apart as possible and then have the trees closer within rows for a given number of trees per unit area.

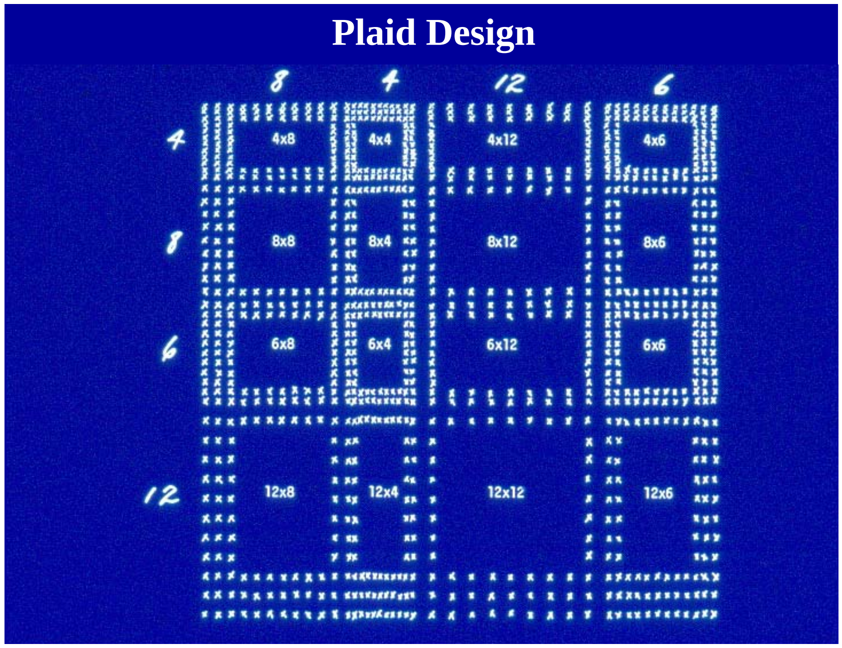
So much is dependent on initial spacing. It is going to impact the quantity and quality of the wood produced. It will impact the timing of all subsequent cultural treatments; it impacts the kind of genetic stock that you might select. Weed control and fertilizer regimes and the time when you can implement the first thinning are all highly dependent on initial spacing, as is the decision on whether or not you might need a pruning treatment, etc. Finally, it impacts harvesting costs, which will be greatly influenced not only by the number of trees, but the configuration of planting and how efficiently you can use different kinds of harvesting equipment in that stand. So this is a very key decision.

Spacing Trials Overview

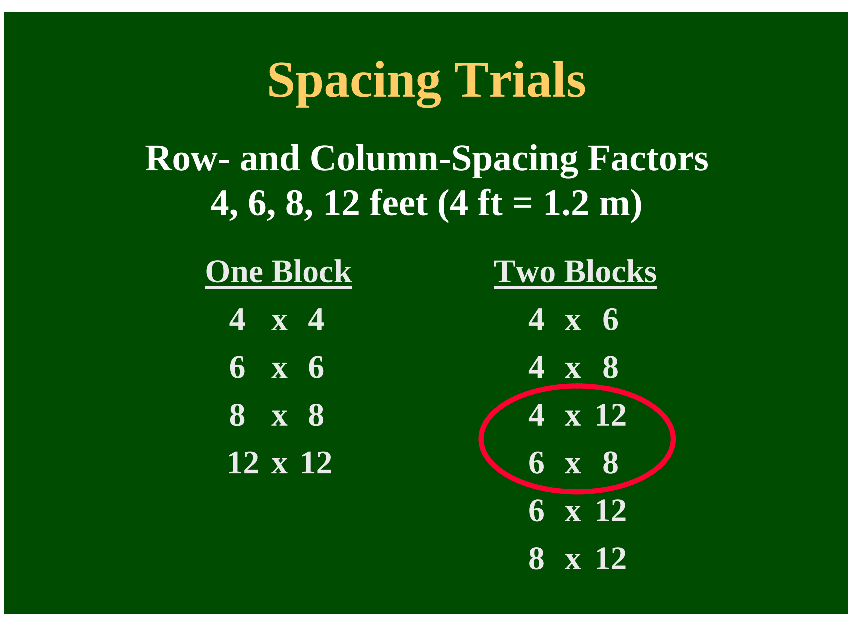
- 4 locations (two Coastal Plain, two Piedmont), 12 blocks, 16 treatments/block
- A bare-ground installation
- Densities from 2722 to 302 tr/ac (6726 to 746 tr/ha)
- Spacing rectangularity from 1:1 to 3:1
- Annual measurements
- Measured and maintained by VT personnel

As I pointed out, we have four locations – two in the Coastal Plain and two in the Piedmont. There are three reps at each of these locations so we have 12 reps, and at each of the replicates there are 16 treatments in each block. We started with bare ground and planted these ourselves. The densities are quite wide, from 2722 trees/acre (6726 trees/hectare) to about 302 trees/acre (746 trees/hectare).

We wanted to study spacing rectangularity (Sharma et al. 2002) – that is, configurations from square spacing to more rectangular spacings (i.e., from 1 to 1, to 3 to 1). We took annual measurements starting with year one. In the case of our region-wide studies in operational stands, our cooperators help with the measurements, but in this particular case, Virginia Tech personnel do all of these measurements and maintenance.



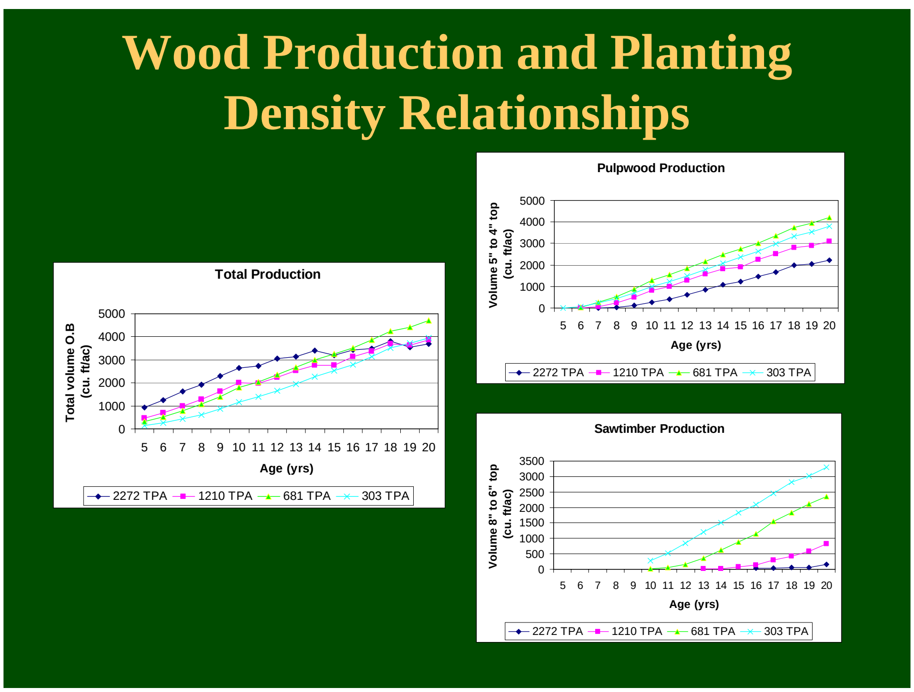
We chose a so-called plaid design, where you have row and column spacing factors. The factors used were 4, 6, 8, and 12 feet, and we randomly assigned one of those spacings to each of the rows and then repeated the process of random assignment for the columns. That then creates this plaid design that fits together in a very compact manner, making optimal utilization of space and plant resources. There is a constant number of measurement trees – that is, 49 trees (7 × 7) – along with three guard rows. With this particular design in these row and column spacing factors of 4, 6, 8, and 12 feet, you wind up with one block of each of the square spacings and two of each of the rectangular spacings.



One of the things we wanted to study was rectangularity, so we made sure that within the design, we would have spacings that were identical in terms of amount of growing space per tree but with different rectangularities. The 6 × 8 is essentially a square spacing, and the 4 × 12 gives us a 3 to 1 rectangularity.

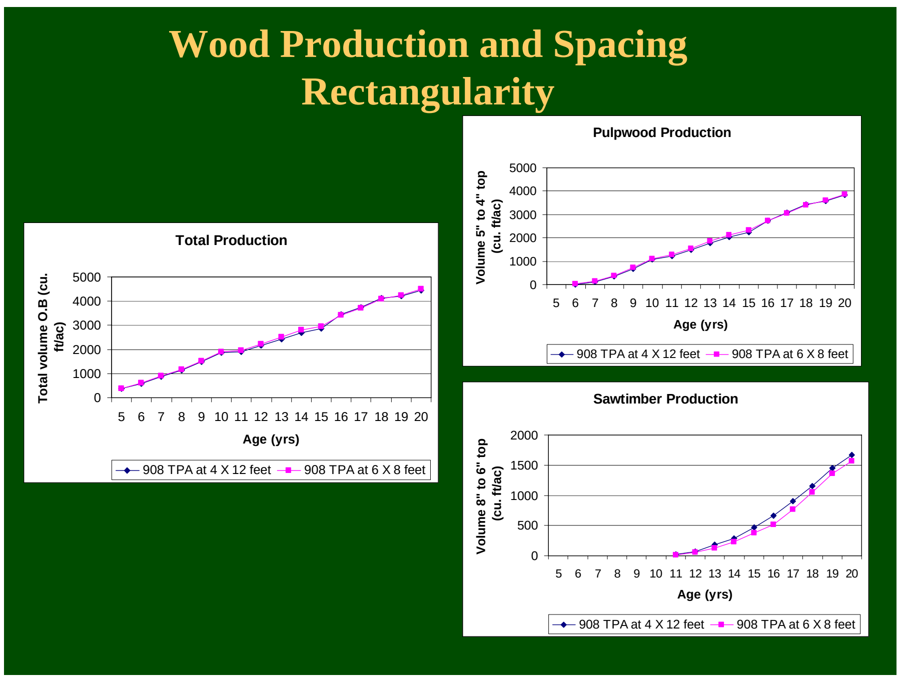
In the first year the seedlings don’t do much except put down roots, but by the second year they’re up and going, and by the third year they’re quite well established. We controlled the competing vegetation in a widening band around the trees for the first three years. After that we did no additional vegetation control. By five years the trees have generally captured the site and are shading out vegetation in the understory.

The point of this is that a lot of the action with regard to stand dynamics and development occurs very early on, and we make a lot of decisions about things like weed control, fertilizer applications, etc., very early in the life of the stand. We did not have juvenile growth models that were even in existence, let alone being adequate. We needed to study growth at much earlier ages because decisions made at the time of planting have significant impacts on stand development.



We looked at wood production relationships at age 20, and it became evident that total volume for all the spacings began to converge by around age 15 or so, as you would expect. But our real interest is in terms of products. For pulpwood production, the 8 × 8 foot spacing is the highest, and that's consistent with other results; if you just want to grow pulpwood on typical pulpwood rotations, with no thinnings, plant 600 or 700 trees per acre. That's a standard recommendation, good and safe.

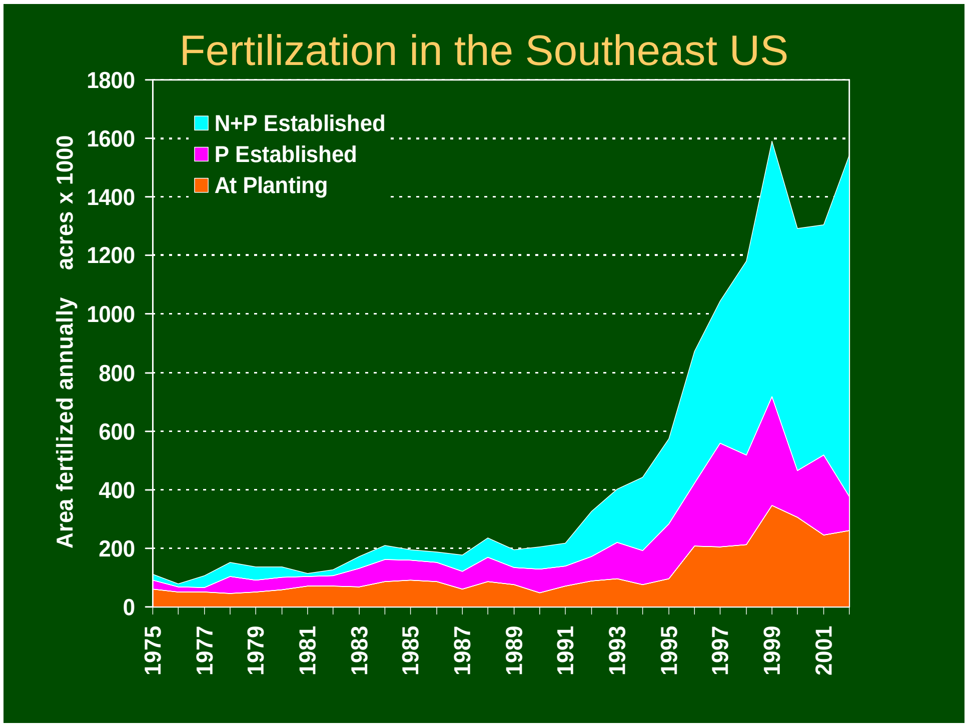
But the widest spacing obviously produces the most sawtimber volume, as again you might expect. However, the very widest spacing – and many people still find this hard to be believe – is second in terms of total pulpwood production. The results show that we can actually get by with lower stand densities, lower planting densities, and heavier thinning treatments than what we had ever envisioned until we actually looked at this in an experimental sense.



Again, we're primarily interested in this rectangularity issue because of the site preparation cost. The results show that there is no difference in total production, no difference in pulpwood production, and there is no significant difference in saw timber production between the 4 × 12 and 6 × 8 foot spacings. In fact, as we have looked at the rectangularity effect, there is one – and only one – relationship that we've been able to find that is statistically significant. The more rectangular spacing results in a larger maximum branch size, that is, those branches that go out between rows are longer and, of course, they're larger in diameter. Average branch diameter is not different between the two, but maximum branch size is. As a result of this study, some of the companies are going to more rectangular spacings than they've ever used before in an effort to save on site preparation costs and on harvesting costs.

Study Four: Forest Fertilization

We have a cooperative fertilization study with North Carolina State University. Our research group does not put in fertilizer trials, but we work on forest fertilization cooperatively. Forest fertilization can make a dramatic difference. In some cases, the decision on whether or not you fertilize with phosphorus is the difference between growing trees or not growing trees.

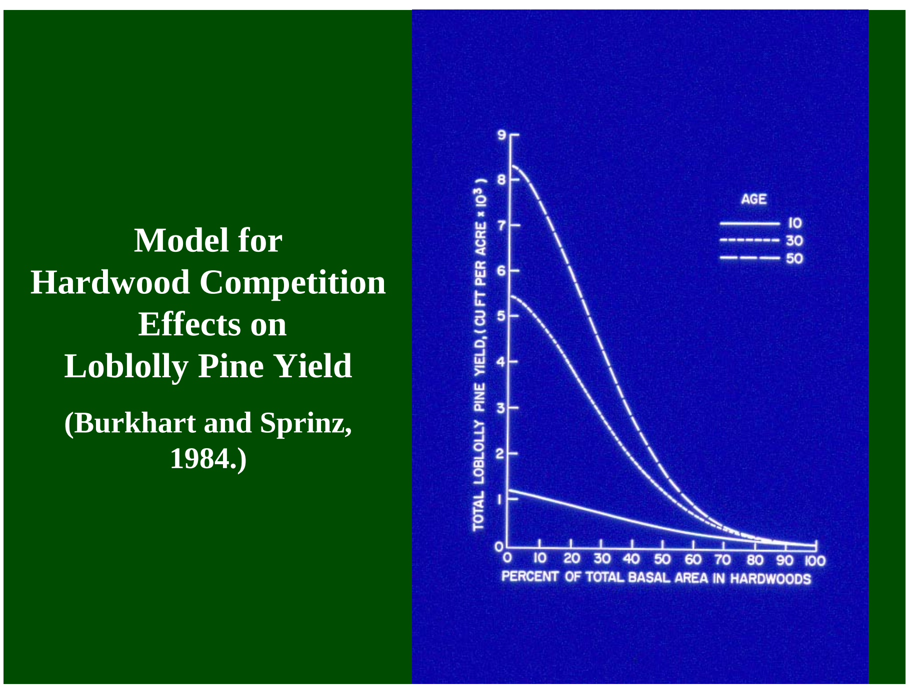


We've been studying forest fertilization in the South for a long time, when the really concentrated research effort began in the early 1970s. From 1975 to about 1990, forest fertilization was going on, but at a relatively low level. One might ask, with such dramatic results, why weren't they fertilizing more? The answer is that the response was not consistent, and sometimes there was no response at all. We had to learn about weed control and stand structure and timing of forest fertilizer applications on different soils and in different climates and so on, to really gain confidence in the use of this particular treatment. Since the 1990s fertilization has really taken off, with very large fertilized area every year because people have confidence from the results of fertilizer trials and growth and yield forecasts.

Jari Hynynen from Finland visited us for a year and developed stand response models to varying levels of nitrogen fertilizer (Hynynen et al. 1998). His studies showed that the response (in basal area) of different levels of nitrogen with phosphorus also being applied peaks out after about two years. Height growth response peaks somewhat later. In his study he looked at three levels of phosphorous: 0, 28, and 56 kilograms per hectare. There was no difference with regard to the two different levels of application. You either put phosphorous on or you don't; it's just a simple switch, and then you get different response levels due to different levels of nitrogen application. But you get a very different response to nitrogen depending on whether or not you also applied phosphorus.

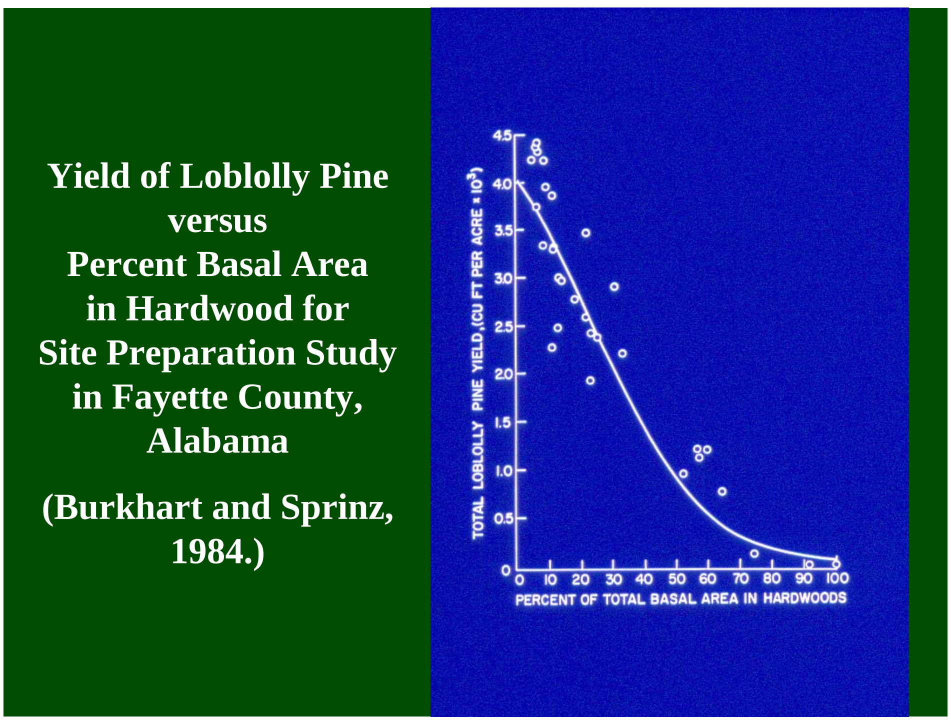
Study Five: Vegetation Control

We have some very fierce competitors with our pine trees. These hardwoods are absolutely fierce competitors, and they have to be controlled if we're going to grow pine. Pine has to have mineral soil and full sunlight to regenerate, and without vegetation control, we generally will not successfully establish pine. During the 60s and 70s the industry routinely applied 2-4-5 T for vegetation control, but in 1979 it was suspended for forestry use by the Environmental Protection Agency. You can still apply it to agricultural crops and the rangeland, but it cannot be applied to forest crops. All of a sudden we had a great need for models because without them we could not fully document the benefits of weed control for pine production.

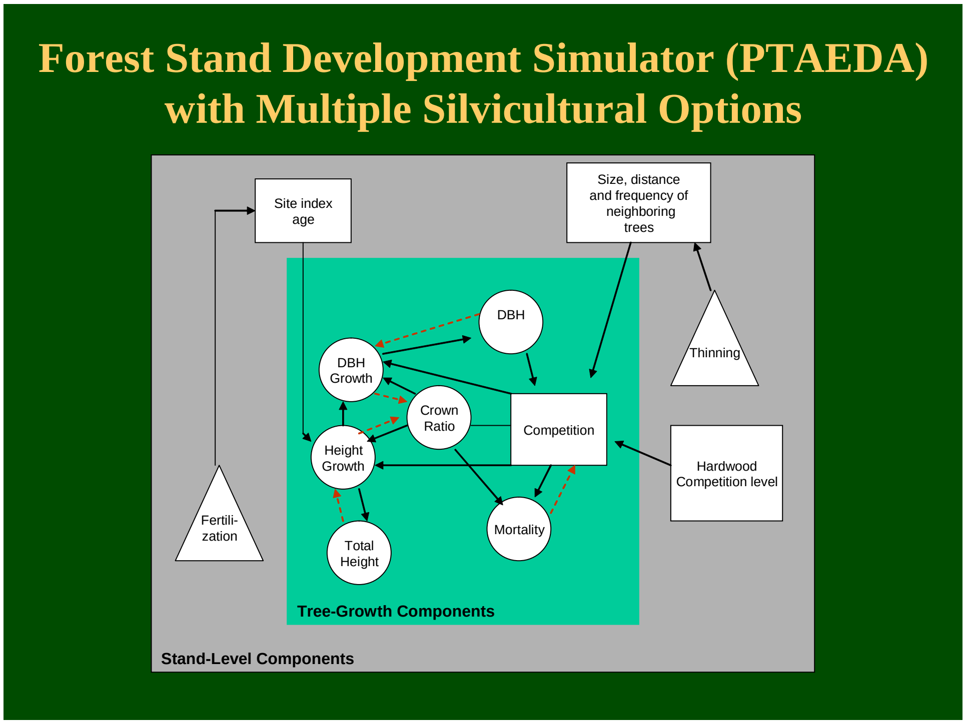


The general relationship between crop yield and weed density is shown in the graph on the right, and it's a common relationship that holds true for lettuce or lodgepole pine or any crop that you might wish to grow. You'll find this general relationship in any weed science book. But while we knew what the cost was of applying these herbicides, we could not document the benefits of applying them, and this put us into a bit of a crisis mode to do modelling with regard to hardwood competition effects on pine production. This was an issue throughout the nation. Oregon State, Auburn University, the U.S. Forest Service, and Virginia Tech teamed up on a project funded by the Environmental Protection Agency and by forest industry. The regulator and the regulated collaborated because both needed to know the benefits of vegetation management and weed control. The focus was on the two major conifers for commercial production – that is, Douglas-fir and loblolly pine; our job was to develop a model for loblolly pine.

And you see the results from the model that we released in 1984, showing the impact of weeds on pine production at varying ages. We had pretty limited data with which to work, and, indeed, we don't put plots in stands that are not majority pine. The most hardwood we had in our data set for modelling was 25%, by basal area in hardwood, so we needed to validate this model.



There was an old site preparation study that Auburn University had put in and had abandoned at age 11. At age 24 these plots were remeasured, and we ran the model against that independent data set (circled dots). The results were quite satisfactory. The general shape of the relationship held true; it showed quantitatively the benefits of weed control. Often times we use all of our data in terms of fitting models. We want to use all the information that we've got, but we also need to be looking ahead with regard to validation. That's a very important step.



In the case just described, we were trying to evaluate weed control alone. But weed control, fertilizer, and thinning all work together, and we need to incorporate them all in a system that examines the effects of various combinations of treatments. We've incorporated hardwood competition effects into an overall stand simulator, as well as thinning effects and fertilizer effects, as you see in the simulator flow chart (Burkhart et al. 1987).

Incorporating Genetic Effects

Options

1. Purely theoretical approach
2. Develop assumptions and perform simulations with currently-available models
3. Use early data (row plots; block plantings) to modify extant models
4. Rotation-age plantings
5. Combinations of 1-4

Incorporating Genetic Effects into Growth and Yield

I'll contend that in some circumstances we can account for genetic effects with our growth and yield models. Incorporating genetics is challenging because it is a very fast moving target. We are continuously changing the genetic base. So what might we do?

