IMPLICATIONS FOR SILVICULTURE FROM THE TARAWERA VALLEY REGIMES TRIAL

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ABSTRACT

A replicated spacing/thinning trial in the Tarawera Valley, New Zealand, illustrates some of the silvicultural aspects of thinning radiata pine. Stands which have not received a thinning are liable to volume loss through natural mortality and reduced increment through suppression. Malformed trees will be present in the stand and this may result in volume loss or restrict the choice of harvesting method. Piece sizes will be smaller in unthinned stands than for thinned stands of the same age and the work content per unit of wood extracted is therefore likely to be greater.

Thinning offers a choice; firstly to remove malformed trees, and secondly to mould the residual crop according to the morphological features desired. Over the range of post-thinning stand densities quoted here (1000-375 stems/ha thinned at approximately 11.5 m) increment of basal area per hectare was uniform — individual tree growth being greatest in the lowest stocking. This allows the forester to determine the size of his crops at harvest. Piece sizes for the thinnings documented were small.

Increasing the minimum length or minimum small end diameter regarded as harvestable decreased the volume potentially available. This effect was greatest for the earliest thinnings.

When foresters are charged with providing a resource of raw material for industrial processes they can and should design the regimes they employ to achieve their objectives as efficiently as possible bearing in mind all the biological aspects mentioned here.

INTRODUCTION

In this paper it is intended to first list then discuss with examples the principle "biological" or "silvicultural" aspects of thinning radiata pine. The examples quoted are those most readily available and it is not intended to infer that the values used here are generally applicable even within New Zealand; the aim being to provide a common base for discussion, not a widely applicable model.

The principal source of data is a spacing and thinning trial in the Tarawera valley near Kawerau, New Zealand. The object of this trial is to gather physical data necessary for the economic evaluation of a number of alternative regimes for sawlog and pulpwood crops. It consists of about 90 plots, hexagonal in shape and laid out in a honeycomb pattern in four adjacent stands, each of which has been established at a different spacing.. The plots were laid out in imperial units but are almost exactly 0.06 ha in area for the inner plot where trees are measured and all plots have a surrounding area to act as a buffer between treatments of 0.12 ha. There are three replicates for each treatment.

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The stands were established in 1963 and have been measured each winter since 1969. In July 1974 the Predominant Mean Height (P.M.H.) was 21.5 m indicating a very high quality site. For this discussion a major limitation is that the stands are young (11 years) and the data of necessity incomplete.

RESULTS AND DISCUSSION

Unthinned Stands

Thinning is a positive action and before it is consciously undertaken it is as well to consider the condition of unthinned stands.

The four planting espacements in which the Tarawera Valley trial was established were 9 × 9, 7 × 7, 6 × 6 and 4½ × 4½ feet, that is 2.7 × 2.7 m, 2.1 × 2.1 m, 1.8 × 1.8 m and 1.3 × 1.3 m; and control plots in each of these provide an indication of the changes which occur when stands remain unthinned.

First, competition for light, water and soil nutrients becomes so severe that some trees eventually die, i.e. "natural mortality" occurs. This is illustrated in Fig. 1 where the number of surviving trees per hectare are shown for each of the four stands. The trend is similar to that illustrated in Beekhuis (1966). Ure used similar figures when developing his 1953 thinning regime; this was designed to "cut all the stems which would be dead before the next thinning was due" (Peniston, 1960). Avoidance of mortality or rather the loss of wood through "natural mortality" can be quoted as the primary silvicultural reason for thinning. It follows that the second reason for thinning will be to maintain increment. Nowhere to my knowledge are stands in production forests (as opposed to experimental areas) established at spacings as close as 1.3 m. However, this example does serve to illustrate the loss in growth that follows from extreme competition (an effect which will be seen in wider plantings but at a later stage of growth). As shown in Fig. 2 the living basal area is now less in the stand

