WOOD DENSITY AS A CRITERION FOR THINNING DOUGLAS FIR

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SYNOPSIS

The use of wood density as a criterion for selecting Douglas fir trees for thinning has been shown to be feasible for first thinnings of a well-stocked stand (399 stems per acre) aged 40 years. It proved possible to favour the inclusion of trees with high wood density, and to exclude 76 of the 80 trees per acre with lowest wood density, during a thinning which left 166 well-formed stems per acre for future growth.

The immediate effects of this selection on the average wood density for the site were not very marked, and resulted in an estimated increase of only 0.008 g/cc. The effect on future wood production (as estimated from wood density of the outer growth layers at breast height) should be more marked. 97% of the trees will be producing mature wood with basic density 0.40 g/cc or better, and the average modulus of rupture of mature wood produced from now on will be improved by approximately 5% (290 lb/sq. in.) as a result of the selective thinning. The development of new techniques to use wood density as a criterion for selection could well improve on these results, and, if malformation is not severe after the first thinnings, it should be possible to make even more effective use of wood density as a selection criterion during subsequent thinnings.

Selection to increase wood density would be of value when selecting trees for special purposes, such as seed production, even using the relatively costly methods currently available for estimating the wood density of standing trees. It is also believed that the results justify further experimental work being undertaken to develop instruments for the economical estimation of wood density so that it can be used for tree selection on a larger scale.

Any review of the literature covering the broad field of wood quality research will reveal a spate of articles dealing with methods of improving the wood properties of forest trees. Selective breeding for stem characteristics such as straightness, small branches and wide branch angle is obviously aimed at improving timber grades by reducing defects such as knots, sloping grain and reaction wood. Similarly, silvicultural operations such as thinning and pruning are also directed towards selecting trees with desirable habits of growth for later crops.

Another field of research deals with the possibility of using selective breeding to improve intrinsic wood properties such as wood density or fibre length. But one possibility that has received

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very little attention so far is the removal of trees with undesirable intrinsic properties during thinning operations. The difficulties in the way of this development are obvious. First, the properties would have to be determined for every tree. Secondly, this would be a recurrent cost which would have to be undertaken in every forest area to be treated, whereas, in selective breeding for example, the work has to be done only during the testing of parent trees and their progenies. And, thirdly, the purchaser of the timber would not necessarily be able to recognize the improvements that had been made, and would therefore be unwilling to pay a higher price for them.

Yet if these difficulties could be overcome, the use of thinning to influence wood properties has some very attractive features. It would not rely on random parental combinations to achieve its results; undesirable trees would be physically removed from the final crop, variability could be reduced, and average values for a given property manipulated towards the desired direction. Moreover, although it takes one-and-a-half rotations of a forest crop to achieve results through selective breeding, the results of thinning would be available in half a rotation — an important consideration when long-term prediction of technological requirements is so difficult. It is much easier to predict the sort of timber that will be needed 40 years hence, than it is to predict requirements 120 years from now.

The main problems are therefore threefold: to devise methods for the routine recognition of wood properties of standing trees; to examine the application of these criteria in thinning practice; and to investigate the economic practicability of timber improvement by these means.

Of recent years the development of stress-grading machines has provided vivid proof of the variability of the intrinsic strength of many timber species. The fact that some quite knotty piece of timber may have such good intrinsic strength properties that it will prove superior to a similar piece of the same timber with fewer or smaller knots, is one of the most striking features of machine stress-grading. Here then, for the first time, is an obvious demonstration of this variability on a commercial scale, and any forester who can guarantee a high proportion of good timber grades from machine stress-grading might justifiably expect a better return for his efforts in producing it. It was with this thought in mind that the work described in this paper was undertaken.

Many methods are available for estimating the strength of the timber in standing trees. For example, wood density is closely related to the major strength properties within any one species. One or more increment cores taken from each tree at breast height (b.h.) will provide sufficient test material, and the simplest techniques for measuring wood density require no more than three minutes' work for each tree. Of course, even this would be totally uneconomical for application on a commercial forestry scale, although the work might be undertaken for special tasks such as the selection of trees for seed-production areas. Other methods have been proposed: Polge (1962) used a torsimeter attached to a standard increment borer, and found a close relationship between the density of the wood and the torsional force required to turn
the borer at a fixed depth within the tree. Further simplification of this method, or the development of other methods, might well provide the means whereby timber strength could be used as a practical criterion for routine thinning operations.

