Management of Naturally Regenerated Totara on Farms - thinning and pruning

INTRODUCTION

Totara (*Podocarpus totara*) is a prominent feature of the rural landscape in many regions throughout New Zealand. Scattered trees and groves of young naturally regenerated totara are common in productive pasture from Northland to the southern parts of Southland (Bergin 2003).

In Northland regeneration of totara on farmland is so prolific that many landowners regard it as a weed. Naturally regenerated totara stands in this region have the potential to provide a sustainably managed resource of high-value and high-quality specialty timber. Management of such stands by thinning and pruning should improve growth rates and tree form.

Integrating totara into our pastoral landscapes provides a range of other benefits such as enhancing indigenous biodiversity, providing shelter for stock, and improving erosion control on steep hill country. Promoting the further establishment, development and management of totara forests is an appropriate sustainable land use option in many areas.

This article considers the management potential of naturally regenerated totara and provides results from silvicultural trials established by the Northland Totara Working Group in pole stands on farms. The performance of these stands five years after they were thinned and pruned is summarised and recommendations are provided to assist landowners in the management of regenerated totara on farmland.

◀ *Naturally regenerated totara is a feature of pastoral hill country in many regions including Northland.*

Stands of totara regenerating along riparian areas are common on farmland throughout New Zealand including this stand at Takaka, Golden Bay, northern South Island. ▶

NATURALLY REGENERATED STANDS

Naturally regenerated stands of totara are found in many pastoral areas throughout New Zealand (Wardle 1974). Low palatability to stock and the ability to regenerate on marginal hill country are key attributes that have contributed to the widespread distribution of totara in our modified landscapes.

Most of these stands range in age from 50-120 years and are the result of regeneration since original forest clearance for agriculture. Totara occurs as scattered trees or in groves, along fencelines and roadsides (Esler 1978), in more extensive regenerating stands in scrub on hill country, and along riparian areas and river flats where it is sometimes mixed with kahikatea *(Dacrycarpus dacrydioides)* (e.g., Duguid 1990; Wardle 1991).

In Northland, totara readily regenerates on steep hill slopes in pasture where some grazing pressure exists (Bergin 2001). As it is relatively unpalatable to stock, invasion on steep slopes can become a problem for landowners who wish to retain land in pasture. Regeneration in pasture is often in the form of dense totara-dominant stands but there are substantial areas of reverting shrubland with various proportions of totara, kanuka *(Kunzea ericoides)*, manuka *(Leptospermum scoparium)* and gorse *(Ulex europaeus)*.

Totara is found regenerating on farmland often in mixture with other relatively unpalatable species such as manuka, kanuka and gorse.

A familiar site along many rural roads in New Zealand is totara regenerating along fencelines from bird distributed seed.

Scope for management

The abundance of totara on reverting marginal hill country provides a considerable resource with the potential to be managed as a future long-term supply of specialty timber. Totara has timber qualities that are highly valued both for traditional and contemporary uses (Bergin 2003). With most sources of old-growth totara suitable for timber now exhausted or in reserves, there is wide interest in establishing and managing totara for market and non-market benefits (e.g., Forest Research Institute 1997). Wood from naturally regenerated totara on farms is widely used in Northland where it is regarded as an excellent native timber that is relatively easy to mill, dry, work and finish for a range of high quality uses, and therefore considered to have good market potential (Quinlan 2011).

Naturally regenerated totara-dominant stands in Northland eventually develop into highly stocked pole and semi-mature stands that thin naturally (self-thin) over time (Bergin 2001). However, severe competition results in very slow growth rates in unmanaged stands. Improved stem diameter growth rates are expected to be achieved by thinning which can increase the growth rate of individual trees through the redistribution and concentration of a site's growth potential on fewer stems. The growth of selected crop trees can be enhanced by the removal of suppressed and dying trees along with malformed or otherwise undesirable trees.

SILVICULTURAL TRIALS

Long term silvicultural trials were established in 2007 in naturally regenerated totara-dominant pole stands on farmland by the Northland Totara Working Group (refer box Page 4). The aim of these trials was to determine optimum thinning levels to boost growth and to compare strategies for pruning to improve stem form. These trials have recently been re-measured five years after their establishment.

