Eucalyptus plantations for sawlog production in Tasmania, Australia: optimising thinning regimes

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Abstract

In Tasmania, plantation grown *Eucalyptus globulus* and *Eucalyptus nitens* are managed to produce high quality sawlogs for sawn timber and veneer products.

In contrast to dedicated pulp regimes, sawlog production requires a more intensive approach. Notably, this includes the timely application of thinning operations to ensure adequate piece size over 20-25 yr rotations.

Early plantation sawlog regimes in Tasmania advocated a single intensive thinning from initial stockings of 1100 stems ha^{-1} to a final crop stocking of 300 stems ha^{-1}, around ages 5-6 yrs. Typically, however, this has been delayed until ages 10-12 yrs to increase thinning volumes, and through their sale, provide an early return on the investment.

As the estate has matured, new challenges have emerged, each with consequences for the timing and intensity of thinning operations. These include: contractor availability, machine suitability, site conditions, changing markets, and other environmental constraints, notably exposure and its effect on stem form and tree stability.

This paper describes (a) the broad rationale behind thinning operations in Tasmania, (b) conflicts affecting the timing and intensity of thinning and (c) how these conflicts might be resolved.

1 Introduction

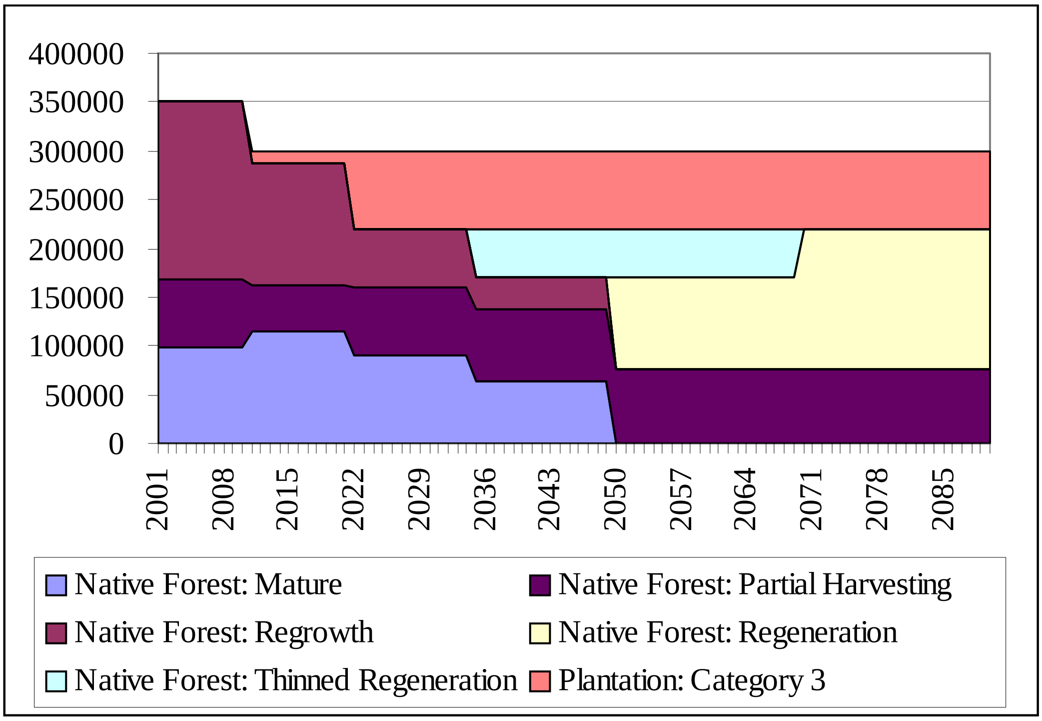
In 1998 Forestry Tasmania developed a Forestry Growth Plan endorsed by the State Parliament. The plan had five key elements:

1. Long-term security of lands for conservation and sustainable timber production,
2. World-scale forest resource establishment through intensive forest management, including plantations and thinning (of native regrowth and plantations),
3. Improved road and transport infrastructure to deliver economic log transport,
4. New processing, new products and new markets to improve the diversity of the Tasmanian wood products sector,
5. Investment ready sites to allow private sector firms to make confident investment decisions on new value-added processing investments.

Silvicultural management of eucalypt plantations on State Forest in Tasmania must be considered in the light of this plan as well as legal, social, economic and environmental considerations.

Section 22AA of Tasmania's *Forestry Act 1920* reads; *"Each year, from multiple use forest land, the corporation must make available for the veneer and sawmilling industries a minimum aggregate quantity of eucalypt veneer logs and eucalypt sawlogs that meet the prescribed specifications.*" The minimum aggregate quantity is currently set at 300,000 m^3 (Forestry Tasmania 2002). The Five Year Wood Review Report (Forestry Tasmania 2002) sets out how the proposed plantation estate on State Forest is anticipated to contribute to meeting this legal requirement in Tasmania, this is summarised in Figure 1.

