Harvesting native trees – estimated versus recovered volumes

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Podocarp-dominated forest with tawa understory in the silvicultural treatment (1979)

Abstract

Harvesting of native trees from natural stands is managed under the provisions of the Forests Act 1949 through Sustainable Forest Management (SFM) Plans and Permits administered by Te Uru Rākau (Forestry NZ). They require continuous cover forestry principles to be applied by specifying (for podocarps) and shade-tolerant exposure-sensitive broadleaved hardwood species the removal of single (or small) groups of trees. Stipulations in the Act, such as targeting trees predisposed to early death and windthrow, reflect that much of the available merchantable resource on private land is in old-growth forest.

Those applying to harvest native trees are required to provide comprehensive pre-harvest inventory estimates of standing merchantable volume by species before plans are approved. These estimates are among important criteria that govern either how much volume for each species will be permitted for harvest or if a harvest will occur. An important consideration for landowners will be whether the effort and cost in obtaining and registering a plan and undertaking a harvest will result in usable volumes of potentially high-value timber and if it will be profitable.

A selective logging trial was undertaken by the NZ Forest Service (NZFS) and (the then) Forest Research Institute (FRI) in mature dense-podocarp forest in Whirinaki Forest in 1979. The estimated standing merchantable volumes and recovered scaled roundwood volumes have been compared for 471 trees representing five podocarp species and tawa (*Beilschmiedia tawa*)

felled and measured by local NZFS Conservancy staff at the time. Comparisons have been made within and between species, and between the three experimental tree selection criteria used.

Large variations between estimated and recovered volumes were seen for individual trees and species. The results indicate that estimating the likely recoverable volume from any individual tree is more problematic than at the species and forest level. Generally, scaled roundwood volume exceeded estimated standing merchantable volume for all species, except miro, (*Prumnopitys ferruginea*) by an average of 12.9%. A significant proportion of mataī (*Prumnopitys taxifolia*) were initially assessed as non-merchantable cull trees through age-related stem rots and defects. However, the mataī scaled volume exceeded the estimated merchantable volume by almost 40%, including cull trees.

Tree selection criteria in the silvicultural selection treatment that emphasised the removal of unstable defective trees could be viewed as a conservative approach to logging in this forest type, and had an overall slightly negative impact on the volumes and values recovered from this forest type. Early post-logging mortality surveys confirmed better stability of the residual forest, although this result has been lost over time. The group selection treatment was most likely to result in the recovery of good volumes of timber and enhanced regeneration of podocarps through canopy and soil disturbance.

Logging resulted in significant localised disturbance, but the forest surrounding cleared gaps remained virtually undisturbed. The individual selection treatment was most closely aligned to the current prescriptions of the Forests Act, but resulted in more diffuse disturbance to the forest, both in the canopy and on the ground. In all treatments regeneration failed to replace felled trees. The various logging treatments had implications for the estimated value recovered; the group and individual treatments would have had similar returns per hectare, while the silvicultural treatment returns would have been significantly less.

This selective logging trial represented only a single site and, as such, it is not representative of the forest remnants likely to be found on private land that may be subject to SFM plans. However, it does indicate some of the complexities that forest owners might expect to face when estimating likely returns (volume and value) when contemplating sustainable forest management operations. Sustainable forest management may in the future be more about carefully managing and eking out a valuable natural resource, while hopefully in other areas the forest is allowed to follow its natural processes, including periods of death and regeneration.

Introduction

New Zealand Forest Service (NZFS) selective logging trials in podocarp forest concluded in 1979 with the Okurapoto Trial in Whirinaki Forest Park. The trial consisted of 40 ha of mature-podocarp forest – Types LI and L2 (McKelvey & Nicholls, 1957); Type L5 (Nicholls, 1976) – roughly divided into four equal-sized blocks (Smale et al., 1985). Three different tree selection criteria were tested (see below), while the fourth was as an unlogged control.

