HARVESTING: RADIATA PINE PRODUCTION AND COST TRENDS

C. J. TERLESK*

ABSTRACT

Estimates of harvesting production rates are often required by forest managers prior to the commencement of the operations. In an effort to meet this requirement, various harvesting studies have been combined into a series of graphs linking piece size with production rates and direct cost per cubic metre either at the landing or on the logging truck.

Ground and cable extraction operations in both clearfelling and thinning are covered, but the data for cable logging operations are weak and this area requires further research effort.

The crew numbers and capital investment have been allowed to fluctuate with piece size to give a better representation of a balanced logging system. To ensure greater homogeneity of the data the standard FRI costing format has been used to calculate the cost per cubic metre. All production rates are calculated on a 100 m haul distance, with the exception of the clearfelling cable operation which is standardised at 200 m.

The various graphs show that small piece size reduces production rates and inflates cost. Small piece size material is relatively more expensive at the landing or on the truck than larger piece size material in both thinnings and clearfellings utilising either cable or ground extraction systems.

The information in this report is gathered from operations solely within the Bay of Plenty region, and primarily from high-producing contract crews. Production rates therefore appear high by some standards but they are achievable.

Costs will date rapidly and technology will cause production rates to alter over time. However, the relationship between piece size and production should continue to give a reasonable estimate of achievable production rates in current and proposed long-length Pinus radiata *(radiata pine) operations.*

INTRODUCTION

Estimates of production rates and costs of harvesting operations are often required by forest managers for budgeting and planning purposes prior to the commencement of the operations. To help satisfy this requirement a set of graphs has been constructed to

*Forest Research Institute, Private Bag, Rotorua

show daily-production and direct-cost-of-production trends for a range of long-length radiata pine tractor and cable operations. Both these parameters have been related to piece size (standing stem volume).

The Data Source

The data base for the production graphs is from detailed unpublished production studies undertaken by the FRI Harvesting Group over a number of years. These studies are supplemented by unpublished production information supplied by the Kaingaroa Work Study Unit. The terms "tractor" and "cable" define the terrain conditions under which the data were collected — tractor implies easy conditions, cable implies steep and more difficult terrain.

To ensure greater homogeneity of the data, the standard FRI costing format (unpublished) has been used to calculate the cost per cubic metre. For the same reason, the harvested material is delivered to one of the two common points — the landing or the truck. All production rates are calculated on a mean haul distance of 100 m, with the exception of the clearfelling cable operation which is at 200 m. Crew numbers and capital investment have been allowed to fluctuate with piece size to give a better representation of a balanced logging system.

The information in this report is only indicative, gathered from operations solely within the Bay of Plenty region. The FRI Harvesting Group have traditionally studied contract crews who have a record of high and sustained production; therefore the production rates will appear high by many standards. They are, however, achievable given the necessary ingredients of high motivation, experience, and sound management, and the absence of forest resource and processing plant supply limitations which sometimes impinge on high production rates.

GROUND EXTRACTION

Production Thinning

Figure 1 — Production rates

The eight points shown on the graph cover a range of piece sizes from 0.044 to 0.64 m^3. The range of stockings before and after thinning is also shown. A linear trend has been assumed, to show a daily production rate of 20 m^3 at the 0.044 m^3 piece size rising to 80 m^3 at the 0.64 m^3 size.

The four points at the lower end of the range represent harvesting operations where one machine carried out the logging opera-