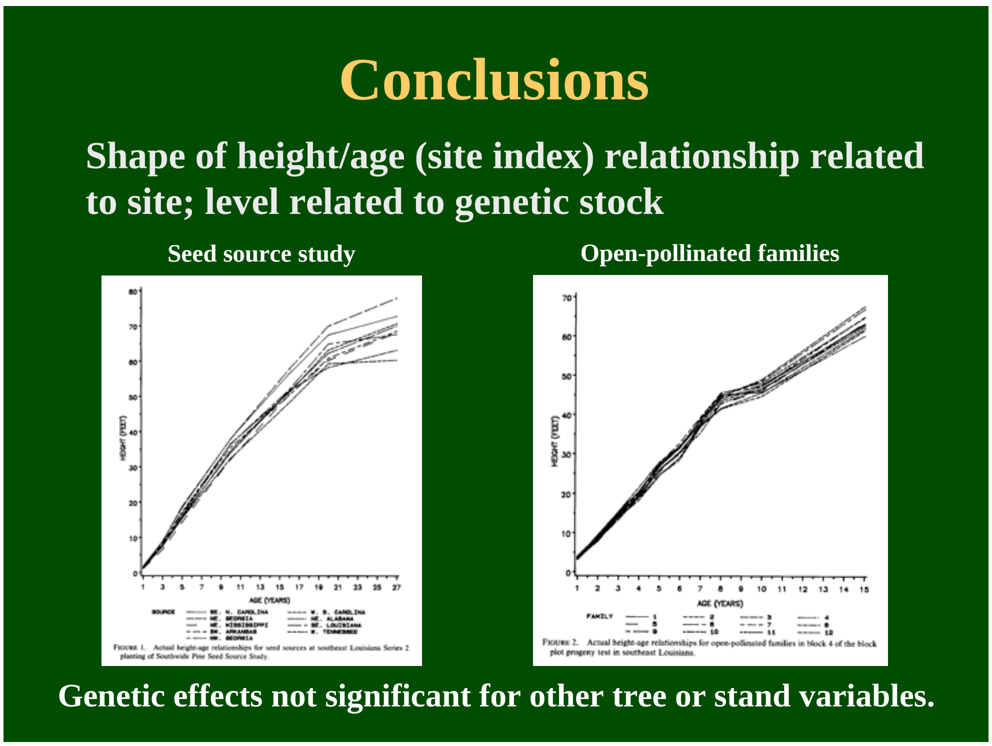
Well, we could take a purely theoretical approach, but to my knowledge we don't really have an adequate theoretical basis by which to quantify purely on the basis of theory. We can develop various assumptions and perform simulations with our currently available models, and a lot of people have tried that.

We can use early data from the single-tree plots. Hopefully there will be some block plantings, too, so we can study how various genetic stocks will react when they are planted together, for example, as families or clones as opposed to being planted in mixtures. We would like to have rotation age plantings, and we are shooting for these. But obviously by the time we get there, the genetic material will have moved far, far ahead of where the genetic material was when those particular plantings were made.

In reality we will probably apply combinations of these different kinds of modelling approaches. So, with the theoretical basis that might help guide us with regard to simulations with our extant models, those results might actually cause us to modify, change, or rethink some of our theoretical constructs. The early data we can use in simulation; this might impact the theory which again might come back and impact the simulations we do. Ultimately we hope to have rotation age or near rotation age data that's going to again help to guide us with regard to simulations and theory.

Past Studies with Genetically Improved Stock

Twenty years ago, industry approached us and said, "We've got all this seed orchard planting material coming on line and upper management is asking us what in the world is it going to look like? What's it going to produce? What kind of products are we going to get, etc.?" To help answer these questions, we created a post-doctoral position, and Marilyn Buford worked with us for two years, publishing her results in *Forest Science* in 1987 (Buford and Burkhart 1987).



The study used provenance data, the only rotation age data available at that time, and first-generation open pollinated stock. Although these graphs represent very low intensities of genetic selection, the study concluded that the shape of the height-over-age curve – that is, the site index relationship – is determined by the site characteristics, and the level is determined by the genetic stock. We looked at all sorts of other variables, such as stand structure with regard to the height diameter relationship, tree volume, and taper relationships, and so on. And there were no significant differences.

The bottom line conclusion was that to predict growth and yield in plantations, whether established with varying seed sources or with this open pollinated first generation stock, it is first necessary to get the site index right. This was relatively easy in one sense in that you can rely on the single tree plots with regard to the height relationship. It was necessary, but it was also sufficient to modify site index – because basal area, volume, product distributions, and so on, all follow from adjusting the site index value.

That was sort of a good news/bad news conclusion to me. The good news was it was pretty simple. Users, managers – you've just got to nail the site index for a given particular family. But the bad news for me was it's kind of an uninteresting result, just adjust site index, and it may not hold up in situations of more intensive genetic selection.

Not the Case for Radiata Pine in New Zealand

Carson et al. 1999. Forest Science 45:186-200.

Variable	Gain over control	
	Open pollinated	Mix of crosses
Height	4.5%	5.3%
Diameter	6%	11%
Basal area	12%	30%
Stem volume	15%	34%

Developed "genetic gain multipliers" for incorporation into stand growth models.

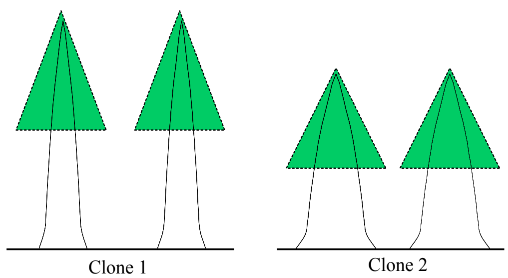
Keep in mind that this (adjustment of site index alone) is not always the case, and it certainly was not the case with data from radiata pine in New Zealand. This is, of course, a different species, but it also has a longer history of breeding and a higher level of genetic selection. Sue Carson and her associates found significant gain in height but an even bigger gain – a disproportionate gain – with regard to diameter, basal area, and volume production (Carson et al. 1999). Based on this, they developed genetic gain multipliers to be incorporated into growth and yield models. The good news is that these particular multipliers can be incorporated into models that exist for a particular forest population with different silvicultures, and you can make these adjustments for a different genetic stock.

It follows that the very simple adjustment of "well, just get the side index right" may be sufficient for the very early stages of a genetics program, but it is not likely to be sufficient as you go towards higher and higher levels of selection intensity.

Clonal Forestry – a New Modelling Challenge

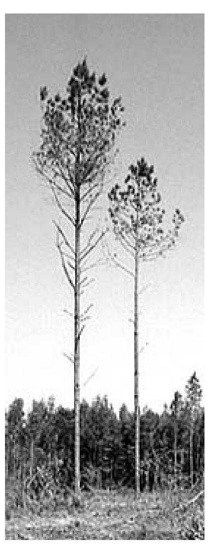
With somatic embryogenesis, we're rapidly moving towards clonal forestry. We're starting to plant clonal loblolly pine in significant numbers, and within a couple of years, there will be a significant area in clonal plantings. One thing that seems certain is there will be increased uniformity in such things as branching and crown structure of individual trees.

"Population Averages" will not have much meaning for clones.



Population averages are not really going to have much meaning with regard to clones because different managers or different organizations are going to be deploying different clones for different kinds of product objectives or management objectives. Simply trying to get some sort of a population average for growth and yield modelling isn't really going to suffice.

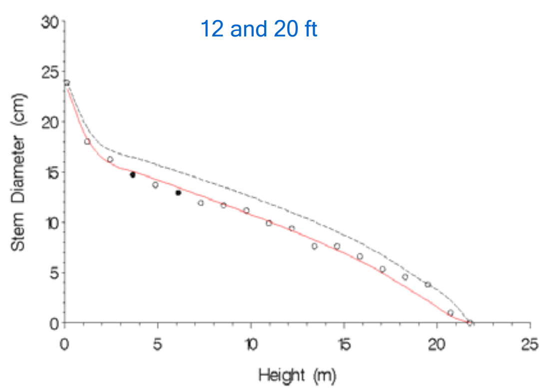
Will need to adjust relationships for clones



Max and Burkhart (1976) nonlinear mixed-effects taper equation

$$\frac{d_{ob}^2}{D^2} = \hat{\beta}_{1i}(x-1) + \hat{\beta}_2(x^2-1) + \hat{\beta}_{3i}(\hat{\alpha}_1 - x)^2 I_1 + \hat{\beta}_{4i}(\hat{\alpha}_2 - x)^2 I_2 + \varepsilon$$

$I_j = 1$ if $(\alpha_j - x) \geq 0$, 0 otherwise j=1,2.



What we're going to have to do, in my view, is to adjust our relationships specifically for clones. We can do this with modelling procedures like mixed models in which you have population-specific parameters and individual-specific parameters that are estimated. Shown here is just one example with regard to taper functions. The top line is the population average. Now if you have some specific measurement data on an individual – as we show here – you can adjust the equation. Here we chose two upper stem diameter measurement points, 12 and 20 feet. The bottom line is what would be the individual adjusted taper function. It follows that we can do clone-adjusted tree volume, taper, height over age, and other functions. To do so, we will need to obtain some additional calibration data in the field, but I can also imagine doing timber inventories in which clones will be a stratification variable. And I think we're going to be able to make much more precise predictions for clones because of their uniformity. But it is going to require the input of some additional measurement information.

Microsite Influences and GIS-Based Precision Silviculture

In spite of the uniformity, in spite of genetically identical individuals, there will still be variability in the stands due to microsites. This environmentally-induced variability will affect individual tree performance, but clonal stands are going to be a lot more uniform than anything that we have managed or seen in the past.

It is important to develop good land classification and soil maps, and most of the industrial properties have excellent kinds of soil mapping. We will make decisions on deployment with regard to planting, spacing, site preparation, clones, and silvicultural treatments, hopefully optimizing the use of the landscape. We will monitor the state of these plantations with remote sensing techniques where we can detect pest or nutrient stresses and then take corrective action in a true GIS-based kind of precision silvicultural system. This is where we want to go.

Wood Characteristics

Wood characteristics are also going to be affected, and those characteristics change with time. As we cut rotation ages to half or even one-quarter of what we've been used to, we obviously are going to affect wood characteristics. What that means depends on what kind of product you're trying to produce, but it's going to have to be taken into account. In addition to age, the geographic location and environmental effects also have an impact on wood characteristics, and the silviculture that we apply also has a great impact.

Impacts of a Changing Environment

The final point that I'll try to cover has to do with accounting for the impact of changing environmental conditions on stand growth. In the past, when we have taken our plot measurements and fit our equations to them, we assumed that unmeasured weather variables will average out. We also assumed that all other environmental impacts are going to be the same in the future as they were in the past. Well, that's not really true. We have rising CO_2 levels, and we can detect changes in tree growth and stand production from this increased CO_2. We have changing chemical composition in the environment, that is, more nitrogen, sulphur deposition, etc., and this presents the possibility of some rather broad-scale kinds of environmental changes. So how can we account for some of these types of impacts or changes?

There are a lot of different ways you could go about this. One approach that we took was to develop a linked model system in which we linked the growth and yield model – PTAEDA2 – to a process model – MAESTRO – that some of you might be familiar with.

With these linked models we were able to estimate the change in site index over a given period of time. We looked at changes in net photosynthesis, as estimated from the process model MAESTRO, and then at changes in stand density, which comes from the growth and yield model.

Bias

Observed		Predicted			
		No SI Adjustment		SI Increase	
ft^3/ac.	m^3/ha	ft^3/ac.	m^3/ha	ft^3/ac.	m^3/ha
4891	342.2	4284	299.8	4875	341.1

There is an apparent increase in growth rate that results in biases in our predictions. You see here for a set of plots over a 15-year period, the ending volume was 342.2 cubic metres per hectare. If we do not take into account changes in the environmental conditions on those plots over that time period, we get a biased prediction of 299.8. Using the adjustment equation previously shown, we get a predicted value of 341.1, which is not significantly different. So, you don't need to throw your empirical models away, but you might need to adjust them with some process information to obtain unbiased predictions.

Summary

- Analytical methods and computing power generally do not limit development of reliable growth and yield models.
- Long-term empirical observations on stand development are expensive to obtain and often limit modelling efforts.
- Modelling is essential for integrating and synthesizing diverse information and identifying knowledge gaps.
- Questions posed will be more complex.

Summary Points

1. Our analytical methods and our computing power is generally not going to limit the development of growth and yield models.
2. Long-term empirical observations are typically our limiting factor. It is very difficult to get the financial and other commitments necessary to develop these kinds of databases.
3. Modelling is essential, it is absolutely essential, for integrating all of these diverse sources of information and for identifying knowledge gaps.
4. Finally, the questions that are being posed to us are going to continue to change and they're going to be even more complex in the future.

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QUESTIONS

Thom Erdle

I'm curious how you deal with the possible site quality effects of increased production off any given hectare. Is there any kind of site index feedback or adjustment that accounts for the fact that you're producing and removing that much more biomass from a site under these intensive regimes.

Dr. Burkhart

Right and so how do we account for possible changes in basic site quality as we're going through time? Of course the inputs with each subsequent rotation are different. And what some people find difficult to imagine is that we had greatly increased productivity with each subsequent rotation. There is no type of productivity fall down. Instead we're getting increased production.

But our inputs are much more intensive and at a much higher level, so how do we account for that? Again, we're relying on the site index concept. What that requires is that we have some measurement on the stand. In some sense, you have to know how it's growing to predict how it's going to grow. The whole site index concept is a little bit circular, but height age methodology is a wonderful integrator of a whole host of environmental, site, and biological factors that we just simply cannot successfully integrate any other way.

But through experience and with data, we've got a pretty good idea of what the future site index will be on any given site, any given set of site conditions, if we apply these particular inputs. So you have an initial estimate of site index; then, of course, you have subsequent entries into the stand to obtain data to update and improve your estimates as you go through the rotation. That's one of the beauties of managed stands – while you're in there constantly doing something to them and thus modifying their trajectory, you're also obtaining data by which you can correct and adjust and improve your predictions of future performance.

Paul Le Blanc

A question on your spacing trial. The 4 foot, 6 foot, 8, and 12,…was there a height difference among the different spacings?

Dr. Burkhart

There is. At the higher densities you get a height suppression, not only of average height but of dominant height. Now if you're in the moderate range of densities, where we commonly manage plantations, you can assume height-density independence. But at high densities you can't…it's just simply not true.

Jan Volney
This is very encouraging. With your management you seem to have obviated the need for pest control. Is this indeed what you have or are pests a problem at all in this system?

Dr. Burkhart
Pests are definitely a problem, and the hardest thing about this talk was probably not what to include but what not to include. So, that's the piece that I left out. Several pests are problems. In terms of pathogens, fusiform rust is common, and there are certain parts of the pine-growing belt in which fusiform rust is a major problem. Of course, a large part of the genetic program is aimed at selecting for fusiform resistance, so we have less fusiform problems and we'll have even less with clones than what we've had in the past. Fusiform tends to enter the growth and yield prediction system largely through modifications in the mortality function. Of course, with thinning, we'll take out any fusiform infested stems, so the diseased or damaged stems are the first to come out and then we select the smaller ones from there.

Then in terms of insects, we have the southern pine beetle, and other bark beetles. I know you've got the mountain pine beetle and the folks on to the west have the western pine beetle, and certainly bark beetles are our major problem. We can control bark beetles by controlling stand density and stand health. If you've got low density, vigorous growing stands, you're probably not going to have a lot of bark beetle problems and we're talking about very short rotations. But if you have high-density stressed stands, you're going to have southern pine beetle problems.

In those spacing trials, I didn't tell you about the various ways that they have been compromised and their integrity has been interrupted over time. In those very close spacings, we've had southern pine beetles come in and we'll have to quickly cut the very close spacing plot out of that particular replicate in order to save it. So, if you've got dense stands, beetles will certainly come in, in particular in years of drought, of water stress.

And in terms of silviculture and southern pine beetles, or silviculture and any kind of pest, it's typically a mixed bag. If you thin, initially right after thinning – because you'll have some damage to the roots, and you'll have some trees that are barked up and this kind of thing – you will increase the probability of southern pine beetle infestation. But then the probability of outbreak will be decreased in subsequent years. So it's a real mixed bag and I just chose, because of time limitations, not to include those specific issues, but I appreciate you're bringing it up.

Ted Szabo
I would like to know, Dr. Burkhart, if you could give us an idea of what will happen to the delivered wood costs, when you're going to plantation more and more.

Dr. Burkhart
Delivered wood costs? Well, we hope that it will be less of course, that's the idea, is that by practicing very intensive management on small areas, relatively small areas, that in fact we will have high enough production to drive down delivered wood costs. You probably have seen, there was an article in the *Journal of Forestry*, maybe two or three years ago, about delivered wood costs around the world. And, if you read that article, and I don't remember the specific numbers, but we don't have an especially high, nor an especially low delivered wood cost for southern pine, but we're hoping to drive that down. I can't tell you what it will be or how much, or if indeed that's even going to be achieved because the exact numbers with regard to the cost of some of these silvicultural treatments, harvesting costs, etc., are not really readily available and we haven't even tried to look at that particular question *per se*.

Keynote Speaker

INCORPORATING GENETIC GAIN INTO STAND LEVEL MODELLING: A GENETICS PERSPECTIVE

Alvin Yanchuk
British Columbia Ministry of Forests

Alvin Yanchuk is currently Manager and Senior Scientist, Forest Genetics Section, Research Branch. He has been with Research Branch since 1988, in various capacities from Technical Advisor, Quantitative Geneticist to Group Research Leader. Before that, he spent four years with Narinder Dhir as the lodgepole pine breeder in the Alberta Forest Service. Current research interests are in the areas of pest and disease resistance breeding and deployment, advanced generation breeding strategies, and in forest gene conservation research. In 2000, he spent a year with the FAO in Rome as consultant on forest genetic resource conservation and management.

Overview

In this presentation I will attempt to give a broad overview of some of the challenges of growing trees in Canada, specifically addressing three different issues. The first has to do with deployment policy guidelines of selected material. Second, I will discuss predicting genetic gains and modelling genetic improvement in growth yield. Third, it is also important to understand the basis of what we do in tree breeding, and some of the limitations and approaches we use to predict the value of the selections.

In developing any forest gene resource management policy, we felt that it was important to be able to tell foresters, the public, forest managers, and others that our plantations are at no greater genetic risk than our wild forests. So, the first question is - if you have a plantation, is it at any greater risk to an exotic pest than the wild forests are? The second question is that although we know we do have current risks and pests, for instance, spruce weevil, mountain pine beetle, and so on, with the material that we are developing, can we understand the mechanisms of resistance? And can we use them in a wise fashion so that we do not get caught in this evolutionary game with pests and potentially lose the resistance? In this regard, there is a lot of good research and our understanding is increasing quite a bit from crop literature.

Third, and more importantly, we want to understand growth potential in stand conditions, so we can understand, when selecting improved genotypes, why they may grow differently. This involves identifying a group of genotypes with desirable characteristics, putting them together and out in plantations, and examining how this ensemble behaves in terms of growth and yield. We also need to examine how stable these populations are over space and time, and how widely they can be planted. We typically constrain that with so-called seed planting zones. I will discuss some of the tree breeding jargon and terminology, and the concept of breeding values, and link those into a concept that we use in B.C. called genetic worth (GW), and how we have developed a system to use this in stand level projections for foresters. Finally, I will try to touch on a few important future research issues; and as Dr. Burkhart mentioned in his presentation, the issues are going to get much, much more complicated.

A Brief History of Tree Breeding and Deployment

One of the places where we have seen early and great successes, of course, is in the southern United States, where they moved relatively quickly to the use of half- or full-sib forestry families, once superior and reliable parents were identified in the breeding programs there. They discovered early on that there were considerable advantages in using family groupings of seed in nurseries, as the germination is more uniform. Full-sib family forestry is occurring where controlled crosses are made among the better parents and from these, rooted cuttings are typically developed. These practices certainly have made their way through the nursery systems and even into a good understanding of some of the silvicultural characteristics of improved families – how they grow in terms of branching characteristics, stability across different kinds of sites, etc.

In all programs around the world, there are always faster growing families not being used in seed production systems, as their offspring typically have poor characteristics for other traits (e.g., form, wood properties). Yet, in terms of growth and yield advantages, planting out half-sib or full-sib family blocks, and supposedly increasing the uniformity of the wood furnish, is not well supported by any data that I am aware of. Moreover, there is no value added yet which has made its way to anyone's bank account from greater uniformity in harvested stands, even in eucalyptus. Probably one of the most advanced programs in the world, the Aracruz operation, plants about 45 million rooted cuttings of eucalyptus from a dozen or so clones, and four or five of those clones make up about three-quarters of that 45 million. They plant them in large clonal blocks and harvest them likewise. But still, after harvest, they all get mixed into one big furnish at the mill. So to this day I have seen no evidence that increasing uniformity in our plantations will be reflected in increased value through the supply chain. I hope some day I will be proved wrong, but the point I would like to make is that we must be careful about how we are justifying deployment strategies for genetically improved material.

British Columbia's Reforestation Landscapes – what is a stand?

Reforestation landscapes in B.C. have changed over the years. When I started with the B.C. Forest Service in the mid 1980s, you could still find valley-to-valley clearcuts, but now we see much more complex stand structures in the cutting patterns. Nevertheless, the concept of what is a "stand" is still a bit of a baffling question, particularly with respect to what we are actually trying to predict – across these variable continuums of populations and site qualities. So the concept of a "stand," even from the perspective of planting and estimating growth and yield has changed, and probably will continue to change. Of course, our ability to really manipulate the land base is going to be completely determined by nature. In some areas, such as around Burns Lake, B.C., the mountain pine beetle will quickly return us to the previous large openings. If it is difficult to relate "stands" to today's or tomorrow's practices, how then can we "roll them up" in our models and forest level forecasting?

Deployment for Unknown Risks

Returning to the first point I wanted to make about deployment for unknown risks, the initial work done back in the early 1980s, still represents one of the most important pieces of thinking in forest genetics. The first and perhaps most important paper along these lines was by Dr. Bill Libby, entitled "What is a safe number of clones?" In that paper, Bill pointed out a few very interesting robust results that have somewhat guided many tree-breeding programs and forest genetics programs around the world. This work was followed up by several people: Jim Roberds, Gene Namkoong, John Bishir, Tore Skroppa and others; these models were basically single-gene gene models or single-gene genotype models and they examined the fundamental question of, "In a natural or wild stand, what is the frequency of susceptible genes or genotypes that you would sample that would put your production populations (plantations) at risk? These are mathematics-based analyses with assumptions that plantation failure occurs when, say, 50% of the trees die. They were not stand or other forms of growth and yield models, so there were many questions about the robustness of the results related to more conventionally accepted benchmarks of what is an economic loss.

Amazingly, their results have held up well over the years and the same general conclusions are usually reported, in that no more than 30 clones or genotypes provide any advantage. This result is basically rooted in the central distribution theorem that after sampling 30 individuals, you have done a very good job of sampling the normal distribution, and thus you represent wild populations very well. However, in some situations, one clone is best – for example, if you have a low-frequency gene or low-frequency genotype that is susceptible, or will die, by sampling one you have a better chance of avoiding it in your sample. But by sampling many more, you simply increase your probability of incorporating it into your population; however, the risks of this approach are pretty obvious and require no further elaboration. All these results are incredibly sensitive to gene frequencies of resistant genes or susceptible genes in natural populations, and worse yet, we generally do not know what they are, and we are forced to plan around an unknown entity.

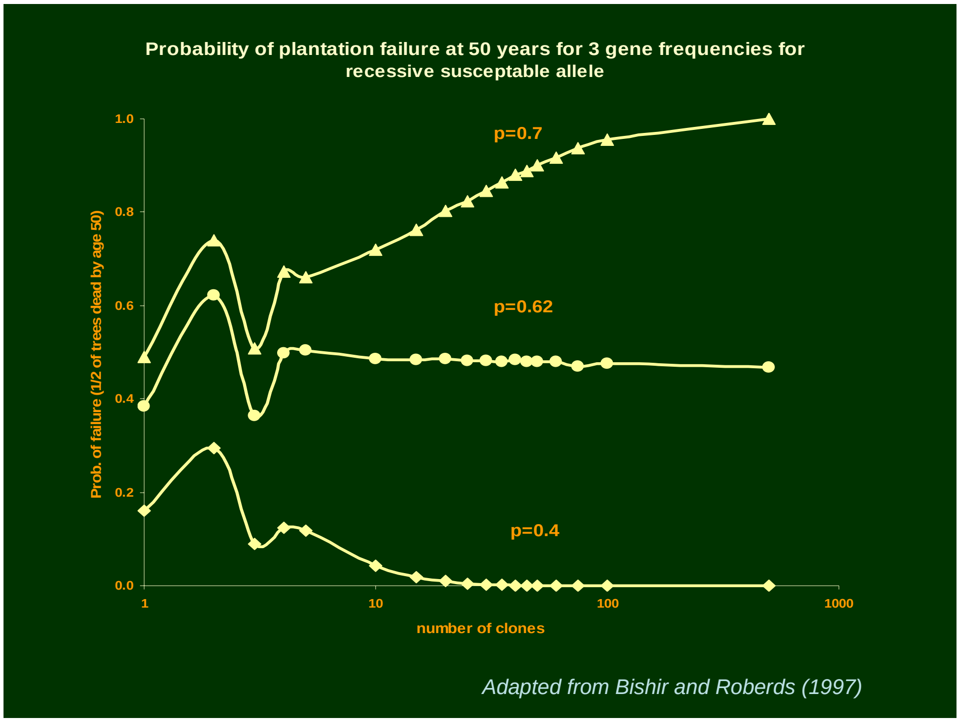


Figure 1.

For example, in Figure 1 (on the *x*-axis) we have an increasing number of clones or genotypes against probability of stand failure at 50 years (i.e., 50% of the trees die), for three gene frequencies (for a recessive susceptible two allele locus example). So, for example, if there is a recessive susceptible gene ('a') in lodgepole pine in B.C. that's susceptible to mountain pine beetle (MPB), and the gene frequency of 'a' is at 40% of the population, and if you remember from the Hardy-Weinberg theory, you square the 0.4, you would expect that 16% of your trees will die. But we can see that the trajectory of the results is very sensitive to the initial gene frequency. Even more important is that the number of clones does not matter much, in that the net result would tend to be the same (or stabilizes) once you get over 10, and there is no great decrease in risk if you sampled 10 or 100 in most cases.

These basic results emerged from these mathematical models, and they set the stage for much of our genetic diversity and minimum genetic diversity standards. But we were not particularly confident that we could rely on these in the long term, so we tried to take advantage of the B.C.

Tree and Stand Simulator (TASS) model developed by Ken Mitchell and others in B.C. TASS is an individual tree, competitive-driven model that is suited for this type of analysis. We can change coefficients in the model, assign different values to different trees, and play different games with different kinds of genetic attributes we want the trees to have. TASS has a very solid basis in our system, as it is the basis for our Managed Stand Yield Tables in B.C.

