GROWTH MODELLING STRATEGY

Industry Research Requirements

Growth Modelling Steering Group Industry Members

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1. INTRODUCTION

Background

The forest industry relies on estimates of yields; yields of log products, of wood fibre and of carbon, when making decisions about forest management, investment, acquisition and disposal, marketing and supply chain management. Growth models are essential components of the yield estimation process.

The forest industry needs a *P. radiata* growth model, or models, for generating yield estimates; right now and for the foreseeable future. Industry members are comfortable with pooling resources and collaborating on data collection, on research directed at building models that address future needs and on development of models to use today, as evidenced by their participation in the research co-operatives.

Over the past several years, modelling has been carried out by various research coops to varying degrees, and in relative isolation. With the impending amalgamation of the Coops into FFR, expected next October, the NZ forest industry perceives a need for modelling research to be more coordinated and focused.

A Growth Modelling Steering Group, comprising representatives from industry and Ensis, met on 26th February of this year to initiate discussions on these topics. Material and views were presented, and it was agreed that a consensus should be sought through an email forum among industry representatives.

This paper is the result of these discussions. It presents the key features that industry requires in a growth model, reviews the current status of growth models in use, and suggests a workplan for future research.

Growth modelling defined

For the purposes of this exercise, a growth model is defined as a set of functions and algorithms that simulates the growth of trees. Tree growth is here defined as the projection of diameter, height and frequency through time.

It is acknowledged that industry is interested in projections of other attributes, such as wood quality, branch size and resin occurrence, and that ultimately a growth model may incorporate these auxilliary functions. However, for the purposes of this exercise, industry wishes to focus on the narrower definition of tree growth.

Growth models are normally implemented in software along with other models; for example volume functions, thinning algorithms and log making algorithms. In this context, the term growth model does not refer to a software implementation or to the other models in that implementation. It refers simply to functions and algorithms for simulating the growth of trees.

This report is confined to NZ *P. radiata* growth models. However, this does not preclude these principles from being applied to growth modelling for other species.

2. GROWTH MODEL REQUIREMENTS

Industry view

The SGMC has recently surveyed members as part of a strategic review of modelling. The questionnaire response indicated that any new model should:

- Be empirical
- Include both individual tree, distance independent and stand level functionality
- Include recently collected data
- Be regionally based, and/or responsive to freely available site variables
- Cover ages 5-40, provided accuracy is not compromised.

Empirical models, as opposed to process or physiological models, were favoured simply because the method is proven and presents the only reasonable approach to generating useful models in the foreseeable future, in the view of the members. Future models might use different methods but members felt these methods aren't ready for mainstream use yet.

Requirements

To be generally useful today, a *P. radiata* growth model or suite of models must:

1. Be able to grow and retain the identity of individual trees provided as input;

2. Be usable from age 5 to age 40;

3. Be usable across the full range of NZ *P. radiata* sites;

4. Be sensitive to the effects of silvicultural modification across the range of regimes commonly found in the current crop;

5. Be responsive to genotype

6. Use input variables that are readily available from inventory measurement itself, or easily generated from knowledge of the location of measurement;

7. Engender confidence in the predicted yields.

Each of these points is expanded on below.

Growing and retaining identity of individual trees

The predominant source of input data for growth models in use today is forest inventory; trees measured on the ground in plots. As a minimum, given a list of trees at the level of an inventory plot, defined in terms of dbh, height and frequencies (/ha), a growth model must be able to provide new values of dbh, height and frequency at another age.

Retaining the identity of input trees is important because we want to be able to feed downstream models (such as bucking, thinning, and wood property models) with data at the lowest level it was collected. It would be the function of the downstream models to determine at what level to use the data. For example, it may be that:

a) the tree-level data is complete and can remain with the individual tree (eg species, pruned height, defects, mid rotation diameter distribution),
b) the tree-level data is incomplete and requires values to be calculated for unmeasured trees or the stand (eg standing tree velocity measures), or
c) the tree-level data is complete but would benefit from redistribution across the stand (eg pre-age 5 diameter distribution).

Growth throughout the rotation

Inventory data is collected at all ages and a model must be able to project this data from age of measurement to end of rotation. A practical range would be from age 5 to 40 for P. radiata.

