The silvicultural legacy of R.T. Fenton – its genesis, its heyday and reflections

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Abstract

Early attempts to grow radiata pine in New Zealand with regimes that included commercial thinnings were generally frustrating. Extraction of thinnings was typically very unprofitable and severely compromised the volume and value of the final crop. In response, R.T. Fenton led the development of the direct sawlog silvicultural regime. In it, thinnings are early, heavy and entirely pre-commercial. Combined with aggressive pruning and a shortened rotation, this became the predominant regime in New Zealand from around 1970.

Concerns over underestimated sacrifices in stem volume production, and poor form on some sites, led to upwards revision of final stockings. The mid-1990s, with forest ownership changes and concerns over rising costs, have been followed by a significant shift away from pruning. However, an unpruned direct sawlog regime, as proposed by Fenton for the production of framing timber, has become the norm but again with a higher final stocking.

Introduction

While untended crops of radiata pine have often succeeded remarkably well, the species is very responsive to intensive silvicultural intervention (Burdon et al., 2017). Getting the intervention right, however, has proved very challenging.

Our main focus on how the challenge was met involves the Central North Island forests because of their historical predominance in the country's commercial forest estate. Developments elsewhere, however, also contributed. Also, while the focus is on the work and influence of a single individual, many others have contributed greatly to the story.

When the huge commitment was made in New Zealand after 1920 to radiata pine it was doubtless assumed, if often tacitly, that classical practice would be followed with thinnings providing intermediate yields. In this context, A.R. Entrican, who had pioneered pulping of radiata pine, had viewed commercial thinnings as pulpwood only. Of course, that almost universally did not happen in the stands from the 1925–1935 planting boom for a variety of circumstances and technical factors:

Figure 1: Aggressive 'green' pruning to keep knotty core small

- Funding retrenchment and gross disruption with World War II
- Continuing shortages of skilled labour
- Primitive logging gear for the piece sizes and terrain
- Availability of pulpwood from other forest operations, namely, as clearfelling residues of radiata pine and thinnings of other species
- Poles market covered by thinnings of other species
- Some easy terrain where those species were grown

- The Sirex epidemic having 'done the thinning job' on radiata pine planted during the 1925–1935 planting boom
- Thinning being complicated by the level of malformation, which precluded 'mechanical' (e.g. whole-row) thinning.

The situation did not change rapidly after the war, when afforestation was at a low level, and harvesting of radiata pine was widely inhibited by a combination of slow market acceptance and cheap native timber. One event, namely, the Tahorakuri Burn near Taupo in 1946, produced 12,000 ha of super-dense regeneration, which totally overwhelmed any tending resources. However, there were some developments, which include the following.

The early attempts

In the Rotorua region, where natural regeneration could often be over-dense, J. Ure proposed a thinning regime in 1949 (Mason, 2023). Implicit in it was a concern over tree form, addressed by delayed reduction from high initial stockings, and it featured late commercial thinnings.

On coastal dune sites, where terrain was easy and tree form very good, thinning was far simpler. Also, it had the benefit of relieving the nitrogen-fixing lupin from shade, boosting both its growth and that of the remaining crop trees.

In Southland, where C.H. Brown became Conservancy Forester in 1956, the tending focus with radiata pine became entirely on young stands. There he supplemented the adoption of quite aggressive early thinning with work study on pruning that he carried out himself (Fenton, pers. comm., 1965).

Despite disappointments, some attempts continued at commercial thinning of radiata pine stands away from coastal dunes, but they were generally very unprofitable for longstanding reasons. A common response, in Australia as well as here, was to defer thinning in the hopes that it would eventually become profitable. However, even if it did, it would leave a crop vulnerable to climatic damage and with some other problems.

Attempts at pre-commercial thinning that saved money and avoided post-thinning vulnerability to wind damage included poison thinning. These were generally short-lived, often saving little in costs, posing occupational safety hazards, or killing crop trees in 'flash-back' through root grafts. The advent of lightweight chainsaws, however, made pre-commercial thinning far cheaper.

The rise of FRI and *dramatis personae*

In 1960, the scene was set for more creative solutions. First, Dr Dennis Richardson was appointed as Director of Research for the Forest Service, heading the Forest Research Institute (FRI) with a new level of authority (Kininmonth, 1997). A general innovation of his was holding large symposia, the first being on Thinning and Pruning (Brown & Bunn, 1964).