Before spending much time and effort in attempting to develop equipment of this sort, however, it is necessary to know how effectively the new criterion could be applied. For example, one often hears a forester state that in some species a stand “thins itself”—that the removal of malformed and suppressed stems leaves so few trees for selection that there is little choice. If this is so, then the opportunities for exercising an option in favour of high wood density would be few, and any effort expended in identifying trees with desirable properties would be largely wasted.

This report describes trials in which wood density was used as one of the criteria in selecting Douglas fir trees for thinning.

**REASONS FOR USING DOUGLAS FIR**

The excellent strength properties of Douglas fir from North American forests have earned it an international reputation for structural use, and the properties of locally grown timber are equally favourable (Harris and Orman, 1958). Consequently it is probable that New Zealand-grown Douglas fir will also be used primarily as a structural timber and there are therefore good reasons for trying to retain for the full rotation those trees that will produce the strongest wood, and for removing any less desirable trees as soon as practicable.

Besides producing strong timber, Douglas fir has the reputation of being relatively free from malformation and of being a silviculturally “plastic” species; in other words, it is amenable and responsive to a wide range of treatments in the forests. It is therefore a species that offers very good opportunities for the employment of criteria other than stem form and vigour in selection for thinning.

Finally, because it is likely to be widely used in structural sizes, the use of stress-grading machines may well provide a basis for payment for any improvements made.

**METHODS USED**

*Estimation of Wood Density*

An area was selected in compartment 1148, Kaingaroa Forest. This had been planted at 8 ft × 8 ft spacing in 1926 (40 years old), and a one acre plot was marked out (69.5 yd square). This was found to contain 399 standing live trees. Two increment borings were taken at b.h. from each tree in this plot for determination of wood density. Each tree was marked with a number tag, and diameter at breast height (d.b.h.) was recorded.

From each increment core the outer 10 growth layers were dissected out, and green volume was calculated by using a standard factor to convert the length of the boring to volume in cubic centimetres. The borings were then oven dried, and basic density calculated from the oven-dry weight.
The variation of wood density within a stem follows a regular pattern (Harris and Orman, 1958), and therefore average wood density within the merchantable stem can be estimated from the average density at b.h., or even from the density of the outer 10 growth layers at b.h. Analysis of data from 24 trees, aged from 25 to 40 years, felled and examined in detail for determination of the physical properties of Douglas fir timber, has shown that the coefficient of correlation between the wood density of the outer 10 growth layers at b.h. and average wood density of the entire stem is 0.882. In other words, approximately 80% of the variation in wood density between trees can be accounted for in terms of the observed density of the outer growth layers at b.h.

The development of a simple means of estimating the wood density of standing trees will probably use only the outermost wood of a tree. It was therefore felt that the present study should be based on the same material, and no attempt was made to obtain more complete data by using larger or more extensive samples.

For final calculation of the average wood density of all the trees on the one-acre plot, tree average density was first calculated from the regression:

Tree average density = 0.5877 (Density of outer wood) + 0.1439
which has a standard error $S = 0.0168$.

The Douglas fir volume table (Burstall and Duff, 1959) was then used to calculate individual tree volumes, and these were multiplied by tree average density, so that the average wood density produced by the site after various thinnings treatments could be determined.

**Marking for Thinning**

The trees were marked for thinning by two experienced rangers. Paper tags were stapled on to each of the trees assumed to be left after thinning. These tags were removed after each marking so that the area could be re-assessed in an unbiased way each time a new criterion for thinning was introduced.

In all, four separate markings were done. The first of these was a marking to the prescribed stocking of 140 to 160 stems per acre based purely on stem form and vigour. For the second, 40 trees with lowest wood density (10% of the total) were marked with a yellow tag, and the markers were instructed to treat these as malforms. That is to say, the trees could be left in if their removal would create undesirable conditions in the stand, but otherwise every effort should be made to take them out.

The third marking depended on the result of the first and could have aimed at removal of a lower or higher proportion of low-density trees. In the event it was decided to aim at removing the 80 trees (20%) with lowest wood density, and a further 40 trees were therefore marked with yellow tags.

