GROWTH HABITS OF RIMU IN WESTLAND'S TERRACE FORESTS AND THEIR IMPLICATIONS FOR FOREST MANAGEMENT

C. G. R. CHAVASSE and W. W. TRAVERS*

SYNOPSIS

The terrace forests of Westland constitute one of the largest remaining areas of podocarp timber in New Zealand. Attempts are being made to manage these forests, on a sustained yield basis, by selection management. The silvicultural characteristics of rimu (Dacrydium cupressinum), the major species, are closely studied, and it is shown that some of the features of crown and stem are related to vigour. A vigour classification is related to management systems. An even-age system, although feasible, would probably not be successful because of a long regeneration period and the difficulty of obtaining full stocking. Uneven-aged management, on a selection system, appears to have the best chance of success. Data and estimates from stand studies are used as a guide to management and initial silvicultural operations. Further studies on the managed stands should eventually provide reliable stand data for successful selection management of the terrace forests.

INTRODUCTION

The native forests of New Zealand are being cut out at the rate of 30,000 acres per annum. The remaining accessible volume, excluding reserves, is estimated to be 1,800 million cu. ft (Thomson and Williams, 1964). Of this volume, approximately half lies in the Westland Conservancy. The N.Z. Forest Service Annual Report of 1964 stated the policy of attempting to manage Westland's remaining terrace forests on a sustained yield basis. There are approximately 85,000 acres of State forest land available for this form of management.

Rimu is by far the most common merchantable tree of the terrace forests and any system of sustained yield will depend on the silvicultural characteristics of this tree. It is therefore important to know, rather precisely, what the more important features are, for, to quote Köstler (1956): "The most important part of silvicultural work is the marking of trees intended for felling; the scribe is the tool proper to the silviculturist".

Studies of the terrace podocarp forests of Westland were commenced in 1925, and continued from 1928 to 1934 under the aegis of the Canterbury School of Forestry (C. E. Foweraker and F. E. Hutchinson—unpublished papers). No further work was done until 1952 and since then almost continuous study of the original Canterbury School areas has been undertaken by C. G. R. Chavasse,

* Respectively Senior Forester, N.Z. Forest Service, Invercargill, and Trade Commissioner (Timber), Sydney, Australia.
C. Bassett and W. W. Travers. Additional investigations and experiments have also been carried out in other areas.

The areas selected for study of vigour were the Canterbury school plots, where growth rates of the previous 30 years were known; supplemented by a further series of plots established for thinning studies. The plots covered a wide range of age-classes, indicated by mean plot d.b.h. range from 6.7 to 22.35 in., and these were compared with mean data for the major National Forest Survey terrace forest types P1, P2 and P3 (Masters et al., 1957).

PART I

GROWTH HABITS AND THEIR RELATIONSHIP TO TREE VIGOUR

This part of the study covered 289 trees, with a wide distribution of diameter-class and vigour. Before studying the characteristics of individual trees it was considered necessary to examine the stands in some detail to determine whether some stand characteristics were related to soil and other site conditions. There were, for example, certain marked differences in stand composition by species; in the proportions of vigorous and poor trees; and in exposure, stocking and stand increment. The plots studied were not comparable as to site or as to forest type, but as the study was mainly concerned with individual trees this was not considered important. In the analysis of characteristics it became clear that the more important indicators of vigour were not restricted to any one site type.

The basis for determining vigour was diameter growth over a period of time, and this varied considerably over the range of diameters studied — from 4 to 49 in. Seven grades of vigour, ranging from very vigorous to poor, were recognized. A graph

![Graph showing mean annual diameter growth of trees of given d.b.h. in each of seven vigour classes for rimu in terrace forests of Westland.](image)

Fig. 1: Mean annual diameter growth of trees of given d.b.h. in each of seven vigour classes for rimu in terrace forests of Westland.
of the annual diameter growth for the seven vigour classes is provided in Fig. 1. As far as the stand as a whole was concerned, the major factors affecting vigour were stocking and exposure, and it is important to note that both affect crown size. This will be further discussed below.

In the more vigorous stands, one feature which is not clearly understood was the appreciable silver pine (Dacrydium colensoi) component, particularly in the younger rimu stands. It is possible that silver pine improves the site, as it is known to be the pioneer species on the most inhospitable terrace soils. Rimu cannot become established directly on these, but infiltrates into the silver pine stand as it develops.

