CURRENT RESEARCH INTO RADIATA PINE THINNING OPERATIONS IN NEW ZEALAND

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ABSTRACT

Economic evaluation of alternative silvicultural regimes for radiata pine has shown that a substantial opportunity cost can be incurred if the growth of the crop trees is penalized, and their date of harvest deferred, in the interests of obtaining a sale for thinnings. The effect is greatest when a pruned final crop element, that has been defined from an early age, is allowed to be severely checked through competition from unpruned neighbours. In this instance, the case for production thinning depends largely on whether the unwanted trees can be extracted before they markedly impinge on the growth of the pruned final crop trees. Such competition is apparent from an early age in selectively pruned stands, to the extent that production thinning becomes difficult to justify. It is feasible, however, that the onset of competition may be delayed by distinguishing the crop component of the stand from the thinnings component from the outset, by separating the two elements as much as possible, by applying treatments to the crop that will give them a distinct competitive advantage, and by arranging the thinnings in ways that favour mechanization and cheap extraction of small diameter material. Trials have been established to test the concept, and more are planned.

INTRODUCTION

Sawlog regimes for radiata pine which include production thinning have been criticised on economic grounds by Dr R. T. Fenton. In comparing a sawlogs regime which included production thinning with one which did not he states: "The production thinning management regime is inferior in every respect to the direct regime; it costs more than twice as much per cu ft., produces lower grades, needs as much labour, and has greater managerial, physical, fire and marketing risks" (Fenton, 1972). The "direct regime" is one in which the stand is reduced to its final crop stocking as soon as the crop trees can be, or have been defined (in this instance, when the crop trees have been pruned to 6 m).

It may seem illogical that in spite of these discouraging statements other members of the same research group have been examining the prospects of production thinning during the past two years; Dr Fenton borrows a phrase from Johnson to describe it as "a triumph of hope over experience". However, the hope is justified because there is scope for improvement in our present production thinning operations, and research is required because production thinning will continue in any case. Ironically, Dr Fenton has contributed to the work by identifying the cost and problems of production thinning, thereby indicating where research effort should be concentrated to improve the operation.

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The Problems and Costs of Production Thinning

Essentially, the problems of production thinning are that the residual crop trees interfere with the felling and extraction of the thinnings (the degree they do so being influenced by topography, thinning method, stand height and stocking), and that the volume/hectare and piece size removed are substantially less than provided by clear-felling. Generally, the result is that the unit cost of wood produced by production thinning is relatively high, and that some of the final crop trees are damaged (Fenton, 1972; Park, 1972).

Other less obvious costs of production thinning are the costs plus interest of roads and landings required for harvesting the thinnings, and the loss of production from these areas for the rest of the rotation. Also, holding a high stocking to provide a production thinning invariably reduces the growth rate on the final crop trees, the result of which is an increased interest charge on the crop through prolonging the rotation to grow a mean crop tree of a specified size (Fenton, 1972).

It is apparent therefore that for production thinning to be a profitable operation the following conditions must apply:

1. The direct and indirect costs of the operation must be kept below the mill door value of the thinnings. It would be reasonable to allow for the cost of an alternative earlier thinning to waste.
2. The final crop trees must not be damaged, or their growth unduly retarded by the presence of trees to be thinned. Ideally, the time to production thin is when the marginal revenue obtained by holding the thinnings to produce an increased piece size, and increased volume/hectare, equals the marginal cost of losing diameter increment on the final crop trees.

These two requirements are the basis of the current research on production thinning in New Zealand.

RESEARCH ON THE OPERATION OF PRODUCTION THINNING

The unit cost of a production thinning operation depends on many factors, several of which have been quantified by work study. The most important are: the average size and variation in size of the trees harvested, the volume/hectare harvested, the shape of the terrain, the performance and suitability of the equipment and method being used, the motivation of the harvesting crew, the number of productive hours/day, and days/year worked.