For the final marking, some account was taken of the 80 trees with highest wood density. All trees in this category which had d.b.h. above 10.0 in., and which were not severely malformed (64 trees in all), were marked with a blue tag. The markers were advised to include these trees wherever it would not cause overcrowding, or wherever one could be substituted for an otherwise suitable untagged tree. The 80 low density trees were to be avoided, as before.
RESULTS

Marking for Thinning

There is no doubt that the job of marking was considerably complicated by having to take wood density into account. The forest rangers who undertook the work are very experienced, but both agreed that this sort of thinning could not be handed over to the average marker without a good deal of additional training.

Nevertheless, all the markings in this study were carried out in a normal way, without any re-examination or readjustments of marking once the area had been covered. Thus the numbers of stems per acre (s.p.a.) designated to be left after thinning can be regarded as a spontaneous expression of what was felt to be adequate for the site.

After the first routine thinning, 142 s.p.a. were left. The exclusion of the 40 trees with the lowest wood density presented no difficulties, and all were left unmarked, s.p.a. after this marking being 140. When 80 low-density trees were tagged for exclusion, the situation was more complicated. Four of the trees could not be excluded without leaving undue gaps in the canopy. As no choice was offered between trees in the lower 10% or lower 20% of the wood density range (all bore similar yellow tags), it happened that two of the trees marked to remain fell in the lowest 10% group and had been excluded in the previous marking. If the two categories had been distinguished, it is probable that selection could have favoured the trees of higher wood density even within the low-density group. However, the inclusion of two trees with very low wood density has little effect on the final assessment, and the important feature of the exercise was that it demonstrated that 76 out of 80 low-density trees could be excluded.

It was particularly interesting to be able to compare the appearance of all the low-density trees in the area. They fell into all diameter classes, and had no distinguishing morphological features that would separate them from the remainder of the trees. Consequently it sometimes happened that a tree of large diameter and good form had to be excluded. In these circumstances there was naturally a tendency towards including two or more smaller trees in its vicinity to compensate for its loss. As a result, s.p.a. after this marking rose to 153.

When 64 high-density trees were tagged, it was found that 39 had been selected in the previous marking. When all the paper tags from this marking had been removed, the stand was remarked in the same way to include as many as possible of the high-density trees. In all, 166 s.p.a. were marked, including 52 of the high-density trees. It will be seen that the same result would have been achieved if the previous marking had been allowed to stand, and 13 high-density trees of newly-discovered “merit” had simply been recruited as supernumeraries. It therefore appears that with the exclusion of the 80 low-density trees the stand did, in fact, “mark itself” and any additional criterion could only change the marking in a purely arithmetical sense.

The retention of 166 stems still made quite a practicable thinning, however. The intensity of the thinning was adequate, and the net result would be to have a better selection of high-density trees for any subsequent thinning operation.
Effect of Thinning on Wood Density

Because low-density trees had no distinguishing morphological characteristics, the routine marking had no significant effect on wood density—i.e., the criteria used for selection were not related in any discernible way with wood density. The results of this and subsequent markings are presented in Table 1 and Fig. 1.

From Table 1 it will be seen that the markings that took wood density into account had the desired effect of increasing the average density of the outer wood of the trees remaining. The improvement is less marked when considered in terms of the average wood density of whole stems or the weighted average wood density for the site. The reason for this is that the core wood of all trees is of lower density than outer wood, and since it occupies approximately the first 15 growth layers from the pith at all levels in the stem, it represents a relatively high proportion of total stem volume at this age. In fact, it is not the present or immediate effect on the wood density of the stand that should be considered at this stage of development, but rather the future production of timber by the selected trees. This will continue at density levels equal or superior to the present material of the outer growth layers, and the effect of the thinning on future wood production is therefore best represented by the outer wood values of Table 1 or Fig. 1.

The virtual elimination of those trees producing low-density wood is illustrated by the way the “tail” on the left-hand side of the histograms in Fig. 1 is cut off in the three lower figures. The reduction of this undesirable variability is also reflected in the improved “lower decile value” (wood density below which the lowest 10% of the recorded values occur) in Table 1.

The increase in outer wood density from 0.428 to 0.444 g/cc as a result of selective thinning represents an increase of 286 lb/sq. in. in the average modulus of rupture, and 152 lb/sq. in. in maximum crushing strength for future timber production (from Harris and Orman, 1958—Table 18).

Looking further ahead to second and subsequent thinnings, it is probable that less emphasis will need to be placed on the removal of malformed stems, so that, by the time the stocking has been reduced to 80 s.p.a., most of the trees with wood density 0.40 to 0.45 g/cc should have been eliminated.