The trials were set up in collaboration with landowners, Scion and the Diversified Species theme of Future Forests Research, with support from the Ministry of Primary Industries' Sustainable Farming Fund, Northland Regional Council, Far North District Council, and Tāne's Tree Trust (Bergin 2008).

Interest in management of regenerated stands of totara is high amongst land owners and farm foresters.

Form pruning of a naturally regenerated totara pole with a double leader.

Northland Totara Working Group

The Northland Totara Working Group (NTWG) was formed in 2005 to promote the management of naturally regenerated totara trees on farms for both timber-production and for environmental benefits in Northland. The group is represented by a wide range of stakeholders and has gained national profile due to the interest in managing regenerating totara.

Stakeholders include Tāne's Tree Trust, the NZ Landcare Trust, local landowners in Northland, the NZ Farm Forestry Association, the Northland Regional Council and local district councils, wood millers and processors, research providers, Enterprise Northland, and the Indigenous Forestry Unit in the Ministry for Primary Industries.

Promoting the sustainable management of totara for commercial wood use is seen as an effective incentive to develop this resource on private farmland integrated with current agricultural land uses, an outcome that will also lead to many environmental and landscape benefits. Development of an industry based on this sustainable land-use option is the longer-term vision.

Trial areas

The trials were located in three Northland districts – Whangarei/Glenbervie, Kaeo/Okaihau and Herekino (Figure 1). Depending on stand size, two or more Permanent Sample Plots (PSPs) were established within each of 14 stands at 9 farm sites across the three districts. This allowed establishment within each stand of a control PSP with no silvicultural treatment along with one or more thinned and pruned PSPs, thus allowing a direct comparison of the effects of silviculture to be made against an unmanaged stand. A total of 38 PSPs were established.

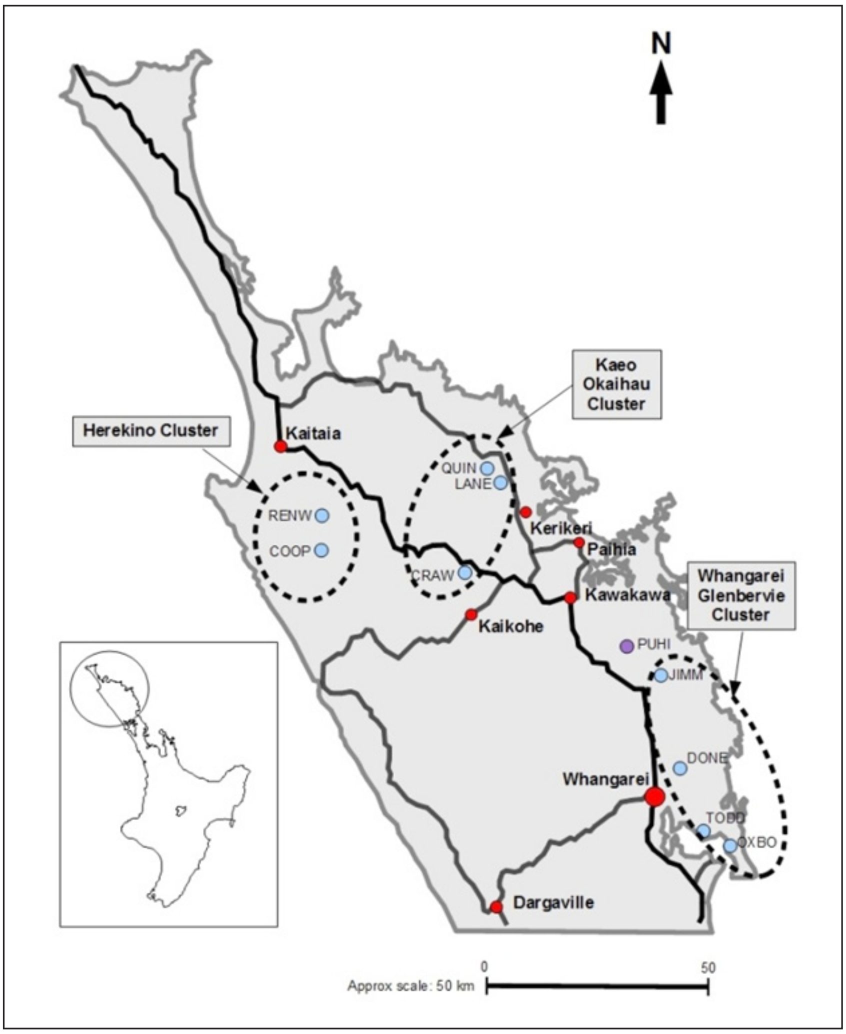


Figure 1: Location of sites within clusters in 3 Northland areas where PSPs have been established in naturally regenerated totara stands.

