CHILEAN EXPERIENCE WITH MID-SIZE HAULER OPTIONS

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INTRODUCTION

Chile, along with New Zealand, Australia and South Africa, has large areas of plantation forest established with the species <u>Pinus radiata</u>. The silvicultural management regimes adopted by some of the Chilean companies are similar to those of some New Zealand companies.

In the past decade Chile has sent many study teams to look at New Zealand's management and operational practices (as well as the practices of Australia and South Africa). In the past twelve months, New Zealand has reciprocated with visits by formal study teams from the NZ Forest Industry Council, a large forest company and LIRO.

This paper concentrates on the considerable experience Chile has with mid-size hauler options and the use of intermediate supports. Chilean experience is combined with New Zealand machine and labour costs to better evaluate the use of this alternative for New Zealand.

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FORESTRY IN CHILE

Chile has a total area of 75.7 million hectares. Of this total, 33.8 million hectares are potentially productive and productive forested terrain (INFOR. 1991a). The forests are concentrated between 30° and 50° South latitude. In 1991, 9.16 million hectares were considered as productive forest, with 83% in native forests and 17% in plantations (1.5 million ha), Figure 1.

The native forests mainly consist of associations of broadleaved species and harvesting is done traditionally using selective cuttings to produce wood for veneer, sawlogs and chips.

Eight-four percent of the plantation area is in radiata pine, 8% is in Eucalyptus and the remainder is in other species. The plantation forest estate is still increasing: 107500 hectares were planted in 1991, with 63.7% (68471 ha) of Pinus radiata and 29.5% (31672 ha) of Eucalyptus (INFOR, 1991b). In 1976, the government participated with 50% of the new planted areas, but in 1991 all new plantations were established by private organisations.

In 1990, log production by the Chilean Forest industry was 14.26 million cubic meters (solid without bark) (INFOR, 1991a). In addition, approximately 5 million m^3 of native woods were used for fuel and heating. The main products were sawwood (49%), chips (15.8%), and chemical pulp (15.3%). Of the total production, 75.2% (10.7 million m^3) was radiata pine wood, Figure 2. It has been