The proceedings emphasised the need to combine the two measures, with the need to prune early enough to keep knotty cores small (Figure 1). Less effectively conveyed, though, seemed to be the need for prompt felling of unpruned trees after a selective green pruning. Otherwise, the crop trees would on almost all sites lose crown status very quickly.

Of more consequence were Richardson's appointments in the area (Burdon et al., 2017). He appointed E.H. Bunn as Head of his large Silviculture Branch, moving him from work on trying to enrich cutover native forest with exotics. Bunn had an all-consuming interest in forestry, and at least one highly formative experience had predisposed him to 'expect the unexpected' and therefore explore some quite extreme possibilities.

Within the Branch an Economics of Silviculture unit was created in 1964, with Fenton as Head. A brilliant, colourful eccentric, his junior subordinates found him charismatic (Burdon & Kininmonth, 2014). He had come from being Technical Officer at the Comical Hills State sawmill in the Southland Conservancy. There he had had a vivid experience, with Corsican pine, of the futility of long-delayed pruning. This had been expensive, but did nothing for the timber grades, which were disastrously affected by early, heavy thinning.

Also, in Southland he was closely familiar with the work of C.H. Brown. Above all, he was not one to flinch from pursuing an argument to its logical conclusion. He also had full support from Bunn. His first assignment in the role was a theoretical economic analysis of afforesting a large block of undeveloped pumiceland in the 'Maraetai Study' done jointly by Lincoln College and the Forest Service. In it he modelled then standard tending practices. A parallel study was done for developing the same block for pasture. The projected economics of the alternatives were comparable. After this, he spent two years on leave to gain his PhD.

In mid-1967, Fenton, with an enthusiastic young team, began seeking an economically optimal regime, similarly assuming cost/return structures, yield functions and log assortments. Of the authors, Rowland Burdon, while not one of the team, was a close onlooker.

New regimes

Early on, Fenton and his team identified several problems with past commercial thinning in addition to immediate unprofitability:

- Damage typically occurring in the final crop
- Loss of productive area from thinning skids or landings

- Losses from climatic damage after waiting for saleability of thinnings
- Some additional tendency for final stocking to fall short of prescription
- Cumulative loss of yield in cheaply logged final crop.

Also, the second log was identified as inherently problematic, being too high to prune, yet too big to be unimportant.

Later, within three years from starting, they had devised a radical alternative to traditional pruning and thinning practice in the direct sawlog regime. It was radical in foregoing extraction thinnings in favour of early, heavy pre-commercial thinnings. As such, it was a sweeping embrace of practice towards which the industry had been tentatively inching its way.

On the journey, he intensively consulted the work of I.J. Craib, who had proposed very aggressive thinning regimes for pines and tanbark wattle in South Africa, albeit where a dry season meant competition setting in well before crown closure. The announcement (Fenton & Sutton, 1970) was summarised as follows (with figures roughly converted to metric units):

> *An alternative, and potentially more profitable, regime is proposed which eliminates any production thinning for major produce by reducing the stand to the final crop in two stages to 380 stems/ha at 11 m top height, and to 200 at 17 m. This regime, designed to maintain near-maximum growth on the final crop trees, is expected to produce trees of mean d.b.h. 75 cm. in 25–26 years on sites of index 29 m. The regime aims at producing board grades only.*

As such, it entailed aggressive pruning. Also, it meant effectively defining the stand tending within about the first 10 years.

The low final stocking was favoured for the thick clearwood sheath that it promised after pruning, along with an early harvest that lowered effective growing costs. The volume yield was projected from the model of Beekhuis (Fenton & Sutton, 1970). Importantly, though, it entailed a projection into a stocking beyond the range of data used for building the model. Expected profitability, for both internal rate of return and net discounted revenue, was clearly better than that of the regime modelled in the Maraetai Study.

Fenton strongly emphasised that it was counterproductive to wait for thinnings to become large enough to be saleable. He viewed delayed commercial thinning or no thinning as an admission of defeat, the former risking severe climatic damage and both largely denying benefits from pruning. He saw it as far better to pre-empt with early, pre-commercial thinnings. This would assure better resistance to climatic damage, avoid the damage and other productivity losses associated with extraction thinnings, and allow full benefit from pruning.

