SILVICULTURAL PROPOSALS FOR RADIATA PINE ON HIGH QUALITY SITES

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SYNOPSIS

An evaluation of current production thinning in radiata pine grown on high quality sites indicates that it has failed to increase realizable volumes, provide adequate intermediate returns (sufficient to compensate for the loss of growth on the final crop trees) or significantly improve selection and quality of the final crop trees.

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 150 s.p.a. at 35 ft, and to 80 s.p.a. at 55 ft). This regime, designed to maintain near-maximum growth on the final crop trees, is expected to produce trees of mean d.b.h. 22 to 23 inches in 25 to 26 years on sites of Index 95 ft.

The regime aims to produce board grades only.

PRODUCTION THINNING IN RADIATA PINE

Management of both private companies and the Forest Service almost invariably prescribes production-thinning, and often, second-log pruning. The clearfelling of untended stands prescribed on steep country — for pulpwood of radiata pine (*Pinus radiata* D. Don) (Fenton and Grainger, 1965) and for Douglas fir (*Pseudotsuga menziesii* Mirb. Franco) (Fenton, 1967a) — were exceptions. (Another was the modification of Schedule B proposed by Bunn, Familton and Fenton to the Forest Research Institute meeting on Thinning and Pruning — Bunn, 1963). Pulpwood crops without production thinning — based on the assumption ". . . that little would be gained by planting at a greater rate than the sustained yield annual cut . . ." were subsequently proposed for Nelson (Kirkland, 1965). Elsewhere production thinning is included in all theoretical prescriptions, even on steep country; regimes are given in Bunn, 1963.

Fundamentally, the inclusion of production thinning in management prescriptions has been intended to:

(1) Increase yields.

(2) Obtain intermediate returns.

(3) Allow greater selection of the final crop.

These objectives are analysed below.

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Increased Yields

The yield from modified Rotorua Conservancy prescriptions used in financial analyses (Fenton and Grainger, 1965) for a sawlog regime totalled 11,300 cu. ft net of which 2,300 cu. ft was pulpwood from a production thinning at top height 90 ft. The rotation of 36 years for a site index of 95 ft (Lewis, 1954) resulted in final-crop trees of 22 to 23 in. d.b.h. which were 140 ft high, with a net m.a.i. of 314 cu. ft. Inclusion of an earlier production thinning — at top height 70 ft — would increase m.a.i. to 355 cu. ft, but this operation has been carried out in only two compartments to date and the resulting stocking was lower than prescribed. The earlier production thinning could (ignoring extraction tracks and roads) theoretically increase cubic volume yields by 7½%, assuming the prescription to be perfectly executed, but this increase would all be in small diameter logs. If periodic thinnings are made at 5 or 10 ft height intervals (Hummel and Christie, 1953) as in U.K., or less intensively, at 5 year intervals (Lugton, 1968) as in New South Wales, then yields may increase, but, in the last 15 years of relatively intensive tending in New Zealand, there has been little indication that these intensities are practicable. Yields from an alternative regime are given later.

Intermediate Returns

The successful extraction of the full physical yield interacts with the financial success of the operations. The total volume of radiata pine production thinnings in State forests from stands 25 years and younger was less than 1.5% of the total volume of that species extracted in 1967; much of it was of 23- to 24-year-old stands of exceptional size in Rotoehu Forest (Tustin, 1968). The efficiency of thinning operations in actually carrying out prescriptions was investigated (Fenton *et al.*, 1965) and generally when major produce (pulp and sawlogs) was extracted, results were:

(a) An 18 to 41% lower stocking than prescribed.

(b) Butt log damage, of unknown significance, to about 25% of the remaining trees.

(c) Only 35 to 55 s.p.a. pruned to 18 ft or higher remained after final thinning.

The necessity for lower extraction costs has been stressed (Fenton and Brown, 1963) but total costs average 10 to 12.6c per cu. ft compared with a clearfelling cost of half this, or less (Tustin, 1968). The manpower involved in the one production thinning of the first Maraetai study (Fenton and Grainger, 1965) was over 20% of total forest labour force.

To date, almost all operations have been on tractor country; in Whakarewarewa forest even steep slopes are being worked with tractors.

The sawtimber grades of production thinnings at top height of *ca.* 100 ft have been summarized by Tustin (1968), who concluded that grade outturn (N.Z. Standards Institute, 1962) will not be better than 40% Box, 22% Merchantable and up to 38% better grades. A further study of 22-year-old thinnings from Gwavas Forest by K. C. Chandler and I. G. Trotman gave 52% Box, 20% Merchantable and the balance in better grades. To these indifferent yields must be added the high cost of conversion; the average log sawn to date has been between 7.3 and 11.7 in. s.e.d. (Tustin, 1968). Detailed, up-to-date sawing costs are not available, but costs of production in frame mills of 12 in. s.e.d. logs are half those of 6 in. s.e.d. logs (Williams, 1956; Fenton and Brown, 1963).

