

Refining the Sustained Yield Calculation: Modelling Processes to Address Social and Production Issues on State Forest in Tasmania

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Abstract

Forestry Tasmania is a Government Business Enterprise that administers a land base of 1.502 million hectares. The land base is a diverse mix of reserved and production native forests, hardwood and softwood plantations. Forestry Tasmania has a legislated requirement to make available 300 000 m³ of high quality eucalypt sawlogs per annum.

Forestry Tasmania's current management strategy has evolved from the Tasmanian Forest and Forest Industry Strategy of 1990 and the Regional Forest Agreement (RFA) in 1997. This evolution has been in an environment where recognition of the needs for conservation and sound forest practices have resulted in significant areas of forest being withdrawn from wood production and included in conservation reserves. At the same time wood production operations on the remaining land base have become increasingly regulated, further constraining wood production flexibility.

Forestry Tasmania has a long track record in leveraging technology to explore opportunities and risks. The RFA five-yearly review of sustainable yield in 2002, referred to as the Wood Review, and subsequent projects examining the impact of spatial issues on sustainable yield, signals further improvement in the use of technology to inform a range of forest managers.

The paper examines approaches to quantifying management complexity by reference to some recent modelling projects:

- The Wood Review 2002 was underpinned by a complex model that included native forest and plantations, managed under various silvicultural regimes. It was a single model for the whole state and the discussion will focus on the benefits of this approach.
- Although 86% of old growth forest in Tasmania is formally reserved or unlikely to be logged, the remaining coupes of old growth is still a contentious issue. We will discuss our approach to refining our understanding of management options for future sawlog production versus maintenance of key old growth elements.
- Intensive forest management - plantations and commercial thinning of native forests - is an important strategy for future high quality eucalypt sawlog production. However environmental and burning restrictions are important issues in the establishment of these areas and hence forest management on a broad scale. The example touches on issues and outcomes.

Keywords: sustained yield, forest estate modelling, spatial harvest planning, optimisation, heuristic, old growth forest, forest practices code

The Wood Review 2002

Background

In November 1997, the State of Tasmania and the Commonwealth of Australia signed a Regional Forest Agreement (RFA) for Tasmania. The RFA set aims and objectives for forest management of both private and public land for 20 years.

A key element of the RFA was the five-yearly review process. For the initial agreement, the State produced a view of the sustained yield of high quality (eucalypt) sawlog. It agreed to review this every five years. In both instances this task fell to Forestry Tasmania.

Forestry Tasmania is a Government Business Enterprise that administers a land base of 1.502 million hectares. The land base is a diverse mix of reserved and production native forests, hardwood and softwood plantations. Management within the remaining land base is a continuing challenge for an organisation that has clear commercial goals, but is subject to more public interest consideration, both through legislation and the political process, than a private commercial entity.

An underpinning of forest management on Crown land is the legislated requirement to make available 300 000 m³ of high quality eucalypt sawlogs per annum.

A Profile of Forest Management

Forestry Tasmania's current management strategy has evolved from the Tasmanian Forest and Forest Industry Strategy (TFFIS) of 1990 (Forests and Forest Industry Council of Tasmania, 1990), and the RFA in 1997. This evolution has been in an environment where recognition of the needs for conservation and sound forest practices have resulted in significant areas of forest being withdrawn from wood production and included in conservation reserves. At the same time wood production operations on the remaining land base have become increasingly regulated, further constraining wood production flexibility.

In 1982 about 13% of Tasmania's land area was reserved. By 1990, after the TFFIS and other land use policy decisions, this area increased to 21%. At this time 1% of State forest was formally protected in forest reserves. Post RFA, some 40% of Tasmania is now in formal and informal reserves. This level of reservation has had a substantial impact on the available wood production capacity from State forests, as much of the increased reserve area has been from the State forest estate. Now, 12% of State forest is in formal forest reserves. Post RFA, the area potentially available for wood production within State forest is some 17% of Tasmania.

Consequently, the inventory, or standing volume, of wood available has been progressively reduced. The reduction in standing volume limits the options for meeting wood yield requirements, and maintenance at pre-existing levels requires the growth of wood resources at a rate higher than relatively unmanaged forest will produce. Formal review processes have, over the last fifteen years, reduced the available sawlog supply by 25%.