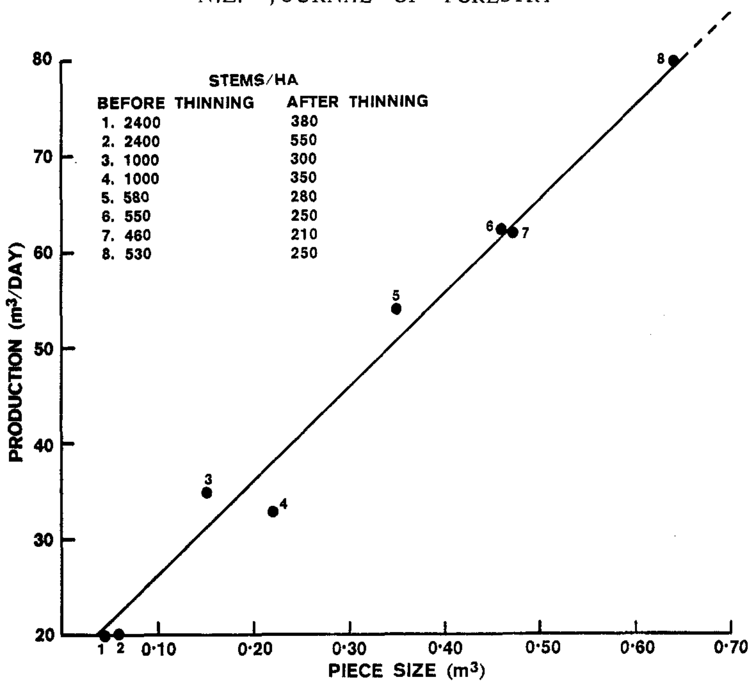

FIG. 1: *Production thinning — radiata pine. Ground extraction daily production trend.*

tion and the stacking on the landing. The second four points represent operations where an additional specialist machine was employed for stacking.

Because all the harvested material was used as pulpwood, precise measuring and cutting to length were not required. Trimming, however, was carried out to a fairly high standard.

Production rates increase steeply with increasing piece size.

Figure 2 — Cost of Production, December 1977

The graph initially shows a rapidly declining direct cost per cubic metre for produce delivered and stacked on the landing. The trend *based on this set of data* is, however interrupted by a further capital injection around the 0.35 m^3 mark. This represents the inclusion of a rubber-tyred stacking machine and an operator.

For lower piece sizes (0.05 to 0.22 m^3) one machine of a relatively low capital value both hauled and stacked the production. The net effect of increased capital in this example is an increase in the cost per cubic metre. The stacking machine did not generate

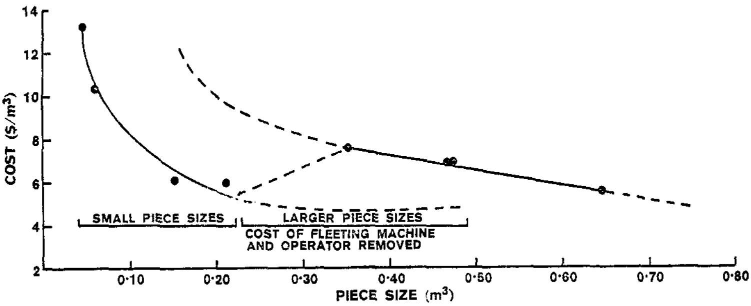

FIG. 2: *Production thinning — radiata pine. Ground extraction-cost trend/ m^3 on landing 1977, with and without fleeting machine and operator.*

sufficient extra production to offset the cost of the additional capital invested, thus overriding the benefit expected from increasing piece size.

The effects of increasing labour and capital inputs on the per day cost of the total logging system and on costs per cubic metre are shown for two examples from the basic data in Table 1.

TABLE 1: EFFECTS OF INCREASED LABOUR AND CAPITAL INPUTS

Piece Size (m^3)	*Capital Invested* ($)	*Man-power*	*Daily Cost* ($)	*Daily Production* (m^3)	*Cost* ($/m)
0.22	31 000	3	215	36	5.98
0.35	103 000	5	443	58	7.62

The daily production in the second example (0.35 m^3 piece size) would have to increase to 74 m^3 to equal the cost of the first operation. This represents a 27.5% increase in production.

The cost trend for larger piece sizes is shown with the fleeting machine and operator included. The trend of the solid line indicates that cost per cubic metre steadily decreases with increasing piece size. The trend, however, is true only for a small range (0.35 to 0.64 m^3) of piece sizes; further injections of labour and capital inputs will alter the cost line unless it is associated with increased productivity. The dotted line purports to represent the cost trend outside the data range and emphasises the effect of the fleeting machine on costs in the smaller piece-size operations.

This graph also includes the cost trend when the cost of the fleeting machine and its operator are taken from the cost structure of the larger piece-size range. The relationship between cost and piece size assumes a more familiar pattern — a rapid initial decrease in cost with increasing piece size, followed by a flattening out of the line as larger average piece sizes are encountered.

Over the piece-size range 0.30 to 0.50 m^3, labour and capital inputs remain constant in the example. Therefore, decreases in the cost of production are directly linked to increased productivity arising from increased piece size. Further reductions in cost could arise from further increases in productivity through reductions in capital and labour inputs, and improved methods.