TREATMENTS AND MEASUREMENTS

All PSPs were measured in 2007 before any silviculture using the methods of Ellis and Hayes (1997). Diameter at breast height (DBH at 1.4 m above ground) was measured for all stems with DBH ≥50 mm. Heights of a sample of canopy trees were also measured.

Before thinning, mean DBH ranged from 10-23 cm and mean tree height from 6-14 m. The thinned plots were re-measured immediately following silviculture. All plots were re-measured five years later in 2012.

Analysis of tree growth

A height-diameter function was fitted for each PSP measurement to enable heights of all trees to be estimated. As no specific volume function has been derived for totara, the function developed for pole rimu by Ellis (1979) was used to give an approximate stem volume for each tree using the measured DBH and estimated height.

Stocking of stems ≥50 mm in DBH, and mean height, DBH stand basal area and volume was then calculated by species for each PSP measurement. Annual volume and DBH increments were calculated for each PSP over the 5-year period. The effect of thinning on the growth increment was tested using analysis of variance (ANOVA), comparing thinned plots with the non-thinned control plots.

Size/density chart

Size/density charts, where the mean DBH is plotted against stand density on a log-log scale, are useful tools that can be used to assist with decisions regarding the timing and intensity of thinning (Reineke 1933). A size/density chart was developed for totara, using measurements from the thinning trials along with additional data from naturally regenerated stands in Northland.

Using this chart, a line indicating the maximum stocking that can be maintained for a given mean DBH was derived for the species. Overseas experience suggests that for a wide range of species, stands benefit from thinning when the stocking is greater than 55% of the maximum, and that stands should thinned down to 25% of the maximum stocking. Based on these rules, a thinning schedule table was developed for totara providing the stocking above which a stand should be thinned, and the stocking it should be thinned down to, tabulated against mean DBH.

THINNING AND PRUNING

Stands were thinned from densities of over 6000 stems per ha to levels of stocking ranging from 800-2000 stems per ha. This equated to a reduction of 25-74% of stems ≥50 mm DBH. This level of thinning was considered to be fairly conservative due to concerns about stand stability after treatment. Selection of trees for thinning was influenced by natural variation in spacing, species composition and tree size, with smaller diameter trees and those with poor form selected for felling.

Form pruning involved removing all branches from 2-8 m above ground level on all residual crop trees, including multiple leaders and larger steep-angled branches. Height of pruning was determined on tree height, with the aim of retaining at least one third of the green crown.

Thinning underway within Permanent Sample Plots established in naturally regenerated totara pole stands in Northland - Kaeo, Far North (above), and Glenbervie (below).

Trees within thinned plots were pruned up to 8 m high. Pruning height was determined on the basis of leaving a minimum of one-third of the green crown.

Estimated age of stands

Basal discs sampled from felled trees were used to obtain growth ring counts to estimate tree age based on methods described by Bergin and Kimberley (2012). Assuming growth rings are annual, estimated ages of thinned stands ranged from 47-95 years. The wide range in ring counts in stands indicated a significant period of recruitment of up to 30 years.

Cross-sectional discs were taken from a sample of trees felled during thinning operations to obtain growth ring counts to estimate stand age.

GROWTH RESPONSE TO THINNING

Volume increment

Over the five years since trial establishment, volume growth of live trees has been significantly higher and mortality significantly lower in thinned compared with unthinned plots (Figure 2). The combined effects of greater growth and lower mortality has resulted in an average net volume annual increment in thinned plots of 7.7 m^3/ha/year, more than double that of unthinned plots at only 3.1 m^3/ha/year, and this difference is statistically highly significant ($p=0.0035$).