Maintenance of existing levels thus requires more intensive management to improve forest growth and productivity through thinning and plantations, on parts of the remaining

productive State forest land base. However this must occur in a more restricted operating environment.

In the TFFIS and RFA wood reviews, assumptions (matched by on-ground implementation) on more intensive management have been incorporated to improve productivity and maintain long term wood production to support the Tasmanian forest industries. The TFFIS included thinning options, and the RFA provided for a plantation program to augment future production.

The Forestry Growth Plan of 1998 defined a forward wood production plan from the RFA. The objectives of this Plan were to:

- ensure the supply of 300 000 m³ per year of high quality eucalypt sawlogs in perpetuity;
- develop a world scale, internationally competitive plantation resource; and
- develop new value-adding markets for Tasmanian wood products.

Forestry Tasmania has energetically pursued a strategy of Intensive Forest Management (IFM) since the RFA to build a world scale estate. Since 1998 about 15 000 hectares of hardwood plantation have been established, and 4000 hectares of native forest have been thinned, on State forest land. In parallel, there has been a surge in investment in eucalypt plantations by private companies. These achievements are detailed in the RFA indicators report (Anon., 2002). However, private plantation owners are not obligated to produce high quality sawlog, and much early planting has been specifically focussed on the production of short rotation pulpwood.

As in the initial post-RFA review, a significant area of the future plantation land is anticipated to come from replanting of suitable land following harvesting on State forest. This area is now reduced in total as a result of both environmental and site suitability considerations.

Forestry Tasmania is committed to the maintenance of natural forest cover as provided for in the Permanent Forest Estate Policy. The RFA indicator report (1.1.a) confirms that the requirements of this policy are being met on State forest. Forestry Tasmania anticipates it will be able to meet all its obligations in maintenance of the permanent forest estate, yet have sufficient land available for IFM to meet its wood production goals.

The Forestry Tasmania Eucalypt Resource - A Brief Description

Native forest is managed under a number of silvicultural regimes depending on the forest type and altitude.

In wet eucalypt forest the predominant silviculture involves clearfell harvesting, followed by burning and aerially sowing seed to successfully regenerate the forest. The estimated rotation age is about 90 years under this regime.

Dry eucalypt forests, or forests at high altitude, are predominantly cut using partial harvesting systems, employing a range of silviculture, including seed tree, shelterwood, potential sawlog and advance growth retention (Forestry Commission Tasmania, 1994). A rotation is less well defined, but the initial partial harvest, and a number of the subsequent stages of partial harvesting will occur in a 90-year time horizon.

As part of the IFM strategy, some previously regenerated native forest on productive, flat sites will be thinned over the next 15 years. The reduction in competition between remaining trees after thinning will accelerate stem growth and result in a reduced rotation age of about 65 years.

Plantations will be established under one of two regimes, using *Eucalyptus nitens* or *E. globulus*, either low pruned or high pruned. It is assumed 15% of area planted will be suitable and high pruned to produce high quality sawlogs. On the remaining area trees will be low pruned only. From all plantations a variety of logs suitable for solid wood products, and pulpwood, will be produced.

A Consolidated Review for a Diverse Resource

The process of completing a resource review of sustainable yield is described in detail by Whiteley (1998). However, strategic models are relatively simple formulations, only broadly incorporating tactical and operational planning issues. The complexity of operational decisions has precluded inclusion in the strategic analysis. In any event, the data to adequately describe such complexity is usually limiting.

The first challenge is to describe the forest in terms of area and yield. Besides inventory, logging calibration (recovery), forest stratification (photo-interpretation (PI) typing) and growth models, which are all non-trivial investments in such a diverse estate, the process of 'couping up' to create 'provisional' coupes has been a key element in describing the area. Couping up identifies large areas of unproductive or unavailable forest and provides a link between operational and strategic planning.

The basic operational unit for timber harvesting is a coupe. Forest zoned as available for harvest has been mapped into provisional coupes, as if they were to be harvested in the near future. The mapping is the responsibility of the operational planning staff. The area of forest that is important for commercial wood production is estimated, although within this, further discounts are applied.

The second challenge is to combine the data into a model that adequately represents the forest and can run scenarios in a reasonable time frame. Our insistence on the coupe-based approach over long time horizons creates significant mathematical difficulties for commonly available linear program (LP) models. In the 1997 review, model size was reduced to the software limitations, by running at the supply zone level.