Figure 1. 2002 review of high quality sawlog sustainable yield from State Forest in Tasmania



Plantation grown material is expected to meet minimum dimensions for prescribed sawlogs (ie 30cm minimum SED, 3.6m minimum length) and be suitable for rotary peeling into various quality veneers, for gluing and reconstitution as solid wood products (including laminated veneer lumber – LVL). The bulk of plantation material will be unpruned, this material will be suited to internal layers for laminated veneer products and has already proven suitable for structural timber products such as EcoAsh®. The pruned logs will provide high quality material suitable for face veneer and select grade solid wood products.

1.1 Plantations and the National Forest Policy

There are several policy statements, agreements and strategies that relate to plantation development in Australia. Key policy statements include the national Forest Policy Statement and the National Principles on Forest Practices Related to Wood Production in Plantations.

The 2020 Vision is a strategic partnership between the Commonwealth, State and Territory Governments and the plantation timber growing and processing industry. The overarching principle of the Plantations 2020 Vision strategy is to enhance regional wealth creation and international competitiveness through a sustainable increase in Australia's plantation resources, based on a notional target of trebling the area of commercial tree crops by 2020. This is the key document in relation to plantation development in Australia. Apart from Tasmania and Northern Territory, all new plantation development is on cleared, privately owned land.

Furthermore, various State Governments have released forest strategies, which also make reference to plantation developments. These include:

- Victoria; “Our Forests Our Future” - Commitment to reduce harvesting in native forests and provide support for private sector investment in plantations to substitute for lost volumes.
- Tasmania; “Forestry Growth Strategy” - Increase in plantation area managed on solid wood regimes to make up for increased reservation of native forests. The Tasmanian Community Forest Agreement includes provision for limited conversion of native forest to plantation on public and private land.
- New South Wales - Forests NSW has issued Ecologically Sustainable Forest Management (ESFM) plans for the coming five years for the Upper North East, the Lower North East, South Coast, Eden and Tumut State forest areas. The plans set out broad strategies, performance indicators and measurable outcomes for forest management in the regions, including the strategies that Forests NSW will put into practice to achieve objectives in key areas of forest management. Due to severe reductions in native forest harvesting there is a clear need to expand the plantation estate on previously cleared land.
- Western Australia; WA Forest management Plan 2004-2013 - Significant reduction of harvest from native forests. All new plantation activity confined to private land. No strategy regarding the replacement of native forest resource with plantation material.
- South Australia’s forest industry is entirely based on plantations, primarily softwood on public and private land. The newly developed hardwood plantations are entirely on private land.
- Northern Territory has recently emerged as a significant developer of plantations including conversion of native vegetation. Most of the activity has occurred on the Tiwi Islands. The draft NT Parks and Conservation Management Plan 2005 makes no comment about forestry activities.

1.2 Production goals (of plantations)

In general, eucalypt plantations in southern Australia have been established to provide pulpwood. These are mostly planted with *Eucalyptus globulus* ssp. *globulus.* There is some interest in alternative species, but these are still minor contributors to the plantation estate. In Tasmania and Victoria, *Eucalyptus nitens* is used as a substitute species where temperatures limit the use of *Eucalyptus globulus.*

Forestry Tasmania is the only State enterprise in southern Australia that has pursued a significant production goal of solid wood (sawn timber and veneer) from plantations. There is considerable interest and effort in solid wood regimes being shown by the non-industrial private forestry sector. Gunns Plantations Ltd is the only managed investment scheme which has offered a eucalypt solid wood regime to investors to date.

In NSW and Queensland there has been significant government investment in research into eucalypt species which may be suited to solid wood regimes. There is some private sector interest in processing small diameter timber for solid wood (eg FEA Ltd) and investment in solid wood plantations of teak and Pawlonia.

1.3 Tasmania

In Tasmania, intensive ‘solid-wood’ regimes have been developed to provide high-value sawlog and veneer products from hardwood plantations, principally of *Eucalyptus globulus* and *Eucalyptus nitens*.

Sites with favourable soil and climatic conditions are chosen where growth rates (MAI) in excess of 20 m^3 ha^{-1} yr^{-1} can be expected over a 20-25 year rotation (Neilsen 1990; Gerrand et al. 1993; Laffan 1993). Each site is established at 1100 stems ha^{-1}, of which 350 stems ha^{-1} are pruned (lifted) to 6.4 m in a series of three ‘lifts’ between ages 3-5 years. Pruning ensures the development of high-value ‘clear wood’, wood free of knots and other defects, along the length of the pruned stem. Each lift is timed to ensure that no more than 40% of the live crown is removed thereby avoiding impacts on growth rates (Pinkard and Beadle 1998). Furthermore, trees with large, dead or acutely angled branches are left unpruned to avoid an increase in the risk of decay entry via the pruned stub (Wardlaw and Neilsen (1999).