There is evidence (Mackintosh, 1974a) that the application of the harvesting crew to their work is the most important factor. It is elusive to quantify, as it depends on such characteristics as the leadership qualities of the crew boss and a sympathetic and informed management which is willing to encourage and reward initiative, enterprise and effort. Relevant comments from reports on harvesting operations studied (*see also* Appendix) are:

> "Given a well motivated, well controlled and directed gang of men, high levels of man-day and machine-day productivity can be achieved. The level of capital investment, however, must be suitable and closely controlled in order to achieve low costs of production." (Terlesk and Walker, 1972).
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> "The four-man gang was selected for the study because of their history of consistent

work habits, high productivity, and co-operation with study personnel." (O'Reilly and Terlesk, 1972).

"Another factor of importance in the working of this crew is the co-operation and co-ordination between all crew members—in fact this may be the most important factor." (Mackintosh and O'Reilly, 1973).

"Regard to the careful balance of labour and capital, coupled with sound management policies, will assist in keeping costs as low as possible." (Mackintosh and Walker, 1973).

Another very important aspect of harvesting crew performance is considered to be good training, and the next stage of a current research project is to give a thinning crew the best training that can be obtained, and to measure the effect of this training. It is realised that this will be difficult to do because of the influence of other factors such as increased experience.

Although it is difficult for research to play a direct part in assisting with the management aspect of a field operation, one benefit it has achieved has been to introduce tachographs to measure the working hours of the logging and transport machines (Terlesk, 1972). These have been fitted to the machines of several operators and have in some cases been of considerable benefit in improving the operation. It is felt that many organisations are losing production through poor machinery utilisation and poor organisation so the simple expedient of fitting tachographs to their equipment, and of using them intelligently, could lead to marked improvements in management operations.

In examining the extraction of thinnings, we have concentrated on analysing the work elements, and developing suitable methods, for operations timed when they should be done rather than at the stage that they are at present being done. This work has given us some insight into the manner in which stand conditions can influence extraction, enabling us to postulate how stands might be modified to simplify thinning. To date, our investigations have been limited to felling and extraction, and to equipment that has been available.

Machines that have been examined are:

— Holder A.G. 35 articulated tractor (30 h.p.) with winch and blade (Muir, 1973).
— Fiat 640 agricultural tractor with front and rear wheel drive, and simple hydraulic grapple (McConchie and Muir, 1975).
— C4 Tree Farmer skidder (83 h.p.) with a winch.
— 230D Timberjack (97 h.p.) with an Esco swinging boom grapple.
— Drabant logging tractor (18 h.p.) with a winch.

Access in the stand and the size of the load to be extracted are the two dominant factors which determine the suitability of these units for a particular thinning operation. The extracting unit should be related to the piece size, but where small machines could be used for this reason, they may not cope where stumps and slash from a previous crop or from previous thinning operations impede access. The problem with using a larger machine that can cope with ground obstructions is to make up loads of sufficient size that fully exploit its capacity and justify its capital cost.

From results of recent trials, the following general points are made:

1. The stand features which have major effects on the productivity of a thinning operation are:
   (a) Piece size (Mackintosh and Muir, 1974)

(b) Ease of movement in the stand, for both the tractor and personnel
(c) The number of trees to be removed, and the residual stocking.

2. A grapple has the potential for much higher production than a winch and strops, but requires good access to all logs and more skill from the fellers.
3. The more straight-forward and systematic the operation (which often means some form of row thinning), the higher the productivity.
4. Attaching (breaking out) and releasing the loads are the elements most influenced by the piece size and distribution of the thinnings, and they are generally the most time-consuming elements of the tractor cycle.

In future investigations, the breaking-out and load-releasing elements of the operation will be given particular attention. The time consumed by these operations can be reduced by:

(a) Altering the felling pattern.
(b) Pre-bunching the logs.
(c) Using a grapple where possible rather than strops and a winch.
(d) Using light weight polypropylene strops and quick methods of attaching them to the winch rope.
(e) Using twin winches and fairleads, and radio control of the winches.

Whether or not a prescribed production thinning can be economically justified depends very much on the age and condition of the stand being thinned, especially when the economics of the thinning operation are considered in relation to those for the crop over the whole rotation. For this reason our research into thinning has included work on shaping our stands in such a way that production thinning can be done at a reasonable cost without marked detriment to main crop values.