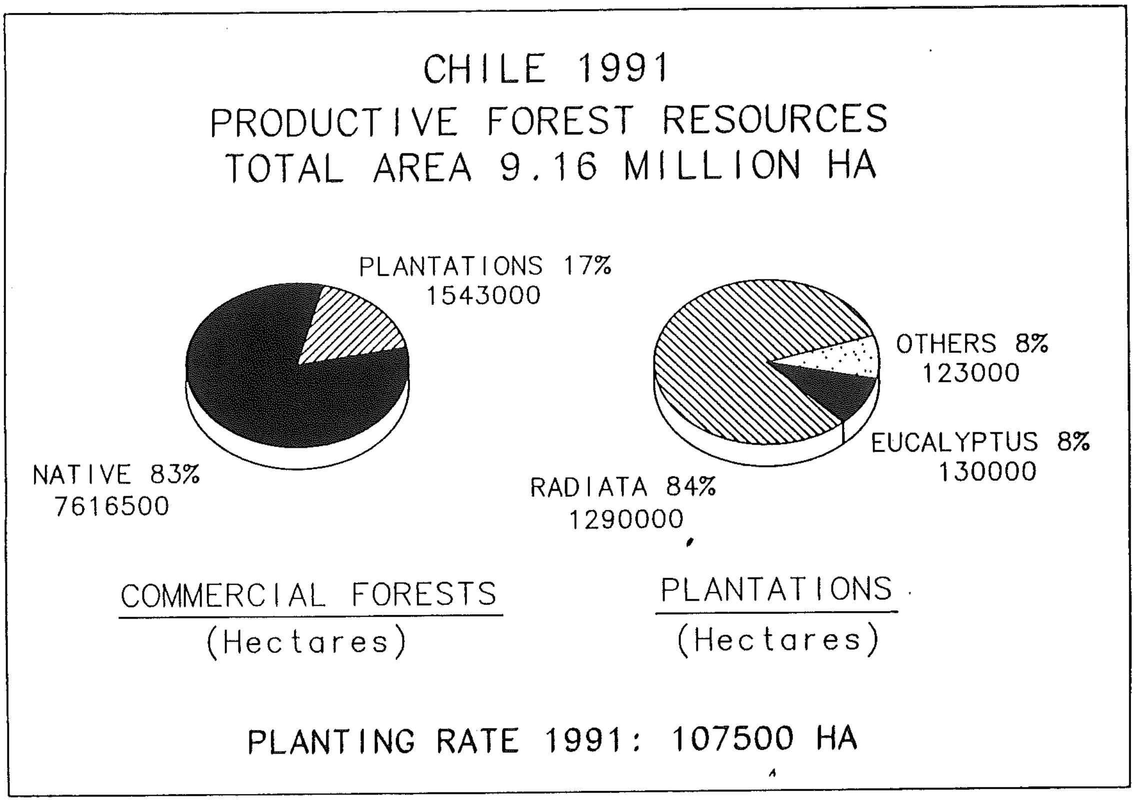

Figure 1. Productive forest resources in Chile - 1991.

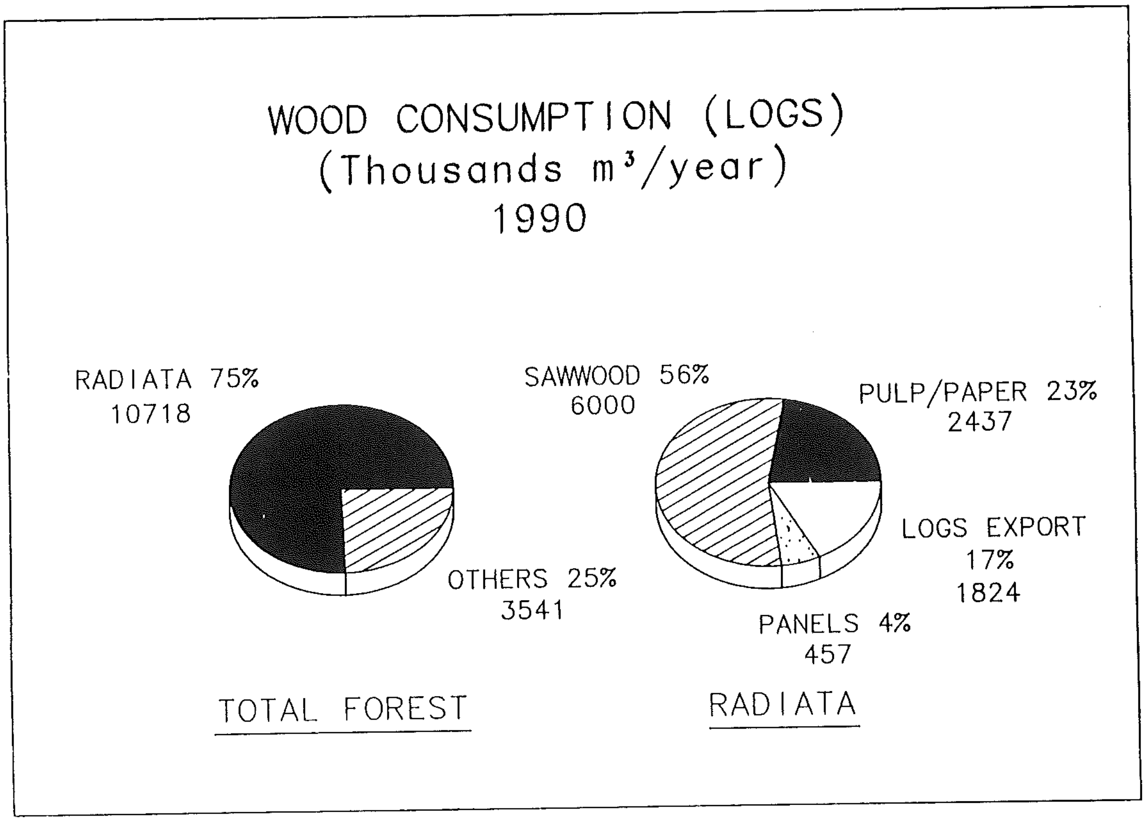

Figure 2. Total volume harvested in Chile - 1990.

estimated that log production will increase to 19 million m^3 for 1992 and 24.7 million m^3 for 1997. This additional volume will come mainly from plantations.