1.3.1 The need for thinning

Thinning is carried out to reduce stand density. This serves to reduce competition for essential growing resources and thus promote increment of the retained stems (Savill and Evans 1986). The first thinning should be timed to coincide with the point at which tree crowns and/or root systems interfere with each other, subject to economic constraints (Smith et al 1997). Where sufficient funds are available for long-term investment, the thinning should take place when the benefits (of thinning), discounted to present at compound interest, equal the cost of the operation. If sufficient funds are not available, the thinning typically is delayed until it returns a profit through sale of thinnings.

In Tasmania, early sawlog regimes advocated a single heavy thinning to the final pruned stocking, applied early in the rotation to maximise clear wood production from pruned stems (Volker et al. 2005). However, economic analysis (Gerrand et al 1993) demonstrated that in order for plantations to maximise financial return, thinning should be delayed to provide an early return on investment through sale of thinning products such as pulp or small dimension logs. Current operational practice is to aim for a single thinning to a final stocking of 250-350 pruned stems ha^{-1} between ages 10-12 yrs. The stand is then grown on before clearfall around ages 22-25 yrs. The total area of eucalypt plantation by age class managed by Forestry Tasmania for sawlog production is illustrated in Figure 2.

Figure 2. Plantation estate managed for sawlogs in Tasmania.

1.3.2 Conflicts

In Tasmania, the pursuit of thinning revenue has meant a tendency to forget that thinning is first and foremost a 'silvicultural' treatment. Subsequently, as the eucalypt plantation estate managed for high-value solid wood products has matured, forest managers have found themselves faced with a range of additional challenges, or 'conflicts', each with consequences for the timing and intensity of thinning operations, and ultimately, clearfall outcomes. These are described below.

1.1.1.1 Contractor availability and machine suitability

The operational reality of thinning eucalypt plantations in Tasmania is relatively recent, and thus contractor experience and availability is limited at present. Contractual arrangements, such as long-term access to resource and tenure of contract must be established in order to attract appropriate investment in machinery.

Harvesting contractors have traditionally worked in native forest clearfall situations associated with large piece sizes. Thinning operations require smaller, more versatile machinery, to manoeuvre through stands without damage, and to handle smaller piece sizes. To be financially viable, contractors must be very efficient with the use of their machinery and be able to process large amounts of material in a short time frame. At present there are a limited number of contractors with the appropriate machinery.

1.1.1.2 Markets

Markets for thinning material have traditionally been pulpwood sales. Whilst a useful outlet, it is variable in nature with contractor quotas constantly changing, and it provides lower royalties than other potential products. Changing quotas affect the viability of operations, and the ability to get coupes thinned at the optimum time to achieve silvicultural and financial goals. Reliance on one product, particularly with long cartage distances from some areas of the State, is not a viable long-term proposition.

1.1.1.3 Planning and coordination

To ensure coupes are thinned on time to achieve silvicultural and financial goals, an organisation requires a comprehensive and robust system to track and model coupes. At present, there are limitations to this, with a reliance on local knowledge on the status of coupes, and use of plantation ages as indicators for timing of thinning.

Pre-thinning inventories are an expensive and time-consuming exercise, with limited results. Stands are assessed in terms of pre-determined products, thus not allowing new market opportunities to be explored. In addition, coupes with relatively low volumes and small piece size might be eliminated from potential thinning programs without considering the possible implications for producing clearwood and other high value products at the end of the rotation. There is a need to obtain strategic information about a coupe at an early age, and be able to use a model to determine the optimum time to achieve silvicultural and financial goals, and utilise markets.

In Tasmania, there is currently a requirement to produce a detailed and comprehensive Forest Practices Plan for mechanised thinning operations under the Forest Practices Code (Forest Practices Act). This can be a very time-consuming and expensive process, affecting the timing and viability of thinning operations, and the ability to schedule coupes according to market requirements. Whilst the need to adequately consider the protection of natural and cultural values, and comply with appropriate legislation is recognised, a simplified approval process would greatly assist in the scheduling of thinning operations.

1.1.1.4 Operational constraints

Roading of coupes to provide access for winter operations and/or cartage has historically been a constraint when determining if and/or when a coupe would be thinned. It was considered that the expense of roading sometimes outweighed the economic benefits of a thinning operation, and thus a coupe may not be thinned.