FIG. 1 CHANGE IN NUMBER OF SURVIVING TREES

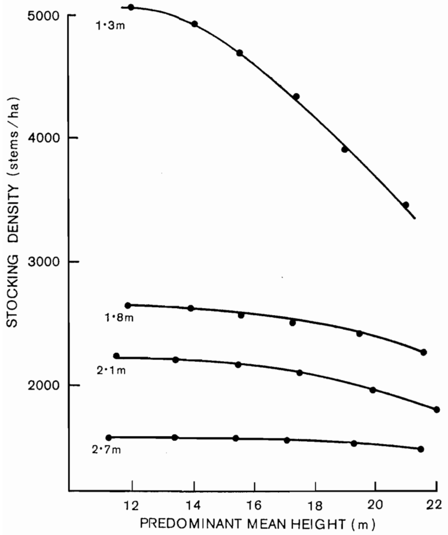
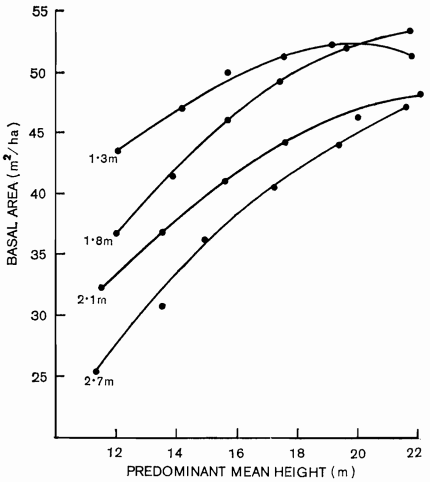


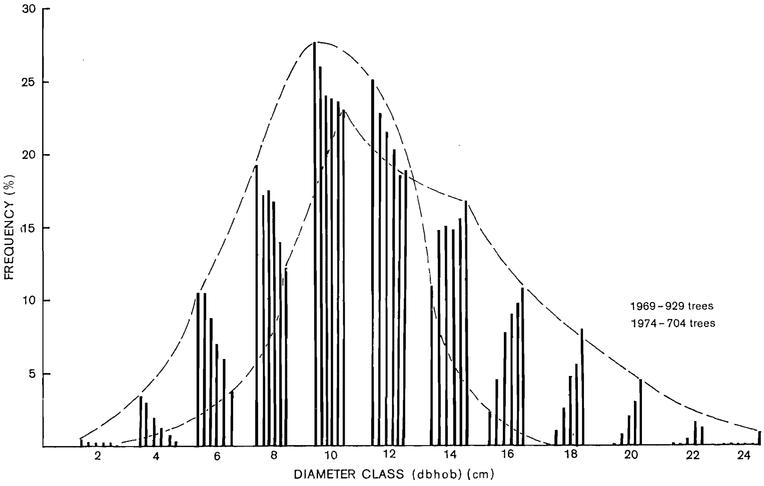
FIG. 2 GROWTH IN LIVE BASAL AREA



NOTE: Curves in Figs. 1 2, 4 and 5 are hand-drawn

established at 1.3 × 1.3 m than in that planted at 1.8 × 1.8 m. In the period over which this stand has been measured (1969-74), 1637 trees per hectare have died and in the last period assessed this loss was more than enough to cancel out growth on the surviving trees. Mortality is not the only reason for the drop in basal area growth, however. The changes in diameter distribution in the 1.3 m stand are illustrated in Fig. 3.

FIG. 3. DIAMETER CLASS DISTRIBUTION FOR 1·3 m UNTHINNED STAND 1969-1974



In six years the familiar bell-shaped distribution has changed to something approaching a bi-modal one while the stand mean d.b.h. (o.b.) increased from 10.1 cm to 13.3 cm. However, throughout this time the 10 cm diameter class has remained the most common class. Although in 1969 62% of all trees were in the 10 cm or smaller classes by 1974 this had reduced to 39%. However, much of this reduction is due to mortality, not growth—over the class limits—89% of all deaths occurring between 1969 and 1974 also came from the 10 cm or smaller diameter classes. This suggests that many of the trees which in 1969 were smaller than the stand mean have not appreciably grown in diameter and an examination of assessment records for individual trees confirms this. It is clear from its appearance that the stand can now be readily divided into two groups, a vigorous emergent component and a stagnating component which will soon succumb.