Analysis of the Woodhill spacing trial (Sutton, 1968a), showed that, if a "profitable" first thinning with a net return of $28 per acre was replaced by a thinning to waste two years earlier costing $16 per acre, the Land Expectation Value at 5% interest was increased by nearly $24 per acre. This increase was due simply to the increase in mean tree size and the enhanced returns resulting from the application of the current local price size gradient. The advantage of alleged intermediate returns is, therefore, only too easily disposed of for most operations to date (apart from those extracting minor forest produce) have resulted in minimal or negative returns. The 80 or so final crop trees per acre carry, on most radiata pine stands, *all* the accumulated costs of the forest; risk of losing any in extraction thinnings must be minimized. Further, any loss of increment on the final crop stems which is attributable to retaining stems for a production thinning, and any subsequent lengthening of the rotation, as for second-log pruning (Fenton, 1968) are economic factors which must be included in any analysis of profitability.

The argument that a utilization company pays the cost of extraction plus a stumpage is not relevant for it ignores the effect these high costs of thinning will have in depressing final crop stumpages at any subsequent stumpage revision. Nor may a realistic economic analysis be based on such an argument.

Improved Selection

The third assumed advantage of successive thinning operations is improvement in tree selection for the final crop. Tree selectivity may be improved by successive thinnings, but the degree of selection required is largely a matter of obtaining good butt and second logs; the remainder of the tree is of far less importance. The relative sawn-outturn by log height class is given in Table 1, and results by gross value in Table 2. Thus 60 to 72% of the gross value is in the two lowest logs, depending on the final height/d.b.h. relation

TABLE 1: SAWN OUTTURN BY LOG-HEIGHT CLASS

Forest	*Compartment*	*% of total sawn outturn* Butt	*Second*	*Third*	*Fourth*	*Fifth*
Kaingaroa (1)	1045	31	25	20	16	8
	1061	32	26	20	14	8
Waiotapu (2)	28	32	29	19	14	6
Hull's trees (3)	—	35½	28	20	13	3
Dusky (4)	9a	30	26	20	16	9

(1) Fenton, 1967b.
(2) Results from F.R.I. Economics group study — in preparation.
(3) Fenton, 1968.
(4) Fenton and Familton, 1961.

TABLE 2: GROSS VALUE BY LOG-HEIGHT CLASS

Compartment	*Treatment*	*% of value by log-height class* *Butt*	*Second*	*Third*	*Fourth*	*Fifth*
1045	Belatedly 0/18 ft pruned	37	24	18	13	7
1061	Very belatedly 0/7 ft pruned	32	28	20	13½	7½
Waiotapu	0/18 ft pruned, results corrected for time of pruning	40	28	16½	10½	5
Hull's trees	0/36 ft + pruned	42	30½	16½	9	2

Sources — as in Table 1.

and on the degree of tending. If only three saw logs are taken per tree, and the top logs are pulped, the proportion of gross value in the lowest two logs increases to over 80%. It can be anticipated that, if values allowing for sawing cost are used, the proportion would be still greater. Hence selection is, or should be, based mainly on the quality of these logs.

The only dominant requirement of the butt log is straightness (Fenton and Familton, 1961; Fenton, 1967b), as the pruning schedule (prescribed later in this paper) will dominate other gross features of the trees. The real test is the second log — which is unlikely to be pruned (Fenton, 1968). As the object of pruning the butt log is to produce clearwood, increment must be concentrated on the pruned trees, hence either frequent or heavy thinning must apply, yet the size of the largest branches above the butt log are unlikely to be below the maximum (*not average*) of 1.3 in. required to allow a piece of 4×2 in. timber to be graded in No. 1 Framing grade (Sutton, 1968b). (4×2s are by far the most important of the sizes of framing timber required by the market.) As most thinnings result in knot size maxima in excess of the framing grade allowance, unpruned logs from thinned stands must be either sawn to boards, or grown to a large enough diameter to yield good framing between knots (Fenton, 1967b). The only board grade which is independent of knot conditions (alive or dead) and even knot-size, is Factory grade. Fortunately, radiata pine's branching pattern is such that Factory grade is frequently produced in second logs (Table 3).

TABLE 3: FACTORY GRADE PRODUCTION

Compartment	*% Factory grade per log-height class* *Butt*	*Second*	*Third*	*Fourth*	*Fifth*
Kaingaroa, Cpt. 1045	Pruned	24	13	5	3
Cpt. 1061	21 (1)	29	14	9	6
Waiotapu, Cpt. 28	Pruned	34	12	4	0
Dusky, Cpt. 9a	30 (2)	21½	11½	1	1½

Sources — as for Table 1.
(1) Belatedly 0/7 ft pruned.
(2) Belatedly 0/8 ft pruned.