Research on shaping a crop for production thinning is based on two considerations:

1. The thinnings must be removed before they significantly reduce the diameter increment of the final crop trees.
2. Because of this, the piece-size will be small and the volume/hectare low. To harvest them at a cost which is less than their value, will require stand conditions that are as favourable as possible for felling and extraction.

A favourable thinning situation would be:

— Where the thinnings are extracted by rows
— Where the stand is on flat or easy country
— Where the tree size and quality are uniform and the volume/hectare removed is sufficient for the harvesting machines used to operate efficiently
— Where the stand is close to a good market paying prices for thinnings that more than cover direct and indirect costs.

Three trial areas of 15 ha each have been established in different parts of the North Island with a view to providing one production thinning that can be extracted without undue hindrance or effect on the growth of the final crop. The three trial areas are on easy country, and are all reasonably close to processing plants which use small thinnings. They compare early selective thinning to waste with a selective production thinning and row production thinning for pruned stands being grown for sawn timber or veneer.

Rationale for the Thinning Trials

Over a sawlog rotation, initial stockings ranging from 1500-3000 stems/ha are reduced to final crop stockings of 200-300 stems/ha; the question at issue is when and how should the unwanted stems be removed? It might clarify matters if we first examine the functions that these additional trees are supposed to serve. Reasons advanced for the usual 8 : 1 ratio of initial : final crop stocking are:

— The high initial stockings are required to ensure there are adequate trees of good vigour and form to select for the final crop.

— Relatively close uniform spacing is required in order to limit the size of the branches of the butt logs.

— The extra trees if extracted as thinnings contribute to the total yield of wood recovered/ha, and presumably to a higher M.A.I. of processed product.

Investigation of alternative sawlog regimes for radiata pine that incorporate pruning have revealed that all of these premises can be challenged. Normally, such high initial stockings are not required to obtain sufficient final crop trees of good form, provided the stands are reasonably uniform in height development and individual trees are not allowed to become suppressed by their neighbours. It has been found that a stand reduced to 750 stems/ha at time of low pruning will normally provide sufficient trees of good form for the final crop.

Where the wood quality of the butt logs of crop trees is controlled by pruning, close initial spacing to control branch size is obviously not required. It has been found that green pruning without thinning in close-spaced stands has the effect of transferring increment from the selected pruned trees to their unpruned neighbours, with the effect that many pruned trees lose vigour and become dominated. Thus, holding a stand at its initial stocking until thinnings become merchantable often results in the suppressed pruned trees having to be removed. Once the crop trees have been identified by being pruned it would seem illogical that they should be subjected to intense competition from unpruned neighbours that have been rejected.

The remaining argument for leaving additional trees after the final crop element have been selected and pruned (top height 12 m) is that they could give an increased yield of harvested wood if they can be extracted profitably before they have too detrimental an effect on the growth of the crop trees. Evidence from selectively thinned stands suggests that there is very little latitude in this regard. If stands remain at stockings of 750 stems/ha or more after a top height of 12 m, then the growth of high pruned trees will suffer, resulting in longer rotations and higher interest charges. It is feasible, however, that if we can segregate the crop from the thinnings so that the latter do not impinge on the crop to the same degree, it may be possible to delay thinning sufficiently to improve the economics of harvesting them.

The approach adopted for the row thinning trials, therefore, has been to distinguish crop rows from thinning rows from the outset. They incorporate the assumptions that 200 suitable crop trees/ha can be selected from initial stockings of 750 stems/ha, that the crop trees can be rectangularly spaced in bands without detriment to their growth, that branch development for crop trees can be controlled by high pruning, and that extraction of small trees will be simpler and cheaper if they are in lines or bands so that machines have ample room to manoeuvre. The main crop rows are being progressively thinned to waste following each pruning lift so that the pruned crop trees do not have to compete with unpruned trees immediately adjacent to them. There is evidence that such thinning compensates for the loss of growth the pruned trees might otherwise sustain through the effects of green pruning. The thinning rows receive an early thinning to waste to remove culls, malforms, and wolves. Three different stockings are being tested; in each case, they will be extracted as soon as it is demonstrated that they are impinging on the growth of the main crop. Adjacent plots at the same stocking will be selectively thinned at the same time for comparison. For production thinning in these circumstances to be justified, the value of the wood extracted will have to exceed all the direct costs by a sufficient margin to cover all the extra management costs and risks.