This is not to say that plant and clearfell (i.e. non-thinning) regimes have no place in forestry, in certain circumstances they do. Growing unthinned stands on a short rotation may be a useful device to make good unexpected supply shortages or perhaps cope with the lumpy nature of wood demands for industrial processes. If mortality trends have been determined for the site in question it will not be difficult to calculate a planting density which will result in negligible mortality for the rotation length envisaged.

Something which cannot be avoided by such regimes, however, is tree malformation. On the fertile sites in the Tarawera Valley, malformation which could cause a reduction in the harvested volume occurred in up to 44% of the trees (Table 1).

The exact amount of these losses will depend on the particular method of harvest. In the example shown here it is assumed that the wood was harvested in 1.2 m billets. Volume was lost if forks forced recutting into shorter lengths or individual billets were rejected because they were kinked or had an extremely large (ramicorn) branch. The reduction in volume would be less if, for example, on-site chipping was used but in none of the cases investigated here did it exceed 6%. More important to those carrying out the operation is the effect of this degree of malformation on the method of harvesting. It may, for example, be sufficient to preclude the use of fully mechanised tree harvesters.

In order to document the results of "plant and fell" regimes, sample areas of 0.06 ha have been felled in each of the four stands and the wood potentially available carefully assessed. The results obtained so far are presented in Table 1. This trial has many years to run and more data are required before a full evaluation of the many alternatives is possible, but already some trends are clear.

The shorter the rotation envisaged the greater the number of stems required to maintain maximum increment. However, by stand height 19 m (10 years on this site) mortality in the stand planted at 1.3 m has already cancelled out any initial advantage in volume.

TABLE 1—Volumes available at clearfelling — plant and clearfell regimes

Nominal Spacing (m)	Stand height P.M.H. (m)	Malform-free Volume* (m³/ha)	% of Total Volume	Number of Billets/ha*	Sawlogs** Volume; Number (m³/ha	No./ha)	% Malforms
1.3 × 1.3	19.0	265	97	16 250	30	220	20
1.8 × 1.8	19.5	300	98	14 260	90	620	29
2.1 × 2.1	22.0	300	94	12 800	100	620	43
2.7 × 2.7	17.1	210	95	9 980	50	350	44
2.7 × 2.7	21.5	340	98	14 480	150	960	33

Note: Volumes obtained from sample areas have been adjusted to conform to the stand mean, volume is to 10 cm (i.b.).

* Assumes volume would be harvested in four foot (i.e. 1.2 m) billets, volume does not include shorter lengths resulting from cutting out forks or crooked billets.

** A sawlog is 4 continuous billets that are straight and have s.e.d. (i.b.) 15 cm or greater.

Re-arranged in order of M.A.I., these results are:

Spacing m	Stand Height m	Age years	M.A.I. m^3/ha/yr
2.7	21.5	11	30.9
1.8	19.5	10	30.0
2.1	22.0	11	27.3
1.3	19.0	10	26.5
2.7	17.1	9	23.3

The volumes to be harvested are low for clearfelling, the piece sizes small and number of billets per unit area high. All this will have a bearing on the cost of extraction. The type of produce from such regimes is limited mainly to pulpwood. The volume potentially available as sawlogs is highest from the 2.7 m stand at 21.5 m height— only 43%.

Mean tree dimensions are shown in Table 2, and these are also small and the volume per tree low. The work content of harvesting must in consequence be high. Planting espacement has an effect on tree size and volume; at the same height (22 m) the stand planted at 2.1 m has a mean tree d.b.h. of 19.1 cm compared with 20.3 for the stand planted at 2.7 m and a mean tree volume of only 0.190 m^3 compared with 0.246 m^3.