The presence of small (less than 0.5 in. diameter) branches and/or stem cone holes would preclude the recovery of much Dressing grade, even if other characteristics such as knot-size, branch angle (steep-angled branches have a high chance of having bark-pockets on the upper side) and miscellaneous defects were not limiting. The incidence of small bark-encased knots and cone holes in upper logs is given in Table 4.

TABLE 4: INCIDENCE OF SMALL BARK-ENCASED KNOTS AND CONE HOLES

Compartment	*No. per 100 bd. ft. per log-height class*			
	Second	*Third*	*Fourth*	*Fifth*
SMALL BARK-ENCASED KNOTS:				
Kaingaroa, Cpt. 1045	17½	26½	32	37
Cpt. 1061	20½	27	32	32
Waiotapu, Cpt. 28	11	13½	10½	8
Hull's trees	—*	14*	30½	29
CONE HOLES:				
Kaingaroa, Cpt. 1045	1	8	19	47
Cpt. 1061	3½	16	29½	46
Waiotapu, Cpt. 28	1	7	24	67
Hull's trees	—*	12*	40½	126

* Trees well pruned to half-way up third log.
Sources as in Table 1.

Tree selection, therefore, by top height 35 to 40 ft will be adequate to guarantee the timber quality of most boards. To prune stands intended for Framing production is an inefficient investment, as the desired increment on pruned butts will be at the expense of Framing grades on higher logs — unless, of course, finger-jointed Framing is to be considered; if thinning is light to restrict knot size within the limits for Framing grades, then pruned logs will be restricted in size.

Many of the problems of selection would apparently be averted if the second log is pruned. The clearwood sheath and yield can now be calculated from data from a grade study of trees from Waiotapu Cpt. 28. If pruning is done to 28 ft by 45 ft top height and to 36 ft by 55 ft (a severe treatment, but the only one which would give small cores), the minimum core diameter will be 5.0 in. (Fenton *et al.*, 1963). To this must be added an average of 1.5 in. for nodal swelling, to obtain a diameter-outside-pruned-stubs of 6.5 in. if branch diameters are less than 2 in. At Waiotapu deviation in stem form and occlusion scars were such that a further 3.5 in. diameter must be allowed above the diameter-outside-stubs before full length clear boards are obtained. The minimum core is thus 10 in.; the intervening boards are of Factory grade, containing progressively fewer defects. The clearwood sheath, on the Rotorua Conservancy regime, would then be of only 3 in. radius for a tree of 22.5 in. d.b.h. This is too small to give appreciable yields of Clears, and long rotations would be necessary to obtain Clears from this log — Clears which would replace as much Factory as Box grade. The financial returns from this pruning are negative if rotations are of over 36 years (Fenton, 1968), particularly when the cost of holding the stand (namely, the invested capital) for the additional time necessary to produce upgraded timber from the pruning is considered — *i.e.*, the opportunity cost.

Hence, until studies on a wide range of operations demonstrate:

(a) That extraction thinning is feasible at a cost of not more than, say, 50% greater than clearfelling;

(b) That prescriptions are applied within 5% limits;

(c) That intermediate returns are obtained;

(d) That the cost of delayed or lost increment on final crop trees is negligible, or fully compensated by other financial benefits (including lessened transport costs),

there is only a theoretical case for production thinning. The argument can be taken further still if risk, particularly of wind-blow in tall, old stands, is invoked.

A REGIME WITHOUT PRODUCTION THINNING, OR SECOND-LOG PRUNING

What are the alternatives? Framing production may best be obtained from unthinned stands, but is not considered further in this paper; the object of the schedule given in Table 5 is board production.

TABLE 5: SCHEDULE FOR BOARD PRODUCTION

Age	*Mean top height (ft)*	*Operation*
Minus 1	—	Thoroughly burn site, for several preceding years if necessary.
0	—	Plant thoroughly hardened stock — autumn sown if necessary — from March to October. Rows 10 ft apart; 7 ft between plants (or 12×6 ft).
0 & 1	—	Release cut if necessary.
4–5	16–18	Prune 2 trees in 4; 0/8 ft or half height, whichever is the lower.
6	28	Prune 150 s.p.a. to 14 ft or half height, whichever is the lower.
8–9	34–36	Prune 80–90 s.p.a. to 18/20 ft. Thin (preferably by poison) to 150 s.p.a.
11–12	55	Thin by power-saw to 80 s.p.a.
25–26	118–120	Clearfell; 9–9,500 cu. ft yield.