We can conclude that by reducing competition through the removal of suppressed and malformed trees, thinning has improved the growth of remaining trees and also reduced mortality. The ability of totara to respond to thinning is clearly shown by the fact that the gross annual increment (i.e., the growth of trees live at the end of the 5-year period) was greater in thinned than unthinned plots, despite the latter having a greater number of trees per hectare. Reduced competition in thinned stands has almost eliminated natural mortality which is particularly encouraging as there was concern that the more open thinned plots might suffer increased windthrow.

Thinning of dense naturally regenerated totara stands involved removing some of the larger dominant trees as well as poorly formed and smaller diameter trees to achieve reductions in stocking of up to 50%.

Diameter increment across sites

DBH periodic annual increment averaged across all sites for thinned and unthinned plots is shown in Figure 3 for the 800 largest diameter totara trees per hectare and for all measured totara trees (i.e., those with DBH greater than 50 mm). The comparison based on all measured trees is somewhat misleading as unthinned plots tend to contain larger numbers of smaller, slower-growing trees compared with thinned stands where many smaller trees were removed. The comparison based on the largest 800 trees per hectare gives a more accurate indication of how thinning has affected the growth rate of potential crop trees.

For the 800 largest diameter trees per hectare, DBH periodic annual increment in thinned plots averaged 4.5 mm per year, compared with 2.8 mm per year in unthinned plots. This difference was statistically highly significant and shows that diameter growth rates of individual trees in thinned stands have been significantly boosted by the reduced competition.

Diameter increment by site

At all sites, growth rates in thinned plots were faster than in unthinned plots, although there were differences between sites in this response to thinning ranging from 23-164%. Responses to thinning were found both in a slower-growing stand where mean annual increment in DBH increment increased from 1.7 mm to 3.8 mm, and in a faster-growing stand where it increased from 4.5 mm to 7.2 mm. Further work is required to determine if differences in site characteristics such as fertility, drainage and soil type may influence growth rates and responses to thinning.

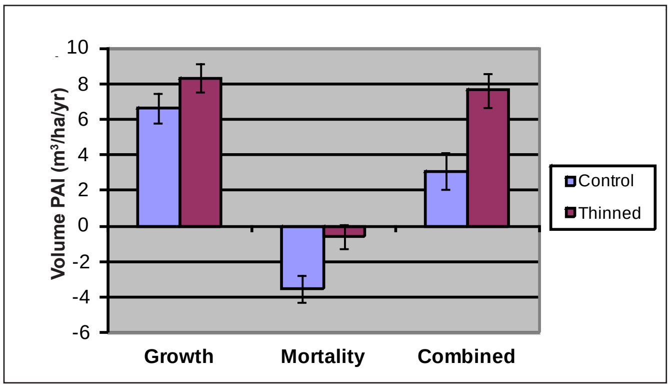


Figure 2: Periodic gross annual volume increment (PAI) per hectare, mortality, and net volume increment (combined growth and mortality) for control and thinned plots across all sites over the 5-year period since thinning. Error bars show standard errors.

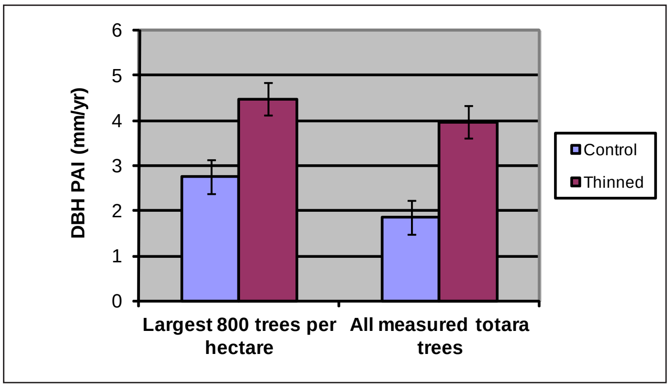


Figure 3: DBH periodic annual increment averaged across all sites for thinned and unthinned plots over the five-year period since thinning. Means are shown and for the largest 800 diameter trees per hectare for all measured totara trees. Error bars show standard errors.