TABLE 2—Mean dimensions of trees extracted in clearfelling

Nominal Spacing (m)	Stand Height P.M.H. (m)	Mean d.b.h. (o.b.) (cm)	Mean Height (m)	Mean Volume (m^3)	Mean Number Billets
1.3 × 1.3	19.0	13.7	16.1	0.082	5.0
1.8 × 1.8	19.5	17.8	17.2	0.156	7.3
2.1 × 2.1	22.0	19.1	18.8	0.190	8.1
2.7 × 2.7	17.1	17.5	15.2	0.139	6.7
2.7 × 2.7	21.5	20.3	19.8	0.246	10.5

Thinned Stands

Thinning, by removing a living element from a stand, permits the residual members of the stand to use the sunlight, water and soil nutrients that had previously been captured by the thinnings. The silvicultural effect, if the residual trees can make use of the additional growing space, is to redistribute the growth potential of the stand from many trees to fewer trees. This redistribution of growth is illustrated in Fig. 4 — where the growth of the unthinned control is compared with growth from stands which have a range of residual post-thinning stocking rates. The most important feature of this graph is the parallel nature of growth in basal area for a wide range of residual

FIG. 4 BASAL AREA GROWTH OF STANDS PLANTED AT 2·1 m

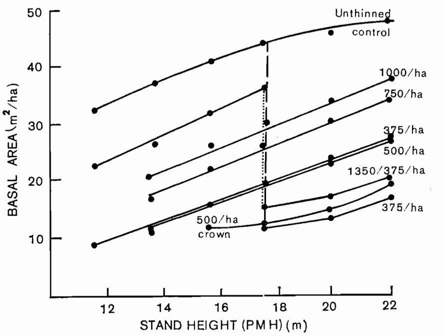
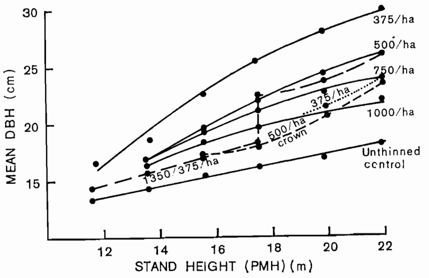


FIG. 5 INCREASE IN MEAN DIAMETER IN STANDS PLANTED AT 2·1 m



stockings — 1000/ha to 375/ha. Initially this was virtually identical to the growth on the unthinned control but mortality has now cancelled out much of the growth potential in the unthinned stand.

This growth pattern may well be different on other sites and may change on this particular site as time proceeds, nevertheless it is clear that over a very wide range of crop stockings basal area growth per unit area has been constant. The important corollary to this is that individual tree growth has accelerated to exactly compensate for the reduction in live stems. Height growth has been unaffected by stocking rate so volume increment will be proportional to basal area increment and therefore also equal within the range of stockings tested here.

The three lowest curves illustrate cases where there has been a reduction in the rate of growth. The first line illustrates a reduction to 375 stems/ha where the thinning was delayed to 17.5 m to control branch sizes. For the first year after thinning, growth was less than for the earlier thinnings but the second year has seen an increase to something approaching the increment of stands thinned at 11.5 m. The second graph line (up from the bottom of the page) illustrates growth following a "crown" thinning. This stand was thinned to 500 stems/ha at 15.5 m height but the crop was chosen only from stems in the 14-19 cm d.b.h. range. This left a uniform crop of trees that had formerly been co-dominants, both dominants and sub-dominants being removed in the thinning. For the first two years after this thinning increment suffered but in the last period (1973-74) the growth increased to be comparable with the conventional thinnings. The third line also shows a temporary drop in the rate of increment. This is an example of a second thinning to 375 stems/ha which has occurred at 17.5 m (the first thinning to 1350 stems/ha having taken place at 11.5 m). For both cases where the thinning was delayed until 17.5 m, it seems likely that the drop in increment which followed reflects the time required for the residual trees to capture the growing space vacated by the thinnings, i.e. to occupy the site.