Results to date indicate that the presence of the thinning rows may begin to influence the growth of the main crop rows by top height 12 m. Production thinning at this stage is scarcely worthwhile as the material extracted is of small piece size, low volume, low value, and high cost. Piece size and volume extracted would be substantially improved if thinning could be delayed to top height 17-18 m but by then, it is anticipated that they may be encroaching significantly on the growth of the crop. The present trials were superimposed on existing stands, so the designs were selected to fit in with the initial espacement used. In new trials being laid out this year, the crop rows will receive additional treatments aimed at giving them an advantage from the outset so that the onset of competition from the thinning rows may be delayed. Various initial espacements in rows and clusters will be tested.

If stands are not going to be pruned, then the control of knot size is obviously very important for stands being grown for framing timber. It can be achieved by maintaining stand density at a stocking that will keep the maximum branch size index (mean diameter of the 16 largest branches per 6 m log length) below the critical knot size for No. 1 framing for at least one, and preferably two, log lengths. The stocking required to obtain branch control to this degree varies for different sites and soils (Bunn, 1971) so knowledge of stocking/branch size relationships for major site types is a basic requirement for deriving suitable framing regimes that exclude pruning. If branch control is to be maintained over two log lengths (to 12 m), the stand has to be kept at an appropriate stocking until top height 18-20 m. In New Zealand, stands have often been kept at their initial espacement until they have reached this height, but experience is showing that they are very prone to wind damage if they are production thinned at this juncture from a previously unthinned state. It is becoming apparent that it is advisable to carry out an earlier thinning to waste to a predetermined stocking that is sufficient to maintain branch control within specified limits. What the "predetermined stocking" and "specified limits" will be requires local data on stocking/site/branch size relationships, and an analysis of the interactions between branch size index, knot size, sawn timber dimension and log size in order to determine what branch size can be tolerated. Studies on second logs (the 6 to 12 m log height class) of crop trees in the Rotorua region indicate that a maximum branch index of less than 4 cm is required to obtain 50% of the sawn output as No. 1 framing grade. Expressed in terms of stocking, this would require that we retain in the vicinity of 600 stems/ha until top height 18 to 20 m. A lower stocking would suffice on a lower site quality or on a nutrient-deficient soil. A thinning at this juncture, removing coarse dominants as well as the suppressed and malformed elements, would be advantageous in the interests of growing a more uniform stand and shortening the time required to grow a mean crop tree of specified diameter. Whether or not production thinning is justified will depend upon the markets available for the small diameter, low value material and the costs of producing it, and its demands for scarce capital and labour that could perhaps be used to better effect on other operations. Its "profitability" must be evaluated within the context of costs and returns over the whole rotation rather than for the operation on its own.

CONCLUSIONS

Every aspect of production thinning; the crop management, the bush men, their equipment, and the economics of the operation, are influenced by its complexity. The factor that probably contributes most to this complexity is the special arrangement of the thinnings in the crop to be thinned. For this reason, we are examining the prospects of growing stands to suit the extraction of the thinnings without loss of final crop volume or quality. The case for production thinning is not proven until it is shown that it can genuinely increase the profitability of growing plantations.

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APPENDIX — Extracts from Unpublished Reports

STUDY OF A 21-YEAR-OLD PINUS RADIATA THINNING OPERATION, FACTORS AFFECTING HARVESTING TIMES (O'Reilly and Terlesk, 1972)

Total Time/turn

When used in multiple regression analysis, only travel loaded distance and the number of trees were significantly correlated with total turn time. These two factors accounted for only 33% of the total variation in total turn time.