We also have an interesting problem of spruce terminal weevil in B.C., but we are lucky in that our research has been able to find trees that show strong resistance; it is in fact one of the most successful resistance breeding programs for pests in the world – and our seed orchards are now starting to produce resistant material. A lot of research has also been done on the basic life stages of the terminal weevil, and we thought it would be a useful system to try to incorporate into TASS, for example, to build an insect population dynamics with the spruce terminal weevil.

In TASS, we assign planting positions and genotypic and phenotypic values while assigning these clones with different attributes (e.g., growth rates, resistances, etc.). Using TASS as the tree-growing engine, we can then evaluate the impact of insect attack on leader and subsequent impact on volume production. Although the exact mechanisms of resistance are still not clear, we do know and expect there is a hierarchy of resistance features, which may include volatiles important in attracting insects to trees, resin flow, toxicity of the resin to the insects, and finally tree vigour itself. We also know some of the features can be around resin canal structure where the weevil punctures and penetrates a resin duct, causing flooding or resinosis that "pitches" the weevil out. Although other mechanisms may be present, we started off this research by programming these factors into the model, as well as changing tree vigour coefficients to represent genetic material that might grow faster or slower.

We also coded in a positive correlation between growth rate and resin flow, which we observed in our spruce genetic experiments. With the model, we can also change temperature, which affects the activity of the weevils themselves. We ran some alternative plantation sizes in the model, mostly one hectare, but a few at five hectares (which took two days to run). Weevil distribution was another consideration; we were curious to see what happened if we allocated weevils evenly over our plantation versus a more realistic situation where they might come in a pulse and establish in one corner. Site index, of course, would also be related to temperature and was changed accordingly. We chose 2, 6, 18, and 30 randomly selected clones or genotypes for our simulations. As mentioned earlier, more than 30 is generally not necessary and we thought that 2 was probably the bottom limit to anchor ourselves. The next question is whether to plant in random mixes, in single-clone blocks, or in a mosaic of clone blocks. Although we used the spruce terminal weevil model, the same approach could apply to any pest on any species for which the model is developed, through appropriate adjustments to the parameters used in the model.

While we may visualize patterns for random mixes of two clones as being “alternating,” in reality you tend to get clumping effects – these little clumping effects will actually be important later on as we will see.

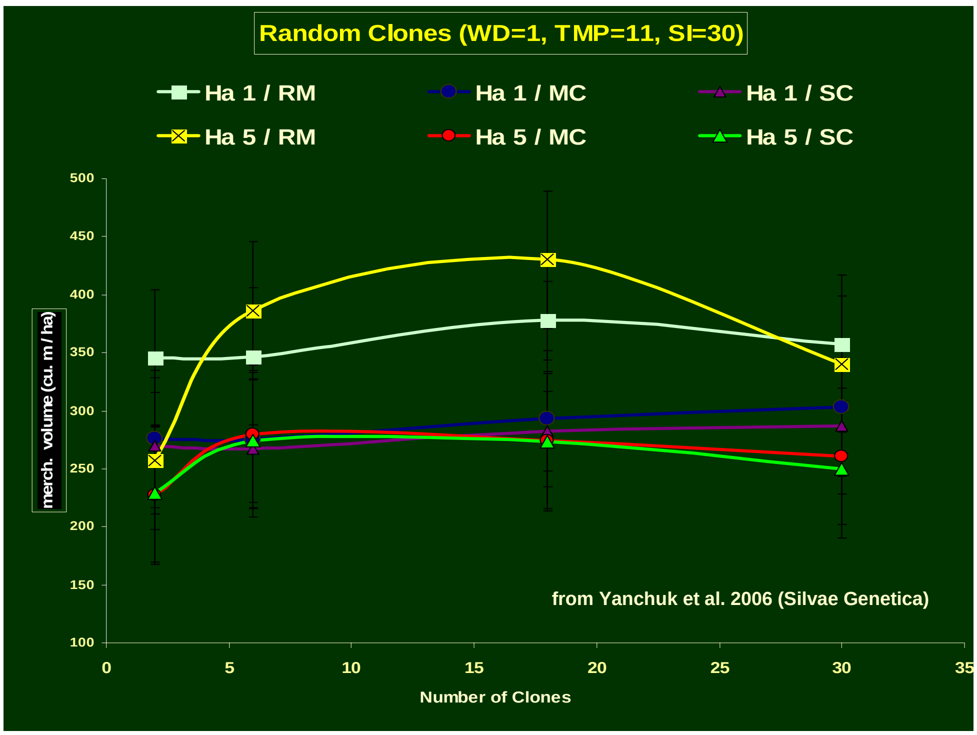


Figure 2.

Figure 2 is a graph I have taken from our work (Yanchuk *et al*. 2006). The *x*-axis is the number of clones, the *y*-axis shows cubic metres per hectare of merchantable volume at age 80 for Sitka spruce. Looking at the 1-hectare results, we did not observe much difference by increasing the number of clones from 2 to 6, 18, or 30, but somewhere around 18 for the random mix planting patterns seems better; however, the big difference is that of random mixes versus the clonal block scenarios. This suggests that as you plant these trees out in mixes, the better clones/genotypes will do a better job of genotypes building their proportions up over time in stands. Whereas, in non-mixed clonal blocks, you get more intra-genotypic competition, causing some sort of stagnation effect.

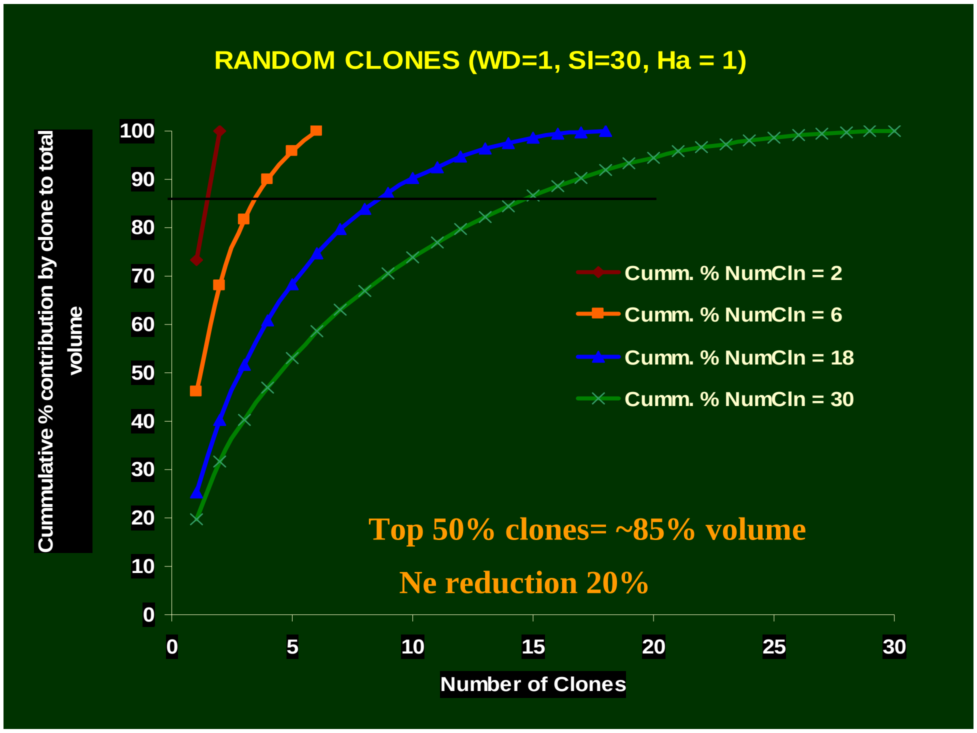


Figure 3.

So, by randomly mixing your genotypes, you may allow the better genotypes or phenotypes to sort themselves out in microsites and overall their net representation goes up. The interesting thing is that in the 5-hectare run, which probably builds up the clumping effect even more, the results are a bit more exaggerated. Figure 3, which is based on the average of 30 independent computer runs, shows the relative proportions that different clones will contribute; for example, you can see that on average if you picked two clones at random, the best clone produces about 70% of the volume. In the six-clone run, the best clone would produce just under 50% of the volume, and for 18 clones, the best one produced at about 25%. The bottom line is that about 50% of the genotypes produce about 85% of the volume.

Geneticists also like to measure the loss of genetic diversity, so what we call an effective population size was calculated, looking at the effective loss of genotypes in these different scenarios. They are reduced by about 20% in all cases. So, in the case of 18 genotypes the effective remaining representation was about 14. This may have some implications if your forest management strategy assumes some of these plantations will naturally reproduce; otherwise, the loss of genetic diversity in production populations is somewhat academic and the important results are what we have shown.

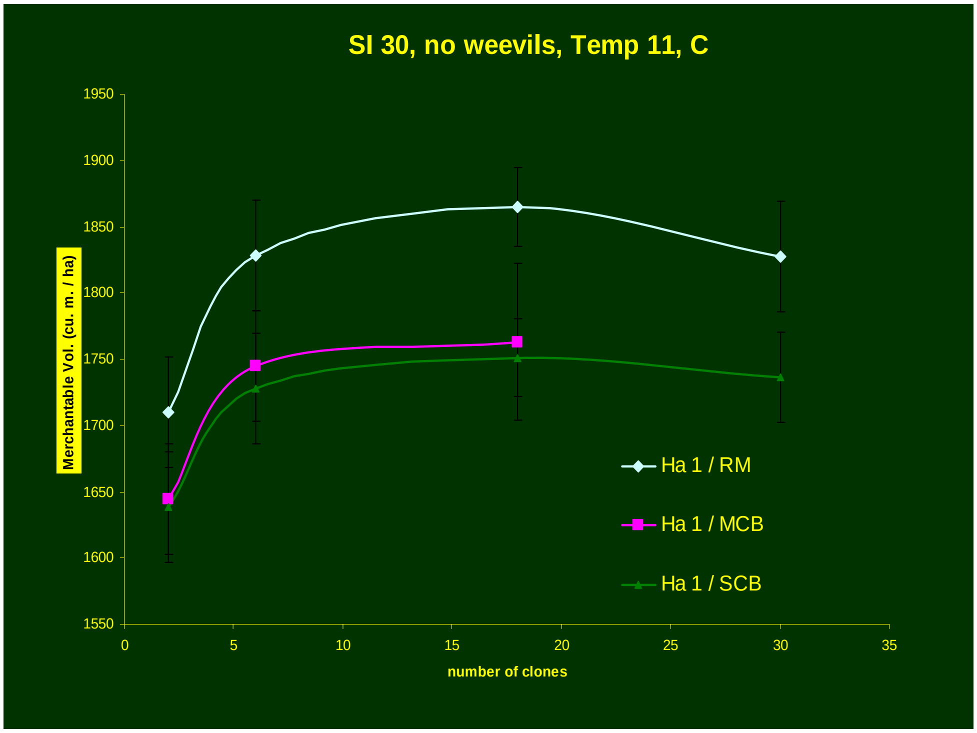


Figure 4.

Interestingly, if we shut the population dynamics model off completely, the results are similar (Figure 4). Basically, even without a pest agent causing differential damage, normal stand competition lets individuals sort themselves out, and somewhere around 18 is probably an optimum. One should have been able to guess at this finding without a complex computer model; namely, if you only sample and plant two genotypes, you do not get a good representation of the population – even though the "good" genotype will be representing itself in more than half the stand over time. If you sample 30, you can get some very good genotypes for some traits, but their net presence may be low (e.g., 3%), and an optimum seems to be around 18.

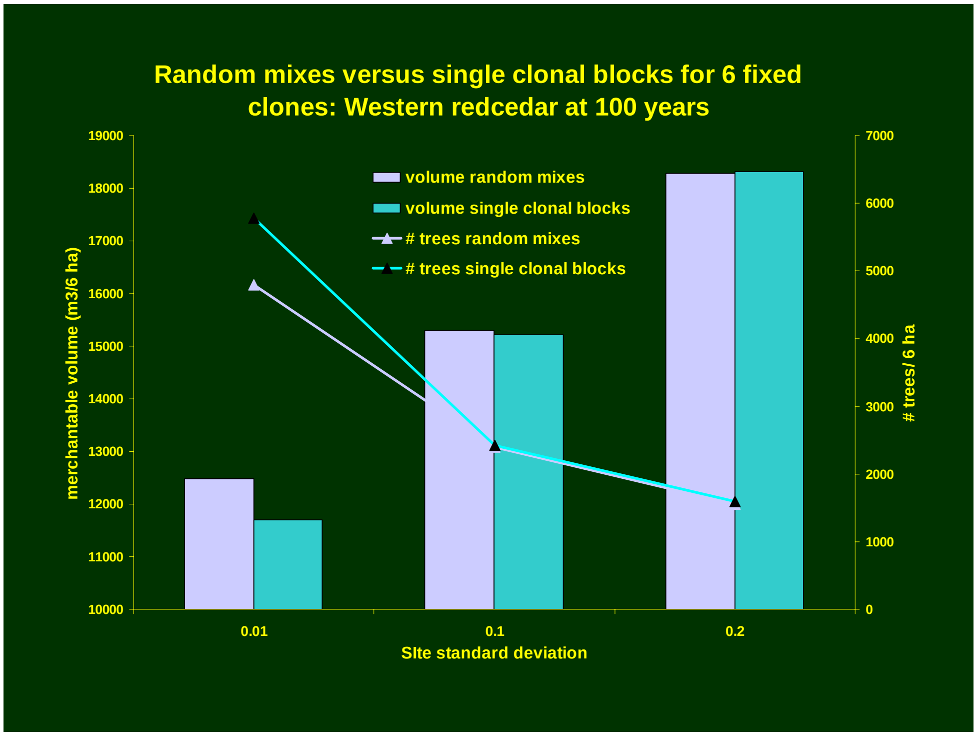


Figure 5.

Another important component is site variability. Figure 5 shows results from further simulations with western redcedar in TASS, where we took six very good clones, with relatively small differences in their growth coefficients, and grew them to 100 years, again looking at mixes and single-clone blocks. In Figure 5, you see that in the more uniform sites, the net volume differences are large because you again tend to get more inter-genotypic competition. However, more important is that random mixes are never worse than clonal blocks. As you increase the variation, even in the clonal blocks, the environmental factors tend to govern the selection of the better individuals because the heritability or the genetic control of height growth in forest trees is only about 20%.

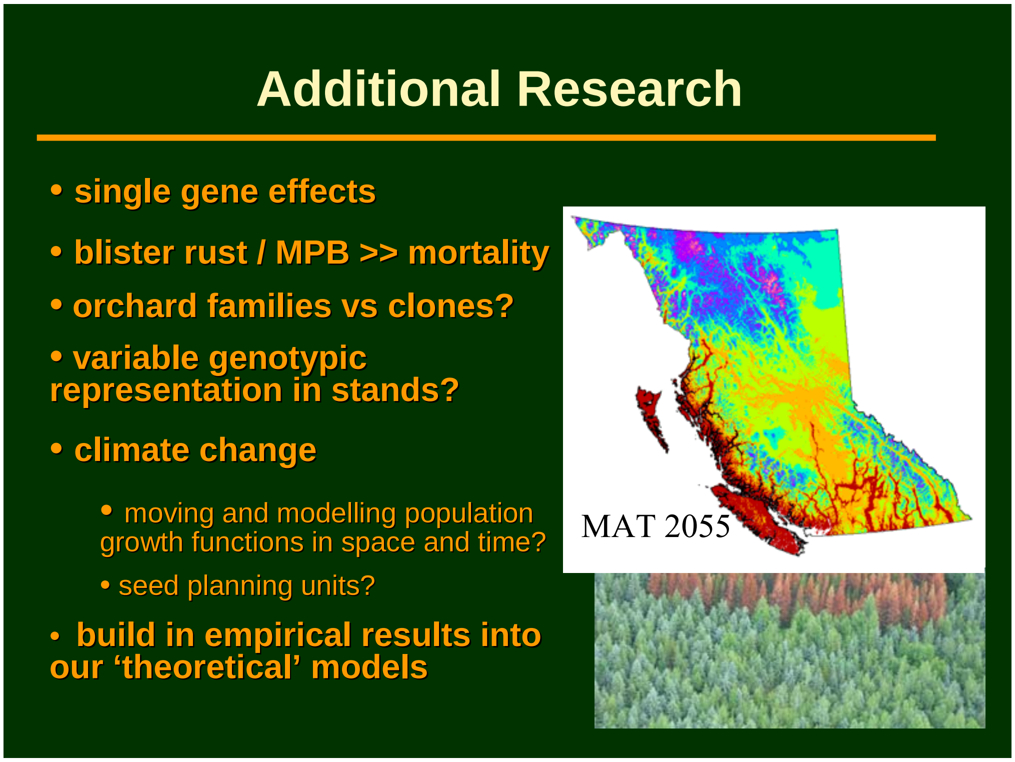
So the environment has a huge effect and, as there is more variation, there will be more sorting out of 'better' individual trees in a stand. You may ask what the site standard deviation is for any particular site, but that is difficult to know or even guess. Moreover, Sitka spruce would interpret sites differently than western hemlock, etc. Individual tree species respond differently to site variability, and this may not coincide with our own views or experience. Therefore, we need to plan around a safe and conservative deployment system, which random mixes seem to give.

Conclusions from Modeling

For our pest behaviour and polygenic resistance model, incorporating three resistance traits with normal distributions for unknown risks, acceptable numbers of clones were around 5 to 25. For both known risks and unknown risks of pest behaviour, deployment of a random mix is always better, although we still need to consider the evolution of treatment resistance in pests and diseases. Growth and yield predictions can be highly variable and driven by site variations. We saw that the best genotypes do most of the work, although we do expect a net representation loss of about 20% of those genotypes.

Policy Implications for British Columbia

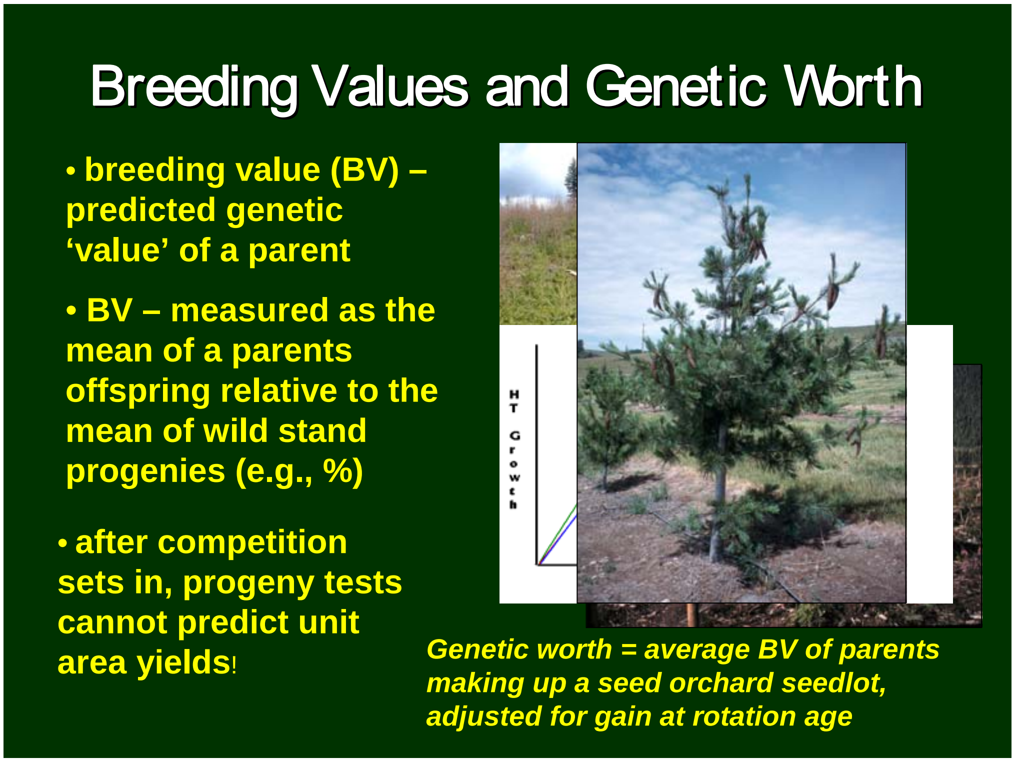
British Columbia has vast and variable landscapes and extensive management with long rotation ages for most species. As such, our deployment policies must be very conservative. We recommended a minimum deployment standard of an effective population size of 10 under the Forest Practices Code, which is not too different from the recommendation for Alberta. Random mixes appear to be the best and responsible deployment strategy for us at this time, considering the difficulties of characterizing or monitoring individual stands. But our first objective, from a forest genetics perspective, is to basically "bullet-proof" our plantations from future and current risks; so while we can model the effects of genetics on growth and yield, we can also use growth models for forest gene resource management issues. Finally, if we do so-called "bullet-proof" our stands as discussed (i.e., not at any greater risk than naturally regenerated stands), then we likely accommodate forest and landscape genetic issues as well, as long as we operate within well defined seed zones.



Additional Research

With a dynamic growth and yield model, such as TASS, and inputs into the model that can reasonably emulate pest, disease, or growth differences among genetic entries, we can examine many scenarios that are otherwise not possible to study. For instance, in the future we hope to incorporate true 'single gene' effects, diseases (e.g., blister rust where trees are killed), clones versus seed orchards' seed, and different mixtures of better or worse clones.

One of the big unknowns is how these genotypes and stands will perform over time with climate change. We have been working on this for the last five years, and now with Andreas Hamman at the University of Alberta, you are likely going to surpass us in answering some of these questions. Questions such as: With changing expectations and climate, how can we model population growth changes in space and time? Will seed planning zones still have value in light of these changes? What will be the rate of change of average temperatures, and how will this affect growth rates and site index? And last, but not least, we need empirical data to validate our theoretical models, because what we have talked about so far is basically inputting a lot of theory and assumptions into our current stand models.



Breeding Values and Genetic Worth

I will switch now to the concept of breeding values (BV) and genetic worth (GW). "Breeding value" is a term that has been in tree breeding and plant and animal breeding for many years, and basically it is the predicted genetic "value" of a parent. Every organism has a breeding value for some trait of interest. The main approach that plant and animal breeders use to figure the underlying genetic potential of the individual is through the concept of progeny testing; in other words we use an individual's progeny to evaluate how much better its genotypic value is than the rest of the population. We select dozens or hundreds of parents and plant out their offspring in carefully designed replicated experiments. We have used various designs over the years, such as block plots, row plots, single-tree plots, and now we are using incomplete block designs to increase the precision of ranking and scoring parent tree BVs. We express BV in B.C. as a percentage difference over a so-called wild stand local (control) in the appropriate seed planning zone.

Progeny testing properly takes a lot of work, money, and experience. We take great care in keeping animals out and weed control is important, both of which reduce extra environmental noise. There is an important point to make here – many people say, "Progeny tests are not very representative of real-world plantations." True enough, but the point is that we have to look for genetic differences and in a design where the best families can be identified and their relative differences can be measured with some precision. So, when we say that this improved material will grow 10% better, it will always grow 10% better. But if your plantation is performing very poorly because of animal damage, weeds, and neglect, and your expected growth is reduced from 10 cm to 1 cm on average, you may not be able to observe that 10% increment for the better, even if it is still there.

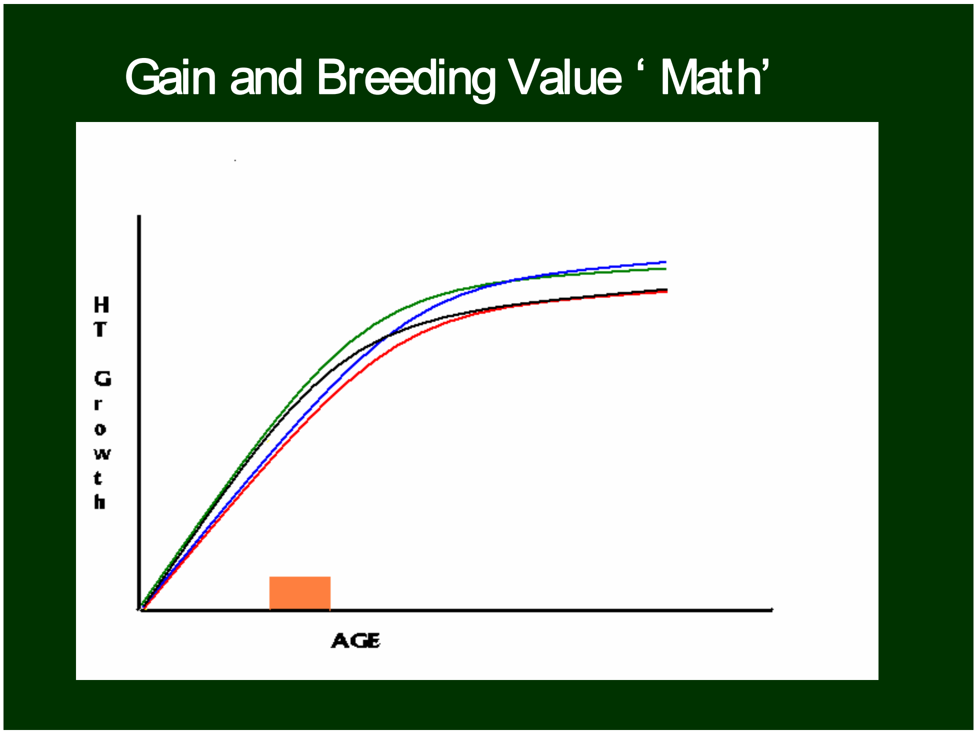


Figure 6.