The rooting habits of rimu and their possible effect on tree vigour were not studied, but it is probable that they play some role in vigour. They will also be important when considering management, particularly with regard to the choice of method of extraction of logs. Cameron (1963) discusses the significance of rooting habits on the success or otherwise of rimu regeneration and it has been observed that rimu regeneration is rarely found under mature trees of the same species. Rooting habits are therefore likely to be of importance in the establishment phase of regeneration or advance growth.

CHARACTERISTICS OF INDIVIDUAL TREES

The Crown

(1) Crown Freedom

A feature of exposed stands is strong abrasion of the crowns. Free crowns in exposed situations thus give no indication of vigour. Where no such abrasion is evident it was found that trees with crowns free on three or four sides, within the range from 6 to 28 in. d.b.h., showed vigorous growth. Trees in the lower part of the canopy showed reduced vigour. For example, trees up to 8 in. d.b.h. can maintain average growth rates provided there is overhead light, while completely overshadowed trees above 4 in. d.b.h. can be described as suppressed, except where there are two distinct canopies. In this case average or better growth rates can be found in trees up to 4 in. d.b.h.

The critical point for crown freedom occurs in rimu trees at about 12 in. d.b.h. Up to this point shade tolerance is a dwindling factor, and above it rimu becomes increasingly light-demanding; by about 24 in. d.b.h. rimu can be considered fully light-demanding.

Crown freedom is thus an important diagnostic feature in estimating vigour in trees above 6 in. d.b.h., and is of the greatest importance in trees above 12 in. d.b.h. The implications of this are that, in fully stocked stands, thinning should commence when the mean d.b.h. is in the neighbourhood of 6 in. and definitely before it reaches 12 in. To determine where thinning should begin an estimate of both the mean d.b.h. and the stocking should be made.

(2) Dominance

The conventional classification of trees into dominant, co-dominant, intermediate and suppressed gives little indication of vigour.
Within the d.b.h. range 6 to 14 in. it can be considered indicative. Thus it has some value for the tending of pole stands, but little for selection forestry. Poor growth may be found in all dominance classes. Not all trees classed as suppressed show poor growth, and some below 6 in. d.b.h. may be relatively vigorous. On the other hand, many trees with poor growth are found in the dominant class, and this is not altogether attributable to the exposure factor.

The most vigorous trees are usually found in the intermediate class up to 14 in. d.b.h. and in the co-dominant class up to 28 in. d.b.h.

A second study of crown class was undertaken using the categories predominant, upper canopy, lower canopy and under canopy. The best growth rates were found in upper canopy trees between 10 and 27 in. d.b.h., but the classification gave no indication of the poorest growth, which may occur in any class.

(3) Crown Type

Crowns were judged subjectively to be dense, open or straggling. These terms are not easy to define, but are fairly clearly discernible in the field. Vigorous trees may have dense or open crowns, while straggling crowns may indicate poor growth. This feature is not definitive, especially in larger trees.

(4) Crown Symmetry

The study indicated that between 50 and 60% of crowns were one-sided probably owing to crown competition and, for large trees, loss of major limbs. Below 12 in. d.b.h. a symmetrical crown is indicative of better-than-average growth rates. For larger trees, while the proportion of symmetrical crowns is greater in the higher vigour classes, well-formed crowns can be found in lower vigour classes. The feature can, however, be considered indicative.

(5) Crown Form

The commonest rimu crown form in forest conditions is a paraboloid (Fig. 2). Probably depending on a number of factors, the initial monopodial habit and paraboloidal form give way in time to a more branchy habit; crowns then tend to assume a more or
less cylindrical, rounded or irregular form. The last may be a reflection of age, vigour, or the particular conditions in which the tree has developed. The tendency is for paraboloidal crowns to be found on the more vigorous trees. With decrease in vigour there is an increase in crown irregularity.

This feature, though not entirely safe diagnostically, is a strong indication of vigour throughout the range of diameters studied, and would therefore have some importance for any silvicultural work in all types of stand.

(6) Crown Depth and/or Crown Percentage

Both these features proved to be highly variable, particularly in the more uneven-aged type of forest. Neither factor is of any use in the diagnosis of vigour.

(7) Crown Diameter and Crown Ratio

Though there is a good deal of variation in the diameter of crowns, this is a less variable feature than crown length. In the form of crown ratio this feature is of no value for trees above 18 in. d.b.h., where most ratios are fairly close to the mean figure of 9.9. Below 18 in. d.b.h. either crown diameter or crown ratio gives some guide to vigour; this is however not sufficiently reliable to be indicative.