Whilst the goal of plantation establishment is to attain consistency in terms of height and growth throughout a coupe, in reality, this is not always achievable. Variability within a coupe can make it difficult to determine the optimum time to thin, and present problems in handling areas with small sized timber. There has been a tendency to leave these coupes to grow on in order to allow the slower growing areas to reach merchantable size, with consequences for tree stability (see below), or in other cases leave them unthinned.

Similarly, coupes established with little thought to the practicalities of future thinning operations, for example where contour planting has taken place, provide operational challenges to contractors. Factors which make sites unsuitable for commercial thinning include restricted access (e.g. stream crossings, swamps etc.), ground conditions (large rocks, debris from previous harvesting operations), site characteristics (slope, soil physical properties such as erodibility, landslip potential) and windthrow risk.

1.1.1.5 Stability and windthrow

Intensive thinning of highly stocked stands is known to promote forest instability and the risk of windthrow (Cremer at al. 1982; Quine et al. 1995; Ruel 1995), notably in the 2-3 year period subsequent to thinning (Savill and Evans 1986). Typically, this occurs when tall slender trees, each lacking adequately developed ‘structural’ roots, are suddenly exposed to wind loading (Cameron 2002). The threat is exacerbated where thinning is delayed such that the stand exceeds accepted thresholds of stability, notably a height:diameter ratio of 1.0 or MDH of 20m (Cremer et al 1982; Savill 1983), and also on exposed sites characterised by high winds and/or coarse, shallow or poorly drained soils.

Of the existing estate (Figure 2 above), only 10% of this has been thinned. Already there have been several major windthrow events in thinned stands, each affecting in excess of 5-10 ha. In addition to the threat of windthrow, there is growing interest in the relationship between exposure, stem form and wood quality. Exposure can result in stem eccentricity and sweep (Singleton et al. 2003), whilst affecting internal wood properties, each with consequences for log processing and product quality. Recent results from Australia (Washusen 2004) and Spain (Nutto et al. 2004), with *Eucalyptus globulus* plantation sawing studies, suggest that trees grown under less competition through early thinning to low residual stocking tend to reduce growth stresses in the logs produced. This has implications for the quality of logs and recovery of merchantable timber in processing.

To reduce the risk of windthrow associated with thinning operations, it is generally accepted that the final stocking should be achieved either through early or frequent-light thinning. It is worth noting that in the longer term, thinning can lead to increased stability of the remaining trees (Zhu et al. 2002). This results not only from an increase in the availability of growing resources (Cremer et al. 1982), but also a direct physiological response to swaying including again diameter growth (Telewsiki and Jaffe 1981), and also root growth (Grace 1988; Stokes et al. 1995).

1.4 Rationale

Given the obstacles described above, it is clear that the forest manager faces some tough decisions in terms of the thinning regime. One size does not fit all - some flexibility in the regime is required. The following analysis was undertaken to illustrate where and how this might be achieved.

2 Methods

In the following analysis, Farm Forestry Toolbox v.4 (Private Forests Tasmania 2003) was used to model the silvicultural and financial outcomes for a range of management scenarios: site quality (site index 20, 25 and 30, that is, the mean dominant height at age 15 years) by thinning regime (described below).

Basic management up to age 5 yrs for each scenario included: clearing and windrowing, ripping and ploughing, pre-plant spraying, handling (nursery and planting), primary fertiliser application and pruning. In each scenario, pruning was carried out in three lifts: lift 1 - 350 stems ha^{-1} to 2.7m at age 3, lift 2 – 325 stems ha^{-1} to 4.5m at age 4 and lift 3 – 300 stems ha^{-1} to 6.4m at age 5. This assumed approx. 5% reduction in the number of stems suitable for pruning at each successive lift (ie, some of the stems having received their first lift were no longer suitable at the second and third due to form and/or mortality).

Three thinning regimes were considered:

1. Early or 'non-commercial' thinning (NCT) - a single thinning 'to waste', in each case applied at age 6 years, from 1100 stems ha^{-1} to a final pruned stocking of 300 stems ha^{-1} (no out-row).
2. Delayed or 'commercial' thinning (CT) - a single thinning from 1100 stems ha^{-1} to a final pruned stocking of 280 stems ha^{-1} (this includes a 5^{th} row out-row). In each case, thinning was scheduled to take place before the stand reached a mean dominant height (MDH) of 20m (see above).
3. Two-stage or 'double commercial' thinning (DCT) - the stand was thinned 'to waste' from 1100 stems ha^{-1} to 700 stems ha^{-1} at age 6 yrs, and then again 'commercially' at age 10 yrs to a final pruned stocking of 300 stems ha^{-1} (no out-row). In this case there was no restriction on the MDH at the second thinning – it was assumed that the first thinning had improved tree stability.

In each scenario, harvesting was scheduled to maximise the net present value (NPV $AUS). Costs for each of the operations described above in $AUS ha^{-1} were based on State wide averages (not shown). Thinning to waste was considered a cost, commercial thinning and harvesting were assigned revenue only.