- **Group selection** (Conservancy) – discrete groups of five to six, or 10 to 12, trees felled into a common gap
- **Individual selection** (Conservancy) – trees felled singly or in small groups (two to three trees), concentrating on small-crowned average diameter stems
- **Silvicultural selection** (FRI) – trees that contained some merchantable volume, but appeared unstable (butt and stem rot, substantial lean) and were unlikely to remain standing over the next 20 years were felled. Large tawa were also felled to create gaps for planting after logging.

Tree selection criteria and intensities were developed in conjunction with local NZFS Conservancy staff to test a range of methods of harvesting that could be used in other parts of Whirinaki Forest. These did not follow the prescriptions in the Forests Act, although the individual selection method essentially reflects the Act's prescriptions for podocarps (Alan Griffiths, Te Uru Rākau, personal communication).

Prior to logging, rimu (*Dacrydium cupressinum*) was the dominant canopy species. Mataī, miro and tawa were present in roughly equal amounts, although the latter two species were found only in the sub-canopy and understory. Kahikatea (*Dacrycarpus dacrydioides*) and tōtara (*Podocarpus totara*) were also present, but were only minor components of the overall forest structure. The understory was principally tawa, but with notable inclusions of merchantable size hinau (*Elaeocarpus dentatus*), maire (*Nestegis lanceolata, N. cunninghamii* and *N. montana*), rewarewa (*Knightia excelsa*) and red beech (*Nothofagus fusca*).

The forest contained ~130 stems/ha >30 cm diameter, with most podocarps estimated to be between 200 and 800 years old (Katz, 1980). Basal area and volume averaged 64.3 m^2/ha and 540.9 m^3/ha, with individual rimu and kahikatea more than 60 m tall. Mataī and tōtara were some of the oldest components of the forest, with over half of each species classed as non-merchantable. During tree selections and harvesting there were outwardly competing aims of supplying merchantable logs to the mills while minimising the impacts (short and long term) on the residual forest.

Methods

A comprehensive pre-harvest inventory was undertaken by a skilled Rotorua Conservancy cruising team. Assessments followed the indigenous timber cruising guidelines in the NZFS timber sales manual (NZFS, 1960). All trees over 30 cm diameter at breast height (DBH) were tagged and assigned unique numbers. Assessments included species, merchantability status, any obvious or potential degrades, merchantable height (m), and estimated standing merchantable volume (m^3). DBH deductions were calculated (adjusted DBH), where necessary, based on external defects.

Inevitably, some of the log degrade assessments contained some element of subjectivity, particularly for the extent of internal stem rots and decay. All volume estimates were recalculated in 2019 in an Excel worksheet from either the actual or adjusted diameters and merchantable heights. The volume equations used were the mature-rimu, mature-tawa and the native-hardwoods from Ellis (1979). The mature-rimu equation is specified by Te Uru Rākau when calculating merchantable volume for all podocarp species (Te Uru Rākau, 2017).

After felling, longer logs were broken down at the mill into lengths that averaged 4 to 6 m. Scaled log volumes at the mill were derived by Conservancy log-scalers using the centre-girth method where the volume of a cylinder was calculated from the measured log length (m) and measurements of diameter-inside-bark (cm). Final scaled log volumes were transcribed from tally sheets and measurements of logs at the mill yard. For this analysis, comparisons were made between species and the three different logging treatments.

Species results

Four hundred and seventy-one trees were felled in 1979, of which ~82% were podocarps. For all species, nearly 1,500 logs were produced that were on average 5.6 m long and 1.7 m^3. Nearly 12% of the logs produced were discarded at the mill yard because of rots, shatter, twist, excessive sweep, or they were under dimension (mainly miro). Of all the trees and species felled, 11.5% failed to yield any merchantable volume. Cull trees (i.e. no perceived merchantable volume) comprised almost 16% of all trees harvested. They were predominantly mataī and contributed 6.5% of the total recovered scaled volume. The cull trees were felled during the harvest to create a felling path for other trees or because of collateral damage by other trees during harvesting. A proportion of mataī culls were also felled to study the volume recovery from cull trees.