Realized Gain Trials

Another important point is that after competition sets into these progeny tests, you cannot expect to predict unit area yields from them, which leads us to the need for realized genetic gains trials. Figure 6 presents a hypothetical examination of the best and worst genotypes in a population. The green line represents the best genotypes/cases in the population and the red line represents the poorest genotypes/cases of growth potential over time. When competition sets in, as shown at the orange bar at some age, you tend to get a bigger inflection and an upward bias in genetic variance (which would not be there in normal block planting of that one genotype/family). It is basically driven by the fact that your better genotypes are suppressing the lower ones. This is one of the fundamental reasons we have had to go to these large block plots for gain comparisons, in order to avoid inter-genotypic competition. However, an important point to note is that our top genotypes and individuals, even in row or single-tree plots, could still be considered 'site' or 'top height' trees. I will return to this point later.

Estimating Effects of Genetics on Stand-level Yields in British Columbia

In B.C., we have applied the concept of BV by assigning one to each tree for each trait of interest, and these are typically expressed as some minus to plus values (e.g., -40 to +40) with zero representing the average – usually the wild stand population mean. BVs are also adjusted for the expected gain at rotation age, largely because users of the seed were not really interested in juvenile height growth performance. Historically, the so-called "rotation" was fixed at culmination of mean annual increment, and we use rotation ages of 60 for all species except for spruce, which is 80.

So when we select a group of good genotypes with good BV's, for a seed orchard let us say, we can roll these up into a new term called genetic worth (GW). That has helped keep the terminology clean, from an individual's worth to the seedlot's worth.

In New Zealand, they have called these mixes GF rating (Growth and Form), and many other jurisdictions have developed similar systems and terminology. Only recently have we come up with BVs and therefore GWs for blister rust resistance or spruce weevil resistance.

In the early 1990s we were asked to come up with a way to factor genetics and tree breeding into our growth and yield prediction system. At the time, we had several orchards producing seed but the concept of BVs wasn't well developed in our seed orchard management, nor was it integrated into the seed lot tracking and value system. All we did back then was categorize the orchards as to very general levels of gain: 5, 10, 15, etc., and publish those, and people used those gains to directly increase the site index.

Orchardists started to embrace the concept of BV for trees in their orchards as it put more meaning in managing the genotypes – different individuals have different values and they could try to optimize gain and the value of their seed by managing flowering, seed collections, etc. With that, though, we ended up with orchards having a GW based on the BV averages as well as how they manage the orchards. So now GWs are, for instance, 16, 12, 15, 18, etc., rather than in a category. As was said earlier, GW is a volume estimate at two fixed rotation ages, and if we deviate from those then we have to go back and modify the site index in our calculations. The general rule of thumb used was to take GW and divide it by 2 to get back to height gain at the rotation age, and then more calculations are required. To adjust for this, Ken Mitchell, Chang-Yi Xie, and I developed this further and incorporated GW directly into TIPSY, which is a Table Interpolation Program for Stand Yields (which is based on TASS runs) to accommodate these laborious calculations. TIPSY is a user-friendly version of the run outputs from TASS, and with this adjustment we can now adjust genetic worth from age of rotation to any anticipated harvest age. In TIPSY's simplest form, the user punches in the basics, like GW of the seedlot they have, clicks on the genetic worth button, and improved yield tables, with what we expect would occur, are output.

Gain and Breeding Value

A little more on gain and GW is appropriate here, and it ties back to what was mentioned earlier with respect to number of clones or genotype.

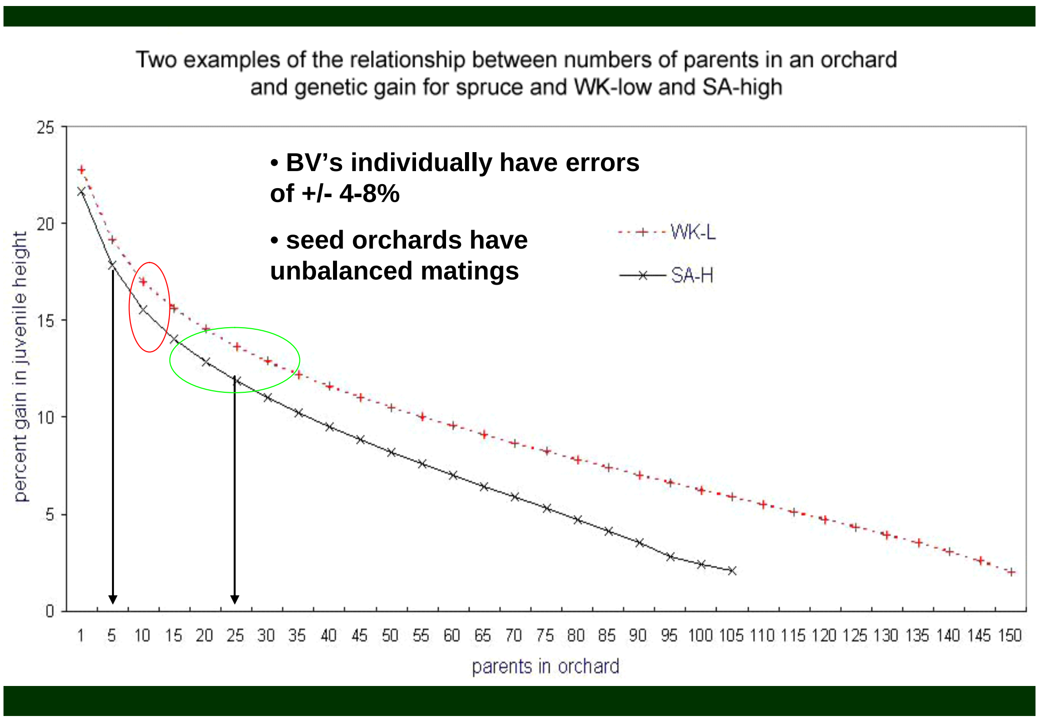


Figure 7.

As we said earlier, GW is an estimate of expected genetic gain of a selected group of parents that we have tested in our progeny tests – perhaps, 10 out of 100, or 40 out of 400. In Figure 7, we see examples of increases in genetic gain on the *y*-axis as we reduce the number of clones for two orchards, West Kootenay Low, and Shuswap/Adams High. We also see a deflection somewhere around 10 or so, and from our previous analyses, for the sake of genetic diversity, between 5 and 25 genotypes is relatively safe. A seed orchard of about 25 parents (green circle), vs. about 10 parents would have an impact on gain (12–14% vs. 15–17%), but the choice may be decided by other factors such as the mating dynamics of the species in an orchard environment, pollen availability, and even government policy. We also showed earlier that there is a fall down in genetic diversity over the life of the stand, somewhere around 20%, which should be factored in as well.

As mentioned earlier, what we are really interested in is gain at rotation and none of the experiments in which we are selecting actually occur at rotation. We are always selecting at juvenile ages and hoping to forecast mature traits later on at a harvest age. This is really a unique problem for tree breeders, and is generally not encountered in other breeding programs with crops and animals. Again in Figure 6, we have our good-growing green genotype and at any point in any kind of test it would be selected. But we may also select one like that represented by the black line which, by its very nature, may want to grow slower later on in its life – and these tendencies for plants and animals to do better in early or late life stages have been shown experimentally from fruit flies and mice to many of the domesticated crops. Continuing the example, at an early age, before competition, we would select the green and black genotypes but miss out the blue. Somehow, we have to factor this uncertainty in when we estimate genetic gains from juvenile selections to mature because we are going to be incorporating some error in selection. But if the green genotypes produce most of the wood in our plantation anyway (as was discussed earlier – that the top genotypes are doing a good percentage of the work), we might be in reasonable shape.

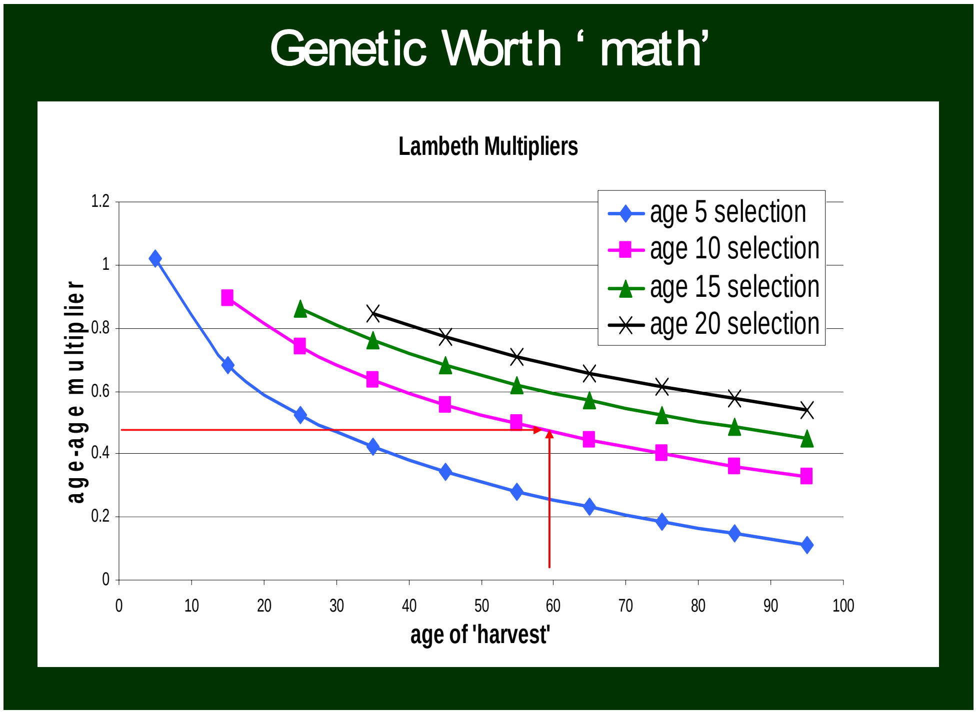


Figure 8.

Genetic Worth and TIPSY Modelling

Clem Lambeth published a paper in 1980 in *Forest Science* where he looked at this problem of age–age correlations, with the best data sets available at that time. Most were not from genetic trials so they were not genetic correlations *per se*, but served well enough to give us a general indication of the relationship across several species and many experiments; he developed an equation that is generic, and a general description of what we think is a fair and conservative model to use in penalizing or adjusting for age–age correlations, being less than one.

Using this approach, you use the ratio of your selection's age over your index age but if you decide to change your index or yield age, you enter the new age in the model and then use a new ratio (Figure 8). These "Lambeth multipliers" or penalizing factors are used when selecting trees earlier than we would tend to harvest them, but if you select later – or harvest earlier – the penalties are reduced, as you might expect. We have published our work on incorporating Genetic Worth into TIPSY forecasts, and it has been a useful publication to describe the approach we currently use (Xie and Yanchuk 2003).

Other Values in Genetics Programs

Although we have been able to provide foresters and users of genetically improved material with some guidance and some projection capabilities of improvement expectations, in many provinces there are limited incentives to incorporate genetics into forestry. Land tenure issues, lack of long-term licenses, true allowable cut effects, etc., make it a difficult investment for industry. However, there is one incentive that has worked reasonably well for us in B.C., and that is of "green-up" or adjacency restrictions on adjacent blocks, that is, licensees get access to timber when adjacent reforestation blocks reach a "free to grow" level of top height of 2 to 3 metres. Tree breeding programs can also accelerate the return on investment by shortening rotation ages, often argued on that basis, as well as reducing weeding costs, which can be substantial. So, while we want to be involved in modelling and predicting the effect of genetic improvement on growth and yield at stand- or forest-level planning, the largest selling feature for us at this point in time is that licensees get their cut block openings "off their books" sooner.

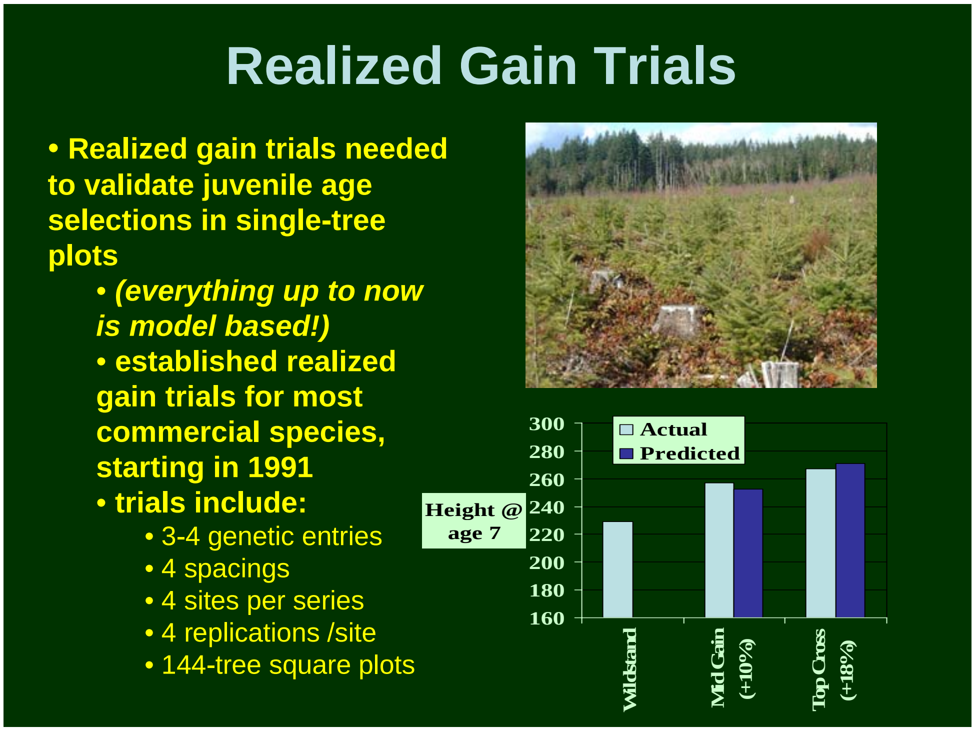


Figure 9.

Realized Gain Trials (RGT)

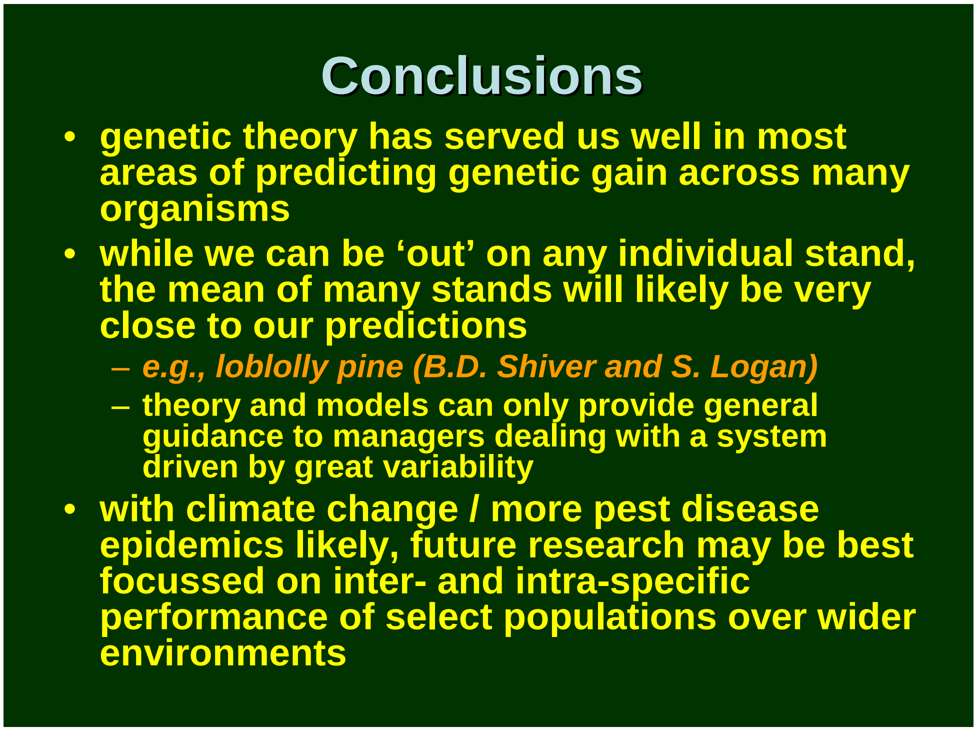
As discussed earlier, we have established large plot trials (Figure 9) for validating our juvenile age selections from single-tree plots to unit area trials, but these were designed with the help of TASS to look at critical questions of plot sizes, etc. In hindsight now, although fortunately we had the ability to put in about 40 of these RGT installations, all with the same design – three or four different genetic entries (e.g., elite, woods-run, and seed orchard comparisons), four spacings, four sites per series, four replications per site, and 144-tree square plots – these experiments probably cost a million dollars to establish. I do not think we could do it again today given the shortage of staff that are competent in doing this, not to mention the money. They will, of course, provide very useful data to be sure; however, it is too soon to talk about results, as in most cases competition has not yet set in. Our oldest installation is in western hemlock, which is age 15 now, and some interesting things are just starting to happen in these trials. Early results from Douglas-fir at age seven show that our predicted height gain from the single-tree plots is tracking very close to what is happening in the large plot blocks (Figure 9), which is what we expect.

The big value that these trials will provide will not be whether there will be three or four 'dots on a graph' that suggest gains are what we predicted, but rather in examining the underlying distribution and performance of individuals over time (and in tracking which genotypes are causing this shift). The mortality functions will be critical, to see if our modelling has been correct and if we may need to recalibrate TASS and TIPSY. Once again, these trials are very, very expensive to put in, and consideration may have to be given to whether there is a better, less expensive way to accomplish the same goals.

Incorporating Genetic Gain into Timber Supply

While we can talk at length about modelling genetic gain, at some point it also has to be rolled up to the forest level, or in B.C., to our Timber Supply Areas or Tree Farm Licenses. A few years ago, we conducted two such analyses for the Arrow Timber Supply Area and the Golden Timber Supply Area. Even with careful modelling, and building genetic worth into the system, there is a big homogenization that occurs across the land base when rolling these into the timber supply analysis. In the Arrow TSA there is almost no effect for the next 50 to 60 years, and a small effect in the Golden analysis in the next 30 years.

The comparison of these two TSAs shows that the operating area being worked in is very important (e.g., affected by the age class distributions), but the overriding factor is how many trees do you plant that show reasonable levels of improvement; so a word of caution – there is no need to get overly obsessed with having perfect predictions. Build a reasonable growth model that realistically can factor in genetic improvement and move forward.



Conclusions

Genetic theory has served us well across most disciplines in agriculture and forestry – predicting and observing genetic response with many organisms over many decades also provides comfort that it will continue to work in tree breeding and will provide value. And while we can be out on any individual stand, what becomes pretty clear, even from some of the latest results we have seen even in the loblolly pine, is that across many stands, we will be close to our predictions. Hopefully we will see that kind of robustness manifested in our realized gain trials as well.

These theories and the models we apply can only provide general guidance to managers dealing with a system driven by great variability. I have tried to show some of the variations that can drive these stand-to-stand differences, as well as using cautious and general approaches to modelling, the kind of future investments you may want to make, and issues around deployment strategies.

With climate change we expect to be dealing with more pests and disease, and likely epidemics. I do not think any of us have any doubt about that, and I am suggesting we may want to focus on carefully designing inter- and intra-specific studies to evaluate performance of multiple species and their populations over wider environments/climates. That, in fact, may be a sounder investment than trying to prove how much better we are over nature in any particular plantation.

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QUESTIONS

Sally John

Alvin, I had a meeting with Clem a couple of years ago on exactly this topic, incorporating genetic information into growth and yield modelling, and we discussed the use of the Lambeth coefficient at quite some length, as you may know. And Clem himself said that he thinks that these coefficients give underestimates of gain, even for a single genotype, and that's particularly true for aggregates of genotypes, like seed orchard populations. And when he developed that in 1980, which is 26 years ago, they weren't meant to be used for population-based gain prediction. He and Lou Anne Dill put out a paper a couple of years ago, revisiting those earlier assumptions, in which the coefficients seem to be quite a bit larger. But I also noticed you went by it fairly quickly here. You said that for predicting rotation age gains, you use genetic worth over two, which is a rough application of the Lambeth coefficient, but you're moving towards the use of feeding stuff directly into TIPSY. Does that mean you're going away from using the Lambeth coefficient in that context? Or, could you elaborate on that a little bit more? I didn't really understand it.

Alvin Yanchuk

No, we're not considering moving away from using Clem's 1980 multipliers just yet. He did publish that paper which had genetic correlations, but the problem with it is, as you know, they're based on 10, 15, and 30 as harvest age. And we're probably farther out than that. I know they're conservative, there's no question about it. But in the overall scheme what I tried to show you is when you start rolling this stuff up, the most important thing is to have a lot of good seed orchards producing, not whether the breeding value is 20 or 19 or 15; just have a lot of this stuff going out and see that it's being managed properly in space and time; for example, like those two Timber Supply Area analyses -- that's the most important thing affecting Crown land management for us. So, I agree, it's conservative. I'm not interested in changing it right now, because I don't know what I'd use. So, it's not a very great answer and I apologize, but, you know, it's my job to take a conservative and responsible approach to the problems in B.C., so I'm going to stick with it until I've had something more comfortable. And that's why we put in a million dollars worth of realized gain experiments.

Willy Fast

I'm sure you're aware, and most people that are working in lodgepole pine in Alberta are aware, there is a well-recognized trend in site index increase in managed and regenerating stands versus natural fire origin stands. I don't know if this is a fair question for you, but is it reasonable to expect an incremental increase in site index for juvenile height growth, not only from the movement from fire origin to regenerated stands, but also by incorporating tree-improved stock?

Alvin Yanchuk

I think everything that we do in tree improvement is fundamentally based within managed stand yields. All our progeny testing are in those kinds of environments and so, what we do is, I think, clearly incremental and on top of that base of what managed stand yield tables would show for so-called second-growth plantations. Actually, I don't think our results are even relevant to so-called wild stand yield tables. If what you were asking was, Are there any weird things going on? No, there wouldn't be, because we're following that regenerated stand model and the whole testing and selection system.

Barb Thomas

In the first part of your talk, you discussed the deployment with mixing up your clones. Would you recommend that same strategy with a clonal species?

Alvin Yanchuk

Well, when you say a clonal species, do you mean like aspen or like yellow-cedar?

Barb Thomas

Like Aspen.

Alvin Yanchuk

Yellow-cedar, yes; aspen, I'm not – yes, I would. I'd still mix them up, unless you had some kind of re-coppicing establishment objectives, or something like that. But for single planting harvest systems, I think I'd mix them up.

6. FOUR APPROACHES TO MODELLING

Four invited papers provided the plenary group with insights into the various types of models available or under development and their utility or potential for forecasting post-harvest stand development. The organizers deemed this discussion and the options presented important to the attendees for the following reasons:

- People responsible for forest management planning and forecasting need to understand and make wise decisions on the types of tools that will be used to do this forecasting.
- Users need to understand the advantages, disadvantages, limitations, and reliability of models, and the status of their development relative to the decisions that the models will be supporting.
- Meaningful discussion of knowledge gaps, priorities, and how to better integrate interdisciplinary knowledge into stand development forecasts requires a basic understanding of models.
- No single approach, model, or "magic bullet" is likely to meet all our G&Y forecasting needs. Informed use of a variety of forecasting tools will probably be necessary.

The main focus of this section of the program was to gain an understanding from the speakers on the capabilities and potential of the various modelling approaches to incorporate information from the disciplines of genetics, silviculture, and forest health.

In each case, the presenters were asked to outline their modelling approach and the general structure of their models. They were also asked to describe for their models their advantages, current deficiencies, progress to date in reducing forecasting error, key requirements for data and improvement, and opportunities for integrating multidisciplinary information.

Four Approaches to Modelling: Whole-Stand Models

PRACTICALITY, VERSATILITY, AND VALIDITY AS GUIDING PRINCIPLES IN STAND MODEL DEVELOPMENT

Shong-Ming Huang
Alberta Sustainable Resource Development

Whole-stand models in their simplest and most-used form – volume-age curves – are familiar to most foresters in Canada. But properly formulated whole-stand models have provided the basis for stand development forecasting throughout much of the world to date, and they exemplify much of our understanding of the principles of growth and yield.

The question is, To what extent can whole-stand approaches address current challenges in forecasting post-harvest stand development? Dr. Shongming Huang, Senior Biometrician in the Forest Management Branch of Alberta Sustainable Resource Development spoke to this question. Dr. Huang is also an Adjunct Professor in the Department of Renewable Resources at the University of Alberta. His major area of speciality is forest productivity and modelling.

Abstract

In this presentation, the role of models and model builders in sustainable forest management is discussed, with emphasis on the so-called “whole-stand” approach to modelling. Model types and foundations for building better models are summarized. Issues, priorities, and challenges relevant to present Alberta modelling situations are identified. Current development highlights of Alberta’s Growth and Yield Project System (GYPSY) are presented, where the focus is on building a model that addresses and integrates many of the identified priorities and issues in a practical, user-friendly manner, with a high level of accuracy, simplicity, and versatility. The importance of model validation is stressed, along with some thoughts on dealing with current and future challenges.

Four Approaches to Modelling: Individual-Tree Models

INDIVIDUAL TREE – NON-SPATIAL MODELS AND SOME THOUGHTS ON MODELLING EARLY DEVELOPMENT OF TREES

Phil Comeau, Ken Stadt, and Mike Bokalo
University of Alberta

In individual-tree models, the model simulates the growth of individual trees (diameter, height, etc.), rather than starting directly with stand-level (per ha) variables. The prevalence of mixed-species management in our boreal forests led to interest in this approach in Alberta, where its development has been championed by Dr. Steve Titus and his colleagues. How good a job can such models do in forecasting the development of mixed stands, and can they do a better job than whole-stand models?