Clearfelling

Figure 3 — Production Rates

Figure 3 shows a steady increase in production with increasing piece size, though the production gain appears to diminish in the 3.0 to 5.0 m^3 range. This reduction can possibly be explained by the increased breakage occurring in the larger stems. This is best

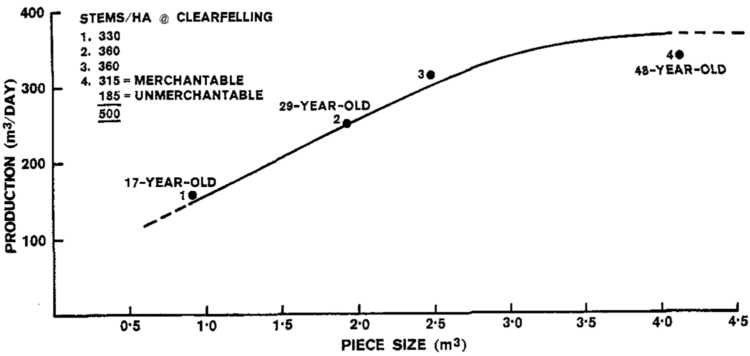

FIG. 3: *Clearfelling — radiata pine. Ground extraction daily production trend.*

demonstrated by examining the effect of breakage on the standing 4.0 m^3 tree which is reduced to a mean piece size of 2.7 m^3 on arrival at the landing. This decrease in piece size and increase in the number of pieces will cause some reduction in production, particularly where very large trees are felled with conventional techniques. Breakage is of much less significance in the smaller piece sizes where the measured piece size arriving at the landing more closely approximates the standing merchantable tree volume. Stems per hectare prior to clearfelling are shown on the graph.

Figure 4 — Cost of Production

Figure 4 shows a small but steady decline in cost per cubic metre with increasing piece size. The return from increasing piece

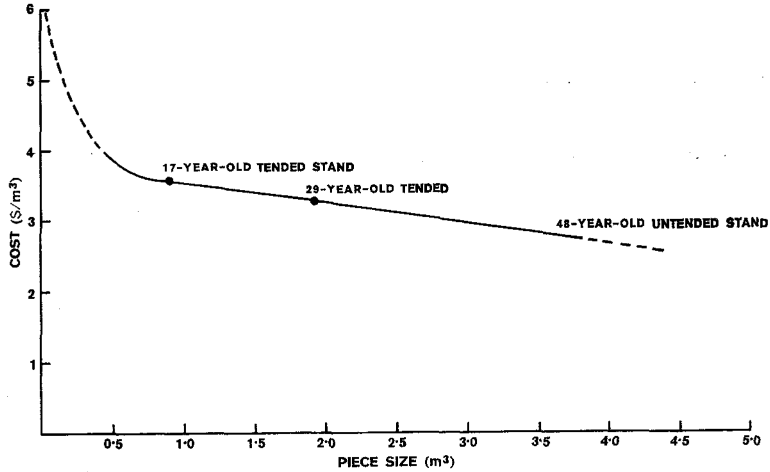

FIG. 4: *Clearfelling — radiata pine. Ground extraction-cost trend/m^3 on truck 1977.*

size diminishes through the 3.0 to 4.5 m^3 range for the reason discussed in the preceding section.

The 17- and 29-year-old stands were managed (pruned and thinned), but the 48-year-old stand was untended. The operations in the 17- and 29-year-old stands both used rubber-tyred skidders, and in the 48-year-old stand a track-laying machine was utilised.

The capital investment and the labour complement for the three operations are shown in Table 2.

The significant factor in the graph is the relatively small reduction (\$0.91/m^3) in cost per cubic metre over an extensive range of piece sizes. The composition and value of the assorted end-products, however, have not been considered in this note. The three operations quoted above were selected as a result of production studies. The crews were considered to be capable of a high level of production, they were equipped with machinery suitable for the task, and they were following suitable work methods.

TABLE 2: CAPITAL INVESTMENT AND LABOUR COMPLEMENT FOR THREE HARVESTING OPERATIONS

Stand Age (*yr*)	*Capital Invested** ($)	*Gang Strength*	*Daily Cost of System* ($)	*Daily Production* (*m³*)	*Cost* ($/*m³*)
17	110 000	6	566	157	3.61
29	172 000	7	782	249	3.14
48	186 000	8	890	330	2.70

* Costs as at December 1977.