Thus over a wide range of stocking, basal area increment is the same except where the crop is not chosen from the stand dominants or where, because of the stand height at thinning and the numbers removed, the crop trees cannot immediately occupy the site. Even in these two cases, the examples shown here suggest that increment increases with time from thinning until it approaches that of earlier thinnings.

The increase with time of the diameter of the mean tree is shown for the different stockings in figure 5. For many end uses a specific tree size is preferred. This is an important consideration and since tree diameter is so strongly influenced by stocking it is a parameter that is easily manipulated by the silviculturist.

If the normal method of crop selection is used, thinnings will be the smallest and least desirable trees in a stand — therefore the quality of the crop will correspondingly be improved. This effect is demonstrated in Table 3 (a) which illustrates the volumes available from second thinnings. The first thinning to waste (or precommercial thinning) had in each case reduced the stand to 1330 stems/ha at stand height 12 m from original stocking. The proportion of trees regarded as malforms at second thinning ranged from 10-23% but this is much lower than the 20-44% experienced when unthinned stands were felled. In the cases illustrated the early thinning without yield has accomplished one of the major objectives of thinning, improvement of crop quantity by removal of malforms. It is within the power of the silviculturist not only to discard poor trees but to further mould his crop by selecting for characteristics he finds desirable such as stem straightness, vigour, branch size and pattern.

TABLE 3—Volumes available from thinning

Nominal Spacing (m)	Stand Height (P.M.H.) (m)		Malform-free Volume (m^3/ha)	% of Total Volume	Number of Billets/ha	Sawlogs: Volume m^3/ha	Sawlogs: Number No./ha	% Mal-forms
(a) Selection thinnings								
2nd Thinning from 1330 to 375 stems/ha								
2.1 × 2.1	17.5		128	98	6622	26	198	21
1.8 × 1.8	17.3		134	99	7176	24	178	16
1.3 × 1.3	17.4		120	99	7099	13	99	10
1.3 × 1.3	21.0		188	97	8977	72	660	23
"Crown" thinning to 500 stems/ha								
2.1 × 2.1	15.5		148	98	7976	Na	Na	30
(b) Mechanical or row thinnings								
From initial stocking to 375 stems/ha, outrow 1 in 3								
1.8 × 1.8	15.6	Selection	85	96	10 116	Na	Na	55
		Outrow	78	99		Na	Na	31
2.1 × 2.1	17.5	Selection	90	96	5090	16	109	34
		Outrow	84	98	4445	12	90	33
2.7 × 2.7	19.5	Selection	72	87	3618	7	37	66
		Outrow	88	96	3674	26	146	57

NOTE: The notes to Table 1 also apply to this table. For mechanical thinnings, 1 in every 3 rows was removed entirely and the crop selected from the remaining 2 rows. The thinnings from these 2 rows form the "selection" component.

Apart from the purely silvicultural reasons for thinning, another important objective is the provision of intermediate yields. The volumes available from the thinnings completed so far in the Tarawera Valley trial area are shown in Table 3. Although all thinnings are first extraction thinnings and the data cover only a limited height range, some general conclusions can be drawn. Volume per hectare will always be less for thinnings than clearfellings. The feasibility of extracting volumes of the order of 120-200 m^3/ha in first thinnings can more accurately be assessed by other contributors but I suggest that these quantities are modest. The cost of extraction cannot be improved by the small tree size and the large number of trees and billets which must be extracted to make up the volume. For example, the reduction to 375 stems from 1330 stems/ha yielded about 130 cubic metres from the two stands established at conventional spacings. If every billet was extracted some 6900 pieces of wood would be removed per hectare. Extraction methods designed to reduce this work load would still have to cope with 955 trees per hectare with mean d.b.h. (o.b.) of about 17.0 cm and the modest average volume of 0.136 m^3 (Table 4).