Podocarps

Two hundred and thirty-four rimu were felled. Rimu comprised half of all the harvested trees (Table 1) and three-quarters of the total scaled volume. Of the 1,066 rimu logs cut, less than 10% were discarded in the log yard prior to milling. Total merchantable scaled volume for rimu exceeded estimated standing volume by almost 10%. One notable rimu produced over 30 m^3 of scaled volume from 14 individual logs, almost 100% more than its estimated standing merchantable volume.

From the 90 mataī felled, 219 merchantable logs were produced and 22 (10%) logs were non-merchantable. Mataī had a high incidence of cull trees identified in the pre-harvest inventory. Some supposedly merchantable trees were discovered to have internal rots only after they were felled. Mataī scaled volume exceeded estimated volume, largely as a result of trees and logs being segregated in the forest. Miro was a significant component of the sub-canopy in this forest type, and 49 were felled producing 90 logs. Over a quarter of these logs were discarded, many because of their small size. Miro was the only species to have a lower scaled volume than the initial estimated standing volume.

Kahikatea and tōtara up to 2.0 m DBH and 30 m of merchantable stem were a feature of this forest type. However, only nine kahikatea and one tōtara were felled. The kahikatea produced 47 logs totalling 119.5 m^3. The single tōtara felled was a cull tree, but this still yielded over 7.0 m^3 of merchantable volume. Scaled volume exceeded estimated standing volume for both species.

Hardwoods

Tawa was the most common understory species in this forest type, with some large individuals more than 1.0 m DBH and up to 18 m merchantable height. Eighty-two tawa were felled producing 95 merchantable logs that averaged 0.91 m^3. Scaled volume exceeded estimated merchantable volume by almost 16%. Six individuals of the other major hardwood species were also felled. These resulted in eight merchantable logs that yielded 5.4 m^3.

Table 1: Summary of felled trees

Species	No. felled	Mean DBH (cm)		Volume (m^3)		
		Actual	Adjusted	Estimated merchantable	Total scaled	Variance (%)
Rimu	234	88.0	82.7	1,598.1	1,753.7	+9.7
Mataī	90	76.3	75.9	221.9	307.8	+38.7
Miro	49	48.7	48.3	72.7	68.0	-6.5
Kahikatea	9	114.4	99.1	108.1	119.5	+10.5
Tōtara	1	113.5	100.0	0.0	7.4	–
Tawa	82	43.7	42.8	74.9	86.8	+15.9
Other hardwoods	6	48.5	47.2	4.2	5.4	+28.6

For the podocarps, scaled volume exceeded estimated volume by 0.7 m^3 per tree and 0.2 m^3 for tawa. At the species and individual tree level there was substantial variation in the roundwood volumes recovered (Figure 1). The residuals, or differences between volumes (scaled minus estimated volume), were generally evenly distributed and followed similar trends of increasing variance with both larger DBH and initial volume estimates. The coefficient of variation in recovered volume (percentage variation) for rimu was 71%, 152% for mataī, over 380% for miro, and over 500% for tawa. As all the variances in volume in Table 1 are greater than +/–5% of the estimated merchantable volume, the difference should be considered significant.

Tree selection effect

The presence or extent of defects or decay was not necessarily fully evident in standing trees. Questions therefore remained as to whether the emphasis on selecting trees in the silvicultural treatment that were unstable and/or had obvious defects and decay would have any significant impact on the recovered volumes in comparison to the other treatments.

In the three treatments combined, 11.1% of the standing trees and 11.8% of the estimated standing volume was harvested. Pre-harvest inventory data showed no statistically significant difference between the three treatment blocks based on the estimated merchantable volumes per hectare for all species combined. The four main species (rimu, mataī, miro and tawa) comprised 98.4% of the trees harvested in the group selection treatment, 94.0% in the individual treatment and 96.8% in the silvicultural treatment (Table 2). The silvicultural treatment harvested the greatest percentage of the original forest (12.9%), but yielded the smallest volume of the three logging treatments (503.5 m^3).

The rimu selected in this treatment were statistically significantly smaller in DBH, merchantable height, and estimated and scaled volumes, compared to the other two treatments. More tawa was also harvested in the silvicultural treatment than the other two treatments combined, with more of them classified as culls (~16%). Despite this, the tawa scaled volume in the silviculture block exceeded estimated volume by almost a quarter.