It was appreciated that timely pruning, which would assure small knotty cores, would entail loss of volume production. However, it was anticipated that this would be outweighed by premiums for clear timber. Even without pruning, some loss of wood volume production with low final stockings was foreseen. However, this loss was believed to be modest, and likely offset by less damage from extraction thinning and loss of productive area to landings.

An alternative regime for producing framing timber also eschewed extraction thinning (Fenton, 1971). It retained considerably higher stockings and omitted pruning. A single thinning came, at around 19 m top height, to 370 stems per hectare (sph).

An extension of omitting extraction thinning was later devised for the conversion of pastureland to pine plantation (Mead, 2013; Burdon et al., 2017). Championed by Leith Knowles (Knowles, 1994), it was widely implemented. In this agroforestry regime, early tree stocking was low, with the intention of pasturage giving an intermediate yield. Pruning was intensive.

The adoption and adjustments

Adoption of the direct sawlog approach came very quickly and was very widespread, and was evident by early 1970 at the second FRI symposium on Pruning and Thinning (James et al., 1970). From then until the mid-1990s the pruning option of the direct sawlog regime was the strongly predominant

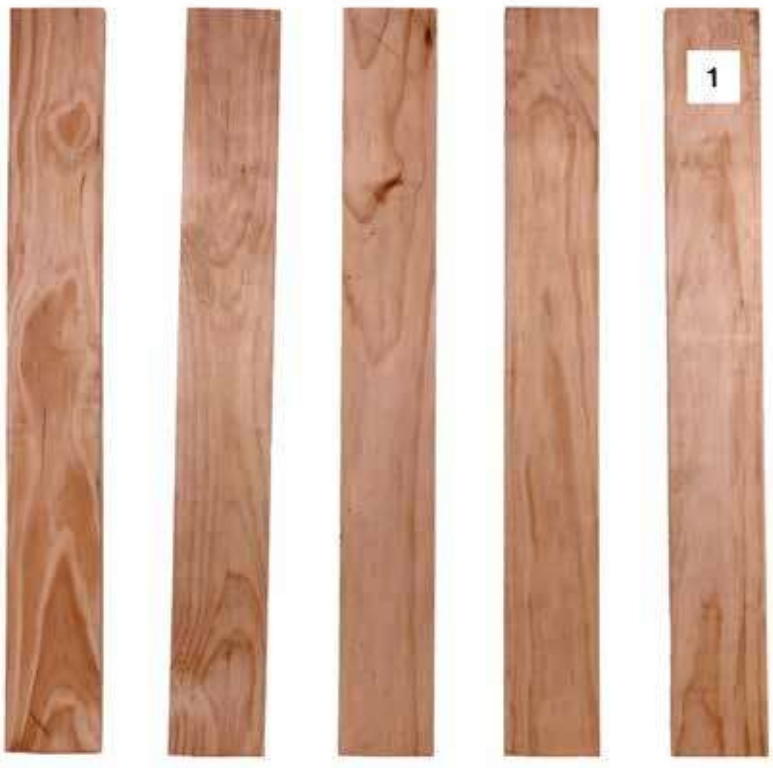

Figure 2: Boards of clearwood length enabled by pruning to butt-log height

practice with radiata pine in New Zealand. This was over a long period of active afforestation and then increasing restocking of harvested areas.

The pruning was underpinned by W. Sutton's research on the market prospects for clearwood boards (Figure 2) or veneers, and then strenuous advocacy (e.g. Sutton, 1976). In research for his DPhil thesis at Oxford, he faced a problem in that clear radiata pine boards represented a product that was essentially not available for testing in the marketplace. So, he had to look at price structures for alternative grades of other species elsewhere and trends in availability of closely comparable alternatives.

The high pruning option was not adopted on all site types. On dry, windy sites, where resin pockets and climatic damage posed special risks, it got widely avoided. On infertile sites that gave small branches and good mechanical wood properties it could also be avoided. Such sites included coastal dunes or infertile clays.

The pruning, combined with heavy thinning, gave a bonus in reducing needle-cast diseases, especially *Dothistroma* blight. This was doubly valuable before planting stock with some selection specifically for disease resistance became widely available. External reaction to the proposed pre-commercial thinning was interesting. For many, leaving stems to rot on the ground was unconscionable.