CABLE SYSTEMS

Production Thinning

Figure 5 — Production Rates

Much of the data in Fig. 5 has been synthesised from one detailed study of a Timbermaster Skyline operating in an uphill situation: the mean piece size in the cable system study was 0.35 m^3 and daily production was 42.0 m^3 over a mean haul distance of 100 m.

These production rates were 72% of those of a ground extraction operation on similar piece size. A range of known piece sizes and production levels were adjusted using this percentage figure to show the production trend in Fig. 5. Stems per hectare before and after thinning are shown in the graph.

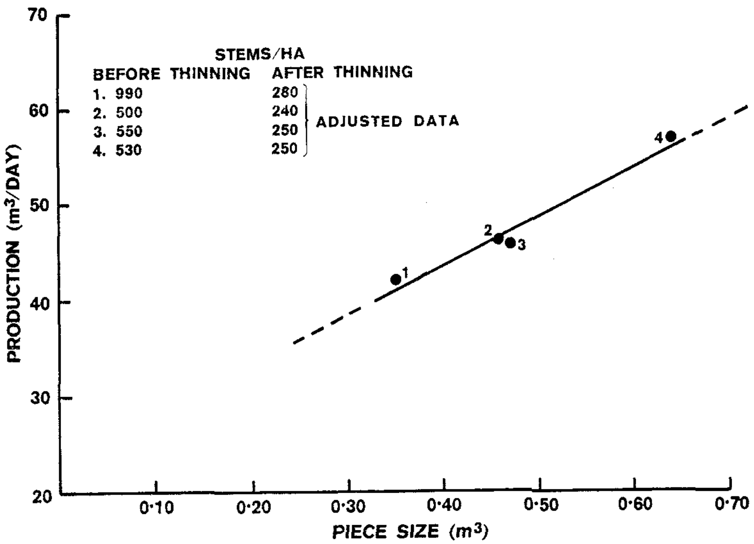

FIG. 5: *Production thinning — radiata pine. Cable system (uphill) daily production trend.*

Care should be taken when using the data because of the limited sample and the method of adjustment. Only a narrow range of piece sizes is shown to ensure that the Timbermaster (or similar) machine is operating within its known capacities. Outside the range of 0.35 to 0.65 m^3 more suitable machines may be available to carry out the havesting operation.

Figure 6 — Cost of Production

Based on the production trends shown in Fig. 5, a cost relationship has been developed to show cost per cubic metre on the landing: a five-man gang is usual in current operations, and capital investment is around $120 000. The Timbermaster is fitted with a hydraulic crane for stacking and sorting the logs on the

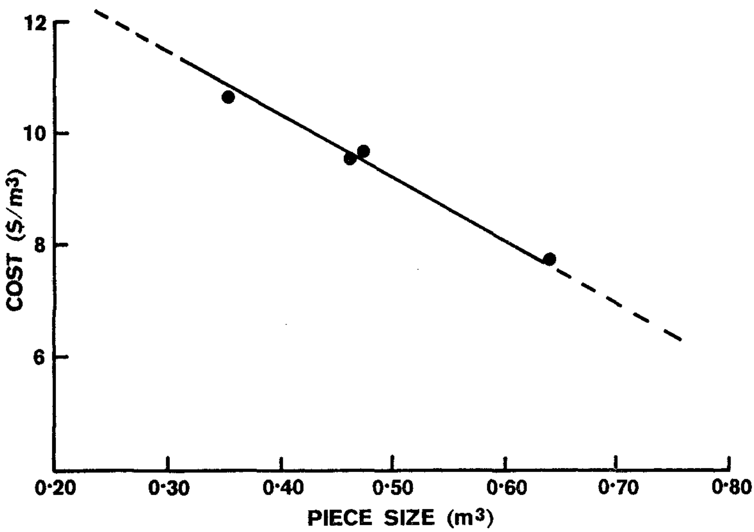

FIG. 6: *Production thinning — radiata pine. Cable system-cost trend/m³ on landing 1977.*

landing and into multi-lift cradles. The capital invested is inflated by the need to have a track-laying machine (HD6) on site for pulling the Timbermaster into position and to load and reposition the multi-lift cradles. Figure 6 does not show an initial trend of rapidly decreasing cost per cubic metre with increasing piece size as shown in Fig. 2. This is due to absence of data for sizes less than 0.20 m^3. Harvesting of piece sizes less than 0.20 m^3 by cable systems with labour and capital inputs similar to those quoted above would certainly induce rapidly escalating costs and produce a configuration similar to that in Fig. 2.