TABLE 4—Mean dimensions of trees extracted in thinning

Nominal Spacing (m)	Stand Height (m)	Mean d.b.h. (o.b.) (cm)	Mean Height (m)	Mean Volume (m^3)	Mean No. Billets
2.1 × 2.1	17.5	17.0	15.0	0.133	6.9
1.8 × 1.8	17.3	17.5	15.6	0.142	7.6
1.3 × 1.3	17.4	15.7	15.7	0.125	7.4
1.3 × 1.3	21.0	18.2	19.8	0.204	9.7
2.1 × 2.1	15.5 (crown thinned)	16.0	14.0	0.096	5.5
1.8 × 1.8	15.6 (select)	15.0	13.8	0.076	5.4
	(row)	15.5	14.4	0.091	
2.1 × 2.1	17.5 (select)	15.0	13.7	0.091	5.2
	(row)	17.0	14.8	0.130	6.9
2.7 × 2.7	19.5 (select)	17.0	15.7	0.113	5.8
	(row)	19.8	16.8	0.193	8.1

Delaying these early thinnings would result in larger piece sizes but only at the cost of reduced increment on the crop element. Adopting row or mechanical thinnings which, because they include the full range of tree sizes in the stand, may raise the average piece size and also result in a more convenient arrangement of the trees to be extracted, will increase yields and lower costs. However, depending on how great a proportion of the stand is removed in the outrows, the size, crown class and subsequent increment of the crop may be lessened. Eliminating whole rows from a stand means that although that part of the stand will contribute to the wood yield, it cannot contribute to the quality of the residual crop.

Table 5 illustrates examples where row thinning has had no detrimental silvicultural effects on the quality of the residual stand and also where, because the removal of 1/3 of the stand forced the selection of part of the residual crop trees from amongst the co-dominants, the diameter of trees in the residual stand has been reduced.

TABLE 5—Comparison of thinnings to 375 stems/ha from original stockings

Original Spacing	Stand Height	Residual Stocking as % of initial stocking	With 1 in 3 Outrow Volume	With 1 in 3 Outrow Mean d.b.h. Residual	Free Selection Volume	Free Selection Mean d.b.h. Residual
1.8 × 1.8 m	15.6 m	15%	163 m^3/ha	19.5 cm	163 m^3/ha	19.8 cm
2.1 × 2.1 m	17.5 m	17%	174 m^3/ha	19.8 cm	171 m^3/ha	20.3 cm
2.7 × 2.7 m	19.5 m	25%	160 m^3/ha	22.1 cm	144 m^3/ha	23.4 cm

Effect of Method of Harvest and Utilisation

The volumes given in previous tables have all been calculated assuming that every four foot (i.e. 1.2 m) billet that was not severely kinked would be harvested. In a "real life" situation, however, other harvesting methods may well be chosen in an attempt to lower costs. Table 6 shows the effect on the volume available of progressively increasing the length of stem considered as the minimum harvestable. The loss in volume is related to the degree of malformation and the size of the trees (i.e. the length to the 10 cm point).

The choice of small end diameter limit to utilisation also influences yields available and the reduction in yield with increases in the size of the minimum acceptable s.e.d.(i.b.) are shown in Table 7. The volume obtained if wood is harvested down to 10 cm diameter is taken as 100%. The amount of reduction in volume depends on the size of trees in the stand. In general the greater the stand height the greater mean tree diameter and the more the stand volume tends to be distributed amongst billets of larger diameter. Thus the volume obtained from early thinnings is much more sensitive to an increase in the minimum utilisable diameter than later thinnings.