(8) Crown Volume

Three components enter into this feature — depth, diameter and form. Crown volume is important, but the last component is difficult to evaluate. For practical purposes, this feature can be discarded.

The Stem

(1) Upper Stem Characteristics

Vigorous trees have intact tops, and generally maintain a mono-podial habit beyond 24 in. d.b.h. and frequently up to 30 in. Lost tops are a definite sign of poor vigour. The tendency is for crowns to approach the “mature type” (with no main stem and leader through the crown) from about 14 in. d.b.h. onward, but still maintain greater than average vigour. Below 8 in. d.b.h. trees with “mature type” crowns invariably show poor vigour.

A definite leader, or the presence of a main stem through the crown, are valuable diagnostic features in estimating vigour.

(2) Forked Trees

The proportion of 25% of forked trees is fairly constant in the stands studied and throughout all diameter and vigour classes.

(3) Leaning Trees

Leaning trees invariably show lack of vigour and generally the more severe the lean the poorer the growth rate.
(4) Stem Fluting

Fluting is not usually found in trees less than 15 in. d.b.h. Above this, it generally increases, both in length and depth, and is found on an increasing proportion of trees. There is no indication that fluting is connected, in any way, with vigour.

(5) Bark Characteristics

The presence of copious loose bark flakes is usually a reliable indication of vigour. In young trees, however, bark characteristics can be misleading. Young dominant trees often have smooth bark, while bark of suppressed trees may be equally smooth.

Adjacent Stems

The basal area of all stems (of all species) within a radius of 10 ft of the tree under study was determined. No indication of a connection between this and vigour was revealed, except in so far as the adjacent trees affected the crown.

No relationship could be established between ground vegetation and vigour.

Conclusions

While it is clear that exposed stands show poor vigour, and that there are differences between forest types on the terraces, certain features studied and discussed above are useful guides for vigour classification in the field. These features may be summarized as follows:

Definitive Features

(1) Crown freedom (except in exposed stands or where the stand contains a high proportion of silver pine):
Vigorous — Trees of 6 to 28 in. d.b.h. with crowns free on three or four sides.
Dominants free on one or two sides up to 12 in. d.b.h.
Weak — Trees of 4 to 8 in. d.b.h. with little or no overhead light.
Enclosed crowns above 8 in. d.b.h.

(2) Upper stem:
Vigorous — Monopodial habit or definite leader.
Weak — Trees with lost tops and leaning trees.

Strongly Indicative Features

(3) Crown form:
Vigorous — Crowns paraboloid on trees up to 20 in. d.b.h.
Larger trees with cylindrical or cylindrical/rounded crowns.
Weak — Crowns irregular or rounded/irregular.

(4) Bark:
Vigorous — Copious loose flakes.
Weak — Lack of loose flakes.
(5) **Crown diameter or crown ratio:**

Vigorous — Relatively high crown ratios for trees up to 20 in. d.b.h.
Weak — Narrow crowns.

*Indicative Features*

(6) **Crown type** (Dominants of any diameter class may be straggling):

Vigorous — Dense-to-open type for trees up to 26 in. d.b.h.
Weak — Straggling for trees up to 26 in. d.b.h.

(7) **Crown symmetry**:

Vigorous — Symmetrical to 28 in. d.b.h

(8) **Dominance**:

Vigorous — In upper canopy between 10 and 27 in. d.b.h. Intermediate and co-dominant classes from 6 to 14 in. d.b.h.
Co-dominant above 18 in. d.b.h.
Weak — May be any position in canopy.

*Poorly Indicative*

(9) **Crown length and Crown percentage** (not in selection stands):

Vigorous — High crown percentage on trees up to 20 in. d.b.h.
Weak — Low relative crown percentage.

(10) **Bark**:

Vigorous — Smooth barked dominants.
Weak — Smooth barked subcanopy trees.

It should thus be possible to recognize vigorous trees at least up to about 24 in. d.b.h., but with decreasing accuracy for larger stems. For more or less even-aged stands (e.g., pole-type stands), thinning can be carried out on the basis of releasing the more vigorous trees for further growth. Marking principles for the second, third and subsequent felling cycles in selection management could also be based on the above vigour characteristics. In virgin forest, it is reasonably easy to recognize the trees which should be removed in the first logging operation.