A basal disc sampled of a felled totara from a naturally-regenerated totara stand which had been thinned five years earlier. Note the increased growth in response to thinning with the outer four rings each up to 5 mm wide compared to inner rings at only 1-2 mm wide.

The unthinned control plot (left) has a stocking of 2500 stems per hectare compared to the adjacent thinned plot (right) where stocking has been reduced to 1200 stems/ha.

SIZE DENSITY CHART FOR TOTARA – A FIRST

What is a size/density chart?

For many years, foresters in North America have used size/density charts to assist with decisions regarding the timing and intensity of thinning (Reineke 1933). In a size/density chart, the quadratic mean DBH is plotted against stand density on a log-log scale. A line representing the maximum stocking that occurs naturally for any mean DBH can be drawn on the chart.

North American studies suggest that inter-tree competition begins at about 25% of maximum stocking, and becomes severe when it exceeds 55%. These values can therefore be useful to judge whether a stand will benefit from thinning and to determine the intensity of thinning required. If a stand is above the 55% maximum stocking line, it can be inferred that it will benefit from a thinning, and the thinning should be planned to lower the stand to the 25% maximum stocking line.

However, for fast growing stands, thinning may be justified at a lower threshold than 55%, especially if maximising diameter growth is a target. Further trials testing different thinning thresholds could confirm if lower thinning thresholds are desirable.

Northland Totara Stands

Data from the Northland trial have been used to derive a maximum stocking line for naturally regenerated totara for the first time. In Figure 4, the unthinned plots are clustered on either side of the line representing 55% of maximum stocking, and are growing slowly and suffering mortality. This can be inferred from the fact that the lines representing these plots typically show a decrease in stocking between the initial measurement (right end of each line) and the recent measurement (left of each line). Also, when DBH increases in unthinned plots over the five-year period, this is invariably accompanied by mortality, and the DBH increase largely reflects mortality of smaller trees.

After thinning, most of the thinned plots are positioned below the line representing 25% of maximum stocking, suggesting these thinnings were fairly aggressive. However, five years after thinning, most plots are approaching or have crossed the 25% line. In most cases, plots thinned to the 25% line or below, show a clear response to thinning. They show little evidence of mortality (i.e., the lines are vertical indicating that stocking did not change over the 5-year period), and generally have faster DBH growth than unthinned plots.

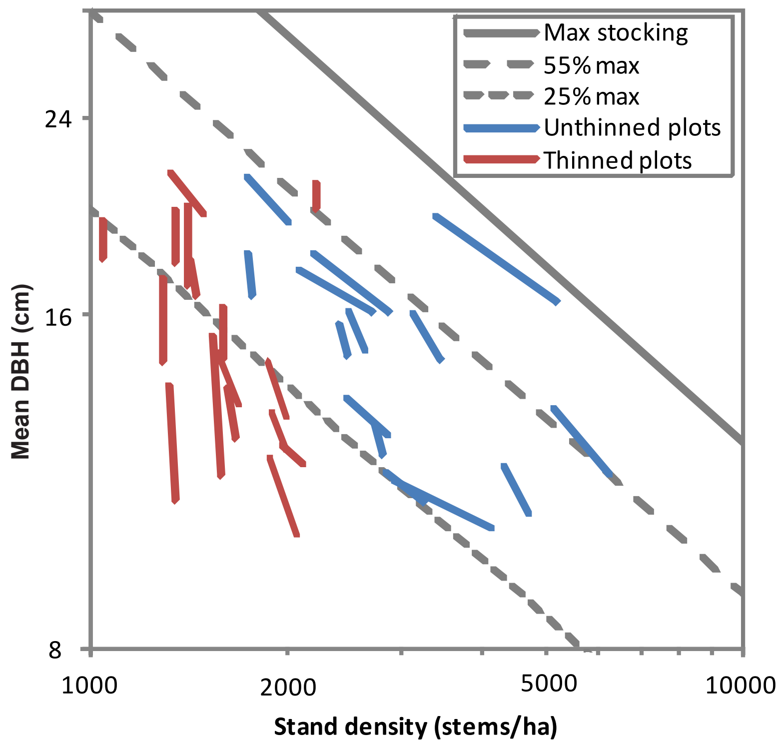


Figure 4: Size/density chart showing thinned and unthinned stands. Each line shows the trajectory of a plot in the DBH/Density space over the 5 year period from trial establishment.