Phil Comeau and Ken Stadt of the Department of Renewable Resources, University of Alberta, described and discussed some of their work and experience in this area. Dr. Comeau, Professor of Silviculture and Stand Dynamics, is also the current Chair of the Western Boreal Growth and Yield Association. Ken Stadt is a research assistant professor in Renewable Resources at the University of Alberta, working with the Mixedwood Growth Model (MGM) development team.

Abstract

In this presentation we will review some important characteristics, benefits, and limitations of individual tree distance-independent models (which include the Forest Vegetation Simulator (Prognosis), the Mixedwood Growth Model (MGM), and others), and we will present some ideas on modelling effects of establishment and early tending practices on early development of trees. Results from some recent work comparing spatial vs. non-spatial competition models will be presented. We will also discuss several issues relating to modelling of the effects of site preparation, establishment, breeding, and early tending on stand development.

Four Approaches to Modelling: Spatial Individual-Tree Models

THE DEVELOPMENT, CALIBRATION, TESTING AND APPLICATION OF A SPATIALLY EXPLICIT, INDIVIDUAL-TREE, GROWTH AND YIELD MODEL

Ian R. Cameron
Azura Formetrics, Kamloops BC

Spear-headed by the pioneering work of Ken Mitchell, a main thrust of G&Y modelling in B.C. has been to take individual-tree models one step further. Spatial individual tree models like the Tree and Stand Simulator simulate the growth of individual trees and stands in a three-dimensional space.

This is appealing to our interest in post-harvest stands because the approach has the potential for simulating stand structures and responses not represented in natural stands. But, does the additional complexity pay off in terms of better forecasts for post-harvest stands? Ian Cameron of Azura Formetrics addressed this and related issues. Ian is a stand modeller and analyst with Azura Formetrics.

Abstract

This presentation describes the experience acquired by a modelling team in the development, calibration, testing, and application of the Tree And Stand Simulator (TASS)—a spatially explicit, individual-tree, growth and yield model.

As the terminology implies, TASS simulates the growth of individual trees with respect to their spatial position in a three-dimensional grid. The simulated trees interact through the competition of crowns for growing space. TASS simulates a wide variety of silvicultural treatments, including planting, thinning, pruning, fertilization, and tree improvement. Yields can be expressed as conventional tree dimensions (i.e., height, DBH, volume) or products (assortments and grades of logs, lumber, and chips). TASS also reports descriptors of stand structure (e.g., crown closure, canopy profiles, snag generation, spatial arrangements) that have become increasingly useful in analyzing the impact of silvicultural treatments on habitat capability and biodiversity indicators.

I will start the presentation with an overview of the architecture of the current operational version (TASS II) and summarize the modifications underway in the development of

TASS III. Then I'll describe how the model has been adapted over time to address new forest management issues, illustrating how the model's architecture facilitates some adaptations but also presents challenges in calibration and testing.

Next I'll show some examples of how the TASS has been tested or validated. Testing has emphasized the performance of the model as a whole more than the fit to individual equations. Considerable importance is attached to comparisons of the simulated response to treatment with results from growth and yield experiments. The type of data used in the calibration and testing, however, has implications for the inference and interpretation of model predictions, which must be clearly understood by users.

The most common applications of TASS are the analysis of alternative silvicultural options at the stand level and the production of yield predictions as inputs to forest-level planning models. In both types of applications, the user may not have available all the information needed to initiate the model runs, thereby requiring various assumptions to be introduced into the analyses. I will give some examples of this process and discuss the potential impact of these assumptions.

In the final section, I'll address additional issues posed by the conference organizers and comment on some of the issues raised by opinion leaders in their pre-conference interviews.

RESEARCH STRATEGIES FOR PROCESS-BASED MODELS IN FORESTRY

K. David Coates
British Columbia Forest Service, Smithers, BC

Major differences have been observed between the development of post-harvest stands and their fire-origin predecessors.

Climate change and the sometimes catastrophic upsets in forest systems from agents like mountain pine beetle have exacerbated concerns as to whether conventional forecasting models adequately represent the biological processes that determine how stands will develop under changing conditions, and process models attempt to bridge this gap.

Is it naive to expect that we can quantitatively model such processes, or can we do a better job of taking them into account? For answers to these questions the organizers turned to Dave Coates, Research Silviculturist with the British Columbia Ministry of Forests.

Abstract

The discipline of silviculture has strong traditions. The sub-discipline of growth and yield has even stronger traditions. Silvicultural researchers are trained in frequentist statistics and have followed an agricultural model of research: few treatment factors, limited set of treatment levels, uniform sample plots, control of stochastic factors that might confound results, and null hypothesis testing. The use of frequentist statistical approaches in silvicultural research has had a profound influence on how silviculture is taught in universities and how practising professionals think. First, there is an ingrained belief in an identifiable best treatment and, second, that applying this best treatment uniformly at the stand-scale is good management. These two simple beliefs have driven the field of silviculture, and more broadly natural resource management, for a long time. There are many examples of this style of research in growth and yield.

Silvicultural experiments and resultant practices in the field were designed to operate at the stand scale, not at the individual tree scale. That is, when applying some new best treatment, it would be applied uniformly at the stand scale. The average stand scale response of the new practice would be expected to be better than the average response of the previous practice. Stand averages were the measure of success. This has resulted in

homogenous conditions at the stand scale. Having silvicultural research and silvicultural practice operate at the stand scale has had an equal, if not greater, impact on how forests are managed than the search for a best treatment implicit in null hypothesis testing. Adopting the agricultural model has resulted in an emphasis on reducing natural bounds of variation in stand-level responses and has prevented silviculture foresters from embracing and managing variability and complexity.

Forest management, however, is evolving rapidly with greater emphasis on more complex stand structures based on a natural disturbance or ecosystem model. Variable structure is desirable within stands after silvicultural manipulation in order to meet a host of forest management objectives. The time is coming when silviculture will be based on maintaining critical processes in forests. The spatio-temporal development of forests after disturbance will be described as changes of tree populations due to survival and growth of residual trees, birth and colonization of new trees, and their subsequent survival and growth. This will be a major shift in thinking away from the agricultural approach of searching for a best treatment. It will require use of different research approaches and require practising silviculturist to think in terms of gradients of response and trade-offs. Tradeoffs in growth and yield associated with different management strategies will be determined by the use of individual tree, spatially explicit stand dynamics simulation models.

In the ecological and wildlife sciences, a major shift in statistical analysis and how biological inferences are made is occurring. The use of model selection by information-theoretic methods, in which several competing hypotheses are simultaneously confronted with data, is gaining support as a means to estimate parameters of interest. At the heart of the method is the explicit interplay between data and models. Different models are formulated as mathematical statements of the quantitative relationships that are assumed to have generated the observed data. Now the result is a mathematical model that predicts or quantifies the relationship between a response variable (e.g., growth of an individual tree) and a process, or set of processes, driving the response. Experiments using information-theoretic methods are a relatively new phenomena in silvicultural research. They are ideally suited for providing parameter estimates based on important processes that can be used in individual tree simulators.

Lastly, forest management in the future must be much more concerned about risk, especially the risks associated with projected climate change. Growth and yield models based on prior performance may be of little value in the future. Process-based or hybrid models that can account for changing conditions will be more resilient in the face of climate change. We will need management strategies that mitigate risk rather than maximize one value under the assumption that it will all work out.

7. INVITED PRESENTATIONS - CONCURRENT

In these sessions, ten speakers were invited to provide practical examples that illustrate the integration of information from the fields of silviculture, genetics, and forest health into forecasts of stand development. They were asked to focus on quantitative forecasting projects and tools that have been successfully applied in decision-making and supported by validation or peer review.

The ten papers were delivered in concurrent sessions of five papers each. Delegates were encouraged to attend at least one presentation from each of the three disciplines – silviculture, genetics, and forest health.

1. Silviculture: Growth and Yield Protocols for Hybrid Poplar Plantations at Alberta-Pacific
Barb Thomas, Alberta-Pacific Forest Industries Inc.

Barb Thomas covered the extent and expansion of the intensively managed poplar farm program at Alberta-Pacific Forest Industries Inc. (Al-Pac) and described the protocols designed to obtain growth and yield measurements. The current formula being used to calculate individual tree volumes was presented as was the development of a new formula based on whole tree measurements. Challenges faced in protocol development and utilization of volume outputs were also touched on.

2. Forest Genetics: Incorporating Genetic Gain into Growth Models
Randy Johnson, United States Forest Service

Randy Johnson provided background on the different methods used to incorporate genetic gain into growth models, and presented preliminary results of a study using Douglas-fir progeny test data to incorporate genetics into regional growth models. The study examines the potential of using growth modifiers in individual tree growth models to account for genetic gain.

3. Forest Health: Fire Behaviour Considerations
Marty Alexander, Canadian Forest Service

Marty Alexander provided an overview for the non-specialist of fire behaviour terms and concepts, existing tools for predicting fire behaviour at the stand level (with particular emphasis on the development of and propensity for crown fire activity), and offered some suggestions for future directions. The limitations of present-day fire behaviour models and systems were highlighted.

4. Silviculture: Mixedwood Stand Development
Vic Lieffers, University of Alberta

Vic Lieffers examined the stocking, growth, and mortality for white spruce in mixedwood stands, using mil-hectare plots as the sample unit. He also examined the free-to-grow (FTG) standard as a means to evaluate the effect of competition. The FTG standard does not isolate competition from other factors affecting tree growth.

5. Forest Genetics: Prediction of Genetic Gain – A Robust Growth Modelling Strategy
Sue Carson, Carson Associates Ltd.

Genetic gain in growth can be modelled as an increase in growth rate (separately for diameter and height). This approach requires existing growth models (which accurately predict the effects of stand density and site quality) and breeding values of planting stock. By utilizing data from large-block genetic gain trials, the approach allows accurate prediction of performance of seedlots and silvicultures that are not represented in genetic gain trials, thus providing a robust solution to prediction of growth of genetically improved forests.

6. Forest Health: Pathological Considerations in Growth and Yield
Peter Blenis, University of Alberta

Integrating loss from pathogens into growth and yield modelling requires an understanding of the unique features of the individual pathogens. The salient characteristics of decays, dwarf mistletoes, armillaria root disease, and rusts were examined in the context of growth and yield modelling. The role of risk assessment in modelling of intensively managed poplar plantations was also discussed.

7. Forest Health: Integrating Spruce Budworm into Growth and Yield Models
Dave McLean, University of New Brunswick

When spruce budworm defoliates trees, removal of the tree's "photosynthetic factory" initially reduces growth rates, and if severe and prolonged over several years, trees die. Thus, the key to integrating spruce budworm into growth and yield models is relationships linking tree growth rate to defoliation level, and mortality rate to defoliation. This gets complicated by differential relationships (growth or mortality response) as a function of different tree species, age, site conditions, hardwood content in stands, surrounding landscape composition, and temporal pattern of defoliation. Incorporation of these relationships into the Spruce Budworm Decision Support System and its usage in planning insecticide programs and alternative harvest scheduling/salvage was described.

8. Silviculture: Long-Term Effects of Density Regulation on Conifer Growth and Yield – Results From Two New Brunswick Studies
Doug Pitt, Canadian Forest Service

The Green River Spacing Trials, established by Dr. Gordon Baskerville in 1959-61, now offer more than 40 years of growth response data with which to weigh the costs and benefits of precommercial thinning. Two J.D Irving Limited trials, established in 19- and 24- year-old white spruce plantations in 1984, compare the outcomes of single-, delayed-, and double-entry commercial thinning. Together, these studies provide long-term managed-stand data that can contribute to the "logical extrapolation" of our growth and yield forecasts.

9. Silviculture: Alberta Framework Linking Regeneration to Growth and Yield
Ken Greenway, Alberta Sustainable Resource Development
Richard Briand, West Fraser Mills Ltd.

Alberta has embarked on a process of developing regeneration standards that are linked to Detailed Forest Management Plan assumptions and goals. Forest Management Agreement holders are required to develop new, yield-linked standards that will replace the provincial reforestation standards by 2010. Sustainable Resource Development has provided the goals and objective for these Alternative Reforestation Standards (ARS), but FMA holders are leading the development through a focused effort to use data, models, and expertise to derive and substantiate the standards. Representatives from Sustainable Resource Development and West Fraser Mills described the process of ARS development and provided insights on how ARS development is rapidly moving reforestation standards in Alberta to a new level of sophistication.

10. Forest Health: A Risk Assessment Framework for Disturbance to Intensively Managed Stands
Jan Volney, Canadian Forest Service

A general framework to capture the effects of multiple disturbance effects on stand development was described. Examples including the effects of drought, fire, and pests on stand development were given to illustrate its application in forecasting yields. A discussion of policy applications and further development needs concluded the presentation.

8. POSTER SESSION

The first day of the conference ended with a poster session and social. Abstracts of the posters can be made available on request and will be circulated to conference participants on DVD.

Posters Presented

- Bending Stress Influences the Tree Bole Taper and Proportion of Latewood
- Competitive Effects of Woody and Herbaceous Vegetation in a Young Boreal Mixedwood Stand
- Effects of Spacing Dense Young Aspen Stands on Growing Season-Frost Regime
- Evaluating the Predictive Performance of Three Growth Models Calibrated for Use in Saskatchewan
- Foothills Growth and Yield Association
- Gap Dynamics of Regeneration Following Harvest of Aspen Stands
- The Mixedwood Growth Model (MGM)
- Stand Structure Classification
- TASS III Boreal Mixedwood Modelling: Light and Understorey Tree Growth
- Western Boreal Growth and Yield (WESBOGY) Association Long Term Study: Development and Dynamics of Young Aspen-Spruce Mixedwood Stands

9. BREAKOUT GROUP SUMMARIES

The second day of the conference was dedicated to breakout groups and a final panel, both addressing issues raised during the pre-conference interview and registration processes, as well as the presentations during the first day. This session represented some of the most important work of the conference. Discussions focused on seven theme areas, listed below.

The plenary sessions and concurrent sessions of the first day provided some context for the discussions by offering new insights and ideas on what might work in advancing collaboration, integration, research, knowledge, policy and practice in Alberta and elsewhere.

Delegates were reminded of the purpose of the breakout groups (underlined) relative to the four major objectives of the conference i.e.:

1. To share and integrate information relevant to the effective management of forest stands regenerated after harvest in Alberta.
2. To identify delivery options for the integration of genetic, growth and yield, silvicultural and forest health information.
3. To achieve understanding by forest managers of how this information can be applied in policy and practice.
4. To identify information gaps and associated research requirements.

Delegates were assigned to breakout groups based on their interest shown in pre-conference survey form, where available. Those who did not fill out the pre-conference survey were assigned in an effort to ensure a good mix of background, employment, expertise, and interest in every group so that the discussions and reports would reflect the integration the organizers were seeking. The breakout groups were asked to identify issues, challenges, and opportunities, with most of their effort and time focused on specific priority recommendations for action.

The themes chosen for the breakout groups were derived from the interviews with the 11 opinion leaders from across the country. The breakout groups addressed these issues in the seven general groupings identified from the pre-conference interviews. The summary reports follow, with full reports provided are available on request and will be circulated to conference participants on DVD.

The seven themes chosen were:

A: Research funding – stability, structure, levels of commitment.

B: Barriers and opportunities for integration of research – technical, institutional.

C: Improving yield forecasting in forest management planning.

D: Data collection, data management and research design.

E: The human factor – training and availability of biometricians, foresters and technologies.

F: Priority-setting in integrated research and growth and yield forecasting – i.e., What to integrate?

G: Implications of climate change in growth and yield forecasting, forest health.

THEME A: Research funding – stability, structure, levels of commitment.

Facilitator: Don Podlubny

Room: Waterton Room

Number of participants: 11

Sector Split

- 2 consultants
- 6 industry
- 3 government (2 SRD, 1 CFS)

Overview

The group agreed that the theme area is appropriate, identified two key issues related to this theme and developed three recommendations.

Issues

***Issue 1*:** Poorly coordinated and poorly focused research.

***Issue 2*:** Funding.

Recommendations

Recommendation 1: Establish a Champion to facilitate and ensure applicability of research.

Recommendation 2: Establish an endowment fund for long-term research.

Recommendation 3: Form a steering committee to address the issues of funding and coordination of research, and engagement with effective organizations.

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THEME B: Barriers and opportunities for integration of research – technical, institutional.

Facilitator: Jim Stewart

Room: Elk Island Room
Number of participants: 14

Sector Split
- 5 government (2 BC Ministry of Forests, 1 AFRI, 2 SRD)
- 5 industry
- 3 consultant
- 1 university

Overview
A suite of issues were identified as barriers to integration of research.

Issues

Institutional Issues

Issue 1: Isolation of people within their discipline or field of expertise (silo effect).

Issue 2: Each discipline has its own jargon, assumptions, methods and skills (culture).

Issue 3: There is a general lack of awareness of what other disciplines do and what is important to them, i.e., communication among disciplines is weak.

Issue 4: Meeting the demands of policy focuses effort and attention on certain kinds of data collection and analysis, leaving little time for anything new or different (policy constraint).

Issue 5: Lack of a visible or adequate payback inhibits effort toward integration (economic constraint), this could be because it is not clear that the exercise has a future due to policy or due to inadequate ROI.

Issue 6: Most often there is no mandate to integrate research.

Issue 7: Incentive for and success of integration usually depends on the personalities involved.

Technical Issues

Issue 8: Perception of "too many models" leaves other researchers unsure of where to focus their efforts.

Issue 9: Model mechanics are intricate and generally obscure to non-modellers (black box); other disciplines are unsure of how to approach incorporating their knowledge into a model; potential users have trouble understanding what the model needs for data and conditions under which it is valid (assumptions).

Issue 10: Different disciplines use different types of data and often at different scales.

These issues were distilled down to two related issues with an overarching theme of leadership/vision in both.

<u>General Issues</u>

Issue 11: Limited knowledge of other disciplines.

Issue 12: Specific nature of models and mandates.

Recommendations

***Recommendation 1*:** Develop a vision and strategy for integrated research programs.

***Recommendation 2*:** Develop Integrated Research Programs that produce models and applications for integrating disciplines in growth and yield and forest management planning.

****

THEME C: Improving yield forecasting in forest management planning.

Group A

Facilitator: Steve Stearns-Smith

Room: Glenora Room

Number of participants: 16

Sector Split

- 7 industry
- 6 government (5 SRD, 1 BC Ministry of Forests)
- 2 consultant
- 1 university

Overview

The group brainstormed a number of issues or barriers to improved yield forecasting. From this brainstorming, the group zeroed in on two major issues.

Issues

***Issue 1*:** Forecasting and application.

Issue 2 Data and inventory.

Recommendations

Recommendation 1: People working at different scales, and in different disciplines, must find ways to improve communication e.g., block silviculturists vs. DFMP planners; timber vs. wildlife.

Recommendation 2: Strive to enhance provincial and regional coordination.

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THEME C: Improving yield forecasting in forest management planning.

Group B

Facilitator: Ken Greenway

Room: Glenora Room

Number of participants: 17

Sector Split

- 6 industry
- 4 university
- 4 government (1 CFS, 3 SRD)
- 3 consultant

Overview

The group identified an overarching issue of inadequate G&Y projections produced by some models. Defensibility of and continuing improvement of these forecasts is sought by all stakeholders including industrial staff, regulators, and general public. The public is an increasingly more important group as their ability to understand the issue and their demands to be part of the SFM process is increasing. For G&Y to be appropriately implemented within SFM process, its credibility must be evident. Continuing improvements in forecasting accuracy are being pursued through changes to the Forest Management Planning Manual and through research.

Four sub-issues were explored that contribute to this problem. In discussing this issue, the group accepted the assumption that the G&Y projection model (the black box) is built and functioning reasonably well (i.e., it reasonably predicts future yields).

Issues

Issue 1. Poor inventory (forest understories).

Issue 2. Risk and uncertainty in growth &yield forecasts in forest management plans.

Issue 3: Limited capacities (financial, data, personnel, skillsets).

Issue 4: Lack of clear decision-making process.

Issue 5: Lack of integrated data from disparate monitoring programs.

Recommendations

Recommendation 1 - Inventories: Inventory that appropriately accounts for the contribution of forest understory should be conducted at a resolution appropriate for use in projection systems.

Recommendation 2- Risk and Uncertainty: Continue to develop processes to reduce risk and uncertainty by testing and refining assumptions, along with a commitment to gather information to improve forecasting in successive iterations of forest management plans.

Recommendation 3- Limited Capacities: There should be increased collaboration amongst companies and research organizations to help ensure available capacities are optimally deployed and to minimize duplication of time, money, and efforts expended on the same issue.

Recommendation 4 – Limited Capacities: Create system and opportunities for greater data sharing (both within Alberta and utilization of data from outside Alberta) to reduce the data gap where appropriate.

Recommendation 5 – Limited Capacities: Assign resources to increase professional development for forestry professionals to widen skill sets and enable better understanding across multiple fields.

Recommendation 6 – Limited Capacities: Make tools available (disseminate existing tools, formulate new tools as needed) to help quantify the defensibility of growth and yield predictions and the implications/risk associated with their weaknesses.

Recommendation 7 – Decision-Making Process: Ensure the people with the right skills and knowledge are engaged at the right time in the process to choose the appropriate growth and yield forecasting system and understand its interactions with the forest management planning process.

Recommendation 8 – Decision Making Process: Ensure that when a decision is made on which model to use for what part of the planning process, that all stakeholder objectives are considered.

Recommendation 9 – Improved Defensibility of Projections: Establish a small team to

1. Determine what the value statement for data owners would be for data to be integrated in a warehouse/store
2. Identify what and where data integration opportunities exist between the data already collected either as regulated or voluntary assessments (Regen surveys, NIVMA, PSPs, etc)

3. Develop a plan/proposal that would "harmonize" data collections, as possible, to develop efficient collection and storage procedures
4. Develop systems to ensure data owners are protected with respect to investments and data misuse.

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<u>THEME D: Data collection, data management, and research design.</u>

Facilitator: Jean Brouard

Room: Acadia Room

Number of participants: 16

Sector Split

- 3 consultant
- 7 industry
- 6 government (4 SRD, 1 SERM, 1 CFS)

Overview

There is a shortage of PSP data in the younger age classes, e.g., 20-40 years. There are also gaps for particular species in specific areas. Non-standardized protocols for data collection were viewed as impediments to optimal aggregation and analysis for research and other needs.

Issues

Issue 1. Data collection and data management – Data gap.

Issue 2. Data collection and data management – Piecemeal approach.

Issue 3. Data collection and data management – Uncertainties in data management.

Issue 4. Research design – Realized gains.

Recommendations

Recommendation 1: Develop and publish – through FGYA or other such organization – a set of standardized terms and criteria to be used in data collection.

Recommendation 2: Consider a standard research protocol for integrated research programs.

Recommendation 3: Assemble information and publish a catalogue of data collections, their characteristics, and their ownership.

Recommendation 4: Establish small-scale research plots with a standard design to validate volume productivity gains from tree improvement and other enhanced silviculture practices.

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THEME E: The human factor – training and availability of biometricians, foresters, and technologies.

Facilitator: Vic Lieffers
Room: Lakeland Room
Number of participants: 13

Sector Split

- 6 government (1 BC Ministry of Forests, 2 SRD, 1 CFS, 1 Manitoba Forestry Branch)
- 4 industry
- 1 consultant
- 2 university

Overview

There is a perception that forestry is an environmentally-unfriendly field, that it is low tech, and where foresters spend all of their time clear-cutting forests. It is also viewed as a sunset industry where young people have poor prospects for a good career. Correcting this perception is a challenge for all sectors of the forestry community.

As researchers from different sectors increasingly collaborate on multidisciplinary research programs, it will be important to adapt current incentive and reward systems, as well as develop effective team skills.

Issues

Issue 1: Image and perception of the forestry profession.

Issue 2: Perception that the forestry profession is devoid of opportunities.

Issue 3: The human element of cooperative research programs.

Recommendations

Recommendation 1: Implement actions to redefine the profession of forestry as one that works with renewable resources, is diverse with a bright future.

Recommendation 2: Forestry professionals must make an effort to represent forestry in the community and the school systems.

Recommendation 3: Develop packages of promotional material for use by teachers.

Recommendation 4: Widen the recruitment circle from different disciplines – Forestry is not just limited to RPFs.

Recommendation 5: Communicate that forestry has opportunities.

Recommendation 6: Review and revise the criteria for accreditation of forestry schools to attract new student candidates for the profession.

Recommendation 7: Develop incentives for hiring from industry and government.

Recommendation 8: Seek new forestry school recruits from related disciplines.

Recommendation 9: Managers facing the challenge of integrated research programs must strive to assemble small teams with the ability and dedication to work collaboratively on the programs.

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THEME F: Priority-setting in integrated research and growth and yield forecasting – i.e., What to integrate?

Group A

Facilitator: J.P. Bielech

Room: Valley Ballroom

Number of participants: 18

Sector Split

- 8 industry
- 4 consultant
- 4 government (3 SRD, 1 BC Ministry of Forests)
- 2 university

Overview

This group included two modellers, but no strong growth and yield voices. Nine issues were put forward, though there was considerable overlap between four of them. These were then collapsed to seven, from which the top three were chosen from which to develop recommendations.

Much of the discussion covered familiar ground: lack of data to build models, lack of data to validate models, lack of good models, lots of data but no good data, etc. A unique discussion concerned the sharing of models versus proprietary rights, and there appeared to be a U.S. versus B.C. split on this issue, though no one was saying that sharing was a bad thing.

Issues

Issue 1: Data needs and gaps.

Issue 2: Filling gaps in regenerating stand data.

Issue 3: Model component sharing.

Issue 4: Social issues.

Issue 5: Incorporating genetic gain.

Issue 6: Coordinated approach to priority setting.

Issue 7: Addressing model gaps.

Recommendations

Recommendation 1: Before initiating data collection and related research to fill knowledge gaps, carefully consider the questions to be answered and examine existing data/research sources.