Inevitably, some problems arose with almost blanket adoption of the direct sawlog regime. First, a concern was raised that the low final stockings incurred greater loss of stem volume production than Fenton and his team had calculated. It came in an Abstract paper, which promised later publication of a full-length paper. However, the full paper never materialised, which incensed Fenton who was well aware of having made an extrapolation in deriving his final stocking.

He was pragmatic over appropriate final stocking: 'If one should retain more stems for the final crop, so be it' (Fenton, pers. comm., ca 1977). With time, after intensive trawling of the expanding database from sample plots, big losses of volume production from the low final stocking of 200 sph became clear (Kimberley et al., 2005). Adjustments duly followed over time (Maclaren, 1993), with current final stockings typically around 300 sph with pruning and 500 sph without (Mason, 2023).

Table 1: Areas of radiata pine plantation currently under different tending regimes as at 2002 and 2023

Regime	Percent of area		Nature of change
	2002	2023	
Pruned with production thinning	17	9	Drop
Pruned without production thinning	50	33	Drop
Unpruned with production thinning	4	4	No change
Unpruned without production thinning	29	54	Big increase

Source: National Exotic Forest Description data based on forest-grower returns

Other problems arose with the low final stocking of 200 sph. These involved tree form and wood properties, especially on fertile or very exposed sites. Branching above pruned logs was liable to become very coarse, even after selection for a 'short-internode' or 'multinodal' branching habit in order to reduce branch sizes. The wood stiffness and dimensional stability tended to be very inferior and far from governed just by wood density. These problems in such sites undoubtedly generated some vehement discontent that arose over the pruned direct sawlog regime.

The agroforestry option for conversion of pastureland fell out of favour quickly. The amount and quality of the pasture was very disappointing. Also, with the much-elevated soil fertility, tree form and wood properties were typically greatly inferior, especially with genetically unimproved stock. One plus was boosted wood yield in the 'farm-site' effect. The problems with gross branching and interior wood, however, had a happy ending in a remarkably good Chinese market for such logs.

Initial stockings tended to evolve over time, and they influence wood stiffness and exert some control over branch sizes. High stockings provided some cushion against malformation incidence and the effects of sub-optimal establishment. Later, improved establishment, and genetic improvement in tree form and foliage disease resistance, encouraged wider spacings (Mason, 2023).

Harvest ages, or top heights, came down through reduced final stockings accelerating attainment of log-size specifications. Sutton (1976) contrasted the 26-year rotation for the direct sawlog regime with the 41-to-46-year rotations that were typical for a yield thinning regime at the time.

Optimising the age entails balancing several factors. Improvement in various wood properties with increasing ring number from the pith generally works in favour of increasing age. Factors favouring reduced harvest age are the increases with stand age in compounding growing costs, incidence of heartwood, and (often but not always) risks of climatic damage. Another consideration, often of more neutral significance, is the age trajectory of annual increment. Preferred harvest ages are now generally in the range of 25 to 32 years.

The wider legacy

Fenton's role as group leader was terminated in early 1971, but be continued to complete publications on the work. However, his legacy was established.

His key prescriptions were soon massively adopted and endured. The process of devising it represented a major step in developing modern industrial forestry, which was to be followed through (Burdon et al., 2017).

Very briefly, the follow-through came in large programmes of modelling detailed log outturns for alternative silvicultural practices and site properties, which harnessed progressively expanding databases using increasing computing power. From that work decision-aid software packages were to emerge, first SILMOD and then STANDPAK, leading through to the Forecaster package that is widely used today.

Later trends in tending practice

Until the mid-1990s, tending practice remained fairly constant. This was apart from upward adjustments to stockings to protect volume yields, and tree form and wood properties on fertile and/or exposed sites. Since then the situation has changed, with a reduction in pruning particularly by large-scale forest growers. This has been driven by factors including the cost of pruning, a relatively small price differential between pruned logs and their equivalent unpruned equivalent and the reduction in yield with lower stockings in pruned stands (Moore, 2021). Manley (2022) estimated that the proportion of radiata pine being pruned by large-scale entities in 2020 had reduced to 19%. There has thus been an overall shift away from pruning, and with it, towards higher stockings.

Retention of pruning (Figure 3) has been most evident in integrated companies that, by processing pruned logs, have visibility of the market and premiums for clearwood. For other companies that prune, there is now a tendency to prune on sites that give low wood density, which is generally acceptable for appearance grades, but which restricts the production of structural logs. Sites that have high levels of resin bleeding, an indicator of resin pockets, are also avoided for pruning.