Clearfelling

Figure 7 — Production Rates

The daily production rates in Fig. 7 were adjusted on a basis similar to that described for Fig. 5. Production comparisons were made between a ground extraction operation and a cable system

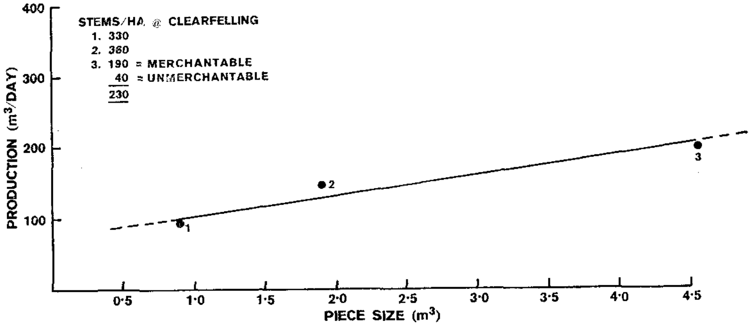

FIG. 7: *Clearfelling — radiata pine. Cable system daily production trend.*

operating in similar piece sizes. The derived factor was used to adjust the other points shown in the graph. Stems per hectare prior to clearfelling are shown on the graph.

The weakness in this approach is the use of a factor derived from a study of a large cable system (Madill 009) to adjust production rates for much smaller piece sizes, where it would be expected that a smaller, less costly machine would be able to handle the harvesting operation more economically. For this reason, only the production trend shown between 1.75 and 4.0 m^3 should be used for estimation purposes. In this range it is possible that the Madill 009 could be used comparatively efficiently.

In addition, the mean standing stem volume of 4.5 m^3 reduces to a mean piece size of 2.6 m^3 when measured at the landing. The significant reduction in piece size through breakage has a marked effect on productivity and requires further extensive research.

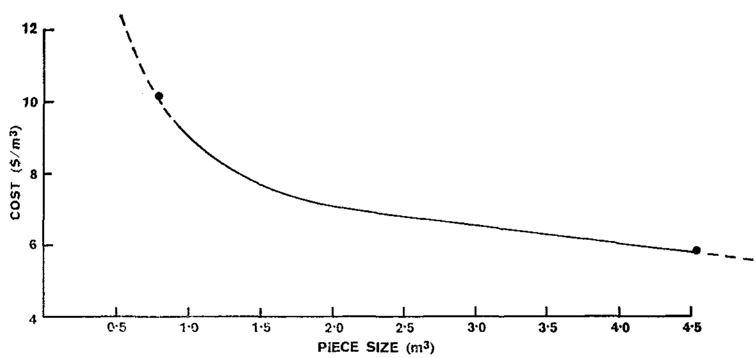

FIG. 8: *Clearfelling — radiata pine. Cable system-cost trend/m^3 on landing 1977.*

Figure 8 — Cost of Production

Cost-of-production figures were adjusted as already discussed. Because of the doubts about suitability of machinery over such a wide range of piece sizes, together with man-power numbers, only the cost estimate for the range of piece sizes 1.75 to 4.0 m^3 should be used.

Further studies are planned and syntheses of existing study data will strengthen the trends shown in Fig. 8. However, as with all "broad brush" approaches, it will always require caution in use.

DISCUSSION OF RESULTS

Previous FRI work has shown that increasing piece size attracts increasing capital investment, the cost of which must be compensated for by increasing productivity to maintain or reduce logging costs (C. J. Terlesk and K. Walker, unpublished data). The effect produced on cost by increased increments of capital without corresponding or sufficient increases in productivity is shown in Fig. 2. Both excessive and improperly used capital and labour will inflate logging costs and this must be considered when formulating logging systems.

For a small range of piece sizes there is an optimum level of capital investment and labour input, a sustainable level of production, which will result in the lowest cost per cubic metre at a given delivery point. This will hold, of course, only if there is a degree of similarity in such factors as prescription, stand and tree characteristics, and terrain and preparation specifications.