Recommendation 2: Develop research programs to establish baseline stand productivity and identify growth and yield impacts of alternative strategies while also bridging knowledge gaps in the short term.

Recommendation 3: Rather than invent models from scratch, research modelling should examine the possibility of adapting the better parts of existing models into the development of new generation models.

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<u>THEME F: Priority-setting in integrated research and growth and yield forecasting – i.e., What to integrate?</u>

Group B

Facilitator: Scott Milligan

Room: Valley Ballroom

Number of Participants: 13

Sector Split

- 4 government (3 SRD, 1 US Forest Service)
- 4 industry
- 3 university
- 2 consultant

Overview

There is a particular need in Alberta for "actual" information on regenerating (managed) stand conditions, including the contribution of genetically enhanced plantations. The objective is to validate yield projections in the early period of stand development – years 0 to 60.

Issues

Issue 1: Data gaps.

Issue 2: Calibration of the genetic multiplier approach to growth and yield forecasting.

Recommendations

Recommendation 1: Existing growth and yield and genetics cooperatives should collaborate in addressing data gaps.

Recommendation 2: Geneticists and other forest management specialists should strive to understand each others' disciplines and work on integrating their efforts.

Recommendation 3: Gather information, calibrate and apply the "genetic multiplier" approach to growth and yield forecasting for Alberta tree species, stand types, and ecological zones.

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THEME G: Implications of climate change in growth and yield forecasting, forest health.

Facilitator: Dan MacIsaac

Room: Wood Buffalo Room

Number of participants:15

Sector Split

- 2 university
- 5 government (4 SRD, 1 CFS)
- 6 industry
- 2 consultant

Overview

The group discussion identified three major issues related to climate change and its impact on growth and yield forecasting and forest health, developing a number of recommendations specific to these issues.

Issues

Issue 1: Linking variables and modelling response to climate change.

Issue 2: Incorporating stochastic events in growth and yield.

Issue 3:. Societal perception (public, forest community, etc) of the impacts of climate change on forest health, growth and yield.

Recommendations

Recommendation 1: Use an iterative process to identify driving variables and useful models to incorporate climate change into growth and yield forecasting.

Recommendation 2: Time scale projections have to be harmonized with management horizons.

Recommendation 3: Use models to do scenario gaming to evaluate alternative futures.

Recommendation 4: Accommodate catastrophic events and their return intervals in modelling.

Recommendation 5: Incorporate assessment of forestry viability on the land base.

Recommendation 6: Utilize a risk assessment framework in yield forecasts, evaluation of alternative strategies and management decision-making.

Recommendation 7: Demystify growth and yield models through effective communications with the forestry community and the public.

Recommendation 8: Incorporate explicit references to genetics, silviculture, and forest health in growth and yield models.

Recommendation 9: Use these effects in mitigations and adaptation strategies.

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10. PLENARY PANEL DISCUSSION WITH FOREST SECTOR LEADERS

The final event of the convention featured a panel of leaders from industry, government, research, and academic sectors. The speakers were asked to reflect on the discussions of the preceding day-and-a-half in light of their own knowledge and experience. From that context, as well as from their own experience, they were asked to suggest:

- How the topics and recommendations from the speakers and breakout groups might be applied in policy and practice – with a focus on the integration of forest genetics, silviculture and forest health in growth and yield modelling.
- Recommendations and priorities for action.
- Options and resources to implement the proposed actions.

The panellists were:

- John Spence, Professor and Chair, Department of Renewable Resources, Faculty of Agriculture, Forestry and Human Economics, University of Alberta
- Kim Rymer, Chief Forester, Alberta-Pacific Forest Industries Inc.
- Gordon Miller, Director General, Northern Forestry Centre, Canadian Forest Service
- Bob Winship, Forest Resources Manager, Weyerhaeuser Company
- Trevor Wakelin, President, Forest Resource Improvement Association of Alberta
- Doug Sklar, Executive Director, Forest Management Branch, Public Lands and Forest Division, Alberta Sustainable Resource Development
- Thom Erdle, Professor, Faculty of Forestry and Environmental Management, University of New Brunswick

REFLECTIONS ON POST-HARVEST STAND DEVELOPMENT

John Spence
Department Chair, Renewable Resources
Faculty of Agriculture and Forestry
University of Alberta

John received his BSc (1970) in biology at Washington and Jefferson College, his MS (1974) in Zoology at the University of Vermont, and his PhD (1979) in Zoology at the University of British Columbia. He has been in an academic position at the University of Alberta in Edmonton, Canada, since receiving his PhD and was appointed as Chair of the University's Department of Renewable Resources in July 2001. He has been a visiting professor at several universities, including Berne, Copenhagen, Helsinki, Oxford, and Michigan State, and a visiting scientist with both the United States and Canadian Forest Services. Research in Spence's laboratory has pursued both basic and applied questions in entomology and in forest ecology.

As some of you know, I am an entomologist who began to dabble in forestry, and then finding it a most salubrious enterprise attracting the attention of interesting people, has made something of a career of it. Over my career I've learned lots from many who have participated in this meeting and just about everybody here on the panel, either by listening to them in various situations or by reading what they write. I'm a good listener. I hesitate to talk too loudly about forestry, although I'll go on passionately and forever about entomology if you'll let me, and there is growing awareness that insects and stand development are not altogether separate topics. However, you've asked your panellists to react to what they've heard. So, let's start with the interesting mainstream of what I've heard here and place it in the context of my own roughly accumulated background. From this exercise, I will draw a set of take-home conclusions. You may indeed take them home if you find them useful. If they are not, I invite you to contribute to my ongoing education by disabusing me of faulty notions.

Simplicity and Complexity in Forestry

I've heard a general recognition that forestry is an extremely complex adventure. It has more layers than any onion I know about and a good deal of potential to make you cry when you peel back a layer to reveal the next thing we didn't understand before we meddled with it. We're in a discipline that's highly inter-connected, probably because it has a multivariate ecological foundation that constrains what can be realized and sustained in both social and economic dimensions, despite my general feeling that both social and economic dimensions are insatiable. Given the goal of forestry to be synthetic in nature and to optimize across dimensions, foresters pay more attention to connections than any discipline I know about. In fact, we can become paralyzed by this complexity if we are too fearful of making mistakes. Foresters must be bold in the face of uncertainty, or we'd not dare to cut a single tree.

Forestry has the sort of abstract connections that essentially connect everything, usually, in several ways to everything else. We might see the central part of forestry, what we've been talking about the past two days, near the heart of this complexity. My guess is that if we're going to try to produce models that help us to achieve better projections of growth and yield or anything else, for that matter, we really need to focus closely on the main inputs and outputs that act directly in that area. Thus, the models should incorporate only factors that directly affect the development of trees, and these will, in general, be those that dominate the interaction between the environment and tree genotype. Even this can be daunting. What we know about the site can be roughly translated to "environment" and the exciting possibilities flowing from developments in forest genetics encourages us to have a hand at managing genotypes to some extent. The tools seem powerful and the possibilities seem enormous. The responsibility, however, should not be taken lightly because in taking such control of a system, we also open its Pandora's box. The outcomes, expected or not, will all be our fault.

Building useful models more complicated than those that track tree development as driven by genotype and environment and incorporate the main interactions will be challenging. A few explicit examples were given here. Dave MacLean, for example, gave an interesting talk yesterday about how one might introduce spruce budworm impact and management into planning for forestry. My colleague, Peter Blenis, discussed some examples where it might pay us to do the same with some pathogens. Nonetheless, I think if you start to draw too far from the central tree-focused interactions, things become too dependent on phenomena that are essentially unpredictable. Thus, as my first take home conclusion, I argue that **we should keep the measurements and the models simple**. There's no point in making very, very precise measurements today when we know that 80 years from now the resulting forecasts are likely to be highly inaccurate. I think that's the situation we're in, so let's invoke the old "**Keep It Simple, *Sunshine*"** (KISS) principle, and try not to spend too much time and energy cracking open metaphorical peanuts with elephants, and so on.

An important part of keeping things simple is being attentive to how much accuracy we need. For example, we don't need gasoline meters in our cars that measure gas use down to the millilitre because all we really want to know is whether we have enough gas to drive from here to, say, Lac la Biche. There is no point to spending money on irrelevant accuracy. My friend and colleague Jim Beck frequently stuns students in exams by asking what the Annual Allowable Cut (AAC) is. The students always fall into the trap of saying what it is supposed to represent conceptually. Jim, formatted with devilish smile, counters with the "AAC is whatever the provincial forester or provincial authority *says* it is," because there's no way anybody could guarantee that the AAC is actually going to be associated with all that the concept holds. Thus, we develop reasonable and well-informed procedures that support simple policies. When the procedures and policies are revealed to be in serious mismatch, as Vic Lieffers and his colleagues have demonstrated quite clearly for our regeneration standards, it is time to change something. As I understand it that is just what the folks in Sustainable Resource Development are in the process of doing. The system is working, if not as fast as some would like. Those who want the system to move faster would do well to remember the Severide Principle (named for CBS news commentator, Eric Severide) who is reputed to have said, "Most problems begin as solutions." Let's be sure that changes are improvements.

Safe-Failure Policies

With respect to policy, my take-home message #2 would be: **keep it simple, keep it flexible, keep it safe**. In the absence of complete understanding (remember the unpeeled onion), we should aim for policies that will fail safely, not those that are fail-safe. If you think we're going to use every stick of wood out there and we're going to calculate the future 80 years in advance – good luck to you. We need policies that provide guidance in the face of uncertainty and not control assuming perfect understanding. And we need to recognize that policies will change as we peel back that onion of understanding. Along the way, we likely need to recognize some responsibility to remedy things that we messed up along the way, even though we were following the policies and best practices of the day.

When I listened to my colleague Vic Lieffers yesterday, talking about free-to-grow standards, I was struck by the following thought. Obviously, what we care about at the end is not whether or not we meet some set of contrived free-to-grow standards on every block. What we care about is whether we have a healthy forest to enjoy during its development and, possibly, to harvest at rotation time. We must always remember to keep our eye on the goal we want to achieve and not worry too much about precise regulation and control of the little points along the way. In other words, don't sweat the small stuff. Just as huge oaks grow from tiny acorns, complex and healthy stands can likely develop from diverse beginnings that we probably don't recognize as such.

The Times are Changin'

Reflections about stand development and climate change constitute my take-home #3, because the venerable site index still frequently surfaces as the effective basis of most of the operational forecasting we do. I don't really have an alternative, but I must tell you that I'm very uncomfortable about the confidence some folks have in site index. Jan Volney and I always preach to this point in class, because predictive use of site index assumes that tomorrow will be like yesterday – when's that ever happened to you? In Canada most site indices are based on forests that were established and grown under altogether different circumstances than they face now. In fact, I think it was J.P. Bielech who mentioned today in his breakout group summary that we're just now beginning to have a few stands in Alberta that are 50 years old subsequent to harvest. We should be very interested in how the data from these stands compares to the site index calculated from natural stands. As we consider how stands will look down the road, we must remember that most stands we use for benchmarking came up after a wildfire or grew in a different climate or in other kinds of situations that are different than they will be from here on. Thus, our basis for prediction is really rather shaky. Things are changing around us and "**site index**" **is going to be a very poor measure of where we go in the future**. We need to develop a new basis for predictions and, as we come to it, we should aim to keep things as simple and straightforward and above board as possible. I take some comfort in the fact that we have Andreas Hammam here in the province now and that he and other members of the Alberta Forest Genetic Resources Council are working actively together to help turn our attention to what we can do to plan ahead in the face of climate change.

Biodiversity as a Sustainability Measure

I have not heard much today, or yesterday, about the new "biodiversity" dimension in forestry, even though we're supposed to be governing how we go forward using biodiversity as a measure of overall forest health and non-timber interests. Given the relationships portrayed in Figure 1, biodiversity concerns will affect our future inventory projections. Dan MacIsaac talked about this issue in his summary today, and because society is very interested in it too, I raise it as take-home message #4. Society has given us the highly integrated, if somewhat impractical measure of **biodiversity to ensure that non-timber values are included in forest management planning, including what we do silviculturally to establish and foster young stands**. It's quite appropriate that silviculturists continue to do what they've been doing, and that's to grow more fibre more quickly and to achieve reasonable projections of future inventory. However, options must now be considered in light of other constraints. Movement toward high-intensity forestry, for example, such as that which has raised fibre yields enormously throughout boreal Fennoscandia, is not likely to be accepted in Canada, at least not on the extensively managed land base. In developing silvicultural strategies, it will be futile to ignore unwanted biodiversity outcomes or to plan to apply Band-Aid solutions post-hoc if management leads to whole-forest configurations that the public does not appreciate and endorse. In fact, modern silvicultural prescriptions should be developed in a manner that embraces socially acceptable biodiversity goals.

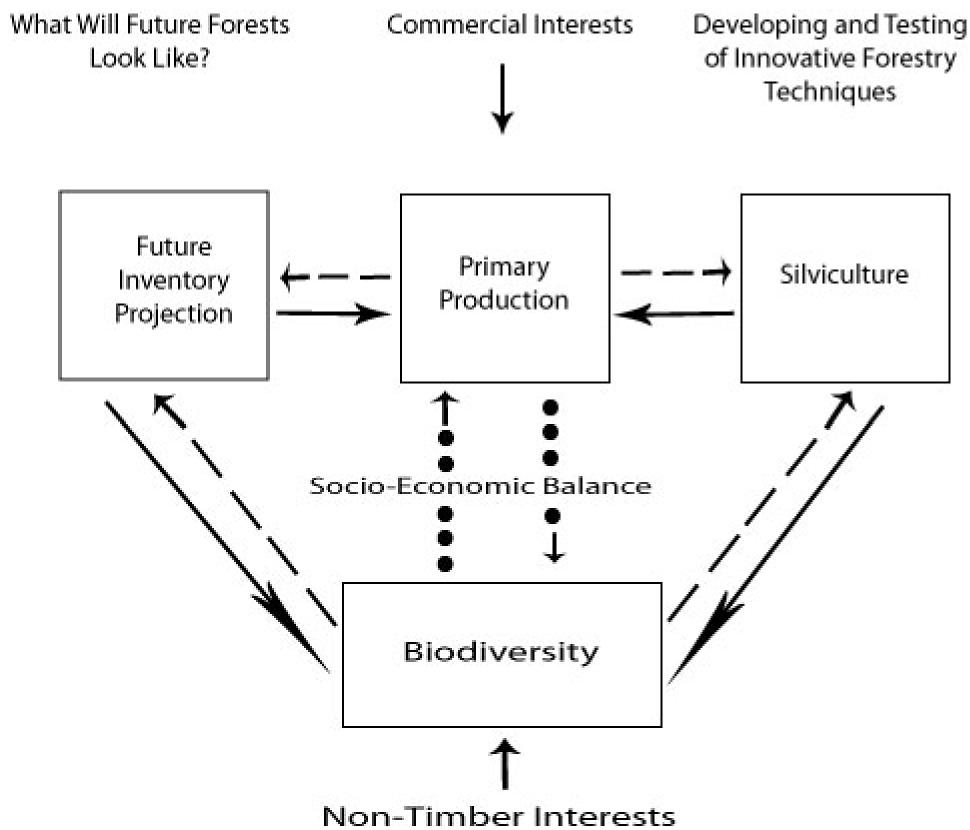

Figure 1. *Schematic diagram depicting the new relationships between biodiversity and silviculture. Under the banner of sustainable forest management biodiversity is to be conserved in future inventory projections and this encourages direct consideration of biodiversity in developing silvicultural prescriptions. Adapted from Langor and Spence 2006).*

The Other Side of the Growth Equation

Take-home conclusion #5 is that **faster growth doesn't necessarily mean more volume or more profit at the end of the day**. For example, Bill Mattson, a friend of mine from the USDA Forest Service who participates in the Free-Air Carbon Dioxide Enrichment (FACE) experiment in northern Wisconsin, has told me that under enhanced CO_2 they get a lot more foliage and the trees grow a lot faster, but they become, unexpectedly and all of a sudden, just great carrots for insect pests that we don't normally see as significant problems, including all sorts of shoot and stem boring beetles. So at the end of the day, as Ted Szabo has cautioned us during this meeting, the delivered cost of the wood is what matters. With climate warming and under elevated CO_2, delivered wood cost may be a lot higher than it has been during recent times, despite the fact that trees are growing faster. Of course the final use of the fibre, which we can expect to change significantly as we place more emphasis on value-added products, will change this relationship in ways that are difficult to predict.

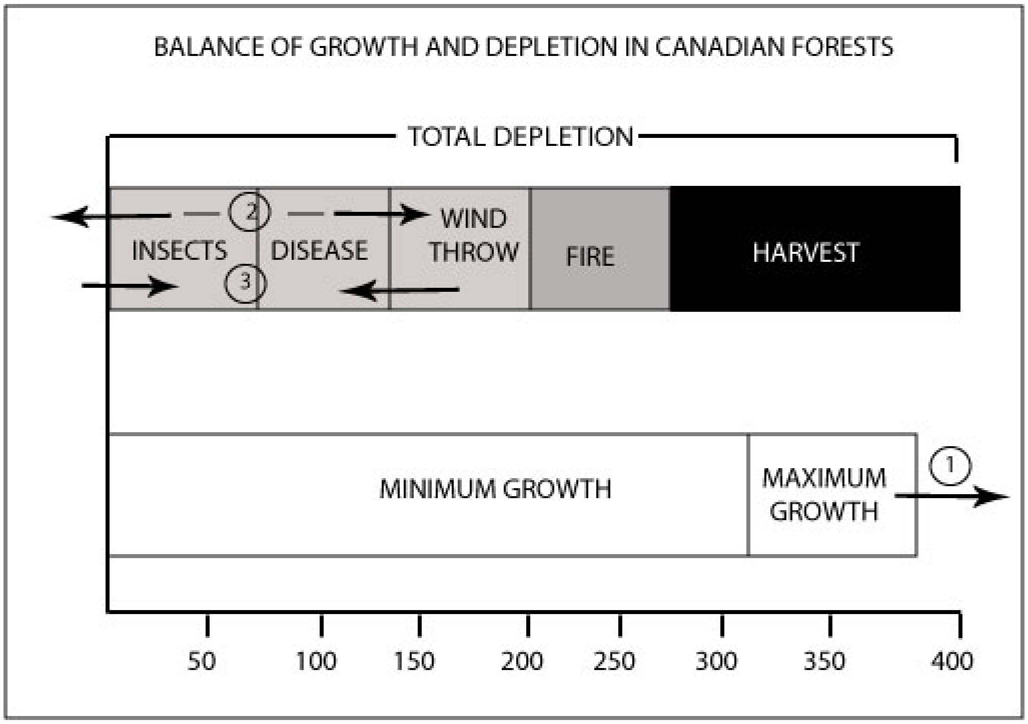

Figure 2*. Balance of growth and depletion in Canadian forests [mainly from Hall & Moody (1994)]. Arrow 1 represents the traditional focus of silviculture in promoting increased forest growth. The arrows numbered 2 represents long-term and inadvertent increases in pest mediated depletion when silviculture focuses exclusively on volume increases. The arrows numbered 3 depict desired effects under more holistic silviculture that includes minimization of depletion as an explicit objective.*

Some of you who have been in my classes will doubtlessly recognize Figure 2, which I have constructed mainly from a CFS information report (Hall and Moody 1994) and a coarse estimate of wind-throw in Canadian forests from work of Steve Mitchell and others. From this, Jan Volney and I have long pushed an important corollary to the fifth take home message. The figure depicts data from the last period for which we have even coarse estimates of depletion and growth for Canadian forestry. The top bar represents total depletion, partitioned by source, and the lower bar the range of estimated growth observed Canada-wide 1982-87. Simple comparison of the range of annual growth and depletion prompts one to ask whether Canadian forestry is even operating within the range of sustainability now.

As we tell our forest entomology students, the data suggest **palatable ways to get more fibre without necessarily growing it faster** (i.e., working on arrow number 1). We've done just about everything we can do to stop fire. In western Canada, annual firefighting budgets can be huge. Wind throw is kind of an "Act of God" that we must simply accept. However, subtle ongoing losses due to insects and diseases are nearly as much as we harvest in Canada, and these figures do not take into account the real disasters such as the present mountain pine beetle disaster and the spruce budworm eruptions that periodically devastate eastern forests with high volumes of balsam fir (i.e., pressures in the directions of arrows number 2 above). Steady depletion from "bugs 'n cruds" is happening all the time in our stands and site index actually takes this sort of damage from past periods into account. The question is – do we need to accept whatever Ol' Mother Nature is willing to give us here? Are we willing to explore other measures like pre-commercial thinning that steal some of this fibre back from the bugs and cruds? Our general goals should include limiting depletion caused by pests, constraining their activities as suggested by arrows number 3 in Figure 2.

Don't get me wrong. I am not arguing that we should cease all efforts to increase growth of fibre on the forest landbase and exclusively develop other options. However, I am saying that enlightened stand management, that is responsive to both public and industrial needs, should consider other options as we go forward in the face of climate change. Most importantly, we surely want to avoid doing things in the forest that might unleash demonic intrusions, such as the current mountain pine beetle eruption into the system. When you **tinker around with a complex system like the forest you may unwittingly generate stimuli in one place that emerges in highly undesirable form in another**. For example, one might find the ultimate cause of the mountain pine beetle eruption at the intersection of years of fire suppression, encouragement of even-aged pine monocultures, and climate change. Managing forests to be more resistant to these sorts of impacts is a long-term enterprise that can be achieved only if silviculture ("the art of growing trees for specific purposes") is viewed from a more holistic perspective than has been fashionable for the past 30 years.

Conclusions

We need some sober thinking about post-harvest stand development in Canada. Nonetheless, there are many opportunities afforded by new technologies and a more holistic view of silviculture. In the above text, I have offered five basic take-home conclusions regarding management of post-harvest stand development.

1. Keep measurements required to model growth and yield as simple as possible. Hope for correspondence between predictions and reality, but don't develop the enterprise with tolerances so narrow that it *depends* on such estimates.

2. Keep policies simple, flexible, and safe. Be prepared to change with new understanding.

3. Site index, although simple, is nonetheless a poor predictor of future stands. Be prepared for change flowing from climate change, exotic species, etc.

4. Conservation of biodiversity may ensure that non-timber values are included in forest management planning but will constrain options for orienting stand management toward productivity.

5. Faster growth doesn't necessarily mean more volume or more profit at the end of the day. Reducing depletion provides some palatable alternatives for getting more fibre out of stands without necessarily growing it faster; pest impacts can be managed with clever silviculture.

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Kim Rymer

Chief Forester, Alberta-Pacific Forest Industries Inc.

Kim received a BScF from the University of British Columbia in 1977. He worked as a forest consultant on the B.C. coast and then moved north to manage the Yukon forest and fire programs before joining Alberta-Pacific Forest Industries in early 1992, prior to the mill start-up. Kim's expertise is largely with forest management, forest policy, and inventory. He is currently the Chief Forester with Alberta-Pacific.

I'm going to split up my comments into those pertaining to intensive management and those pertaining to extensive management.

Intensive forest management is not likely to become too common in Canada's forest industry – at least not until global warming kicks up the temperature a few notches. Even our fastest growing hybrid poplars take much longer than the 7 to 10 years needed in southern U.S., Brazil and many other places. However, intensive management does have its place here, for example, when a marginal volume is needed to meet a mill's production capacity.

The large investments, as well as short rotations where risk factors are largely known, facilitate integration of genetics, silviculture, and health into growth and yield estimates for intensively managed stands. We heard about modelling in the southern US and New Zealand that appears to be well along in integrating a broad range of factors. At Al-Pac we have a way to go with integrated modelling, **but** we do have a geneticist (Barb Thomas) who has become very interested in soils, herbicides, tree diseases, and growth and yield calculations!

With intensively managed stands, the need for precise site-level growth and yield projections requires a good understanding of how the various growth factors interact and good site-specific data. It seems to me that the nature of intensive management forces the integration of disciplines and that it shouldn't be an issue. In fact, it seems relatively straightforward compared to extensive forest management on Crown lands.

Extensive forest management is Canada's mainstay. Generally it is carried out on Crown lands and must address many values and uses, such as wildlife, recreation, tourism, oil and gas, and mining. Our forest industry is largely in the commodity business, producing pulp and paper, lumber, and panel products. We cannot compete head-on with warmer climates when it comes to

growing trees fast. Our competitive advantage is in large, slow-growing forests that require relatively little in the way of costly inputs.
In Alberta, we have 14 years to do whatever needs to be done to establish and set up a stand to fend for itself for the next 50 to 80 years before it will be harvested again (kind of like kids!). Up to 14 years, the choice of stock type, the handling of the seedlings, the method and quality of site preparation, the planting, the weather and the competition control, will all influence the growth of the stand.

From 14 to perhaps 30 years, for many mixed stands types, there will be a competitive phase. It won't be until about 30 years old that you can confidently assign many stands to a growth trajectory. Throughout the life of a stand, there is always the risk of fire, insects and disease, not to mention oil and gas activity. Although we need to attempt to close the loop between the establishment of a stand and its ultimate yield, it must be recognized that many variables will be at work over a stand's 100-year lifespan. For this reason we have to roll these stands up into strata and work with averages, and on a regular basis revisit our yield estimates to reflect change and/or better knowledge.

We've heard from modellers, geneticists, forest health experts, and silviculturists at this conference. It's clear that a lot of good information is available. Understanding all the complex interrelationships and applications is very difficult. Forest managers need models – and to quote Bob Udell, we need practical, versatile, validated models – to sort through the complexities and help us make good decisions.

Forest-level models have advanced a long way in recent years, and provide managers with tremendous new abilities to spatially plan operations and manage landscapes for such things as older forest stands, landscape patterns, and species-specific wildlife needs. It is with the individual tree and stand models – that feed these forest models – that there is much work to be done. Yield models need to be able to better reflect:

- the growth of mixedwood and partially harvested stands
- the effect of a variety of silviculture treatments
- the influence of forest health issues, and
- the potential for gains through introducing genetically improved trees.