Regression equations for estimated element times

(a) BREAKING-OUT		
Pull mainline	$0.2550 + 0.0103X_1$	$r = 0.53^{***}$
Strop	$0.2315 + 0.2657X_2 - 0.1994X_6$	$r = 0.46^{***}$
Winch in	$0.0668 + 0.0126X_3$	$r = 0.83^{***}$
Total breaking-out	$0.5984 + 0.2552X_2 + 0.0239X_3 - 0.2257X_6$	$r = 0.63^{***}$
(b) TRAVEL		
Empty	$0.389 + 0.114X_4$	$r = 0.82^{***}$
Loaded	$0.416 + 0.1225X_5$	$r = 0.76^{***}$
Loaded	$0.1785 + 0.1242X_5 + 0.0032X_7$	$r = 0.77^{**}$
(c) SKID WORK		
Drop	$0.1044 + 0.0656X_2$	$r = 0.31^{**}$
Pile (fleet)	$0.9367 + 0.2224X_2$	$r = 0.22^{*}$
Total skid work	$1.0411 + 0.2880X_2$	$r = 0.27^{**}$
(d) TOTAL TIME/TURN		
Total turn time	$2.929 + 0.8614X_2 + 0.0963X_5$	$r = 0.57^{***}$

X_1 = Length of mainline pulled out
X_2 = Number of trees
X_3 = Length of mainline winched in
X_4 = Travel empty distance
X_5 = Travel loaded distance
X_6 = Men (dummy variable: assisted, use 1; unassisted, use 0)
X_7 = Volume/load

DISCUSSION

One important aspect which has not been discussed as yet, is the wide range of tree sizes present on the 3 acres, with diameter classes ranging from 4-21 in. dbh(ob). The practical importance of this is far-reaching, for it is from this spread of tree size that the feller must attempt to make up an optimum load size consistently. The variation in load volume encountered in this study is relatively great, but much of it is due to the effects of spacing, interference from crop trees, plus this wide range of tree size which prevails. The judgment and ingenuity of the fellers are most important in overcoming these factors in order to produce optimum load sizes.

Planning by the feller also affects the time needed to collect the load behind the skidder (breaking-out). As breaking-out time is strongly correlated with the length of mainline used, the feller can minimize the time needed by felling the trees in a group, and avoid stringing them out. For instance, in this operation, the breaking-out time for 5 trees requiring 35 ft of mainline would be 28% longer than for the same 5 trees requiring only 10ft of mainline. The skidder operator can play his part in reducing the time by positioning the machine to best advantage.

The smaller trees (6-10 in. dbh) made up over half (55%) of the extracted thinnings; these are the tree sizes with the greatest amount of work per 100 cu ft. They accounted for only 38% of the total volume delivered to the skids. The practical effect of these smaller trees on productivity is obvious.

The analysis of the breaking-out phase has indicated to what extent the second man affected the operation (assisted versus unassisted breaking-out) and, quite naturally, it is in the stropping operation that the second man had a significant effect. On the average, the assisting worker shortened the stropping operation 0.20 minutes and, on the total breaking-out operation, reduced the time by 0.23 minutes.

Volume/load was not a significant factor in determining times for the breaking-out operation, the skid work time, or the total time/turn. Volume/load did show up as an important factor in determining the travel loaded time, but it did so at a reduced level of significance (1% instead of 0.1%), and explained only 2% more of the variation in travel loaded time than did the simple equation using only travel loaded distance. The real effect of volume was in increase the travel loaded time by 0.32 minutes for every 100 cu ft/load.

Winch angle (angle of the mainline to the fairlead) was not found to be correlated with either winching time or total break-out time. However, it is important to note that the piece size and load volume were generally well below optimum for the machine, and the winch angle, log layout, and other variables which did not show up as important in this study, may prove significant when the conditions are optimum (or larger). Following on this, it must be stressed that the findings of this study are related to the conditions under which the operations took place, and may not apply even to other operations which appear similar.