It is acceptable to splice together functions that cover age ranges, provided this can be done in a way that is transparent to users, does not require choices on the timing of the splice point and does not generate discontinuities.

It is highly undesirable to have to use different models to grow from different start point ages to the end of the rotation. The main problem is that the different models will produce different answers when used over the range of ages that they have in common and this difference destroys confidence.

Full range of sites

Historically, site differences have been accommodated by building regional models. However, growth modelling regions are not well defined.

Industry preference is for a national model with readily available environmental inputs defining the site, rather than region.

The recently completed LENZ layer (Land Environments of New Zealand) would seem to be perfectly suited. It combines climate, landforms and soils into a single classification. These variables were selected based on their influence on forest growth and environment. The coverage is nationwide, and available in GIS format.

Full range of silviculture

A growth model needs to be responsive to a full range of silviculture.

This is necessary to allow the growth model to be used, for example, as a management tool to examine different silvicultural tending options, one of its historic strengths.

Being sensitive to the effects of silviculture is not the same as being able to simulate silviculture. For example, thinning reduces the number of trees and increases their average size. A growth model needs to be sensitive to the change in numbers and size when simulating the growth of the surviving trees but it does not need to be able to estimate the change in number or size caused by thinning. That is the role of a thinning model. Growth models and thinning models are often implemented together in the same software but they are different models.

Genotype

A growth model should be responsive to changes in genotype, where such changes have proven impacts on growth.

In practice, this is less important when projecting growth in the mid- to later stages of a rotation because it is felt that the impacts of genotype are largely captured in the measured starting points (though this has been considered debatable).

Input variables

Current standard inventory practise includes measurement of dbh, height and stocking (/ha). A model should avoid dependence on other variables, for example crown height, unless those other variables can be estimated from knowns (e.g. pruned height), or can be shown to significantly improve the model. A model might use an extra variable if it is available but should not depend on it. Doing so would mean that you couldn’t use such a model on old data.

Variables that might reasonably be generated from knowledge of the location of the measurement include altitude and latitude and might include other site factors like soil type or rainfall. Industry, when it agrees on a growth modelling strategy, needs to decide what it is prepared to have available as inputs.

Confidence

A growth model needs to engender confidence in its predictions.

Confidence killers include:

- Too many arbitrary choices resulting in different answers e.g. choosing age at which to make transition between models, choosing model or region for regional model sets or choosing site indices. To some extent the arbitrariness is handled at an organisational level by choosing once and sticking with the choice but this solution starts to break down as the boundaries between organisations dissolve. As much as possible, inputs should be measureable or objectively determined.
- Contradictory results between different models projecting from the same starting point.
- Demonstrably unrealistic behaviour for any set of inputs likely to be found in inventory e.g. very high or low stocking
- Results that are demonstrably different to "reality"
- Models that are not perceived to represent the current crop.

An industry approach to growth modelling should aim for the minimum possible number of models to serve the predominant uses, with all inputs able to be objectively and unambiguously determined and should include validation, behavioural testing and other confidence building exercises.

It is acknowledged that different users will have differing modelling requirements. A silviculture manager wants software that facilitates regime analysis, while a harvest planner requires late-rotation yield estimates with high resolution with regard to log characteristics. They might benefit from different software implementations but ideally they would use the same growth model and they should not be forced to use different growth models simply because they need different software or because they have inputs at a different level of detail.

The key point here is that, whatever model or modelling system is used, it needs to give consistent answers across a range of forest management applications.

This can be illustrated by an example of a situation that we wish to avoid:

A forest manager uses one model to do cost-benefit studies on various tending regimes. He bases his decision on the regime that shows the greatest return on investment. This return has been calculated using yields by log grade that have been forecast by the model. A forest valuer then comes along and constructs yield tables for the same resource for valuation purposes. He uses a different model that may be better suited to his purpose, but that gives a different answer.

End result: the valuation is now possibly inconsistent with the regime analysis.

Development and maintenance

To ensure that any model that is developed is relevant to 'current' growing inputs, and to ensure that any model can be kept up-to-date, an appropriate number and distribution of 'permanent growth plots' needs to be maintained throughout the nation, to cover the range of environmental and other factors deemed to be important in modelling growth. To enact this, a coordinated national strategy and plan for a permanent growth plot program is required, so that growth models into the future are current and representative.