Mainly avoiding extraction thinnings with radiata pine has remained a general constant in New Zealand. There remain exceptions though (see Table 1) where terrain and markets are favourable. One such exception is quite early commercial thinning on easy terrain in Kaingaroa Forest. Here, the commercial thinning is treated as a silvicultural operation under the control of Tree Crop staff.

Summary of successes

Despite the problems, there were big successes. Huge areas did get duly tended, with generally little wind damage. The abandonment of the agroforestry option for pastureland conversion came quickly, restricting the area eventually involved. The pruning generally succeeded very well in producing clearwood. It also succeeded well in the markets, being initially backed up by a certification scheme that gave the buyer an assurance of clearwood content.

Figure 3: Pruned direct sawlog stand ready for harvesting

A major success lay in clear radiata pine becoming accepted as a substitute or better for clear ponderosa pine. This produced a very good market in the US. While that got severely dented by the collapse of a house-building boom after the Global Financial Crisis of 2008, pruned logs have continued to command a strong price premium over unpruned. The outstanding amenability of radiata pine to chemical or thermal modification has also meant a boost for the clearwood market.

Going forward, the level of pruning will depend on how well costs can be controlled and the premium for pruned logs increased in order to justify the sacrifice in wood volume production.

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References

Brown, G.S. and Bunn E.H. (Eds). 1964. *First FRI Pruning and Thinning Symposium*. Rotorua, NZ: New Zealand Forest Research Institute.

Burdon, R. and Kininmonth J. 2014. Obituary: Robert Terence Fenton – 21 December 1930 to 21 November 2013. *New Zealand Journal of Forestry*, 58(4): 39–41.

Burdon, R.D., Libby, W.J. and Brown, A.G. 2017. *Domestication of Radiata Pine*. Cham, Switzerland: Springer Nature.

Fenton, R. 1971. Silviculture and Management of *Pinus radiata* for Framing Timber Production. *New Zealand Journal of Forestry Science*, 1(1): 60–73.

Fenton, R. and Sutton, W.R.J. 1970. Silvicultural Proposals for Radiata Pine on High Quality Sites. *New Zealand Journal of Forestry*, 13(2): 220–28.

James, R.N., Sutton, W.R.J., Tustin, J.R. and Bunn, E.H. 1970. *Pruning and Thinning Practice: The Second Symposium on Pruning and Thinning [Forest Research Symposium, No. 12]*. Rotorua, NZ: New Zealand Forest Research Institute.

Kimberley, M., West, G., Dean, M. and Knowles, L. 2005. The 300 Index – A Volume Productivity Index for Radiata Pine. *New Zealand Journal of Forestry*, 50(2): 13–18.

Kininmonth, J.A. 1997. *A History of Forestry Research in New Zealand*. Rotorua, NZ: New Zealand Forest Research Institute.

Knowles, R.L. 1994. New Zealand Experience with Silvopastoral Models at the Stand and Estate Levels. In R.C. Shultz & J.P. Colletti (Eds). Opportunities for Agroforestry in Temperate Zone Worldwide. *Proceedings of the Third North American Agroforestry Conference 15–18 August 1993*, 367–372. Ames, Iowa, USA: Iowa State University.

Maclaren, J.P. 1993. Radiata Pine Growers' Manual. *FRI Bulletin No. 184*. Rotorua, NZ: New Zealand Forest Research Institute.

Manley, B. 2022. Trends in Radiata Pine Tending Regimes Being Applied by Large-Scale Entities – 2010 to 2020. *New Zealand Journal of Forestry*, 67(1): 31–32.

Mason, E.G. 2023. Impacts of Tending on Attributes of Radiata Pine Trees and Stands in New Zealand – A Review. *New Zealand Journal of Forestry Science*, 53:9. Available at: https://doi.org/10.33494/nzjfs532023x178x

Mead, D.J. 2013. Sustainable Management of Radiata Pine. *FAO Forestry Paper 170*, Chap 11. Rome, Italy: FAO.

Moore, J. 2021. Trends in Plantation Management in New Zealand – Past, Present and Future. *New Zealand Journal of Forestry*, 66(3): 26–32.

Sutton, W.R.J. 1976. Comparison of Alternative Silvicultural Regimes for Radiata Pine. *New Zealand Journal of Forestry Science*, 6: 350–356.

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