The points of interest arising from this study are:

1. Volume/load played little (or no) part in determining harvesting times;
2. The number of trees/load, length of mainline winched in, and number of men involved were the important factors affecting the break-out operation, together accounting for 40% of the variation in breaking-out time;
3. Time/100 cu ft to prepared wood for skidding was strongly related to tree size, increasing sharply for smaller-sized trees (10 in. and less). These smaller-sized trees made up over half the number of trees delivered to the skids, but accounted for only 38% of the total volume delivered. Trimming was the greatest time-consuming element/unit;
4. Travel loaded distance and the number of trees/load were the important factors affecting total time/turn, accounting for 33% of the variation in turn time.

A COMPARISON OF THINNING SYSTEMS AND METHODS
(Mackintosh and Walker, 1973)

DISCUSSION

The method which produced the cheapest thinnings was the grapple by itself on row thinning and top hauling, but too much notice should not be taken of the actual production of the different methods, or costs, as there was considerable room for improving the production of all the methods tried. However, the results do lend weight to a few principles of economic harvesting which have been established overseas, and are becoming apparent from harvesting studies done here, and on which the method of thinning the crop should be based.

1. Especially when expensive machinery is being used, the more organised the extraction process the more productive it is likely to be, and with a thinning operation this means row thinning. It was possible to selection thin from two-thirds of the crop by removing one complete row between two selection thinned rows almost as productively as row thinning, but had the trees been too large to man-handle it may not have been. It is suggested that it would be better to plant the crop at a spacing to suit complete row removal for production thinning, and carry out an earlier selection thinning to waste.
2. As already mentioned, there must be a balance of capital invested and manpower or machine and man production. The idea of having the **Drabants** bunch for the **Grapple** was to optimise the use of the **Grapple**, as it was the most expensive item of equipment.

As it turned out the cost of operating the **Drabants** was not justified by the extra production obtained from the **Grapple**, but this could easily change by an increase in the **Drabant's** production, and there were possibilities for this.

3. Tree size is important to production and costs, and is possibly the most important crop feature to consider when developing a method of harvesting. It probably becomes more important as the value of the equipment being used to harvest the wood increases. The method using the highest cost equipment in this study also produced the highest cost wood. The reason for this was that the production of the equipment considered for trimming the logs is sensitive to length/volume ratio, and in the case of this crop the tree size was not as big as this particular piece of equipment was able to process. Volume/lineal foot will probably always be important when equipment has a fixed linear feed speed.
   The cost saving with the grapple was obtained from its quick loading and unloading, which meant that a high percentage of its operating time was actually extracting logs. Had the piece size been of such a volume that one log was a load for it, there would not have been the same gain by comparison to the skidder using a winch and strops.
4. All the elements of the operation must be considered in relation to each other. With the objective of reducing the breaking out time and therefore increasing the production of the logging tractor the bushmen placed the logs in a handy position for breaking out when the **Drabant** and **Grapple** were being used. Although this required extra effort from the bushmen, it obviously increased the logging tractor's production. With more detailed work study the method would doubtless be improved, and the overall gain could be assessed. It was also found that the position, size and shape of the bunches formed by the **Drabant** greatly affected the time taken by the **Grapple** to pick up the bunch.
5. Management considerations may have more influence on the method used than anything else. For example, under favourable conditions to both there would not be a great deal of difference between the cost of the wood produced by three men and a **Drabant** and four men and the **Grapple**, but there was a big difference in the daily volume produced. The **Grapple** produced more than twice as much, and so if the annual requirement for wood can be produced by the **Drabant** it would not be enough to enable the **Grapple** to operate economically, and the **Drabant** would be the better machine to use. The annual requirement for wood and the productive capacity of the system used must match. Evidently management can also have more influence on the cost of the wood produced than the method or the equipment being used, and perhaps this is the first aspect of the operation to get properly organised. To quote A. Jeff Maetin, who conducted a detailed time and motion study on seven logging operations in West Virginia during 1971 and 1972, "Of all the things that affect the cost of logging operations, more attention should be paid to the workman and his attitudes. The skidder operator who is aggressive, bold and active and full of initiative may skid a truckload of logs more a day than the less aggressive operator. The quest for cost savings is often more fruitful when attention is turned into the work habits of the workman rather than the machinery he operates". Similarly, the conclusion of the Battelle study in which 72 pulpwood operations were studied and analysed, was that "Crew aggressiveness can completely counteract all the other factors we stated as affecting harvesting cost." "Crew aggressiveness" was an expression used for rating the enthusiasm of the crew to produce wood. It was found that so-called aggressive crews were constantly seeking to keep busy, had realistic performance stands, had a strong and definite leader, were well trained, and had well maintained equipment. Crews became this way as a result of a management philosophy based on these points. The "aggressive crews" were paid **less**/unit of wood produced than the "non-aggressive" crews, but their weekly earnings were higher. Perhaps providing the crew with good leadership, incentive (not necessarily monetary), and every opportunity and facility for maximum production, is as important as having the right equipment and method of operation.