3. CURRENT STATUS OF COOP MODELS

SGMC state space models

These predict at stand level and cover the full rotation. They do not grow trees. Confidence in the state space models depends on region but in general is suffering because of the age of these models. The most recent updates were 17 years ago with some models being a full rotation out of date. Some of the models can utilise auxiliary inputs, e.g. foliar nitrogen, but do not depend on these.

SGMC individual tree models

These are pure individual tree models. They can not be used safely below age 15, perhaps older, and thus do not satisfy the requirement of covering the whole rotation. They are currently used in both pure form and constrained by stand models. Various functions are from 6-10 years old, although the data used to derive the functions are of the same vintage as those used for the state space models. Confidence in these models suffers mostly because they produce different answers to the state space models.

PMC 300 index model

This is a partially complete national stand level growth model. It does not have tree level growth components and currently lacks a mortality function, although use can be made of existing functions from other models. Despite the name, the model does not require an explicit productivity index; this can be estimated from inputs.

The 300I model appears to require a complete history of stocking changes prior to measurement of input data. These inputs will not always be available and/or will be inconsistent with measured inputs (unthinned parts of nominally thinned stands).

Simple tree growth functions

Users of the current stand models (SGMC state space and PMC 300I) are able to model stand growth and distribute this amongst trees using simple allocation models. Some work by SGMC shows that these simple approaches can have problems over long periods of time; in particular, they under-estimate diameter variance.

Summary

Neither co-operative, on its own or combined, has a complete model that meets the stated requirements.

4. WORKPLAN FOR FUTURE RESEARCH

Short term objectives

It is the view of this group that the immediate priority of the combined research organisation should be to produce a growth model or models that meet the above requirements and cater for predominant uses. These models should be ready for implementation by June 2008.

Readiness implies validation, behavioural testing, comparison with existing models and other confidence building exercises.

There is every reason to use existing functions and algorithms provided they are adequate. Indeed, it is considered desirable to consolidate existing functions and algorithms before progressing further research.

Current workplans

The continuing workplans of the PMC and the SGMC were reviewed. Five current projects were identified as contributing to the short term objectives:

Project	Title
PMC 4.02	Projection of a tree list
SGMC 2.1	Implementation and testing of silvicultural years individual tree model
PMC 4.03	National mortality function
PMC 5.13	Extension of 300 index model to wider range of sites
SGMC 2.4	Future modelling strategy

PMC 4.02 and SGMC 2.1 address the same issue, which is the growth of individual trees, however the SGMC approach addresses too narrow a range of ages to be useful.

The combined workplans of both co-operatives are not sufficient to meet the stated short term objective, without revision. It is likely that additional work will be required, and it is accepted that the resources for this may have to come out of projects with a longer research horizon.

Recommended workplan priorities

The Growth Modelling Steering Group recommends a future research workplan along the following lines:

Category	Description	Due by

Short term (H1)	• Data provision:
	  o Continue measurement of PSPs and trials currently managed by SGMC and PMC.
	  o Rationalise current data set, and develop strategy for strengthening national coverage.
	• Confirm model requirements:
	  o Be able to grow and retain the identity of individual trees provided as input;
	  o Be usable from age 5 to age 40;
	  o Be usable for the full range of NZ *P.radiata* sites;
	  o Be sensitive to the effects of silvicultural modification across the range of regimes commonly found in the current crop;
	  o Be responsive to genotype;
	  o Use input variables that are readily available from inventory measurement itself, or easily generated from knowledge of the location of measurement;
	  o Engender confidence in the predicted yields
	• Complete one model package that meets the above requirements.
	• Validate and test model
		June 2008

Medium term (H2)	• Complete crown model and incorporate into growth model package • Refit model with up-to-date data • Continue internal stem modelling research • Extend model to age 0 • Incorporate disease, nutrition effects	??
Long term (H3)	• Clonal growth • Physiological process models	??

Summary

It is Industry's view that the focus of growth modelling research in the short term, i.e. over the next 12 months, should be on consolidating the current available knowledge, functions and algorithms into a single growth model (or suite of tightly integrated and consistent models), which is then subjected to validation and testing.

New work proposals should be judged against this framework.

Growth Modelling Steering Group – Industry Members

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