DISCUSSION

This experiment has shown that wood density can be used as a criterion for selecting Douglas fir trees for thinning. It has also shown that the density (and hence the intrinsic strength properties) of future wood production can be significantly improved by this type of thinning.

The methods currently available for the assessment of the wood density of standing trees are too costly for application on a large scale. Results obtained so far do suggest, however, that wood density could be considered for certain specialized tree selection programmes where the value of the final product would justify the extra cost. The development of an instrument to make wood density estimation more economical would therefore be fully justified, in the hopes that it could extend the applications where wood density could be used as a criterion for selection.
<table>
<thead>
<tr>
<th>Basis for Selection</th>
<th>No. of Stems per acre Remaining</th>
<th>Total Volume (cu. ft)</th>
<th>d.b.h. (in.)</th>
<th>Ave.</th>
<th>S.D.</th>
<th>Ave.</th>
<th>Lower Decile Value</th>
<th>Ave.</th>
<th>Wood Density of Stems (g/cc)</th>
<th>Weighted ave. Wood Density for Site (g/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Unthinned</td>
<td>.....</td>
<td>399</td>
<td>18,668</td>
<td>13.5</td>
<td>3.4</td>
<td>0.433</td>
<td>0.38</td>
<td>0.394</td>
<td></td>
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<td>(b) Routine thinning</td>
<td>.....</td>
<td>142</td>
<td>9,714</td>
<td>16.6</td>
<td>2.5</td>
<td>0.428</td>
<td>0.38</td>
<td>0.393</td>
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<td>0.392</td>
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<td>(c) 10% lowest wood</td>
<td>140</td>
<td>9,644</td>
<td>16.7</td>
<td>2.6</td>
<td>0.434</td>
<td>0.39</td>
<td>0.397</td>
<td>0.396</td>
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<td>Density tagged</td>
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<tr>
<td>(d) 20% lowest</td>
<td>153</td>
<td>10,026</td>
<td>16.3</td>
<td>2.5</td>
<td>0.441</td>
<td>0.40</td>
<td>0.401</td>
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<td>Density tagged</td>
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<tr>
<td>(e) As for (d) plus</td>
<td>166</td>
<td>10,417</td>
<td>15.9</td>
<td>2.8</td>
<td>0.444</td>
<td>0.40</td>
<td>0.402</td>
<td>0.400</td>
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<td>64 high density</td>
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<td>trees tagged</td>
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</table>
Fig. 1: Effect of using wood density as a criterion for tree selection in thinning.

(a) Unthinned: 390 stems per acre (s.p.a).
(b) Prescribed thinning: 142 s.p.a.
(c) 10% of trees with lowest wood density removed: 140 s.p.a.
(d) 20% of trees with lowest wood density removed: 153 s.p.a.
(e) As for (d) with high wood density favoured: 166 s.p.a.
New techniques would have to be developed before such an instrument could be employed to maximum effect, and it is probable that stand improvement could be taken much further than proved possible under the conditions described in this experiment. For example, one could postulate a marking that would proceed as follows:

(1) To commence marking, examine four adjacent trees of good form and vigour, and select the one with highest density.

(2) Mark “out” any suppressed or malformed trees in the vicinity of the one selected in (1), and choose those trees from which the next selection must be made.

(3) Examine this group of trees for wood density and mark “out” the trees with lowest density plus other suppressed and malformed trees in the vicinity.

(4) Select the next group of trees for wood density evaluation, and so on.

It should be noted that there is no suggestion that malformed or suppressed stems should be left after thinning, nor need they even be examined for wood density. But, under this system, not only would the low-density trees be excluded, as in the present experiment, but wood density would also be used as a selection criterion in every instance where a choice has to be made between two trees of otherwise equal suitability.

It is not suggested that every stand of Douglas fir would necessarily justify the additional effort required to improve wood density. As part of a country-wide survey of Douglas fir, six compartments were recently examined in Kaingaroa Forest, and the following values were obtained for outer wood density at b.h. (g/cc): 0.47, 0.45, 0.43, 0.42, 0.41, 0.41. It is not clear, from the information available so far, to what extent this variation may be due to the environment or to the genetic constitution of these stands, but it is quite clear that the prospects for wood density improvement are vastly different at the extremes of this range. If suitable methods can be developed, it may pay to select a small number of areas where wood properties are favourable from the start, and to concentrate on developing these as specialized stands for the future production of structural timber for special purposes.

ACKNOWLEDGEMENTS

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REFERENCES