Nonetheless, for the 2002 review a single statewide coupe-based model, combining all the forest types and regimes, was successfully run. The problem was formulated in the product 'Woodstock' (Remsoft Inc., 2002) and the interior-point LP optimiser 'Mosek' (EKA Consulting ApS, 2001) provided the solution.

Discussion of Wood Review Outcomes

This five-yearly review built on previous work, and reconfirmed Forestry Tasmania's ability to make available at least 300 000 m³ per year of high quality eucalypt sawlogs for the next 90 years.

There were a number of benefits achieved by formulating a single model for the whole state:

- Consistency in model preparation. The same assumptions and rules framework were applied everywhere, thus ad-hoc adjustments that lead to separate models diverging were avoided.
- Flexibility in model solution. A single problem matrix enables the LP optimiser to consider all options to meet constraints.
- Efficiency in modelling process. In the 1997 review different staff ran each supply zone model. In the 2002 review one person built and ran the model.
- Improved reporting, both in terms of detail and speed. More forest management factors were modelled than ever before, with the final result available in a single location for subsequent query, analysis and reporting.

The outcome of the review was pleasing, and the process a significant improvement on prior practice.

Building the Spatial Picture at the Strategic Level

Defining the Space in Which to Work - Couping Up

In the early to mid-90s, Forestry Tasmania made a significant investment in operational planners' time to describe the forest that was or would be suitable for harvest. This decision, known as couping up, identified harvest units called provisional coupes. Provisional coupes were recorded as a GIS layer.

The provisional coupe has become an important feature of our planning system. It is particularly valued in the following two roles:

- Tactical and operational plan preparation. The principal tool for this planning is the PROVCOUPE database, which incorporates all coupes and a broad range of timber and other management attributes for each of them.
- Strategic wood planning. These plans are based at the coupe level, providing a link to tactical and operational planning processes.

Spatial Planning Using the Coupe

The coupe is a spatial entity. However, its use spatially, that is its relation to other coupes, is limited by the processes that are available to understand the complexity of the situations that invariably arise.

To date, operational planners provide Forestry Tasmania's spatial processing power. However, the power and attention span of the human mind is somewhat limited in its ability to iterate the multitude of options for long time periods that could be usefully considered.

The spatial planning paradigm from North America, where we have sourced our software, builds spatial plans using finer level detail than the coupe. A predetermined coupe layer does restrict analysis of potential options. However, it is of interest to note Nelson & Davis (2002) discuss reducing the amount of spatial detail in models; the result suggested in Figures 8 and 9 of their paper bears somewhat of a resemblance to Forestry Tasmania's coupe layer.

The Future of Strategic Planning - Incorporating the Spatial Element?

It is the authors' view that a better understanding of spatial issues will more fully inform a range of decision makers. The challenge is to do this in a meaningful, but not overly detailed way.

Five years ago, Forestry Tasmania's use of the coupe in strategic wood planning gave us a greater confidence in the outcome than using a forest structure (forest class) approach with non-discriminatory discounting processes on the volumes.

The difficulty with strategic models based on linear programming, or like processes, is that the number of constraints that can be input are both finite and tedious to compile. Spatial optimisation represents a vast problem array that cannot be represented in this way, and rudimentary methods that can access the problem matrix and report the spatial arrangement of a particular solution via a derived GIS adjacency file are about the best that can be expected. The value of this output is limited.

To see if we could develop a better spatial view of our strategic model, at least in the next ten to twenty years, Forestry Tasmania has been trialing harvest block scheduling software called 'Stanley' (Remsoft Inc., 2001). Stanley uses heuristic (approximation) algorithms, rather than a LP optimiser.

We offer two examples to illustrate our thoughts thus far.

An Attempt to Electronically Build an Alternative Coupe Layer - Redefining Old Growth Coupes

Background

Old growth forest, for the purposes of the RFA, is described as ecologically mature forest where the effects of disturbances are now negligible.

The RFA recognised about 1.241 million hectares of old growth in Tasmania. Approximately 11% of this was on private land. On State land, approximately 154 000 hectares of the native forest in coupes is RFA-defined old growth. This represents about 12% of all old growth forest in Tasmania on public and private land.

Although signed off in the RFA, with significant understanding of its importance for sawlog production, the subject "clearfelling of old growth" has become a focus for anti-forestry groups. This has, in particular, reached a crescendo in the 'Tasmania Together' process, a community-based set of benchmarks for Tasmania developed under Government sponsorship.