All stands have a range of diameters distributed around the mean. In selecting a logging system, the mean piece-size tree is usually a key variable in the decision-making process. The chosen system will operate efficiently around the mean tree (all other factors being equal), but will be theoretically less efficient with the smaller and larger piece sizes, particularly where the number of strops used in breaking out the haul is fixed. This must impose a degree of inflexibility and reduce the possibility of varying the number of pieces per haul depending on size. As mean tree sizes increase or decrease, so the chosen system will show increasing deficiencies, reflected in lower production rates and escalating costs. It is at this stage that capital and labour inputs should be changed to optimise production rates and minimise the cost of production.

With very small piece sizes, the amount of capital and the labour inputs required to harvest the produce are irreducible and this is shown in the high cost of production in Fig. 2. The objective here must be either to reduce the inputs to the barest minimum or to embrace the highly mechanised concept, relying on very high production levels to overcome the high cost of the capital investment. Recent studies, however, have shown that cost reductions are difficult to achieve with highly mechanised systems, partly because of low availability and utilisation percentages, and partly because highly mechanised systems are still sensitive to piece size.

From research findings it is possible to make some general suggestions about the type of logging systems and work methods for a range of piece sizes in tractor thinning and clearfelling operations. Comment on cable logging operations will mainly be reserved until proposed studies are completed.

Production Thinning — Ground Extraction

On very easy terrain with clean ground conditions, the four-wheel-drive farm tractor extracting long-length pulp material appears a sound choice for material in the piece-size range 0.05 to 0.25 m^3.

A three-man gang (two preparing material and one operating the tractor) appears to be adequate on a 100 m haul distance to produce 20 to 40 m^3/day.

This type of operation either should have a fleeting capacity incorporated into the logging machine or, alternatively, four to six gangs should be fleeted by one specialist fleeting machine capable of stacking 120 to 240 m^3/day.

For larger piece sizes (0.30 to 0.65 m^3) a four-man gang utilising a 70 to 100 hp skidder is a feasible logging unit capable of producing 60 to 90 m^3/day over a 100 m mean haul distance. Again, serious consideration should be given to the supply of one fleeting machine, perhaps as a separate contract, for a number of these units in preference to one fleeting machine to each unit. Loading out could be handled as a separate operation if cost savings warrant this.

The short pulp system, although labour intensive, appears a reasonable alternative for small piece sizes (0.14 m^3) on even or more broken terrain. A crew of 13 men cutting and supplying one 80 hp rubber-tyred skidder assisted by one man at the breaking-out site should average 100 to 110 m^3/8-hour day over a mean 100 m haul distance.

Clearfelling — Ground Extraction

The smallest piece-size clearfelling operation measured and reported to date is 0.9 m^3. This operation featured a rubber-tyred skidder of the 97 hp class, and a five-man gang. In this particular operation both export and pulpwood logs were being produced and an additional man was required on the landing for the measurement phase. If pulpwood only was being produced (with less stringent measurement criteria) one man on the landing would have been sufficient.

The rubber-tyred skidder carried out all sorting and stacking and still delivered to the landing *c.* 100 m^3/day over a 100 m average haul distance, at a cost comparable then to that of many mature clearfelling operations. However, to maintain comparability between the operations shown in Figs. 3 and 4 a stacking and loading machine has been built into an updated cost structure and, although the production rate of the logging machine increases to 157 m^3/8-hour day, the price increases to \$3.61/m^3 on truck. Without the stacking and loading machine, the cost is \$2.91/m^3. This additional cost of loading (around \$0.70/m^3) should be compared with the costs of other loading approaches before a decision on unit composition is made.

Cable Logging Operations

Thinning and clearfelling logging operations have been included in this analysis to show likely levels of production and costs. Lack of data prevents definite statements on machine size, gang structure, levels of production, etc.

It would seem clear that cable logging production will be less (50-70%) and that costs will be greater (65-85%) than in ground extraction and that thinning of small piece-size material by cable systems will result in comparatively high-cost wood at the mill door. The quoted cost differences are supported by the Forest Engineering Research Institute of Canada (1976) which states that described cable-logging costs range from \$8/m^3 to \$11/m^3 on truck, while current local costs for ground skidding systems range from \$4/m^3 to \$6/m^3 on truck (Canadian dollars).

Further detailed studies are required on many more machine sizes and types, and over a wide range of piece sizes and terrain conditions, before definite conclusions can be reached on performance and cost in New Zealand logging.

REFERENCE

Forest Engineering Research Institute of Canada, 1976. *FERIC Tech. Report No. TR-8.* 31 pp.