The log-grade set (product specifications) used in the analysis are presented in Table 1. Royalties paid for each product (not shown) were based on current expectations of market prices. Products were ranked in order of priority (and in this case value) to inform Farm Forestry Toolbox on how to break down each log at clearfall. Other assumptions: interest rate of 9.25% and stump height (DBH * 0.5)

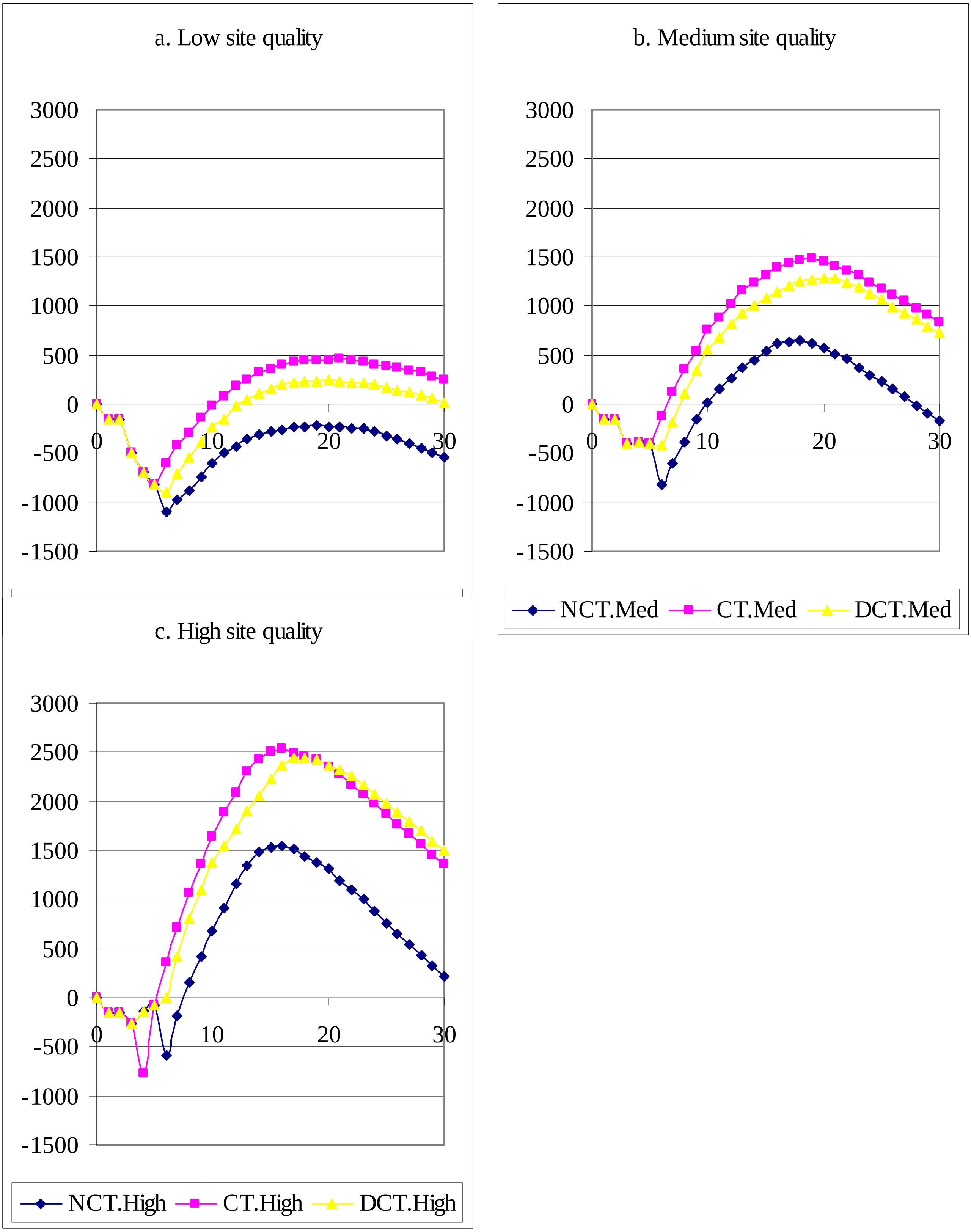
Table 1. Log-grade set used in the analysis

		DUB (cm)		Length (m)		
Rank	Description	Min	Max	Min	Max	Pruned
1	Cat 3 sawlog	30.0	None	3.6	6.4	Yes
2	Small sawlog	20.0	32.0	2.5	11.0	No
3	Unpruned peeler	20.0	None	0.9	11.0	No
4	Pulp	10.0	None	2.4	11.0	No
5	Waste	0.0	None	0.0	None	No

3 Results

The NPVs over time for each scenario are illustrated in Figure 3. In each case, the NPV was adjusted to $0 at year 0 (to maintain confidentiality). It can be seen just how sensitive the NPV is to the timing of the final harvest, becoming more so as the site quality improved. NPV was consistently better under CT, followed DCT and finally NCT. The difference in terms of NPV between CT and DCT became less as the site quality improved.

