COOPERATIVE RESEARCH CENTRE
FOR SUSTAINABLE PRODUCTION FORESTRY

Parameterisation and application of 3-PG as a management tool for *Eucalyptus grandis* in South Africa – report on a visit to the Institute for Commercial Forestry Research, August-September 2003

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Project B4: Modelling production and wood quality

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1. Introduction

This document is based on a report to Colin Dyer, Director of the Institute for Commercial Forestry Research (ICFR), Pietermaritzburg, South Africa, of a four-week visit I made to the ICFR in September 2003 as part of an Agreement (see Background, Sec. 2) between the ICFR and the CRC for Sustainable Production Forestry (CRC SPF). It provides a brief overview of the purpose of the trip (Sec. 3), realised and pending outcomes (Sec. 4), and recommendations I made to the ICFR (Sec. 5). Finally, I identify ongoing work and opportunities for further work arising from this visit (Sec. 6).

I feel confident that my visit provided valuable input to the modelling work of the ICFR. In particular, it has enhanced the skills Luke Esprey can bring to bear on future modelling work at the ICFR. I do not wish to imply that all problems have been solved! Rather, I see my visit as having enabled the in-house solution of problems, and having built bridges for further collaboration.

2. Background

In 2000 the ICFR and CRC SPF negotiated an Agreement for the exchange of data and collaborative work between the two parties to adapt and develop the site productivity model PROMOD for *Eucalyptus grandis* in South Africa. The Agreement runs until 30th June, 2004.

The ICFR agreed to provide, on a confidential basis, data on the growth, soils, climate and silvicultural history of *E. grandis* plantations, to provide the travel costs for a CSIRO scientist to visit South Africa to work on the project for a period of up to 1 month, to provide funding and supervision for a PhD student registered at a South African University to work on the project, and to provide funding for the student to visit Hobart for a period of 2 months.

The CRC agreed to provide, a working copy of the model, a scientist to act as joint supervisor of the PhD student, and to fund the travel costs for an ICFR scientist to visit the CRC for a period of up to 1 month.

Subsequent to this Agreement the following milestones have been achieved

- after a detailed review of alternative models, the ICFR decided to switch the choice of model from PROMOD to 3-PG

- Mr Luke Esprey commenced work on the project as a PhD student registered at the University of Durban under the supervision of Dr Norman Pammente,

- Luke and Dr Colin Smith of the ICFR visited the CRC SPF and various CSIRO FFP laboratories, and

- I have acted as (unofficial) joint supervisor and mentor to Luke.

My visit to the ICFR and the work covered in this Report is another major milestone in this Agreement.

3. Objectives of visit to ICFR

The broad objectives of the visit were to

- provide advice and technical support pertaining to the adoption of 3-PG as a tool for forest management in South Africa,

- identify/develop modifications to 3-PG to enhance its use as a management tool,

- develop/apply technologies for estimating the species-specific parameters required to apply 3-PG for a range of species, and

- provide guidance and mentoring to Luke Esprey.

The focus of the trip was more to enable local (ICFR) staff to understand and apply high-level tools for estimation of species-specific 3-PG parameters, than to resolve all issues identified.

4. Outcomes

The following is a summary of outcomes:

- A talk entitled "*Process-based Models for Forest Management*" was presented to ICFR and local timber industry staff at the ICFR, and to Mondi Forests. It has been published as an ICFR Technical Report.

- An EXCEL software tool (PESTXL) was developed to enable use of the parameter estimation package PEST and the EXCEL implementation of 3-PG to estimate 3-PG species-specific parameters.

- General guidelines for estimating 3-PG parameters were developed, and significant progress was made on parameterising 3-PG for *Eucalyptus grandis.*

- The following modifications to 3-PG were identified as critical:
  a) inclusion of random and stress-related mortality, and stress-related litterfall
  b) improved treatment of light interception by open canopies
  c) consideration of downwards root growth with tree water-stress based only on water available in the rooting zone
  d) effects of stand stocking on biomass partitioning and stand attributes.

- Formula were developed and implemented in 3-PG for
  a) random (age-related) and potentially stress-related stem mortality
  b) effects of stem number and stand-mean stem diameter on stand attributes such as height and total or utilisable volume
  Work on other modifications to 3-PG is pending.

- The prototype of an objective tool for assigning site-specific initial biomass data for use when predicting stand growth with 3-PG was developed.

- I attended and contributed to Innovation Fund Project technical meetings, and a Mondi Forests technical meeting.

- Discussions were held with Luke Esprey and Dr Norman Pammenter with respect to the content of Luke's PhD project and its execution.