TABLE 6—Effect of change in minimum log length on percentage of volume harvested

Nominal Spacing (m)	Stand Height P.M.H. (m)	Minimum Length Extracted 1.2 m	2.4 m	3.7 m	4.9 m	6.1 m
Clearfelling						
1.3 × 1.3	19.0	100	96.5	92.3	88.6	79.0
1.8 × 1.8	19.5	100	98.3	95.5	92.5	88.3
2.1 × 2.1	22.0	100	97.0	90.6	84.0	80.2
2.7 × 2.7	17.1	100	97.2	91.4	86.5	75.7
2.7 × 2.7	21.5	100	98.0	95.0	92.8	90.0
Arithmetic Mean		100	97	93	89	83
Second thinning						
2.1 × 2.1	17.5	100	99.1	98.6	94.3	88.6
1.8 × 1.8	17.3	100	99.6	99.3	96.8	95.5
1.3 × 1.3	17.4	100	99.3	98.1	96.4	95.3
1.3 × 1.3	21.0	100	99.7	99.1	97.7	92.8
Arithmetic Mean		100	99	99	96	93
Crown thinning						
2.1 × 2.1	15.5	—	—	90.5	—	—
Row thinning — selection component						
1.8 × 1.8	15.6 (combined)	—	—	88.1	—	—
2.1 × 2.1	17.5	100	97.0	85.9	79.7	73.8
2.7 × 2.7	19.5	100	91.4	74.2	59.1	49.0
Arithmetic Mean		100	94	83	69	61
Row thinning — outrow component						
2.1 × 2.7	17.5	100	90.4	85.9	80.0	76.1
2.7 × 2.7	19.5	100	95.7	90.6	86.5	74.5
Arithmetic Mean		100	93	88	83	75

TABLE 7—Effect of change in minimum small end diameter on percentage of volume harvested

Nominal Spacing (m)	Stand Height (P.M.H., m)	Minimum Small End Diameter Class								
		7.6 cm	10.2 cm	12.7 cm	15.2 cm	17.8 cm	20.3 cm	22.9 cm	25.4 cm	27.9 cm
Clearfelling										
1.3 × 1.3	19.0	100	99.3	73.4	37.8	11.8	2.7			
1.8 × 1.8	19.5	100	99.5	85.4	63.5	38.1	18.5	7.6	1.1	
2.1 × 2.1	22.0	100	100	89.0	71.4	46.6	28.9	13.9	3.4	0.3
2.7 × 2.7	17.1	100	99.7	84.7	60.2	37.1	17.1	3.4		
2.7 × 2.7	21.5	100	100	89.4	72.6	51.6	26.4	11.3	3.6	
Second Thinning										
2.1 × 2.1	17.5	100	98.2	82.5	59.4	30.1	8.8	2.3		
1.8 × 1.8	17.3	100	99.1	83.2	53.1	24.0	4.8			
1.3 × 1.3	17.4	100	98.5	78.6	44.2	12.6	2.3			
1.3 × 1.3	21.0	100	100	89.4	66.0	35.0	7.8	1.5		
Crown Thin										
2.1 × 2.1	15.5	100	98.1	75.8	51.3	28.7	10.2	1.8		
Row Thinning — Selection Component										
1.8 × 1.8	15.6 (combined)	100	96.9	71.2	39.5	17.0	3.9			
2.1 × 2.1	17.5	100	97.7	73.2	47.4	28.0	11.5	3.4		
2.7 × 2.7	19.5	100	99.3	81.0	58.9	36.2	12.5	7.7	3.5	
Row Thinning — Outrow Component										
2.1 × 2.1	17.5	100	98.1	81.4	54.1	25.2	8.9	2.5		
2.7 × 2.7	19.5	100	99.9	87.3	70.8	51.7	34.5	20.0	2.3	

CONCLUSION

The data presented in this paper have been derived for a specific area in New Zealand — they have been used here to illustrate the principles involved in the silvicultural manipulation of forests as a source of raw material for industry. The data indicate the patterns of survival, growth, volume, and tree size distributions that have occured on this site during the application of a number of silvicultural regimes. The influence of some harvesting practices on volume extracted has also been indicated.

Such a data base, particularly if extended to full rotation length, enables the forester to design his regimes to not only supply the quantities and qualities of wood he requires at the time he requires it, but also to do this at the least cost. In this sense the forester is like the engineer who would no longer consider constructing a bridge or a building without consulting a comprehensive set of data on the strength of building materials. Where the type of wood required from the forest can be specified (and this is usually the case) the regimes should be "designed" using a data base applicable to the site concerned and incorporating all the biological effects discussed here.

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