Tasmania Together has been a launching pad for more conservation claims, even though "High Conservation Values were an explicit focus of the RFA, using nationally agreed criteria for the development of a Comprehensive, Adequate and Representative (CAR) Reserve System" (Drielsma, 2002), and the outcome of this assessment was formally agreed to by Tasmanian and Commonwealth governments.

Discussion

The most difficult forest planning issue is that old growth forest is distributed throughout the provisional coupe area as a complex mosaic containing mature and regrowth trees (Figure 1). The implication is that any action that impacts on the old growth will to a greater or lesser extent impact on the accessibility of the surrounding forest.

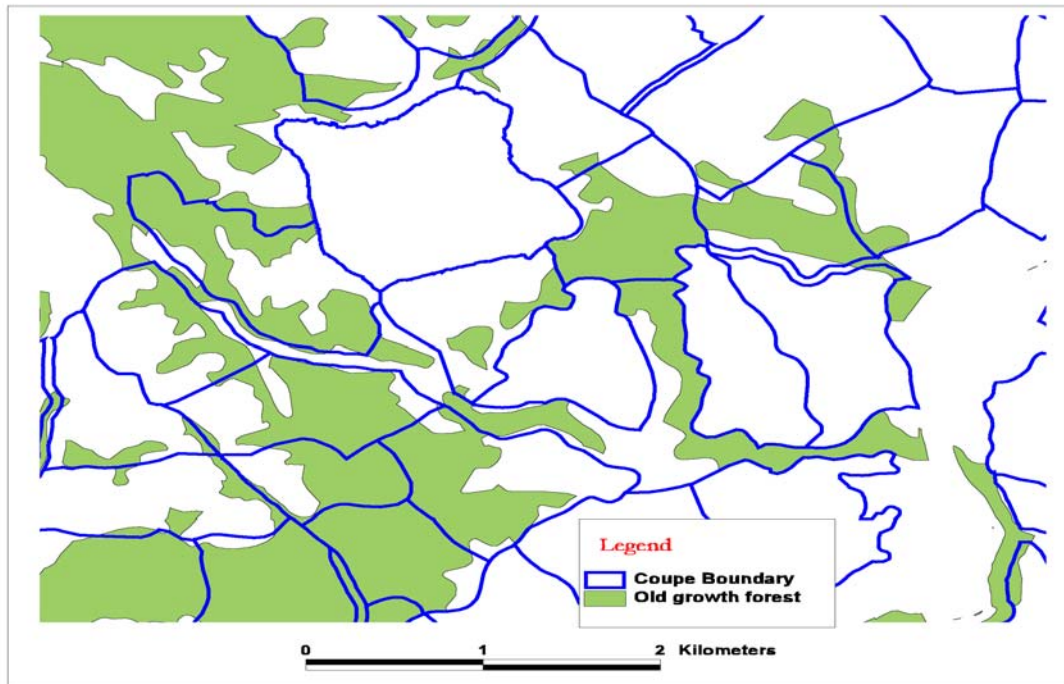


Figure 1: Example of Old Growth Forest Mosaic within Coupes

In building the Wood Review model, the importance of old growth was recognised; each coupe was tagged with a percentage of old growth that it contained. As old growth was a theme within the model, it can be used as a constraint, it can be reported against, or can be remodelled using a new regime. The model is therefore a relatively powerful tool in assessing the impact of simple propositions in a complex environment.

However, to be more credible, a recouped model to group old growth forest from existing coupes to new discrete oldgrowth coupes would be a useful improvement. In this way impacts and strategies can be more fully explored and reported.

In reality this exercise is a prototype for a range of analysis, as it could be applied to a variety of external values that might be imposed over the wood production function. Such values could be biodiversity, water management zones, threatened species, threatened habitat or landscape.

The trial software, Stanley, offered potential as a tool for the task. We thus attempted a process, re-couping the forest using an old growth / non-old growth philosophy. In the finish, we were unable to electronically create a new coupe layer that could be fed directly back into our Woodstock model. We did however come away with a greater understanding of the issues in the process. The realisation was that a project of this nature required many manual decisions, and the software in its current form could only streamline what would still be a significant manual undertaking.