PRODUCTION THINNING AN 8-YEAR-OLD PLANTED RADIATA PINE STAND, KAINGAROA FOREST (Mackintosh, 1974b)

SUMMARY

1. The cost of the thinnings in this operation is very sensitive to log size. An increase in average log size of only 0.4 cu ft (2.1 to 2.5 cu ft) would reduce the cost of the wood for a 6-hour-day from 20.9 to 17.8 cents/cu ft.
2. The best time to pull logs together into groups for breaking out was found to be straight after felling and trimming them. It was important that the fallers had an understanding of the breaking out process, as the tractor's production was partly dependent on optimum size groups of logs in the right position.
3. Although in compartment 1343 the average log size was 29% less, and average load size 8% less than for compartment 72 (natural regen.), the tractor's production was 21% higher.
   The main reasons for this were the extra time spent making tracks and clearing obstacles in Cpt 72, and a reduced time to release the load in Cpt 1343. This was because the strops were permanently attached to the main rope, making it easier to pull them out of the load with the winch once released; and less strops were used as they were attached to a bundle of logs rather than single logs, as in Cpt 72.
4. The reason for the difference in cost between the two compartments was the higher tractor production in Cpt 1343. The felling and trimming work content/unit of wood produced was higher in Cpt 1343 but was compensated by the tractor driver being able to break out unassisted in Cpt 1343 almost as quickly as breaking out assisted by a faller in Cpt 72. The reasons for this were the clear access, and higher stocking in Cpt 1343 enabling logs to be grouped by the fallers.
5. The logs were stacked between the edge of the stand and the road, and so no trees were removed to form a dump area.
6. The annual production from thinning an 8-year-old planted stand such as Cpt 1343 with 4 men and a tractor such as the Holder would be about 160 000 cu ft at a current cost of about 21 cents/cu ft.

PRODUCTION THINNING A 10-YEAR-OLD NATURAL REGENERATION RADIATA PINE STAND, KAINGAROA FOREST (Mackintosh, 1974b)

SUMMARY

1. Logs and stumps from the previous crop were obstacles for the tractor and the fallers, and affected production. They were often hidden by the undergrowth and so could not always be avoided.
2. Because the trees were not in rows it was not possible to organise a load on the ground for breaking out to any great extent. One of the reasons for having the fallers assist with the breaking out was the difficulty with finding the logs.
3. Although the volume lost by cross cutting the logs at 18 ft was 9.2% the average tractor hauls did not decrease as the number of logs/haul increased. The reason for limiting the maximum length to 18 ft was K.L.C.'s transport requirement. (Kaingaroa Logging Co.)
4. One load of logs, 12 ft to 4 in. s.e.d. has been taken in by K.L.C. and fed into the mill. There were problems on the log deck with logs skewing and getting tangled. It is hoped that by limiting the log lengths from 14 ft to 18 ft this won't happen.
5. By selecting suitable areas for landings no more than four crop trees were removed in the formation of five landings. No crop trees were removed for internal tracks.
6. The formation of landings and tracking was all done alone with the Holder. To clear the landings trees were either pushed out of the ground or pulled out with the winch. Fleeting was also done with the Holder.
   Time for forming landings has not been allowed in the Holder's production.
7. The annual production from thinning a 10 year old regen crop such as Cpt 72 with four men and a tractor such as the Holder would be about 140 000 cu ft at a current cost of about 27 cents/cu ft.