The above study indicates a method of classifying trees for sample plot work. It is proposed that the classification should be based on (A) Position in the canopy; (B) Characteristics indicative of vigour; and (C) Stem characteristics. Details of this classification are given in the Appendix. The vigour classification may appear somewhat cumbersome, but after some use in the field it becomes fairly easy to apply. The classification is a three-figure method. For example, a perfect and vigorous tree would be classified as III. The classification should not be used for trees smaller than 6 in. d.b.h. or those larger than 26 in. d.b.h.
PART II

IMPLICATIONS OF THE STUDY FOR EVEN-AGED MANAGEMENT

The stand study was made over 32 plots, covering a range of mean d.b.h. from 6.7 to 22.35 in., with the mean height of dominants 54 to 110 ft and age range of dominants 195 to over 600 years. Mean d.b.h. and mean height of dominants were used in the stand study as they are relatively easy to determine; each of them gives reasonable agreement with other features — stocking, basal area, age and crown dimensions; they reflect reasonably well the required growing space of individual trees and the basal area; and volume ratios agree well on the basis of mean diameter. Though the plots cover different soil, topographical and forest types, for practical purposes they appear to show a marked trend from relatively even-aged stands in the younger phases to markedly uneven-aged stands in the older phases. The silvicultural features of the stands appear to be closely related in all respects, but no doubt site variations are of importance and should be the subject of further study.

Considerable detail was collected during the study and was tabulated for a detailed Forest Service report (Chavasse, 1959). Some of the more pertinent observations as related to even-aged silviculture are as follows:

(1) Mean annual height growth of dominants appears to reach a maximum of about 3.8 in. per annum at about 250 years and thereafter it gradually becomes less.

(2) In unthinned, fully-stocked stands, mean diameter will approach 7 in. at 200 years and 15 in. at about 400 years; corresponding merchantable stems (10 in. d.b.h. and up) will average 11.3 and 17.1 in. at the same ages.

(3) For a long period after the initial establishment of the stand there is continuous recruitment into the 4 in. d.b.h. class. Because of this, stocking tends to increase up to a dominant height of about 66 ft when the stand has a mean diameter of 8 in. But the denser the stocking, the smaller the mean d.b.h. for equivalent heights; and dense stands, with a small mean d.b.h. in relation to height, may be comparatively old. Indications are that first thinning should normally take place at an age between 150 and 200 years, if optimum growth rates are to be maintained.

(4) A study of stands was carried out to determine the area occupied by projection of crowns. This was termed the “growing space”. It was possible to arrive at an optimum growing space figure for stands of different ages. It was found that fully-stocked stands were not conducive to high growth rates of individual trees, and a measure of the necessary reduction in stocking could be obtained by comparison with the actual as against the optimum growing space figures. This is a laborious practice for normal use although it can be applied to sample plot work. For practical purposes stem basal area can be used as a satisfactory guide. This should be maintained at a figure between 120 and 150 sq. ft per acre for merchantable trees — that is, trees from 10 in. d.b.h. upwards.

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(5) With relatively short rotations (less than 300 years) in untended even-aged stands, small logs would form the bulk of the crop but if it is desired to produce larger logs with higher output of clear grades, a longer (400 to 500 years) and more expensive rotation would be required, though there could be a supplementary output of posts, poles, or pulpwood.

(6) Provided full stocking can be attained and there is no thinning in the interim, at 300 years from time of initial felling one may expect the stand to consist of a final crop of some 280 stems, from 6 to 24 in. d.b.h. and a total merchantable volume of about 5,500 cu. ft per acre. This represents a M.A.I. of 18 cu. ft per acre.

(7) Such stands could be improved by a proper thinning regime based on the silvicultural characters of the rimu tree and stand as discussed above and the further details provided by Chavasse (1959). In managed, tended even-aged stands the aim should be to reach a mean d.b.h. of 16 in. in some 375 years. Estimated mean annual increments (for merchantable timber) would approach 30 cu. ft per acre for rotations up to 270 years, but from 280 years the M.A.I. tends to fall. Total production, allowing for a regeneration period of 40 years, should exceed 10,000 cu. ft on a 375-year rotation from time of initial felling.

(8) Although even-aged management is feasible, the natural stand structure of the terrace podocarp forests is an uneven-aged one of varying degrees and it is most desirable, for many reasons, that they should be intensively managed as uneven-aged forest. Observations on the distribution and frequency of rimu regeneration indicate that it is very doubtful if sufficient well distributed regeneration would be available in the required period, or even over a much longer regeneration period, for the establishment of rimu as an even-aged crop.