Forest Practices, Silviculture, Fire and Intensive Forestry

In Tasmania, the Forest Practices Code (2000) regulates and guides implementation of forest operations. Typically we are only able to assess post-facto the outcome of a multitude of decisions made under the Code and include them as a discount to available area in various reviews. In addition to the Code, Forestry Tasmania has also developed spatial requirements for managing fire in the locality of IFM stands.

One of the characteristics of models based on LPs is that if area and/or volume is removed, goals can still be achieved, although intuition may suggest otherwise. In a well-constructed and audited model it is unlikely to be a mathematical error, and sensitivity analysis is usually necessary to understand the relative feasibility of a solution. Relatively 'tight' solutions are likely to have less spatial options, and GIS can be used for limited spatial review. However the effort required to print and evaluate any or all solutions in an estate the size of Forestry Tasmania's will soon exhaust the planning resources of most organisations.

Thus operational, tactical and strategic planners need tools that evaluate how a solution meets major spatial forest practice requirements, the cost and availability of roads, supplies product requirements and meets silvicultural or fire protection limitations.

Can we Model the Spatial Constraints of the Forest Practices Code?

In short, yes. This outcome is encouraging, as it allows us to refresh the coupe concept and develop a perspective that will give a greater confidence in the first ten to twenty years of our strategic advice (all other things being equal).

What Elements did The Successful Model Incorporate?

The following 'macro' level constraints were modelled in this trial of Stanley:

- Maximum coupe size; different targets were set for ground-base and cable coupes
- Minimum coupe size
- Target coupe size
- Green up delay; the time period between harvesting neighbouring coupes
- Burning restrictions around the clearfall native forest / IFM interface

Method

Stanley requires input from a strategic planning model like Woodstock, and a shapefile, such that elements in the strategic model are identified spatially.

The heuristic algorithm attempts to achieve an objective, specified by the user, based on an outcome in the strategic model (eg, area or total volume harvested; discounted cashflow). The percentage of the strategic objective achieved by Stanley in the time horizon modelled is known as the 'score'. The score of any model run is impacted by spatial constraints like minimum and maximum harvest unit area, and green-up delay time and distance. The score can be expressed as an alternative wood supply profile. Figure 2 illustrates an example of a Stanley output compared to its primary Woodstock source.

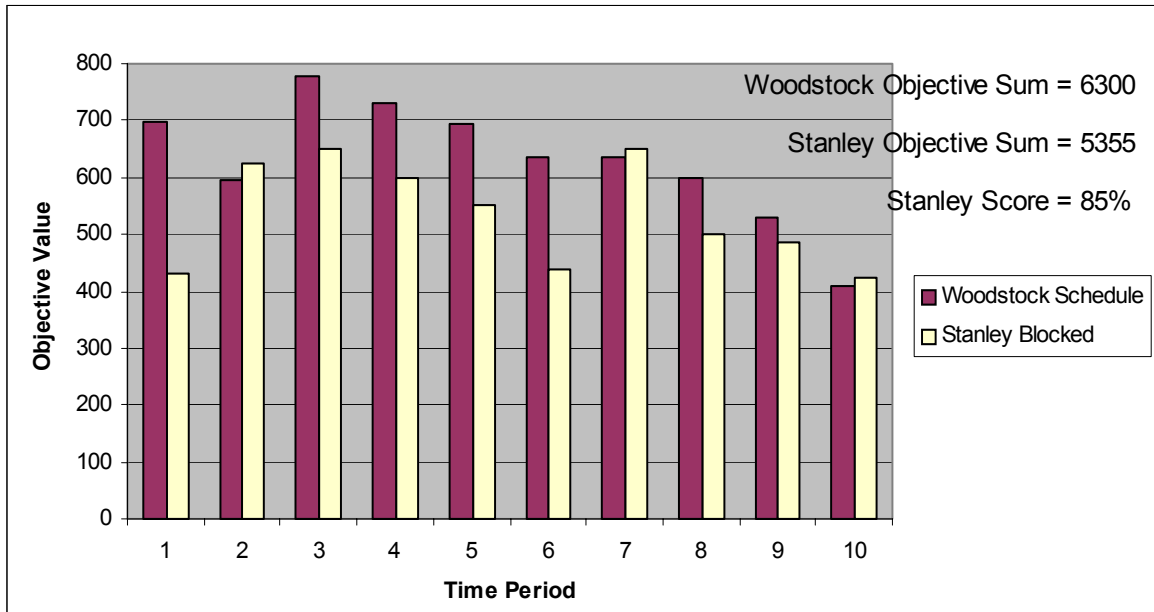


Figure 2: Theoretical Comparison of Strategic (Woodstock) and Tactical (Stanley) Plans