Figure 3. NPV ($AUS) over time for each scenario



Key stand characteristics at thinning and clearfall are presented in Table 2. For NCT, the MDH (m) at the time of thinning was 12m, 15m and 17m for the low, medium and high quality sites respectively. Under CT, thinning was carried out when the stand reached an MDH of 19m, this occurred at age (years) 11, 9 and 7 for the low, medium and high quality sites respectively. For DCT, the second thinning was carried out at age 12 years, irrespective of MDH (20m, 24m and 27m for the low, medium and high quality sites respectively). Here it was assumed that the stand would be that much more stable given that a thinning had already occurred.

Table 2. Key stand characteristics at thinning and clearfall (max NPV $AUS)

			Site quality		
			Low	Medium	High
NCT	Thinning	Age (yrs)	6	6	6
		MDH (m)	12	15	17
	Clearfall	Age (yrs)	19	18	16
		Stems ha^{-1}	298	298	298
		Total BA (m^2)	27	35	39
		Avg tree BA (m^2)	0.09	0.12	0.13
		Avg DBH	34	39	41
		NPV ($AUS)	-222	646	1541
CT	Thinning	Age (yrs)	11	9	7
		MDH (m)	19	19	19
	Clearfall	Age (yrs)	21	19	16
		Stems ha^{-1}	279	279	279
		Total BA (m^2)	25	32	37
		Avg tree BA (m^2)	0.09	0.11	0.13
		Avg DBH	34	38	41
		NPV ($AUS)	458	1479	2531
DCT	Thinning (2^{nd})	Age (yrs)	12	12	12
		MDH (m)	20	24	27
	Clearfall	Age (yrs)	20	20	17
		Stems ha^{-1}	299	299	299
		Total BA (m^2)	25	33	35
		Avg tree BA (m^2)	0.08	0.11	0.12
		Avg DBH	33	37	39
		NPV ($AUS)	243	1288	2447

Clearfall timed to maximise NPV ($AUS) corrected to $0 at year 0

For each scenario, harvesting was scheduled to maximise the NPV (Table 2). At each site quality, NPV was greatest under CT, followed by DCT and then NCT. NPV for each thinning regime increased with site quality whilst the age (years) at which harvesting took place fell, except under DCT. Under DCT, harvest age (years) to maximise NPV was the same for both low and medium quality sites. At each site quality, the number of stems, total basal area (m^2 ha^{-1}), average tree basal area (m^2 ha^{-1}) and average DBH (cm) varied little according to the thinning regime, though each increased with site quality (except the number of stems ha^{-1}).

Log-grade recoveries (m^3 ha^{-1}) for each scenario are summarised in Table 3. No pulp thinnings were obtained under NCT. Pulp thinnings under DCT (2^{nd} thinning) were consistently higher than those obtained under CT, for both DCT and CT pulp thinnings increased with site quality. In addition, and for CT and DCT (2^{nd} thinning) at each site quality, a small amount of small sawlogs and/or unpruned peelers were recovered (not shown) during thinning.

Table 3. Log-grade recoveries (m^3 ha^{-1}) for each scenario

		Site quality		
	Log-grade	Low	Medium	High
NCT	Cat 3 sawlog	30	149	186
	Small sawlog	168	161	169
	Unpruned peeler	6	10	33
	Pulp (thinning)	NA	NA	NA
	Pulp	42	40	38
	Waste (clearfall)	15	13	15
	Total	262	373	441
CT	Cat 3 sawlog	32	129	156
	Small sawlog	164	162	162
	Unpruned peeler	3	15	46
	Pulp (thinning)	63	70	65
	Pulp	42	38	36
	Waste (clearfall)	14	13	14
	Total	317	427	478
DCT	Cat 3 sawlog	15	125	157
	Small sawlog	174	187	180
	Unpruned peeler	4	13	14
	Pulp (2nd thinning)	72	89	97
	Pulp	46	43	42
	Waste (clearfall)	14	13	13
	Total	324	470	504

Total volume at clearfall (m^3 ha^{-1}) increased with site quality and in each instance was greatest under DCT followed by CT and then NCT. The volume of cat 3 sawlogs was very low for each thinning regime on the low quality sites, though increased considerably on medium and then again on high quality sites. The volume of pulp recovered at clearfall varied little for each thinning regime and site quality, ranging between 36 and 46 m^3 ha^{-1}. The same was true for small sawlogs, ranging between 161 and 187 m^3 ha^{-1}. The volume of unpruned peelers increased with site quality, though no trend was apparent according to thinning regime.