PART III

IMPLICATIONS OF THE STUDY FOR SELECTION MANAGEMENT

On the flat terrace lands, there is a catena of forest types developed according to origin and site with a general sequence of the National Forest Survey types, P12, P2, P1 and P3 (Chavasse, 1964). The P12 stands are well stocked with small rimu and silver pine stems, with occasional pre-dominant rimu. This type usually occurs as a thin strip of forest between fringing silver pine and P2 or P1 areas. Type P3 is a fully-developed terrace stand with a higher number of larger trees and usually a correspondingly lower stocking of the small d.b.h. classes. By far the most extensive and important of the terrace forest types are the P1 stands, which are composed of a wide variety of more or less even-aged groups and mixed-age stands with highly variable structure. These terrace rimu forests are not true selection forests. However, N.Z. Forest Service figures reveal that there is adequate stocking in all classes to maintain the stand structures that are found. Over restricted areas in each
type there will be a lack of some classes and an over-abundance of others, but generally there will be a shortage in the smaller classes and too many stems in the larger classes. For silvicultural purposes, one can recognize first the P12/P2 type, in which the aim will be to develop timber-sized trees; secondly, the P1 mosaic, each part of which will require individual treatment to bring it towards normality; and thirdly the P3 stands in which it will be necessary to reduce the large- and medium-timber fraction and induce regeneration, in order to build up the smaller classes.

It is necessary to have some idea of the possible normal growing stock and the increment that can be expected from this volume in order to evaluate actual stands and to act as a model in their conversion to normality. When converting natural stands to what is conceived to be a desirable selection forest structure, designed to achieve maximum production, it is possible to state objectives without obtaining a great deal of information. The difficulty arises when devising methods of working towards these objectives and, since in selection forestry the main silvicultural work will be concerned with individual trees or small groups, it is necessary to know something of the silvicultural requirements of these so that each tree or group can be treated on its merits. The present study was designed to provide some of the necessary knowledge, but even so the definition of the normal or ideal stand derived here should be used with caution while further information is being obtained, particularly on the effects of treatment.

It is assumed, in the first place, that it is desirable to grow timber to a relatively large size, since the first consideration is value increment. The mean volume increment of individual trees begins to fall after about 24 in. d.b.h. and, for the normal tree, loss by increase in shaky heart and internal rot will eventually equal gain in value. From general observations in P1 stands, the point of transition lies at about 32 in. d.b.h.; thus the maximum size of tree should be about 32 in. d.b.h., except for unusually vigorous trees.

Secondly, provision must be made for adequate recruitment to each size class. Thus there must be an increase in the roundwood class above the stocking already found in actual stands. Thirdly, it is assumed that silviculture is designed to allow trees to attain maximum growth rates; thus the stocking in the small-timber class will be reduced from that derived from natural stands.

In order to fulfil these criteria the mean d.b.h. must lie between 11 and 16 in. The study of stands with mean diameters between 11 and 16 in. at b.h. showed that the stocking should be between 130 and 230 stems per acre with a percentage distribution approximately as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>d.b.h. (in.)</th>
<th>Percentage Stocking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundwood</td>
<td>4 to 9.9</td>
<td>40 to 60</td>
</tr>
<tr>
<td>Small timber</td>
<td>10 to 15.9</td>
<td>25 to 35</td>
</tr>
<tr>
<td>Medium timber</td>
<td>16 to 23.9</td>
<td>12 to 20</td>
</tr>
<tr>
<td>Large timber</td>
<td>24 +</td>
<td>4 to 10</td>
</tr>
</tbody>
</table>

The basal area should be between 160 and 183 sq. ft per acre, with preferably 10% in the roundwood class. Stands with a mean d.b.h. of 12 in. had a shortage of large timber while those with a
mean d.b.h. of 15 in. were deficient in the roundwood classes. The ideal stand would therefore appear to lie about a mean d.b.h. of 13 to 14 in. There are many possible variations and no definite conclusion can be drawn for many years. The basis for periodic reassessments to provide the necessary information is now being established in the current selection logging trials. As a guide to practice, some attempt at defining limits is most useful and it is probable that the main error could occur in the roundwood class which is the one of greatest importance. Stocking and basal area, by merchantability classes, are tabulated below for an ideal selection stand.