The present practice of 8×6 ft spacing gives 900 s.p.a., only 80 of which are required for the final crop; logically, only a sufficient number need to be planted to ensure 80 straight butt logs and 80 reasonable-quality second logs. Use of selected seed improves tree form — from 8½% "acceptable" with routine collected seed to 59% with seed from cross-pollinated seed orchard clones (C. J. A. Shelbourne, pers. comm.). Wide initial spacing also leads to increased branch size, but as butt log branches are to be pruned from all final crop stems, before they attain their maximum diameter, this is of lesser importance. The potentially larger branches at the time of pruning may cause a slight increase in knotty-core diameters and pruning costs. In second and higher logs, the branch size will depend on the thinning regime (Sutton, 1968b). Rectangular spacing offers reduced planting, blanking, release-cutting and thinning-to-waste costs as machine, walking and access time is reduced. Wider spacing between rows also improves vehicle access for any production thinning which may become feasible. Branch development is no greater between, than along, the rows (Sutton, 1968c). For an initial stocking of about 600 s.p.a. rows should be at least at 10 ft intervals (10×7=623 s.p.a.) or preferably at 12 ft (12×6=605 s.p.a.), 6 ft being equivalent to two average paces. The pruning proposed removes about 40% of the length of green crown at each operation, and will, based on results from pumice areas, produce a knotty core of 7.5 in. gross (Fenton, *et al.*, 1963; Sutton and Crowe, 1968; Waiotapu Cpt. 28 grade study). The resultant grades for trees of the same final size and age are given in Table 6. (This study will be published later.) Grades are satisfactory and could be improved

TABLE 6: GRADE OUTTURN FROM TREES 26 YEARS OLD, 23 IN. MEAN D.B.H.

Mean d.b.h. — % of Log Height Class

Grade	*Butt*	*Second*	*Third*	*Fourth*	*Fifth*
Box	12.2	22.2	30.6	31.1	28.3
Merchantable	8.0	25.9	43.1	54.8	37.2
Dressing	10.8	12.7	6.8	6.0	2.2
Factory (1)	31.7	33.9	12.4	3.9	—
Clears	37.0	—	0.2	—	—
No. 1 Framing	0.3	3.5	5.8	3.9	17.1
No. 2 Framing	—	1.8	1.1	0.3	15.2

(1) Factory grade which would otherwise be Box or Merchantable.

by selection of final crop stems which can yield more Factory grade in the second log.

The branch sizes of the second and third logs in heavily thinned stands may prove excessive but observations to date tend not to support this. Measurements on dominants in the heavily thinned stand at Ngaumu (reduced to 180 s.p.a. at 45 ft) established an increase in the average diameter of the largest branches of 0.6 in. (from 1.89 to 2.50 in.) over a more conventionally thinned stand (Sutton, 1968b).

Projections of final tree size are somewhat subjective, as no old stands which have been treated on the schedule in Table 5 are available. The yield projections available for thinned stands (Beekhuis, 1966) gave results which are considered to be optimistic when applied to stands of the basal area/top height concerned here. Data from a limited range of heavily thinned plots showed that the orthodox projections of basal area trends are generally applicable after top height 75 ft, but, prior to attaining this height, only three-quarters of the predicted basal area increment is realized.

Volumes have been calculated from basal area and height (Beekhuis, 1966) by: *volume in cu ft. per sq. ft. of basal area = 1.3 top height of stand in feet + 3.*

It is too early to assess whether heavy thinning will affect tree form sufficiently to upset this formula, but the volumes given by this projection were 2.8% *less* than those actually obtained from comprehensive measurements of the 15 Waiotapu Cpt. 28 trees (whose grade results are also fundamental to this analysis). Hence the volume formula has been adopted, and for a site index of 95 ft the final crop of 80 s.p.a. will have a mean d.b.h. of 22 to 23 in. at top height 120 ft at age 25 to 26, and a total volume of 9,000 to 9,500 cu. ft. These projections are considered realistic (J. Beekhuis, pers. comm.).

Studies by the Economics section at FRI confirm that volume loss during felling through shatter, etc., is concentrated in the top logs and a net m.a.i. of about 330 cu. ft per acre can be anticipated from a final crop of trees of this size.

SIGNIFICANCE OF THE RESULTS

The proposed regime frees management from the dilemma posed — and never satisfactorily answered — by topography too steep for today's standards and methods of extraction thinning. It more fully utilizes the great capacity for growth of radiata pine with much the same net yield as current schedules. It is free from the degree of risk due to indifferent execution of extraction thinning prescriptions. It largely rationalizes the choice of final crop trees to their selection mainly on second-log characteristics.

Adoption of these proposals, reducing rotations by 10 years or about 30%, can bring national forest targets forward by a decade. By reducing rotations to somewhat over half a forester's career, it can finally ensure that responsibility for results is recognized, and foresters will be able to follow their own crops right through to final felling.

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