I am preparing an extended document covering details of more technical aspects of my work at the ICFR, including: various (implemented and proposed) modifications to 3-PG, the stand initialisation technique, techniques and protocol for parameter estimation, and comments on the Innovation Fund Project and the proposed 3-PG-based management system. This will be available early October.

5. Recommendations to ICFR

The following are (unsolicited) recommendations to the ICFR and the Innovation Fund Management committee.

- The software tool PESTXL be further developed and documented to enhance its generality and ease of use, and to be made available as freeware.

- Parameter estimation in the first instance focus on only a few carefully targeted species, and estimation for further species be commercial ventures of the Innovation Fund Project.

- In a similar vein, the range of silvicultural options that are considered should also be carefully focussed, with additional options as commercial ventures of the Innovation Fund Project

- The Innovation Fund Project should create markets based on on-going application of its software and other technical expertise, rather than on sale of software.

- The ICFR should make every effort possible to obtain from its own archives and forestry companies the data required for further development and testing of 3-PG and for parameter estimation for diverse species. Draft guidelines on the data required for specific purposes were written, and should be considered for inclusion into protocols for collecting data from existing and future trials.

- The ICFR and the CRC for Sustainable Production Forestry should consider further collaboration on the application of process-based models to forest management.

- I should be formally confirmed as a co-supervisor of Luke Esprey's PhD project and will continue advising him on his project.

6. Opportunities for future work

The following are potential outcomes directly arising from my visit with a high probability of realisation. They fall within the overall objectives of CRC Project B4, and at least one is consistent with my 2003-04 APA objectives.

a) Expansion of the ICFR Technical Report of my talk as an invited review article in Southern Africa Forestry Journal.

The ICFR is keen for this to happen. However, issues for me are (i) the added time needed to convert what is essentially a verbal presentation into a more formal journal article, and (ii) a feeling that the work is more appropriate for publication in a general modelling journal such as Ecological Modelling.

I suspect (i) will the quicker and easier route to take.

b) Development, documentation and release of PESTxl as freeware.

A personal objective in my 2003-04 APA is the development and application of parameter estimation techniques for process-based forest growth models implemented as spreadsheets. These tools will facilitate our work with 3-PG, PROMOD, CABALA and the blackwood model, and any other spreadsheet-based model the CRC or FFP develops. They will provide a sound basis for application of parameter estimation techniques either in-house or on a contract basis. A contract with Aracruz to rigorously characterise differences between 3-PG parameter sets for *E. grandis* clones is highly probable.

Accordingly, I propose this work be continued as follows:

- Complete the development and documentation of PESTXL as a user-friendly tool for estimating parameters in spreadsheet-based models.

- Compare and contrast the use of PESTXL with techniques based on the use of the commercial optimisation packages SOLVER and EVOLVER.

c) Development, documentation and release of an enhanced version of 3PGPJS. This would include both updates to the model to resolve issues such as those listed below, and changes to the 3PGPJS interface to facilitate parameter estimation.

It appears 3-PG will not die an early death! I believe it will be the default process-based model for forest management, because (i) it is freely available, and (ii) it is inherently simple. However, it has various significant limitations, and it is important the Division/CRC ensure the integrity of 3-PG, especially for its own use. Issues that I feel are both significant and probably reasonably easy to rectify include:

- *Light interception in partial canopies*: The Jackson and Palmer formulation for open canopies should be implemented. This should improve representation of light interception pre-canopy closure and post thinning.

- *Modelling water uptake by roots*: Water uptake should be limited to the rooting zone, and the downward growth of roots coupled to the rate of root biomass growth. Consideration should also be given to including evaporation from the soil or understorey in open canopies. This should improve the manner in which 3-PG represents and responds to water stress.

- *Potential effects of tree spacing on growth*: Potential effects of spacing on the allometric relationships underlying biomass partitioning should be considered. This should improve the response of growth and partitioning to spacing, and perhaps also the thinning response. Effects of spacing on stem volume and height:diameter relationships should also be implemented.

- *Stress related mortality and litter production*: Mortality and litterfall currently do not depend on stress factors. At the very least, these processes should be linked to soil water stress.

- *Soil C and N cycling*: 3-PG lacks any consideration of C & N pools in the soil. Existing models that can be implemented include Century and Rothamsted C.

d) Development of a simple technique for estimating the data to initialise predictions of stand development.

While at the ICFR I had extensive discussions around a technique for determining site-specific initial biomass data based on the use of 3-PG to predict a measure of site quality that is only weakly affected by the choice of these initial conditions. My proposed technique appears to be valid in principle, and success will have important implications to the use of 3-PG, and perhaps also other process-based growth models such as CABALA, for predicting stand growth and development as part of tools for forest management.

- Luke Esprey will be furthering this work as part of his PhD project, and I will continue to liase with him on this issue.

7. Acknowledgements

Peter Sands
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