A Permanent Sample Plot within a naturally-regenerated pole stand near Whangarei, thinned five years previously from 3000 stems per ha to 1600 stems per ha. Average height of trees is 9 m and DBH 16 cm after thinning, similar to the target stocking of 25% of the maximum indicated in the recommended thinning schedule (Table 1).

RECOMMENDED THINNING SCHEDULE

Based on the analysis of growth over the first five years since thinning, a recommended thinning schedule for young naturally-regenerated totara-dominant pole stands has been developed (Table 1). This table is a guide for determining if a stand would benefit from thinning and the target post-thinning stocking. The schedule is derived on the assumption that stands with stocking greater than 55% of the maximum that can be maintained for a given mean DBH would benefit from thinning, and that a suitable target stocking is 25% of the maximum.

The table shows, for example, that a stand with an average DBH of 16 cm would benefit from thinning if its stocking is greater than 3,300 stems/ha and should be thinned down to about 1,500 stems/ha. Thinning usually involves the removal of poorly formed trees and non-target species, followed by the removal of small and suppressed trees which can cause an increase in mean DBH. When the target stocking has been achieved, a sample of trees should therefore be measured to check whether the thinning has resulted in a significant shift in the stand's mean DBH which may mean that further trees should be thinned to achieve the target stocking.

Table 1: Recommended thinning schedule for young naturally regenerated totara-dominant pole stands. For any given quadratic mean DBH*, a stand with stocking greater that the 55% of the maximum should be thinned down to the 25% of the maximum.

Mean DBH* (cm)	55% of maximum stocking (stems/ha)	25% of maximum stocking (stems/ha)
6	21,640	9,837
8	12,492	5,678
10	8,157	3,708
12	5,758	2,617
14	4,290	1,950
16	3,324	1,511
18	2,654	1,207
20	2,171	987
22	1,809	822
24	1,532	696
26	1,315	598
28	1,141	519
30	1,001	455

*The quadratic mean DBH is obtained by measuring all stems greater than 50 mm DBH, and then calculating the square root of the average of the squared DBH.