Selection criteria had no impact on the miro component of the trees harvested, despite the slightly lower scaled volume recovered in the individual treatment block. Of the mataī harvested, between one-third and two-thirds were cull trees in all blocks, but for all treatments scaled volume exceeded estimated volume (and by almost 85% in the group treatment). Tree selection criteria had no effect on the residuals or difference between estimated and scaled volumes for any of the four species.

The comparative value of the scaled log volume was calculated using log prices for native timbers published by the Ministry for Primary Industries (MPI) (Griffiths, 2017). The range of values given for logs arriving at the mill was \$350 to \$600/m^3 for rimu and \$75 to \$225/m^3 for tawa. The values were based on log quality and the amount of heartwood present. Estimates of total log value were calculated using these prices, assuming the rimu price for all podocarps and the tawa price for all hardwood species. An initial analysis included some lower prices for podocarps other than rimu, and similarly for the hardwood species other than tawa. However, the effect was minimal as both species dominated the volume outcomes within their respective classes, so just the two log prices were used.

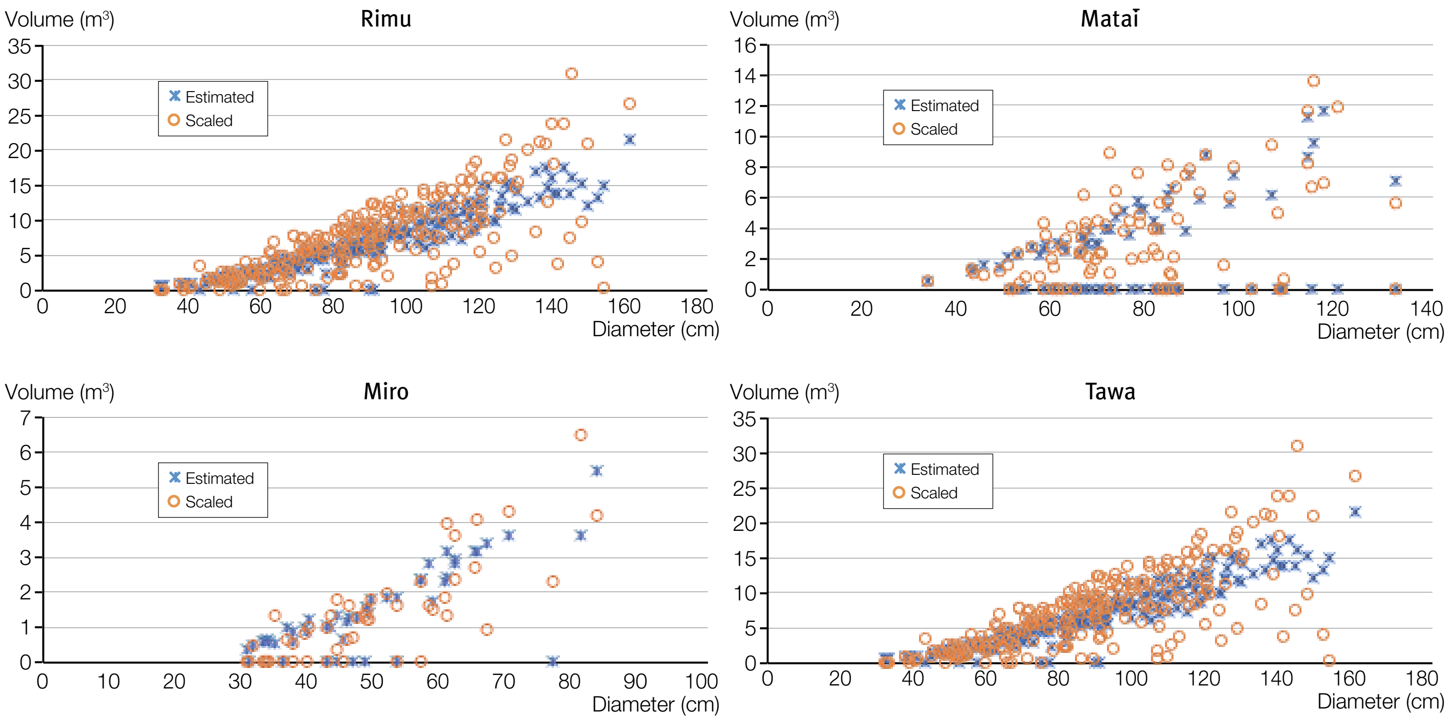

Figure 1: Tree-level differences between estimated and scaled volumes of the four major species