**TABLE 1: STOCKING DISTRIBUTION IN IDEAL SELECTION STANDS**

<table>
<thead>
<tr>
<th>Merchantability Class (in.)</th>
<th>Trees per Acre in Stands of Mean d.b.h. (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>4 to 9.9</td>
<td>120</td>
</tr>
<tr>
<td>10 to 15.9</td>
<td>78</td>
</tr>
<tr>
<td>16 to 23.9</td>
<td>32</td>
</tr>
<tr>
<td>24+</td>
<td>5</td>
</tr>
<tr>
<td>Totals</td>
<td>235</td>
</tr>
</tbody>
</table>

**TABLE 2: BASAL AREA DISTRIBUTION IN IDEAL SELECTION STANDS**

<table>
<thead>
<tr>
<th>Merchantability Class (in.)</th>
<th>Square Feet per Acre in Stands of Mean d.b.h. (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>4 to 9.9</td>
<td>33.10</td>
</tr>
<tr>
<td>10 to 15.9</td>
<td>68.25</td>
</tr>
<tr>
<td>16 to 23.9</td>
<td>63.65</td>
</tr>
<tr>
<td>24+</td>
<td>18.05</td>
</tr>
<tr>
<td>Totals</td>
<td>183.1</td>
</tr>
</tbody>
</table>

Practical silviculture must aim, therefore, at the health and stability of the smaller trees and experimental work should be devoted to evaluating this component of the stand.

To compare the growing stock volumes of the average P1 stand with the ideal selection stand (mean d.b.h. of 13 to 14 in.) the mean merchantable volumes were obtained from N.F.S. data of P1 stands and compiled as follows:

<table>
<thead>
<tr>
<th>Ideal Selection Stand</th>
<th>Cu. ft/Ac.</th>
<th>%</th>
<th>Natural P1 Stands</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundwood</td>
<td>300 to 400</td>
<td>6 to 8</td>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td>Small timber</td>
<td>1,100 to 1,250</td>
<td>22 to 25</td>
<td></td>
<td>14.6</td>
</tr>
<tr>
<td>Medium timber</td>
<td>2,000 to 2,100</td>
<td>40 to 42</td>
<td></td>
<td>41.7</td>
</tr>
<tr>
<td>Large timber</td>
<td>1,250 to 1,650</td>
<td>25 to 33</td>
<td></td>
<td>39.1</td>
</tr>
</tbody>
</table>
Fig. 3: Percentage distribution of merchantable volume in natural stands of rimu and in the proposed model of stands to be managed under the selection system.

Merchandability classes: a, Roundwood. b, Small timber. c, Medium timber. d, Large timber.

It is apparent that the mean P1 volume should be decreased by between 11 and 15%, with a reduction in the large-timber volume and a consequent rise in roundwood and small-timber volumes. Thus the derived growing stock for fully productive selection stands is about 5,000 cu. ft per acre.

The determination of both actual and expected increments is difficult and the following, rates, calculated from available data, may prove to be inaccurate. However, some guide to the degree of increment is necessary and the stand study indicated the following:

(1) With reasonable release in seedling, thicket and sapling stages, the mean d.b.h. of rimu will reach 4 in. in 100 years. The time of passage from that time was estimated from mean maximum growth rates on the assumption that the stands would obtain optimum silvicultural treatment. Corresponding mean annual volume increments decreased gradually from 7.38% in the 5 to 6 in. d.b.h. class to 0.29% in the 31 to 32 in. d.b.h. class. A number of trees exceeded substantially the mean maximum growth rates, so it should be safe to use them for a general evaluation of increment. The trend of optimum annual volume increments in cubic feet and mean percentage per year is shown in Fig. 4.
Fig. 4: Estimated trends of annual volume increment (upper right) and increment percentage (upper left) of rimu trees under selection management.

(2) The increment rate for the actual P1 stands, in the interim period when they are to be worked towards a desirable selection forest growing stock, must be compared with those rates which should be obtained once stands have been moulded to a manageable selection structure. The ultimate increment rates should be in excess of 1% for merchantable timber, and might reach 1.5% for all classes of produce. During the interim period a rate of 0.75% would probably be realistic for P1 stands. This rate is slightly in excess of the figure derived from the C.U.C. series of plots (0.7%), and from N.F.S. figures (0.67%). Mortality through logging damage or windthrow could result in increment rates lower than those stated.