FURTHER RESEARCH

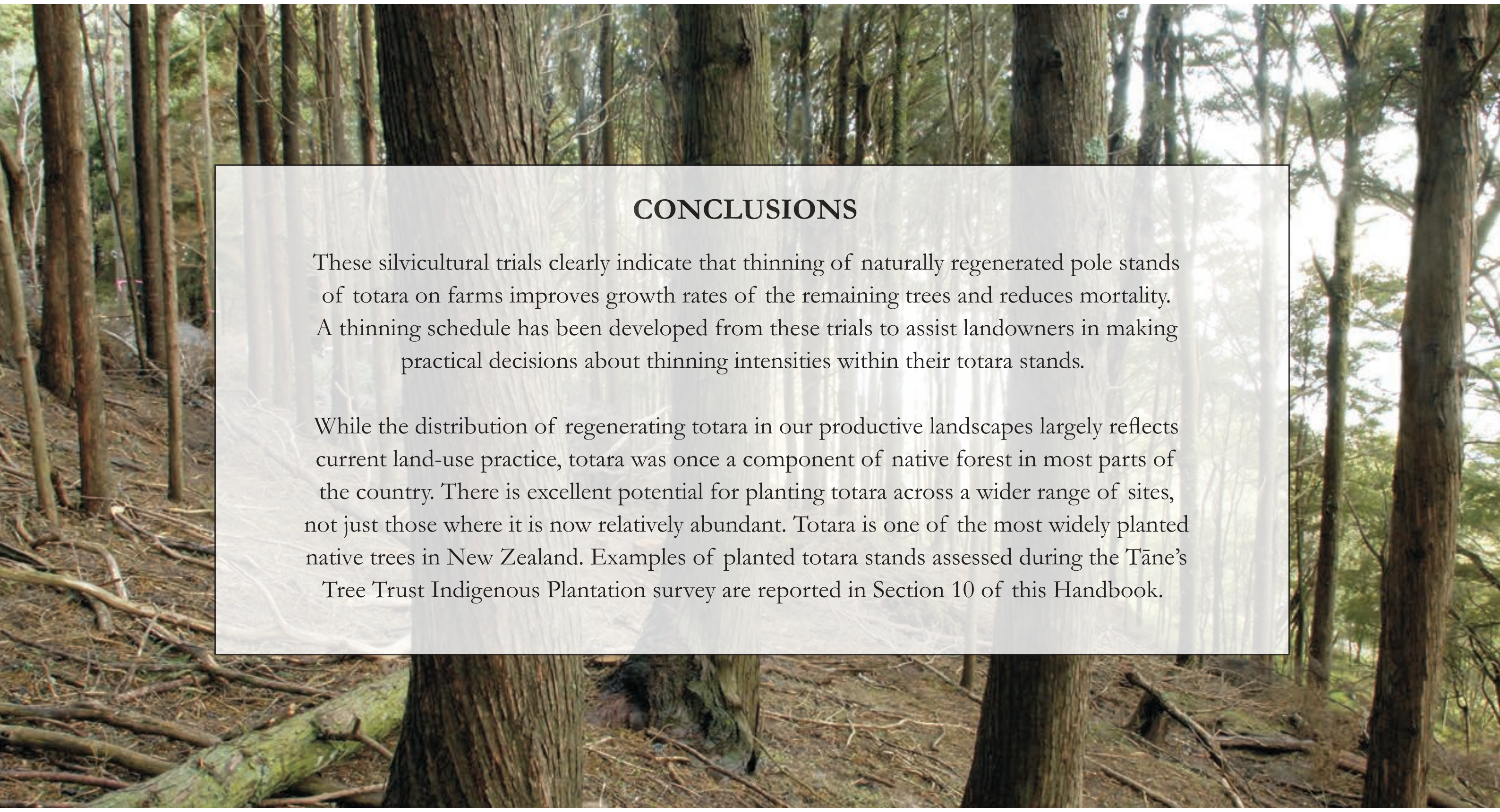
The results of this project highlight several areas requiring further research. These include:

- Determining the factors that account for variability in growth and the response to thinning between sites. This is likely to be related to a combination of the different intensities of thinning and site type. A comparative analysis of growth response to site fertility, soil type and possibly drainage could lead to more precise growth models and silvicultural regimes.

- The size/density chart confirms that some stands were not thinned sufficiently, and the lack of windfall in thinned stands indicates that regenerating pole stands of totara can be intensively thinned. Determining maximum growth rates by testing more aggressive thinning treatments should be undertaken.

- These silvicultural trials focussed on only one portion of the totara resource, i.e., relatively young, dense totara-dominant pole stands on farms with mean DBH from 15-23 cm. Further trials are required in older totara stands with larger diameters, including harvest-sized trees. This will allow extension of growth models based on a range of thinning options across the full age/size range of naturally regenerated totara on farmland.

- Another priority is to develop a species-specific volume equation for pole and mature totara utilising logs recovered from future thinning trials, especially in older stands.



CONCLUSIONS

These silvicultural trials clearly indicate that thinning of naturally regenerated pole stands of totara on farms improves growth rates of the remaining trees and reduces mortality. A thinning schedule has been developed from these trials to assist landowners in making practical decisions about thinning intensities within their totara stands.

While the distribution of regenerating totara in our productive landscapes largely reflects current land-use practice, totara was once a component of native forest in most parts of the country. There is excellent potential for planting totara across a wider range of sites, not just those where it is now relatively abundant. Totara is one of the most widely planted native trees in New Zealand. Examples of planted totara stands assessed during the Tāne's Tree Trust Indigenous Plantation survey are reported in Section 10 of this Handbook.

ACKNOWLEDGEMENTS

Study sites were located on farms owned by Doug and Sally Lane, Roger & Jane Hutchings, Aron & Tina Kilgour, Allan Crawford, Chris Sturge, Jim Mackey, Todd Hamilton, Noel Donelley, Willie Oxborrow, Richard Renwick, Daryl Masters and Paul Quinlan. Alan Griffiths and Warwick Silvester reviewed earlier drafts.

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ISSN: 2230-3014 2014

Printed by Scion Digital Print Centre, Rotorua