4 Discussion

Current silvicultural regimes in Tasmania favour thinning at ages 10-12 yrs rather than applying an early and intensive thinning. This makes sense given the analysis described above, and also, existing wood supply agreements relating to not only sawlogs but also pulp.

However, given the vagaries of contractor availability, machine suitability, site conditions, changing markets, and other environmental constraints, notably exposure and its effect on stem form and tree stability, it is clear that one size, in this case commercial thinning (CT), does fit all.

Unfortunately, by the time any conflict associated with the thinning regime has arisen, it may be too late to make changes. This demonstrates a clear need to monitor growth during the early years of the rotation, notably up to and around the time of the final pruning lift. At this point we can ask the question, "*Can thinning be delayed or should an early or two-stage thinning be applied, and what are the silvicultural and economic implications of doing so?*"

4.1 Responding to conflict

The following discussion is concerned with how some of the conflicts described above might be avoided, and where issues remain, how the thinning regime might be modified.

4.1.1 Contractor availability and machine suitability

As the age of the existing State Forest plantation estate increases, the area potentially available for thinning will increase markedly (see Figure 2). In addition, there are private forestry companies operating within the State, with plantation thinning programs in place. This availability of this resource will give contractors increased security with regard to access, and thus opportunity for longer-term contracts. This in turn will encourage investment in appropriate machinery for plantation thinning operations.

It is essential that forest growers work with contractors to encourage investment in new machinery, and to establish the most efficient operations, to maximise product diversity and output. Smaller processors (18-20 ton) with a Waratah head, allow processing of timber down to 6 or 7cm in diameter. High tracked machines with no tail-swing, allow easier access and minimise damage to retained stems. Operations working with a ratio of 2 processors to 1 forwarder, are the most efficient. Feller-bunchers or 'hotsaws' may be required when understorey is dense.

There remains a need for further research into optimal machinery and systems for cost-effective thinning operations, particularly to recover low volumes of small diameter logs.

4.1.2 Markets

Thinning operations, even at any early age on medium to high quality sites, can potentially produce a range of saleable products. Other than pulpwood, markets are already available for small sawlogs and unpruned peeler logs. Exploratory projects are under way to look at the potential to treat small diameter timber for poles, vineyard- and fence-posts. The planned opening of the Ta Ann rotary veneer mills in the Huon Valley (May 2007) and at Smithton (mid 2008) provide opportunities to recover small diameter logs and utilise them in a relatively high value product. The key is the ability to respond to changing market conditions in a timely manner, and also, without compromising the final production objective of the plantation.

In general, non-commercial thinning provides the best volume recovery and indications of better wood quality in terms of sawlogs, though the economics (NPV) remain poor. This is especially true of the low quality sites. The key is identifying markets for other high-value products, notably small sawlogs, smaller diameter unpruned and pruned peeler logs to maximise returns from early thinning operations and managing the stand accordingly.

Let us look again at the low quality site described above. Without changing the regime (NCT), by simply dropping the cat 3 sawlog from the log-grade set, a very different picture emerges. To maximise NPV, clearfall takes place two years earlier at age 15 and returns a NPV (corrected at year 0 to $0) of $1156. Key stand attributes remain largely unchanged; the number of stems ha^{-1}, total basal area (m^2), average tree basal area (m^2) and average DBH (cm) were 299 stems ha^{-1}, 23 m^2, 0.08 m^2 and 31 cm respectively.

4.1.3 Planning and coordination

There is a need to obtain strategic information about a coupe at an early age. We advocate the use of a model that combines silvicultural and economic goals to determine the optimum regime and utilise markets. Forestry Tasmania has developed a Pruning Assessment Tool (PAT) which will be used in combination with Farm Forestry Toolbox (Private Forests Tasmania 2003), for such a purpose. PAT combines the functions of assessing quality of pruning operations with the need for accurate pre-thinning inventory. This information, along with other appropriate data, can be used with Farm Forestry Toolbox to provide information on optimum times to thin, product availability, and potential economic returns.

4.1.4 Operational constraints

Instead of roading being considered as a specific thinning cost, roading must be considered as a capital cost to be recovered over the life of the current and subsequent rotations. Capital infrastructure will be required to recover any large scale mechanised operation, and if planned and constructed appropriately, can be utilised over subsequent rotations.

The availability of programs such as Farm Forestry Toolbox will enable managers to model individual coupes, thus allowing more appropriate decisions to be made about coupes exhibiting extreme and/or variable growth rates. Whilst requirements to produce high grade pruned sawlogs need to be met from the estate overall, it may be more appropriate for some coupes or parts of coupes to be managed on different regimes to produce other high value products.