What I heard many times over in the last two days is the need for collaborative efforts between researchers from various disciplines, in working towards more comprehensive models. I think it will be incumbent on the researchers to be thinking of the potential end-use of their work and, as appropriate, incorporate these other disciplines in their research.

Gordon Miller
Director General, Northern Forestry Centre
Canadian Forest Service

Gordon Miller earned a BSc (Hons.), MSc and MPM in biological sciences and his PhD (entomology) from Simon Fraser University. From 1978 to 1980, he served as a research biologist with the B.C. Ministry of Forests in Victoria, British Columbia. In 1980, Gordon joined the Canadian Forest Service as a research scientist at the Pacific Forestry Centre in Victoria. In 1986 he was appointed the Director, Protection and Production Program in Victoria. In 1992 he moved to Ottawa to the office of the Deputy Minister as Director of Operations, eventually becoming Director General of the Science Branch in 1998. A desire to return to field operations brought him to the CFS's Northern Forestry Centre in 2003, where he remains as Director General of the Edmonton research centre, overseeing a large program with over 130 full- and part-time staff, as well as leading CFS initiatives involving policy and science.

It's a pleasure to be here talking about issues of substance to the forestry community. I want to talk about fibre, but from a somewhat different perspective than the focus of this conference. Certainly, there is a lot of interest in growing more fibre, largely in the context of integrated land-use management and how industry is going to maintain some competitive position within that context. I think the pressure to produce more fibre per hectare is going to increase as we see more land being tied up by the energy sector and other uses. For example, Alberta's population is expected to grow from three to six million over the next decade, and obviously that's going to result in a lot of additional demands for recreational use, especially in the east slopes. This places our industry under a lot of pressure if we are going to support even the current infrastructure, let alone possibilities of expansion. To do that, we will need to produce a lot more fibre per hectare than we do now.

Here are the main messages of my talk, and I'll speak to each of these points. I think we – as the conference has largely talked about – need to develop good forecasts of stand development. What sort of growth and yield can we expect in the coming years?

But I think we have to think more broadly than that. We need to reflect not only on what forest products we are producing now, but also in the future in light of the market opportunities the future may present. In the Alberta Forest Research Institute (AFRI), we've been having lots of discussions about bio-refineries, and that same discussion is also happening nationally. There is much talk about biomass and how we might be able to produce more energy from the forest. With this as one example, as we look to the future, we're going to have to be thinking more broadly about what productivity means. We will need to think about what the fibre characteristics are like, not just strictly volume. I realize we are already doing some work on fibre characteristics, but we will need to expand the scope to include bioproducts and nano products – not just 2×4s and pulp and paper. Chemicals from trees have all sorts of potential uses and I expect there will be growing interest (particularly in this province by companies like Dow and DuPont) in using forests as feed stock for some of these new products.

The second point. Obviously, when we're practising extensive forestry, the public still understands that we want and need to produce fibre, but that it will be produced in the context of multiple use. That perspective should remain as long as we practice extensive forestry, but if we start moving into more intensive forest management, there could be a real change in that attitude and acceptance. We have to remember that the forest represents many different values to the public, and as our public becomes more and more urbanized, its expectations will change also.

Even though we need fibre from the forests, and we want to grow more fibre per hectare through intensification, we will need to be mindful of producing the fibre within that context of public interests and expectations.

The next point is particularly important: If we're going to be focused on understanding the productivity and fibre availability possibilities in the future, we've got to move to more integrated information from a variety of disciplines. I think this is particularly true when we're talking about opportunities for increasing productivity. To me, this suggests more shared information and databases. None of us has the resources to do all the things necessary right now. I've already heard a synopsis of some of the additional areas where new focus is needed. Not only do we need to cooperate more, but more importantly, we've got to be better at sharing information and data to do a better job of understanding what the possibilities for the future are.

That's not easy; we've talking about this concept for decades. Over the last decade in particular, we've talked and written a lot about the need for better interactions between research providers and research users. For example, within the science and technology community, we've been talking about the need for a lot more interdisciplinary work. Progress in doing this has been slow, and I don't know if we can maintain the slow pace if we're going to stay competitive. Admittedly, we must face many institutional and attitudinal challenges if we're actually going to get more serious about sharing, but I think it's really critical to do so if we really want to understand how the forests are going to be able to contribute to the economy of Alberta in the future. That's something AFRI has talked about, and will be continuing to examine in the coming months.

Having said that, I agree with John's point about keeping it simple. We do not need really complex data and information bases that are difficult to use. The information needs to be friendly and transparent to the people who are trying to use it, which will pose some challenges to the people developing the systems. How can you make sure that the accuracy is there that people need, but allow people to use the information cleanly, quickly, for whatever their ends are?

There has been much discussion at the conference around tree improvement and genetics and silviculture. I think it's also important that we understand that forest health has to be part of the discussion. For example, you can do all sorts of wonderful forecasting of what the pine forests of Alberta are going to look like in the future, but there's a little critter called the mountain pine beetle that's come across the border that could create havoc with any of your predictions, depending on what transpires next. Given the warm winter we're having, it will be interesting to see what the expansion of the beetle population looks like.

We must be aware of some other risks as well. Climate change is one of them. If you look at the climate change models and their predictions, you will see many changes. The boreal forest, for example, is expected to redistribute quite substantially and this suggests that where fibre is actually going to be available from the forest is also going to change over the coming years. Going one step further and looking at one agent – fires – the models predict that we are looking at something in the order of a 40% increase in area burned over the next 30 to 40 years. That's obviously a lot of fibre that may not be quite as handy as one might hope.

My last point really builds off the third. Obviously, we need to combine our efforts. We also need to do this at a higher level and we have not made much headway there. I am aware that a lot of projects are founded on partnerships and all sorts of sharing is happening at that level, but we've got to be able to kick it up a notch.

Things are happening, again with fibre either as a complete focus or as a substantial focus in that context. I would mention a couple. One is local – the Institute for Forest Opportunities Research (IFOR). This is a discussion that we've been having between the Northern Forestry Centre of the CFS and the University of Alberta, as we are trying to find ways of working more effectively together. We have been considering a number of joint projects that we might launch, such as seeing how research might help in supporting development of Alberta's regeneration standards.

At the national level, there is the emerging National Fibre Centre. The CFS is taking a lead on this, under the auspices of the Canadian Forest Innovation Council. This council involves not only the federal government but also provincial governments and industry. It is largely focused on looking at market opportunities for Canadian fibre and backing that up so we're actually managing the forest so we get the forests we need if we're going to produce those particular products, be it 2×4s and pulp and paper or products like bioproducts or nanotech products that may be coming out in the future.

In summary, I have given you my perspective on some of the higher level things being discussed now that have very direct bearing on fibre and on the considerations of this conference.

Bob Winship
Forest Resources Manager
Weyerhaeuser Company Ltd., Alberta Operations

> Bob has been a practising forester, working for industry in Alberta for over 25 years. His experience includes forest management planning, silviculture, timber harvesting, tenure, and strategic issue management. He has worked with deciduous, coniferous, and mixedwood regimes in four subregions. He has been involved with numerous opportunities working collaboratively with the province in the development of policy and regulation.

I caucused some of my Weyerhaeuser colleagues who attended the conference for their input on the three objectives we were asked to address during the presentations, so I could add their views to my own. I would like to emphasize that the subject is important to Weyerhaeuser and its corporate interests. This matter often determines where major capital investments go and do not go, so it is quite relevant.

I'd like to offer you a handful of challenges and, though I will speak in an assertive tone, I want to assure you that I am speaking to myself as well.

Number one: Remember who's paying your wages. Whether it be the policy of the Crown or the direction of your employer where investments are to be made, remember to keep the efforts of this in context and who ultimately is going to depend on the results of your work.

Next, remember who your stakeholders are: who is going to bear the consequences of your work, and how it's going to be used by others. Make sure you have all the objectives in front of you. Yesterday the subject came up of the complexity of models, the scientific soundness and – as one of the speakers mentioned earlier – what is the validity and the practicality of such models. These are often conflicting objectives. Somebody should take on the responsibility though, ultimately, in these decisions.

And on that note, a key one of mine, and one that came out of one of the breakout groups, is defensibility of the models used. I cannot stress this enough as one of those individuals who has had to sell my employer, the Crown, the public, and other stakeholders, and who has had to stand by the results of a timber supply analysis. I cannot do that type of work myself; therefore, I rely on my respected colleagues such as yourselves to assist me in that regard.

Also, I would recommend that we should put a lot of thought and work into a framework-type of thinking. Looking at things from a framework perspective is quite trendy these days in leadership organizations, but it is also quite relevant. Think about the big picture – how does the growth and yield modelling, the silviculture links, etc. – how do they all fit together in one picture? Our speakers have talked about the need to get it together. Well, get it together within a blueprint. I don't know who that person would be, but somebody should start thinking at a framework level.

Now, one point I'd like to repeat, something that previous speakers have talked about and I'm sure subsequent speakers will also – the matter of collaboration and partnerships. I emphasize how increasingly important this is becoming. Companies like Weyerhaeuser – and the whole forest industry for that matter – can less and less afford these types of investments, particularly in Canada. The global marketplace has come home to roost, and you're seeing the changes in the forest industry as a result. The industry is still very important to us. Some things that were once a competitive advantage over my competitors, I can no longer afford to do alone necessarily, but they still need to get done. It is time to collaborate and partner.

I caution us all as foresters, if we don't work together on these imperatives, someone will step in and fill the void. I have a great deal of empathy and understanding for those working for the Crown. When they don't see this effort going on, someone has to make a decision, and they will do it. And I am sure they would like the help doing it, but they need that collaboration and partnership. The threat if we don't work together is – and I've seen the history from my experience – such things as seed orchards left to fall apart and permanent sample plot programs abandoned. It really is a crying shame. As a forester, I hate to see it. But one reason these things have happened is that there was none of that collaboration or partnering to ensure the longevity of these programs.

And for those who work in this industry, my colleagues who complain about the Crown being prescriptive or process-oriented, think about it for a second. Have you offered a reasonable alternative for those people who have that responsibility? If you haven't, take up the challenge.

Next we need to talk about balance. I hear from my more sophisticated and scientific colleagues about the need for more information, more research, and I agree we need all that. More than ever though, we need answers and we need decisions starting tomorrow. Should this be a debate between us as professionals or should we get together and try to strike that balance?

I hearken back to a recent public opinion survey. It seems that over my 25-year career in Alberta the surveys keep saying the same thing from the public. The results normally suggest that as long as you're planting trees back, people think your practices are sustainable. Well, public opinions are starting to mature. Public Advisory Committees, many of which we support, are starting to get up to our level of understanding. They want to know, in a more defensible way, what is that link between what you do and sustainability? We cannot answer them by saying we need more research, we need more data. Be careful what your messages are. It takes only one of us to weaken the public's faith in the work we do.

Lastly, I would draw your attention to what has been mentioned earlier –i.e., the big "what ifs?". As the expression goes, make sure someone's climbing the tree, looking ahead. Mountain pine beetle in Alberta could change everything tomorrow.

These issues are important to our industry. The forest industry is huge, rationalizations are happening with changes in ownership and structure, impacting the industry as well as the people who depend on it. Governments also change from time to time, and as elections go by, priorities and funding also change. The type of work we've been talking about, as you all know, is something that has to go on, even beyond my time. We have to work together to make sure we strike that balance between the types of decisions we need to make today and those we make for the future. I respect and admire my colleagues whose career is dedicated to this work, and I would hope that after your time your work continues on. Think about how you're going to make that happen.

My last challenge would be to the conference organizers themselves and the associations that are represented here, the growth and yield associations. I saw a list of about seven or eight on one slide. How do you folks get it together? How do you get it coordinated? What are your opportunities for synergy? What are the risks if you do not? I will leave it with the conference organizers to come up with specific recommendations after this conference is done. If nothing else, we need action on that one item alone. Because if you don't, someone will fill the void.

Those are my challenges to you and to myself. I hope you accept them. Thank you to the organizers for giving me this opportunity.

Trevor Wakelin

President, Forest Resource Improvement Association of Alberta

> Trevor is the Director of fibre resources for Millar Western Forest Products Ltd., a family-owned company based in Edmonton, Alberta, that owns and operates a pulp mill and two lumber mills, and conducts woodlands operations supplying the fibre requirements of all three facilities on the basis of sustainable forest management principles. He has taken an active role in the work of industry associations and the management of industry / government issues in areas such as enhanced forest management, the softwood lumber trade dispute, industry codes of practice, and stumpage and tenure reviews. As well as serving as president of the Forest Resource Improvement Association of Alberta (FRIAA), he currently serves as chair of the Alberta Softwood Lumber Trade Council, and as a director of the Canadian Lumber Trade Alliance. He is past president of the Alberta Forest Products Association (AFPA) and has served the AFPA since 1998 as a director and since 1986 as chair and member of numerous committees.

The Forest Resource Improvement Association of Alberta is a non-profit association that administers programs for the government. As such, we provide many resources towards the improvement of the province's forest resources, as well as towards education and professional development. For example:

- FRIAA has provided the necessary funding to the Foothills Model Forest for this conference.
- FRIAA provides funding through the FRIP program to improve the forest resource – forest stewardship for the benefit of the public of Alberta.
- Additionally, since 1997 FRIAA has provided $55 million towards operational projects that will improve the growth rates of our forests. This represents approximately one-third of all FRIP funds to date.

Comments questioning the validity of Alberta's inventory and its growth and yield models trouble me, as we have put considerable effort into these areas for a long time now. Growth and yield, or as I put it growing more wood, has been around for many decades, in fact centuries in Europe – there is nothing new here, so we shouldn't have to re-invent the wheel.

Today I am going to provide you with high-level remarks, outline some limitations, and provide you with my recommendations. To put things into perspective I will first provide some background.

Putting Alberta's Growth Performance Assumptions into Perspective

My early career was practising silviculture in New Zealand. New Zealand was growing wood with MAIs above 20 m^3 per hectare per year in the early 1960s, achieved through practical on-the-ground silviculture. .Around the world MAIs in excess of 10 m^3 per hectare per year are common, including growth rates in eastern Canada. Yet Alberta suggests growth rates of under 2 m^3 per hectare per year. This seems unreasonably low, and is inconsistent with my own views and observation.

Canada has vast natural forests, with a high proportion of mature timber at risk to insect, disease, and fire. There was ineffective reforestation (planting) until 20 years ago. Our AAC is calculated based on natural yields, and there is a lack of timely interventions (thinning of fire-origin stands). The growth rates of our plantations far exceed the provincial average growth rate. Meanwhile, the forest land base is being eroded due to oil and gas activity and urban sprawl. The industry faces many challenges including virtual doubling of wood costs in the last 20 years, in part due to government offloading of responsibilities to industry.

Millar Western has introduced aggressive silviculture, tree improvement, and risk reduction activities to enhance its AAC and increase growth and yield on its land base to 4 m^3 per hectare per year. Some of these activities are not currently recognized in Alberta's ground rules, yet they are legitimate and reasonable practices.

Growth Potential, Political Will and the Validity of Predictive Models

We have observed growth rates in natural spruce stands equivalent to 8 m^3 per hectare per year, higher in regenerated stands. These could be potentially commercially thinned after 25 years. We have also observed growth response from thinning 100-year-old pine stands, and 60-year-old spruce stands.

Alberta needs a long-term vision to capture these opportunities, as Sweden has done with its vision to double its AAC. We need to be less focused on process, modelling, monitoring, data collection, and more focused on actually growing more fibre on a decreasing land base.

Regulators appear to be becoming more prescriptive, yet do not provide encouragement for innovative forest management and silvicultural practices from the regulators (e.g., thinning not covered in ground rules). There is a lack of local knowledge about enhanced forest management.

The government appears focused on reductions in AAC instead of growing more fibre on less land. The inattention to the eroding land base due to oil and gas activities is counter to my definition of sustainability and does not address the risk from insects, disease, and fire, or the lack of local knowledge pertaining to EFM.

Economics/profitability

Industry requires certainty before significant investments in enhancing growth and yield can be justified (ROI). We are faced with many challenges including cyclical commodity pricing, increasing energy and fuel costs, increasing legal obligations on the land base (government offloading), currency uncertainty, erosion of the forest land base, government policy constraints, and tenure uncertainty, for example:

- The government had indicated that 80-year tenure was being contemplated in the early 1990s, but this is no longer mentioned.
- Incremental AAC gains (AAC effect) are not currently guaranteed back to the tenure holder implementing EFM.

Alternative Funding for EFM

There are opportunities to support enhanced forest management programs. Sustainable funding is available through FRIAA, which provides $15 million annually from FRIP towards this. The government sustainability fund could also help offset the eroding land base through investments in EFM, through the use of current surpluses or the establishment of a FRIP type fund from oil and gas royalties.

Recommendations

1. A long-term vision for the forest is required from government. This will take leadership, to improve the productive capacity of the forest land base – grow more wood while maintaining environmental and ecological integrity.
2. We should establish a strategic action plan consistent with the long term vision, and create necessary government funding to that vision, determining requirements beyond free-to-grow.
3. Alberta should establish a strategic action plan to improve forest health, reducing age class imbalances, developing spread prevention strategies for insect epidemics, e.g., mountain pine beetle. We should ensure sufficient funding for forest protection.

4. We need to determine baseline stand productivity (natural stand productivity), and gains from current regeneration standards, linking them to AAC and identifying the incremental gains available from increased site index.
5. Beyond basic silviculture, we need to determine the gains from EFM activities (crop plans, timely interventions, fertilizing, tree improvement, etc.).
6. To support this, we need to create simple, accurate monitoring and feedback processes that incorporate technology and professional judgement field checking, provide effective linkages to all levels of planning, and incorporate deviations from anticipated stand response.
7. We need to select the appropriate predictive models for use, with simplicity as the guiding principle. There are many models in existence; modelling has almost become a cottage industry. Data requirements must focus on need.
8. We need to create a positive regulatory environment that aggressively encourages EFM, through reduced red tape and bureaucracy, and simplified and clear policies that focus on results instead of process, i.e., are less prescriptive.
9. Alberta needs to incorporate mechanisms to ensure that tenure holders acquire the incremental AAC benefits from EFM. Consideration should be given for longer term tenure to those tenure holders that invest in EFM.
10. Alberta should create a bridging mechanism for growing stock on private land (combine freehold and Crown land into a single management unit).
11. We need to improve knowledge at all levels. We need to provide education and training for both industry and government practitioners, pertaining to growth and yield impacts from silvicultural practices, including trips to other jurisdictions where increased growth rates are being achieved. **WE MUST WALK THE TALK!!!**

Doug Sklar
Executive Director, Forest Management Branch
Alberta Sustainable Resource Development

Doug graduated from the University of Alberta with a BSc (Forestry) in 1974. Since then he has worked primarily in Alberta in a variety of forest management positions in industry and government as well as an independent consultant. Doug has been the Director of the Forest Management Branch in the Alberta government since June 1999.

I'm not going to reiterate many of the points that have been made by the other panel members here this morning. But I have a few comments specifically related to the topic of the workshop and some suggestions for the workshop to consider.

Data Management, Research, and Collaboration

We've heard repeatedly throughout this workshop that collaboration is a good idea. Everybody can appreciate that it's essential to reduce costs and improve the effectiveness of our collective work. I personally am sympathetic with the plea that we heard repeatedly this morning for some kind of centralized body to coordinate research and coordinate researchers. Frankly, I despair at the possibility of that happening anytime in this millennium. It's been tried many, many times without success and in my view is doomed to fail. There are simply too many personalities, too many agendas, too many budgets, and too many organizations in the fray. Although it's a good idea, I think it would almost be a waste of time to spend a lot of time trying to coordinate our research.

There have been a few ideas mentioned to me during the workshop, and before it, that I think would help researchers and the funding organizations prioritize their expenditures. The Forest Management Branch in the past has published discussion papers identifying priority research that we see as being particularly pertinent and relevant to forest management issues in the province. It has also been suggested that we volunteer to coordinate a consultation process with the various communities on a fairly regular basis and to publish what we see as a list of priorities. This could help the various funding agencies, the research groups, and cooperators get organized to pursue those goals.

The second issue that we heard a lot about in this morning's sessions was that of data management. An idea that has been around for some time is the need to form some kind of arms length administrative body to administer what I would call data custodianship. To accomplish this would entail addressing all kinds of issues with data. People view it as an asset and they're reluctant to relinquish control of the use of that information. And yet, I think everybody realizes there's potentially a huge benefit for the research community, as well as the professional forestry community, to somehow have a mechanism to organize access to this information.

The idea of a document that lists forest management priorities as well as dealing with the issue of shared data and custodianship has some merit. It would be necessary to limit the scope, to prevent it from growing exponentially and becoming impossible to manage and coordinate.

The second bullet on the screen relates to the cooperatives, as mentioned in one of the presentations this morning. In Alberta, I think there are six cooperatives functioning – three genetics and three growth and yield. I personally don't see any great need to superimpose any kind of super organization on those cooperatives. I know all of the people either managing or administering those cooperatives, and they're all very effective. Perhaps some mechanism to convene a process where the leaders of those groups or the managers get together on a regular basis and discuss coordination would be sufficient to assist everybody in moving forward.

Alternative Regeneration Standards

There was a presentation yesterday by Ken Greenway and Richard Briand about the Alberta Alternative Reforestation Standards. The Planning Standard and the Alberta Alternative Reforestation Standard have been designed to promote integration of silviculture, management planning, and tree improvement. We realize that the details are endless but the target that we are aiming for is to provide some direction for the various researchers and industry groups to focus the direction that they are moving in.

In spite of the sense that everything is going to hell in a hand basket, there is a lot of activity going on, particularly in two cooperatives that are working on alternative reforestation standards. There's been quite a bit of progress, and I have a great deal of faith in the people involved in those efforts, that they will bring them to fruition.

The second bullet deals with this perpetual issue that comes up that we need to do a better job of predicting the future. Well, pragmatically, all we can do is use the best information we have now, monitor it closely, and then adjust in the future. There is a vein of thinking in certain sectors of the community that we should be addressing all of this uncertainty in the future now and reducing annual allowable cuts. I think you can see from my colleagues at the table here, that's not going to be a very popular idea. We have to move forward with the best information we have now and adjust.

The issue of pine beetle has been brought up repeatedly. I think anybody would be foolish to discount the seriousness of the potential threat in Alberta. On the other hand, we (to date anyway) have seen relatively minor incursions into the province and the province has strategies and activities underway to attempt to control this. If it does come to pass, we will be locked into a salvage strategy much like they are in B.C. But the province will be doing everything that it can in conjunction with its industrial operators to preclude this from happening.

Strategic Direction

My final point is with respect to the strategic direction on this whole issue of growth and yield, and as it relates to the whole issue of reducing risk. We have a limited number of people to work on these issues within the regulatory framework, and they're very busy. We'll be focusing a lot of our effort in dealing with the cooperatives whose work covers the large part of the forested land base of Alberta.

This effort must be administratively feasible. We've already heard this morning in the comments from the panel members that we should be keeping it simple. Still, those of us who work in the regulatory environment are saddled by the responsibility that whatever we do has to be defensible and credible. It's a constant debate about how much information is necessary. But whatever we collect, we have to be able to manage the information and use it effectively. Our basic strategy for moving forward with this is one we have always embarked upon. Our first strategy would be to try and facilitate discussions and reach agreement and then we move to mediation and then we move to arbitration. Nobody should labour under the delusion that we're afraid to arbitrate if we get frustrated with the process.

Thom Erdle
Professor of Forest Management
Faculty of Forestry, University of New Brunswick

Thom has worked as a professional forester in New Brunswick for 25 years and has been employed in the industrial, consulting, government, and university sectors. His work has focused on forecasting stand and forest development and forest management design and evaluation. He is currently professor of forest management at the University of New Brunswick.

Good afternoon all. I'll be honest with you, this speech is somewhat intimidating for me and I'm going to tell you why. It starts with you and your situation as I understand it. You've got WESBOGY (Western Boreal Growth and Yield Co-op) – 20 years old at least. You've got the Foothills Growth and Yield Association ably managed by one of the best growth and yield folks around. You've got the Mixed Wood Management Association and the Sustainable Forest Management Network, which is centred here. You've got the MGM and GYPSY models, and you get $400 cheques from your government.

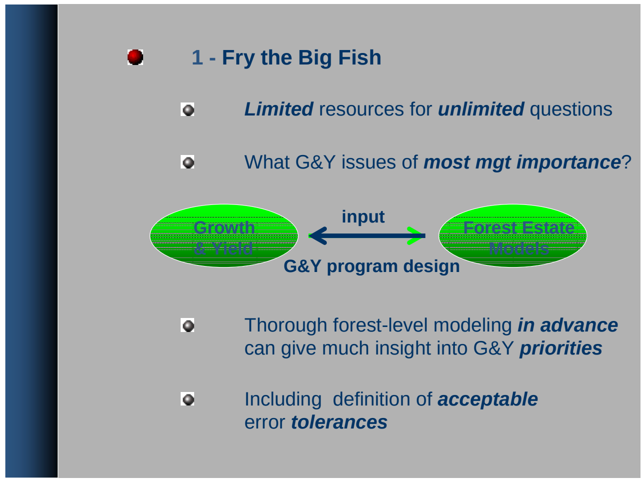
I'm not a growth and yield expert and don't purport to be. I have absolutely no influence or control over budgets or resources or anything that goes on in Alberta or even New Brunswick, as far as that goes. I'm an academic and I'm from the east. I'm hoping there's a little fine thread of credibility left and I'll assume that there may be.