At this stage in the development of selection management, it is difficult to predict yields, particularly from ideal stands. To obtain realistic yield figures, three factors have to be taken into consideration — recruitment into each class, the increment in each class, and the ages of trees in the large-timber class, from which is derived the period over which this class should be liquidated. This should give a measurement of the total yield and the yield from
each class. The stand study gave enough data on these three factors to make reasonable yield predictions. For example, it is possible to estimate the annual rate of volume recruitment to each class with some precision; thus, the 9 in. d.b.h. class should all move into the 10 in. class in 9 to 10 years. But since on silvicultural grounds one or two of the 9 in. class might be extracted before they pass to the next class, and because a few trees might lag, the volume passing to the next merchantability class is taken as 75% of this figure. A levy of yield for ideal stands based on liquidation of large timber in the requisite conversion period (i.e., 120 years), recruitment from lower to higher classes, and liquidation of the residual increment, resulted in the following approximation.

<table>
<thead>
<tr>
<th>% by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundwood</td>
</tr>
<tr>
<td>Small timber</td>
</tr>
<tr>
<td>Medium timber</td>
</tr>
<tr>
<td>Large timber</td>
</tr>
</tbody>
</table>

The implications are that once the ideal stand has been achieved, increments of about 60 cu. ft per acre per annum would be feasible. This is twice that considered possible under even-aged management, but the d.b.h. distribution is markedly different in selection stands, with a higher percentage in the smaller classes, while the increments percentages also vary markedly from small to large sizes. Young stands with annual increments from 60 to over 90 cu. ft were studied and the growth rates used above are not by any means the extreme maxima found in practice, though they are the mean maxima. So long as every vigorous tree from seedling onwards is given sufficient silvicultural encouragement, there seems little reason why this increment should not be reached or even exceeded.

In converting the natural P1 stands to ideal selection structure, it will be necessary to reduce the large and medium timber volumes and increase the roundwood and small-timber components of the stand. The time of passage of a vigorous tree through the large-timber class will be from 120 years to about 200 years, depending on the maximum d.b.h. required. On this basis, a “conversion” period of 120 years (with 4, 5 or 6 felling cycles) would probably be the most suitable. The excess growing stock in the medium timber class, plus half its increment, should also be removed in this period. Volume yield per annum for this period should be about 1% of growing stock volume and this approaches the increment determined for ideal stands.

This discussion of the basis for selection management and initial silvicultural operations should be used as a guide for only the first 20 to 30 years of the conversion period. At the end of and during the first period the stands will be further studied to determine the degree of variance from the above estimates. For the second period, adjustments should be made accordingly and in this way no gross management error will be made. Eventually the forester should have a reliable basis for the silvicultural treatment of the terrace podocarp stands under selection management.
REFERENCES


New Zealand Forest Service *Annual Report, 1964*.


APPENDIX

A Classification of Rimu Trees for Vigour and Merchantability

(A) Position in the canopy

1. Predominant

2. Upper canopy

3. Lower canopy

4. Under canopy

(B) Vigour class

1. Trees having at least six of the following characteristics:
   - Crown free on three or four sides.
   - Main stem maintained through crown; definite leader.
   - Crown paraboloid to cylindrical to cylindrical/rounded with increase in d.b.h.
   - Abundant loose bark flakes.
   - High crown ratio.
   - Crown dense to open.
   - Crown symmetrical.
   - High relative crown percentage.
   - Dominants only — smooth bark.

2. Trees having at least three of the following characteristics:
   - Crown free on three or four sides; Dominants only — free on two sides.
   - Main stem maintained through crown.
   - Crown tending to rounded.
   - Crown symmetrical, tending to irregularity.
(3) Trees having at least three of the following characteristics:
   Upper canopy trees — crown free on two or one side;
   Lower canopy trees — overhead light.
   Lack of main stem through crown.
   Crown narrow or rounded.
   Crown straggling.
   Crown tending to irregularity.

(4) Trees having at least four of the following characteristics:
   Bad-to-severe lean.
   Dead or lost top or broken crown.
   Lack of main stem through crown.
   Low crown ratio.
   Crown irregular.
   Crown straggling.
   Low crown percentage.

(C) Stem Class

(1) Perfect — *i.e.*, peeler quality, actual or potential.
(2) Merchantable — average stem with no important defects.
(3) Defective — *i.e.*, damaged, heavily fluted, or with bark pockets, irregularities, etc.
(4) Forked (to be recorded only where the fork is low enough to affect current or future merchantability).