Table 2: Logging treatment comparison

Treatment	Class	Pre-harvest/ha		Harvested trees/ha		Scaled/ha	
		No.	Estimated merchantable (m^3)	No.	Estimated merchantable (m^3)	Total (m^3)	%
Group (12.0 ha)	Podocarps	117.2	560.9	12.8	70.4	84.2	97.0
	Hardwoods	24.7	21.8	2.4	2.1	2.6	3.0
	Total	141.9	582.7	15.2	72.5	86.8	100
Individual (10.5 ha)	Podocarps	97.3	473.1	11.5	70.7	76.0	99.3
	Hardwoods	29.0	25.6	1.1	0.6	0.5	0.7
	Total	126.3	498.7	12.6	71.3	76.5	100
Silviculture (10 ha)	Podocarps	98.1	508.7	10.9	41.3	44.8	88.9
	Hardwoods	28.3	26.3	4.7	4.7	5.6	11.1
	Total	126.4	535.0	15.6	46.0	50.4	100

For the podocarps, the estimated total value of the scaled log volume, in 2017 prices, was between ~$23,900 and $41,000/ha. For the tawa and other hardwood species, it was between ~$215 and $650/ha. Over 140 m^3 of scaled volume was recovered from podocarp cull trees, which was worth between ~$1,540 and $2,620/ha, with most of that value coming from the 104 m^3 recovered from culled mataī across the trial site. The various logging treatments had implications for the estimated value recovered. In Table 3, the group and individual treatments had similar estimated returns per hectare, while the silviculture treatment returns would have been significantly less.

Discussion

This selective logging trial was only a single site, and therefore its results cannot necessarily be extrapolated to other forests or forest types. The Okurapoto area of Whirinaki Forest is acknowledged as having some of the finest high-density podocarp forest remaining in the Central North Island. As such, it is likely not representative of the forest remnants to be found on private land that may be subject to application for and action of SFM plans.

While the results from this trial are valid for the forest and methods used, the difference between cruised and scaled volume from this experimental harvest contradict those obtained from other native forest harvests. The inventory data from several harvests in South Westland podocarp forest where rimu dominated the forest structure and harvested volumes exceeded log scale volumes in all sites by an average of 9% (Alan Griffiths, unpublished data). In both the current study and the South Westland harvests, forest inventories were undertaken by NZFS Conservancy staff skilled in native timber cruising. That skill base has been severely degraded in the years since 1979.

Some of the volume recovery that exceeded initial estimates came from deductions that were expected to occur when the true extent of stem decay was revealed during felling and log scaling. Deductions were also attributed to the presence of heart-shake in both rimu and mataī at the mill yard. In many instances, these deductions were much less than expected, particularly in mataī and cull trees. The lack of losses attributed to breakage and shatter was also a somewhat surprising result. The podocarps in this forest type were tall (up to 60+ m) and several felled trees had three or four leaders originating low on the stem. Shatter and breakage was expected to occur around the crutches between multi-leaders and when felling across rolling terrain. Careful directional felling by the harvesting crew reduced the incidence of these occurring.

Sustainability in the Forests Act is defined as maintaining the ability of the forest to provide a full range of products and amenities in perpetuity while retaining the forest's natural values. In all treatments, where ground and canopy disturbance occurred, these sites quickly became occupied by a dense regeneration of makomako (*Aristotelia serrata*). As the makomako has matured and begun to collapse, a range of common tree fern species have tended to be the predominant replacement. Post-logging regeneration surveys indicate ~46,000 seedlings/ha of all species in all height classes up to 1.0 m tall, with 18 different tree and shrub species recorded (Steward, 2017).