Our modelling required many iterative runs of Stanley, stepwise adding components of the strategic model in a structured priority. For instance, commercial thinning of native forest is considered first to identify harvest units (called ‘blocks’) because the only spatial constraint is a minimum block area of ten hectares. The commercial thinning of native forest is then fixed in space and time (called a ‘preblock’). The next spatial constraints (called ‘userlocks’) are placed around all these preblocks to represent the restriction on clearfelling native forest within a kilometre of commercial thinning blocks for two years before thinning, to three years after thinning.

With the userlocks in place, Stanley blocks clearfelling of native forest, this time applying a five-year green-up delay within 100 metres of neighbouring clearfell areas. This step is further broken down to distinguish different maximum block areas for ground-base and cable harvesting areas, as required in the Forest Practices Code.

At each step there is potential for the score to reduce, as the combination of factors involved interact in reducing the options available for operation within the plan period.

Discussion

Given the different mechanisms in Woodstock and Stanley for handling coupe (ie, Woodstock splits coupes and Stanley can't), and the additional spatial constraints in Stanley, the solutions are unlikely to be the same. At the strategic level, this is not a critical issue; however the range of the solutions and the underlying average provide a useful guide to evaluating the relative risk in adopting various strategies.

The way we have configured our problem using coupe tends to cause lower scores as individual coupes of similar forest type are either included or excluded from consideration in the harvest schedule: ie, we cannot import coupes from outside the time period being blocked to replace ones that have been dropped out of the schedule. Nonetheless, what has been demonstrated is the potential to implement a strategic plan on the ground.

In single periods the spatial scheduling result may be more or less than the strategic plan target, however over the time horizon being blocked scores often cover a range from 50% to 95% in the authors' experience. However no further generalisations can be made, as results are dependent on model attributes. Walters and Cogswell (2002) provide a discussion on this aspect of spatial forest planning.

Stanley has enabled us to quantify the impact of Forest Practices Code requirements on woodflow at the front end of our non-spatial strategic wood plan. Stanley enables us to further explore the sensitivity (cost and opportunity) of various spatial constraints. Stanley allows consideration of a vast amount of information, and the ability to treat it all in a consistent manner, something that very quickly goes beyond any individual manual planner process. Better still, it puts the planner in solution refining, rather than tedious solution creation mode.

References

Anon., 2002. Sustainability Indicators for Tasmanian Forests 1996-2001. Prepared by the Tasmanian and Commonwealth Governments for the 2002 Review of the Tasmanian Regional Forest Agreement. Resource Planning and Development Commission, Hobart.

Drielsma, Dr J.H. 2002. Submission to Tasmania *Together* Progress Board Re: Benchmark 24.2.1.

EKA Consulting ApS, 2001. The MOSEK optimization tools version 2.0 (Build 19). User's manual and reference. EKA Consulting ApS, Copenhagen, Denmark.

Forest Practices Board, 2000. Forest Practices Code. Forest Practices Board, Hobart.

Forestry Commission Tasmania, 1994. Silvicultural Systems. Native Forest Silviculture Technical Bulletin No. 5. Forestry Commission, Hobart.

Forests and Forest Industry Council of Tasmania, 1990. Secure Futures for Forest and People. Recommendations for Tasmania's Forest and Forest Industry Strategy.

Nelson, J., & R. Davis, 2002. Is detail impeding strategic thinking? A critical look at spatial detail in forest estate models. Report prepared for the Interior Lumber Manufacturers Association. March 22, 2002.

Remsoft Inc., 2001. STANLEY 4.5 Users Guide. Remsoft Inc., Fredericton, New Brunswick, Canada.

Remsoft Inc., 2002. WOODSTOCK 3 Users Guide. Remsoft Inc., Fredericton, New Brunswick, Canada.

Walters, K.R., & A. Cogswell, 2002. Spatial Forest Planning: Where did all the wood go? Presented at the INFORMS Annual Conference. San Jose, California. November 25, 2002.

Whiteley, S.B. 1998. Calculating the sustainable yield of Tasmania's State forests. *Tasforests* Vol. 11: 23-31.