STRIP THINNING IN YOUNG **PINUS RADIATA**, AN OPERATIONAL AND CROP ASSESSMENT (Mackintosh and O'Reilly, 1973)

SUMMARY

In an attempt to overcome the problems of production thinning young **Pinus radiata** on steep (> 15°) slopes, a new Zealand Forest Products contractor is carrying out a strip-thinning operation, using a converted RB10 crane. An assessment of the crane has shown that:

1. within the range of tree sizes being harvested, volume/load did not affect the cycle time, and thus
2. length of strip, stocking and number of hours worked/day determined the number of trees extracted, and thus
3. production/day depends upon number of hours the crane worked, the stocking, the length of strip, and the average volume/tree (Fig. 1).

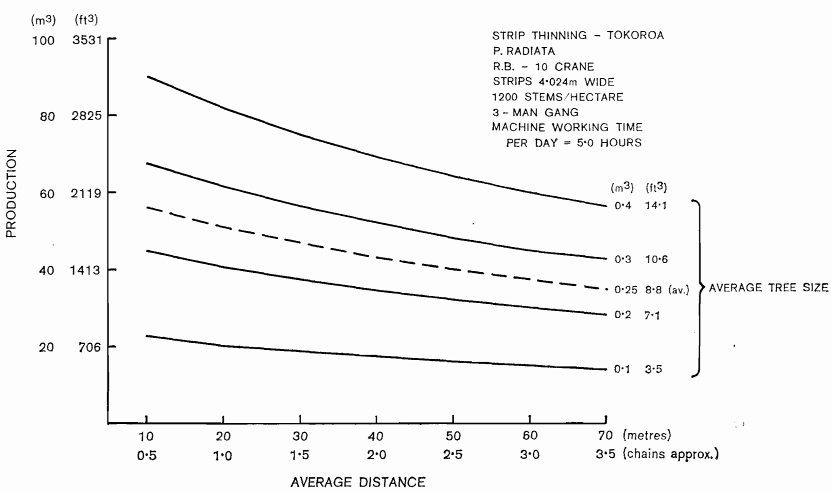
Plots have been established in order to determine the effect of the strip thinning on the remaining stand, and the results will be reported at the end of the assessment period. Generally, it can be said that:

1. The diameter distribution of the thinnings was similar to that of the crop, but the data indicated a higher percentage of malformed trees in the thinnings than the crop trees. Some selection may be possible in a strip thinning operation in natural regeneration.
2. Row thinning has the advantages over selection thinning of increased productivity and less chance of damage to the remaining trees.

The disadvantages (that row thinning offers little opportunity for improving the average quality of the crop, and may not be as effective in releasing the crop trees) can possibly be overcome by an early selective thinning to waste.

The operation was highlighted by close co-operation and co-ordination between all members of the strip thinning team. This, more than anything else, may be the factor which determines the effectiveness of the operation.

FIG. 1 EFFECT OF TREE SIZE AND HAUL DISTANCE ON DAILY PRODUCTION



POTENTIAL OF A HYDRAULIC GRAPPLE ATTACHED TO A FIAT AGRICULTURAL TRACTOR (McConchie and Muir, 1975)

SUMMARY

As a possible unit for extracting small thinnings, a Fiat 640 DT tractor equipped with a hydraulic grapple was used and evaluated. To assess the performance and capabilities of the unit, trials were carried out in stands of young radiata, using the following methods of extraction;

1. Selective thinning, extracting pre-bunched logs.
2. Row thinning — complete removal of every 3rd row.
3. Combined selection and row thinning — extracting pre-bunched logs.
4. Selective thinning — complete tree extraction.
5. Clearfelling — complete tree extraction.

It is evident from the trials that the unit is most productive when working on easy terrain and where the tractor can move freely right to the logs to be extracted. Its production is related to the size of the logs being extracted — the ideal piece size being the optimum load size for the unit. The extraction of small logs is very much improved if they can be bunched prior to extraction. Increased productivity could probably be obtained with increased operator experience and greater flexibility of the grapple, e.g. manual or hydraulic rotation.