Podocarps accounted for almost one-third of all regeneration, with kahikatea and miro being the most abundant. Neither rimu nor mataī appeared to benefit from soil and/or canopy disturbance, while both miro and tawa regenerated in greater numbers on undisturbed

Table 3: Estimated values (in 2017 log prices)

Treatment	Podocarps ($/ha)	Hardwoods ($/ha)	Total ($/ha)
Group	$29,475 – $50,533	$192 – $575	$29,667 – $51,108
Individual	$26,610 – $45,610	$40 – $124	$26,650 – $45,734
Silviculture	$15,670 – $26,860	$418 – $1,250	$16,088 – $28,110

Group treatment with a gap created by felling 10–12 trees (1980)

The same logging clearing in 2005

sites. Tawa represented 41% of the total regeneration with over 19,000 tawa/ha of all size classes, dropping to around 1,000/ha for stems 3 to 30 cm in diameter. Mortality of even relatively well-established tawa appears to be high and ongoing as there were only 26 tawa/ha >30 cm diameter. The tree selection criteria in the silvicultural selection treatment could be viewed as a conservative approach to logging in this forest type, with selective removal of the crop considered to be unstable and likely to fall within 20 years.

In comparison, the Group selection treatment was presumed most likely to result in regeneration of podocarps through targeted opening of the canopy and soil disturbance. However, while the logging did result in significant localised disturbance, the forest surrounding cleared gaps remained virtually undisturbed, except for hauling tracks. The individual selection treatment was more closely aligned to the prescriptions set out in the Forests Act, but resulted in more diffuse disturbance to the forest, both in the canopy and on the ground.

Early post-logging tree mortality surveys initially confirmed that the silviculture treatment had resulted in greater stability of the residual forest. However, later contracted surveys of the trial for MPI have shown that this effect has since been lost in the 40 years since logging was completed. Mortality has been ongoing throughout the forest since logging was completed, with rimu and mataī suffering the greatest losses; miro and tawa were the next most commonly lost. No significant differences in the rate or mode of loss have been identified between the logging treatments and the unlogged control.

Windthrow has been the primary cause of mortality through uprooting and stem snapping, with the latter often related to a defect such as rot. Most of the mataī loss has occurred in trees originally identified as unmerchantable culls, conversely, most of the rimu and tawa loss has been from merchantable stems (Steward, 2017). Also, a substantial component of the volume loss has occurred through sound, healthy trees being hit by others as they fell, causing snapping or uprooting. Windfall events that included three to five trees in one location are not uncommon in this forest type given the size of the trees and stand density.

Little of the early mortality was attributed to trees that had died standing. In later assessments, the incidence of standing-death increased dramatically to over one-third. Mataī and rimu were the majority of dead-standing trees, which is presumed to be an age-related effect. The principal prescription (10(1)) of the Second Schedule to Part 3A Forests Act 1949 calls for the inclusion of windthrow or dead-standing trees as they become available. Further, prescription 10(2)(b) requires for the selection of podocarp (and kauri) to be restricted as far as possible to the selective removal of trees predisposed to windthrow or early death.

Recently, windthrown and a proportion of dead-standing trees (along with trees predisposed to windthrow or early death) are not automatically by definition defective in terms of their timber. It is also noted that the retention of habitat trees is encouraged in the interests of maintaining natural values and flora and fauna, usually those that are likely to support large plant and fauna communities in their crowns, cavities for hole-nesting birds and bat roosts (Alan Griffiths, Te Uru Rākau, personal communication).

To some extent, this forest was already in a state of change before this experimental logging was undertaken. In 1979, there were between 122 and 140 merchantable stems/ha (Smale et al., 1985). Decaying stumps and stems from old or windthrown podocarps show that

Rimu log extraction with FMC skidder

stand density and merchantable volume were higher in the recent past with stocking approaching ~160 stems/ha. It is most likely that accelerating crown deterioration, stem decay, windthrow and standing-death is resulting in loss of volume throughout this forest. These results indicate some of the complexities that forest owners might expect to face when estimating the likely returns (volume and value) when contemplating sustainable forest management operations.

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