So, my anxiety comes from wondering what I can offer to this discussion. I will speak from the forest management perspective because that's more or less where my background is, and I will make some observations from our experience, offering you some comments I might make if I were sitting in a room in New Brunswick. I'm not advising you, but rather attempting to remind you of some fundamentals. Eight strike me as relevant given what I have heard at this conference.

Eight Suggestions

1. Fry the Big Fish

The first one is to fry the big fish. Even in Alberta, I assume you have limited resources. After listening to the discussions yesterday and today, you also have unlimited questions. The key challenge – and it was talked about this morning – is to set your priorities.

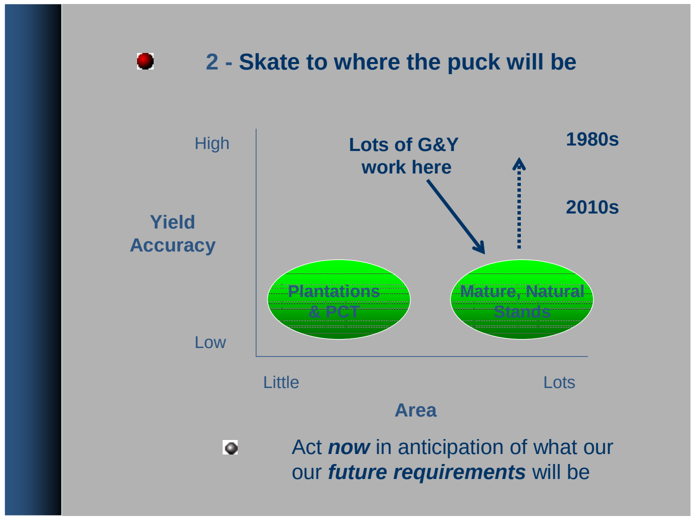


What growth and yield issues really are of most management importance? That's a fundamental point and it's instructive to think about the relationship between growth and yield and what I'll call forest estate modelling or management planning. I think if most people connected those things, they'd draw an arrow and say growth and yield provided input to the forest estate plan. That's true and it's important. But, there's another perspective and that's to reverse the arrow if we're designing growth and yield initiatives. Much of what's been said at this conference is about that challenge, and therefore the forest estate modelling should provide input and insight and guidance to the design of growth and yield programs. This is to ensure that the growth and yield programs do provide useful, effective, and important input to forest management activities.

I enjoyed very much Dr. Coates' comments yesterday and I agree with all of them save one. And that one was that Canadian foresters aren't very good at using models. I disagree – I think we're very good at it – at least very good at using forest estate models. What I would suggest, however is that we mobilize some of that expertise (and I see some good examples right here in this room) to conduct some thorough and thoughtful forest-level modelling in advance of and in support of the design of growth and yield programs. This will help us conclude what those priorities are, not just assume what they are. Most importantly, the examination will help us define acceptable error tolerances. I'm going to come back to that later on.

2. Skate to Where the Puck Will Be

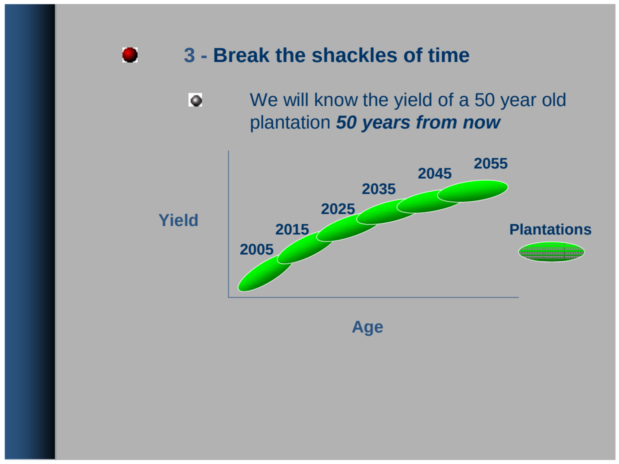
On to the second point. I feel that being in Edmonton you're on pretty safe ground if you quote Wayne Gretzky. He always said he was successful because he skated to where the puck would be. We have that same challenge.



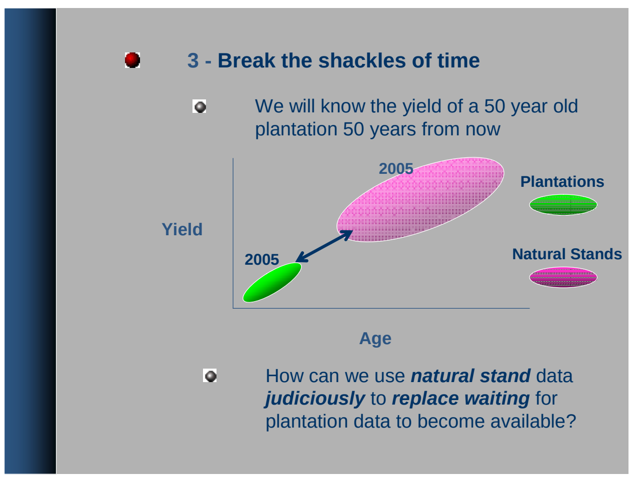
Let me illustrate, using this graph with the land base on the *x*-axis and an abundant scale and yield accuracy on the *y*-axis (thanks to NB growth and yield analyst Chris Norfolk who conceived this representation). In New Brunswick, in the 1980s, we had lots of old, natural stands and some area in plantations and pre-commercial thinnings. Yield accuracy was low in both cases. The solution chosen then was – "well we'll put lots of growth and yield effort here in the old stands because we have so much area of them, and our existing information has low accuracy." This was a good move, and accuracy improved. So now in 2006 or the 2010 decade, we have all this improved information about the old forest, but the land base represented by that type is becoming relatively small. And, we have an expanded land base in younger reforested stands for which we still have low yield and accuracy. So my point is, we need to think ahead and anticipate those kinds of shifts so that we can act now in anticipation of what our future requirements are going to be. In other words, skate to where the puck is going to be.

3. Break the Shackles of Time

This has come up in a number of different guises this past couple of days. I would suggest we need to somehow attempt to break the shackles of time. If we ask the question, "What will our 50-year-old plantations look like?". Well, for those we're just putting in the ground, we'll know in 50 years.



We can set up information programs and get some data here when they're young, we can wait 10 years and get some more data, and get some more data and in 50 years, we'll know what those yields are. This doesn't help us with today's needs.



So, let's flip it around and use what we know about natural stands to help answer this question. But there's a problem here, as Dr. Spence and others have mentioned at this meeting. I recognize that problem but I'm still going to suggest we think about it. We need to take advantage of the data that we do have, even though it's in different stand types, of different origins, etc. – you can make a list as long as your arm about the differences. Nonetheless, as an alternative to waiting, can we take thoughtful, prudent advantage in using the data available today to make judicious decisions as opposed to waiting 50 years? That's a challenge to the community.

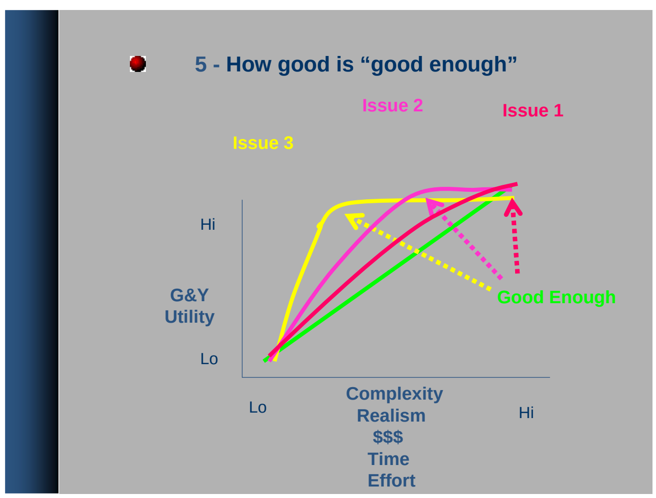
4. Put the Canary in the Mine

Ken (Greenway) referred to it this morning – I call it put the canary in the mine. You know the analogy, the canary tells you when you've got problems brewing in the mine. We need the same warning system. We know our growth and yield forecasts will be wrong. Ken said that and I agree with him. And so, what we really need to do, I would argue (remember I'm speaking my New Brunswick audience, not to you), is to detect, diagnose, and correct error at the earliest opportunity. To do that, we have to put a system in place that allows us to detect problems as soon as possible.

It's not just error in the models we must be on the lookout for, it's error in how we apply the models to the forest at large. That's a fundamental difference in my mind. And it's not just any error, it's error that exceeds the acceptable tolerance. We must also include explicitly as part of our growth and yield strategy. And that's going to lead me to my next and fifth point.

5. How Good is "Good Enough"?

How good is "good enough"? It's a question that warrants explicit examination. We think of growth and yield utility as low to high, just for example. Then we think of our growth and yield efforts and you can measure these in many ways. You can think of these efforts measured in many different forms – the complexity of the models, the realism of the models, the dollars we invest in the models, the time we spend, the effort, you name it, measure it however you want. It is important to examine what these relationships are.



So what do we do to increase the utility? We move up the *x*-axis, and there are certainly some aspects of these issues where this yields good results and higher effort producing higher utility. But I would bet money that there are also issues where it's not true at all. For some issues – forestry management issues – these patterns would look quite different. And so what's good enough for one issue (as shown in yellow) may warrant a very different effort than does the good-enough effort for another issue (as shown in red here). It's incumbent on the management community to convey an indication of "good enough" to the growth and yield community, and not assume that that's just a straight, linear relationship.

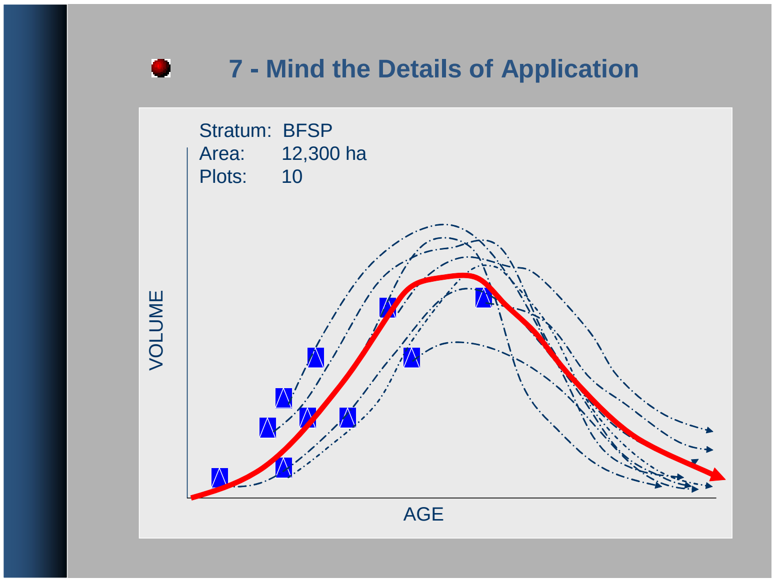
6. Beware of Partial Solutions

My sixth point. Beware of partial solutions. I raise this because I read something interesting coming out on the plane. I had a master's thesis to read and after awhile I picked up a magazine to read. The article said something that had never dawned on me but it was a very intriguing point. It said "look, what if we cure cancer and what if we cure heart disease, but not Alzheimer's?". It sounds kind of funny but think about it. I won't elaborate, but there's an important parallel and here it is.

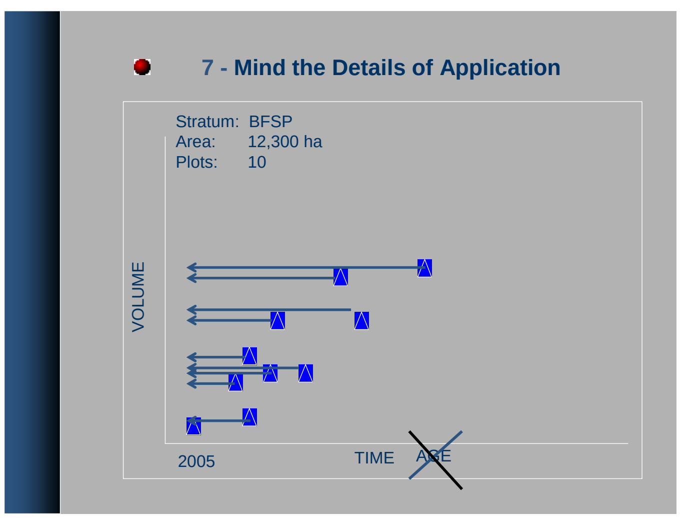
What if we nail plantation yields to a fare thee well – to the 10th of the metre cubed – but we fail to consider their contribution to biodiversity, or their impact on nutrient status (if there is any), or their value as habitat. We end up with partial solutions. How useful are those partial solutions going to be, especially on public lands where all these other issues are important? That suggests to me that although we may think it unnecessary to include these things explicitly in growth and yield investigations, they've got to be accounted for in the overall effort or we're going to end up curing heart disease and cancer and not Alzheimer's, and that's not a good solution. Partial solutions are probably not good solutions.

7. Mind the Details of the Application

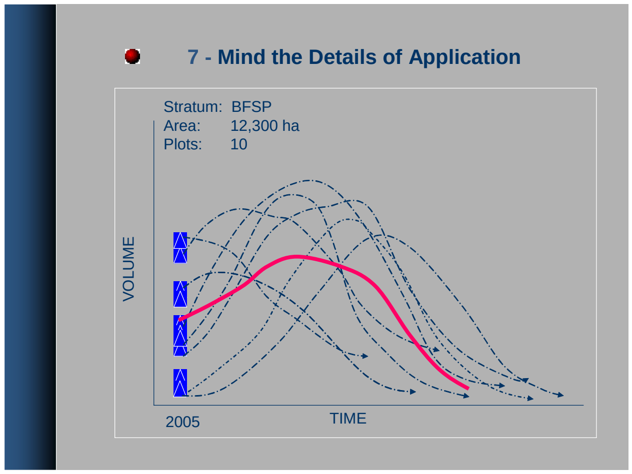
My seventh point is to mind the details of application. Growth and yield – in my biased opinion – must be applied at the forest at large to be useful. A number of important questions have been raised here today, and you are all familiar with this issue. How can the inventory initialize those growth and yield models? And how can we validate, not just the models, but our applications of our models to the forest at large? How can we connect the growth forecasts to our forest stands?



I'll give you a quick example. Here's a particular eastern stratum for spruce (again thanks to Chris Norfolk and the NB Growth and Yield Co-op). We might have gone out last year and sampled a bunch of stands and then used those samples to initialize a growth model that we use to grow those individual stands out. We assume that stratum's behaviour is represented by the average yield projection of those stands, fair enough. We might then take our forest and distribute it according to the age axis and there we go – we've connected the yields to the forest. But have we? We might well say, wait a minute, maybe we shouldn't be thinking age. Let's think about time.



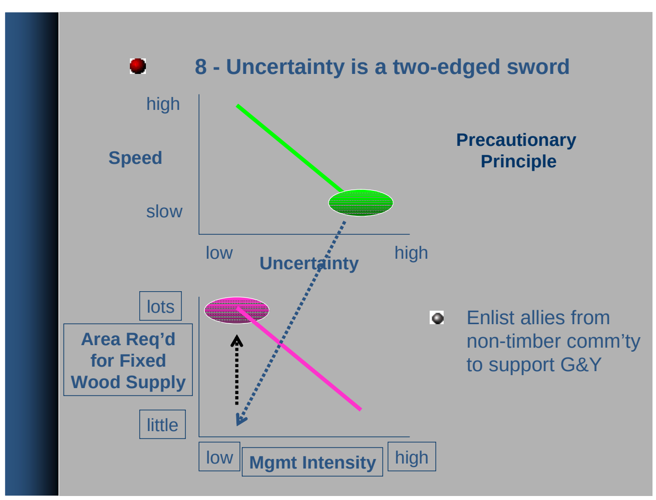
And so if we think about time, a much different picture emerges. If all those stands were sampled in 2005, this is where the measures belong, and they each have a yield forecast.



If we average them and put them together we end up with a calendar – based or a time-dependent yield and we connect our forest to that yield very differently than we do if its an age-based yield. I raise that as a fundamental implementation issue that we really should think about. And I suspect there are other kinds of application issues like that.

8. Uncertainty is a Two-Edged Sword

My final point is that uncertainty is a two-edged sword. I am going to talk about it in terms of the precautionary principle, of which we hear a lot. We heard it this morning, it was on people's slides. I'm an advocate of that, but what does it really say? To me, it says that there's a relationship between uncertainty and speed. Speed can be anything, for example the AAC. The higher the uncertainty the lower should be the speed. So when your uncertainty is high, slow down. In my simple mind, that's what the precautionary principle is. The conservation biologist would probably blow that out of the water, but essentially, I think that's what it is.



What might this mean in relation to our discussions? Well, one example might consider speed is management intensity (and we've got low intensity and high intensity) and we consider that intensity in terms of the amount of land required to meet a fixed wood supply. This shows the relationship and it is the same relationship that Trevor Wakelin was talking about – high intensity practices to produce more volume for the same amount of land, however you want to describe it. But if we use the precautionary principle, it would say, look if our uncertainty is high, slow down. And if this uncertainty is the result of management intensity, we'd slow right down. But that then means that if we want to maintain a certain wood supply, we've suddenly consumed or made necessary for consumption, a whole bunch more area for producing timber. This then means potentially, there's a whole bunch more area not available for something else, or there's a big conflict brewing. My point is that uncertainly cuts a couple of different ways here. One might argue that we really should enlist allies from the non-timber community – which sometimes we view as opponents – but we may need their help to solve this problem because it does cut two ways.

Conclusion

My summary points: Use thorough, thoughtful forest-level analysis in advance to set priorities, anticipate future requirements, and establish error tolerances. Find creative, defensible ways to apply existing data to non-existing conditions. That's a challenge, there are lots of mines in that field, but nonetheless it maybe warrants traversing. Explicitly – either within certain programs or certainly coordinated between programs – include diversity, habitat, and other key elements that relate to stand development. These are important, particularly on a public land base. Enlist non-timber allies and supporters in the growth and yield undertaking. Finally address up-front as part of an overall framework, an early warning system that is designed to pick up error and fix it. Address the means by which you will validate both the models and their application. Find a way to ensure this all works in terms of application and implementation – which means connecting growth and yield to the forest at large.

11. RECOMMENDATIONS FROM THE CO-CHAIRS

We conclude that improved information and knowledge are indeed required for the effective planning and management of stands regenerated after harvesting in Alberta and elsewhere in Canada. We suggest that progress will depend on initiatives and interventions in the following main areas:

- Program alignment - co-ordination and collaboration involving leaders or representatives of existing genetics and growth and yield co-operatives;
- Integration of inter-disciplinary information – development of integrative methodologies, improved access to information, standardization, and common data designs where applicable, resolved custodianship of data;
- Education - focus on integrative approaches and fundamental knowledge requirements through university curricula and extension courses;
- Application - rationalized links to strategic and policy planning, forest management planning, silvicultural practice, and risk management;
- Research - assessment of gaps and priorities; secure funding and maintenance of valuable long-term programs.

Confronted by limited resources and seemingly unlimited questions and opportunities, we propose to focus our recommendations on a few selected action items. Even these selective recommendations exceed the capacities, mandates and authorities of our individual organizations. We are therefore proposing them as 3 facilitated dialogues that could lead quickly to an improved basis for forest planning and management.

Dialogue 1. Technical Program Alignment

Rationale

Forest sector leaders and other conference participants have made it very clear that the existing genetics and growth and yield co-operatives should "get it together" and co-ordinate their activities.

Target Participants

Leaders or representatives of existing genetics and growth and yield cooperatives, programs, and projects.

Desired Outcome

Effective coordination of applied research and information development.

Scope

The first steps should be an exchange of information and meeting of representatives from the cooperatives. The objectives of the initial exchanges would be to explore the concept, possibilities, scope and limitations of collaboration, and to develop a strategy to move forward. While we do not wish to pre-empt the outcome of the dialogue, we note that ongoing active cooperation would be potentially beneficial in the following areas:

- Model development: validation procedures and standards, integration of interdisciplinary knowledge and risk, scale, and resolution issues;
- Incorporation of genetic gain into growth and yield forecasting and monitoring;
- Data for model development: assessment and remedying of gaps, collection, sharing, custodianship, standardization, multi-disciplinary information access, dealing with unavoidable limitations;
- Data and procedures for monitoring (against planning assumptions): opportunities for cooperation and standardization.

Facilitator

The initial meeting could be hosted by a volunteer cooperative or a third party. We note with gratitude that during or subsequent to the conference agencies such as the SRD Timber Management Branch and the Mixedwood Management Association expressed willingness to coordinate the consultation process.

Dialogue 2. Vision, Strategic Direction and Incentives

Rationale

Acting now in anticipation of future requirements ("skating to where the puck will be") requires vision and considerable insight. The final plenary session of forest sector leaders emphasized the need for a clear vision of the goals and priorities for post-harvest stand management and the associated information requirements. It was recommended that efforts to improve growth and yield be prioritized towards those providing the maximum net benefit - a "fry the big fish first" analogy. Strong arguments were made both for and against the intensification of forest management in Alberta. Resolution of these and other "big fish" issues are essential for rationalizing information and planning requirements, for prioritizing investments to enhance forest management, and indeed for achieving sustainability.

Target Participants

- Government policy makers (Deputy and Assistant Deputy Ministers, Executive Directors);
- Forest industry executives (Chief Foresters, Woodland Managers);
- Senior planners and analysts within government and industry.

Desired Outcome

Clear strategic insights into the priorities, opportunities, risks and uncertainties for post-harvest stand management; rationalized definition of forest management planning, monitoring, inventory, and performance requirements.

Scope

The scope of the dialogue would be both investigative and facilitative.
Participative investigation, supported or proceeded by high-caliber technical input, could involve:

- Scenario gaming and estate modeling – identifying the "big fish";
- Evaluation of the inter-relationships and relative contributions of genetics, other enhanced forest management practices, forest protection, and basic silviculture programs;
- Determining acceptable error and uncertainty – "how good is good enough?";
- Risk assessment and management.

The insights provided by this exercise could go a long way to providing incentives and strategic directions for post-harvest stand management. This would especially be so if the investigation were accompanied by dialogue leading to a better consensus on the following issues:

- Role of intensive versus extensive management;
- Objectives versus rule-based regulation of silvicultural performance;
- Growth monitoring, versus regulatory regeneration surveys versus research –finding the right balance;
- Integrated monitoring of genetic gain, growth and yield, and forest health;
- Long term project maintenance and funding.

The results of this dialogue should be conveyed both informally (through briefings) and formally (through documentation of findings and recommendations) to the most senior levels within government and industry.

Facilitator

The scope of the proposed dialogue is similar to and compatible with the "*Foothills Model Forest Resource Management Executive Series".* The goals of the series include bridging the communication gap between scientists and policy makers, and encouraging dialogue between policy-makers from resource-based industries, governments, stakeholders and researchers to ensure research is relevant and applied.

The Executive Series is being promoted by the Foothills Model Forest and funded by FRIAA. We suggest that the Foothills Model Forest be asked to additionally facilitate the proposed dialogue.

Dialogue 3. Education

Rationale

Participants at the conference expressed the concern that foresters are not equipped with the knowledge and awareness necessary to integrate silviculture, growth and yield, genetic and forest health aspects. Doubt was expressed as to whether foresters are receiving sufficient training in some of the basic foundations of forest management (e.g. site, stocking, growth and yield). Education of users was cited as a limitation in the application of decision-support tools like predictive models. There is a puzzling lack of awareness of some of the existing tools available today, and this points to the need for an effective outreach and extension program by educators and others.

The idea of forestry as an integrative discipline involving application of business principles, silviculture, tree improvement, mensuration, pathology, entomology and fire management is hardly new. However, it requires re-assertion in the context of the challenges posed by post-harvest stand management, as well as those posed by specialization within the discipline causing forestry professionals to lose sight of the broader context.

Target Participants

Educators, professional associations, consultants, government, and industry representatives

Desired Outcome

Ensure that through a combination of improved university undergraduate education, post-graduation in-service training, and / or outreach and extension services, forest managers are equipped with the necessary knowledge, appreciation and / or training to integrate relevant disciplines and skills into post-harvest management.

Scope

Examine the adequacy of current education programs relative to skills requirements for:

- Application of growth and yield principles;
- Integration of silviculture, genetics and forest health into forestry planning and practice;
- Management under risk and uncertainty.

Develop changes to university curricula, extension courses and extension services to remedy any current inadequacies.

Facilitator

We suggest that this dialogue should be initiated by the University of Alberta and the Alberta Public Lands and Forest Division Training Section, with input from the College of Alberta Professional Foresters, the Foothills Model Forest, Foothills Growth and Yield Association and Alberta Forest Genetic Resources Council.

Initiation of the Dialogues

We recommend that the 3 proposed dialogues be initiated by a facilitated meeting of senior representatives of the following organizations currently active in the implementation or support of growth and yield programs:

- Foothills Growth and Yield Association, Alberta Forest Genetic Resources Council and other cooperatives;
- Alberta Sustainable Resource Development;
- University of Alberta;
- Canadian Forest Service;
- Forest Resource Improvement Association of Alberta.

The objective of the initial meeting will be to

1. Obtain agreement on the 3 dialogues;
2. Confirm what agencies will lead and / or facilitate each;
3. Identify required resources;
4. Establish firm plans, timelines and accountabilities for completing the dialogues.

Given the Foothills Model Forest's successful organization of the initial Conference, and its relevant experience and credentials, we intend to request the Foothills Model Forest to administer and facilitate the meeting,

Dick Dempster, Director, Foothills Growth and Yield Association
Cliff Smith, Chairman, Alberta Forest Genetic Resources Council
June 2006

12. APPENDIX - DVD

Further details, including full reports of the breakout groups and poster abstracts can be made available on request and will be circulated to conference participants on DVD.