With regard to coupe design, plantations established over the last several years have been modified to better accommodate future thinning operations where possible. These changes include spot cultivating and planting at right angles to the contour, and also, changing the placement of windrows.

It is essential that inaccessible areas or those unsuitable for existing machinery (ground-based or cable) are identified during the early stages of the rotation. These areas may be better managed as pulpwood regimes or NCT regimes where only one visit for harvesting will be economically feasible.

4.1.5 Stability and windthrow

On sites where the risk of windthrow is high, it would be a brave manager who allowed the stand to grow on much beyond the critical thresholds of stability described above. Unfortunately, though a great deal has been learnt regarding the wind-tree relationships for a range of softwood species, these same relationships are poorly understood for hardwood species, notably eucalypts. Thus, predicting the outcomes of any intervention or otherwise on stability and windthrow at a stand level in eucalypts is largely guesswork.

A range of complex predictive windthrow models now exist, however they these have yet to be validated for many hardwood species, notably eucalypts. As such, simple diagnostic models in which the key factors related to windthrow are assessed in the field and tallied (e.g., Harris 1989; Strathers et al. 1994; Mitchell 1995), remain a sound basis for silvicultural decision making at a stand level. To the author’s knowledge, no such schemes exist in Australia.

Subsequently, the diagnostic model WindRISK was developed (Wood et al 2005). This provides a framework for the assessment of key climatic, topographic, site and silvicultural factors known to influence the risk of windthrow. Where a site can be reasonably identified as having an elevated risk of windthrow, it is important that the thinning is completed sooner rather than later, or modified according the Best Management Practices relating to windthrow.

Despite the best intentions, contractor availability or market fluctuations may delay thinning thus compromising the final crop. A sensible approach would be to schedule thinning well in advance, preferably a non-commercial or two-stage thinning. The latter would be particularly advantageous given that tension wood (described above) has been associated with both competition and exposure (to wind). In short, an initial thinning to 750 stems ha^{-1} would reduce competition whilst increasing allocation of biomass to the stem (the thinning response) giving the stand much greater stability by the time of the second thinning.

4.2 Is history repeating itself?

Plantation managers involved in radiata pine management in Australia and New Zealand would be sensing déjà vu when reading the text above. In the late 1970’s clearwood regimes developed in New Zealand and then adopted in Australia and Chile were considered radical. While silviculturists could see the obvious benefits to maximise production of defect free timber with pruning to tight DOS specifications and aggressive early thinning, there was opposition from operational managers who were justifiably concerned with short-term cash flow issues. It is interesting to note that, in Australia at least, the premium for clearwood radiata has virtually disappeared as most of the production is aimed at structural grades where there is no price differentiation. Hence many managers have returned to unpruned regimes with later thinning to control knot size.

The price for small dimension logs (small diameter and length) can be a key determinant in the feasibility of thinning operations at any time during the life of a plantation. While prices for pulp logs and other material remain relatively high, then early thinning regimes can usually be justified on economic grounds. However, if pulp prices become relatively low then the returns from thinning operations end up as a cost, rather than revenue on the bottom line. A threat to these prices is if there is an over supply of pulp logs coming from the large area of plantations dedicated to such regimes in Australia. The premium obtainable for high value logs obtained at the end of the rotation will determine the economic feasibility of the silvicultural regime. The dynamics of these considerations have been played out in many other forests throughout the world in plantations and where thinning operations in native forests have been examined.

5 Conclusion

Foresters will identify with the issues raised in this paper. While policy makers can provide vision for long-term supply strategies, such as supply of high quality sawlogs from plantations, the implementation can be very difficult.

We have identified that there are many environmental, silvicultural, operational and economic constraints to achieving long-term strategic goals at an estate level. These goals must be translated to stand-level management regimes if the stated objective is to be realised. We have found that stand level management must be adapted and options must be considered at key points in the life of the stand.

It is also apparent that forest owners (State and private enterprise) require courage and commitment to see long term strategic goals reach fruition. The decision to produce large diameter, pruned logs from eucalypt plantations has been made in the absence of any reliable information about market suitability of such material. Indications are that the material will require new processing technologies in sawing, veneer and drying to provide high quality products. Already there are indications throughout the world that such technologies are available.

Commitment is required to make available finance to enable stands to be managed to produce the final product and achieve the best long term return for the stand (ie maximise NPV). History has shown that the temptation to achieve interim returns to maintain cash-flow has often been done at the expense of the original strategic goal. This has led to compromises in silvicultural management.

We have shown, through our research and operational experience, that plantation management needs to be dynamic in response to stand characteristics, management objectives, market conditions and operational constraints. We have shown that tools that enable foresters to balance the constraints are essential to rationalise decisions and provide an objective approach.

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