In 1991, Chile exported US$913.1 million FOB of forest products (CONAF, 1992). The main exported forest products were: pulp and paper (45% - US$407 million FOB), sawwood (20%), chips (20%), and logs, panels and others (15%). Forest products were exported mainly to Japan (31%), USA (7%), Belgium (7%), Germany (7%) and South Korea (6%).

PLANTATION HARVESTING IN CHILE

In 1990, the forest labour force, with 98446 jobs, accounted for 2.3% of the total Chilean labour force (INFOR, 1991c). The distribution of these jobs was: 38.4% in silviculture and harvesting, 47.6% in forest industries and 14% in forest services. It is estimated that in the short-term (1992-93), some 20000 new jobs will be created to satisfy the growth of the forest industry in sawmills and pulpmills, paper and panels production. Without any doubt one of the main problems that faces the forest sector is the lack of qualified people (at every level). The need for a more qualified labour force affects not only the forest products industries, but also other activities such as nurseries, plantation tending, forest management and harvesting.

Traditionally, animals were used to log terrain with less than 15% slope. Up to the beginning of the 1980's, the use of animals in logging operations accounted for 40% of the total logged volume, but now it is restricted to small scale operations and accounts for less than 5%. This is a consequence of the need for higher productivity and the handling of large logs. Now, logging in clearcutting operations is done mainly by ground based rubber-tyred skidders, and, in areas with slopes greater than 30%, with cable yarders.

Fifty percent of native forests and 30% of plantations are located on terrain with greater than 30% slope. However, most (83%) harvesting operations use skidders. In terrain with more than 30% slope, cable yarders are increasingly being used and, today, in 1992, 95 units are operating. One third can be considered as medium skylines: 6 URUS IV's, 8 KOLLER K600's and K501's, 4 CYPRESS 1400's, 9 CHAPMAN's, 3 CHRISTY's, 1 ADLER BACO and 1 MADILL 071. Forty-seven percent are small skylines, mainly URUS I and II (31 units) and KOLLER K300 and K301 (12 units). The others are highleads, 9 Logger's Dream machines refitted as skylines and 3 new URUS II Highlead. The rest cover a wide range of different makes and types of equipment. Skylines are used mainly in the European style because of the convex topography - i.e, uphill logging with at least one intermediate support. Last year, however, some downhill logging was also carried out.

The harvesting of 26 to 30 year old Pinus radiata stands is mainly by full tree or tree-length extraction, with trees 30 to 32m long, 30 to 35cm diameter (DBH), with volumes of 500 to 700 m^3/ha and stockings of 600 to 800 stems/ha - also trees of 25m height and 25cm DBH.

The hauler crews in pine forests are comprised of from 10 up to 13 people: 4 to 5 for felling and delimbing, 2 to 3 chokermen (breaker-outs), 1 hauler (yarder) operator, 3 to 4 for bucking (cutting to length), delimbing (eliminate branching defects) and sorting on landing (with skidder, Bell Logger or oxen). In Eucalyptus forests the crew is made up of: 1 man for felling (normally two weeks before the logging), 1 yarder operator, 1 mobile crane operator (loading), 1 man for unhooking on the landing, 1 crew boss and 2 chokermen in the forest.

In general, two thirds of the contractors pay their men on piece work rate (per produced unit), 26% pay a monthly wage plus a production bonus and 8% only pay a monthly wage, or for the time worked (Apud & Ilabaca, 1991). In harvesting operations, the base wage of the crew members is between US$200 and US$370 per month plus a production bonus, although some of the crew members are paid only by piece rate, Table 1.

PRODUCTION STUDIES OF MEDIUM YARDERS

This paper summarizes five time studies on yarding with mid-size equipment and analyses production results in relation to stand details and work methods.

Site conditions

The studies areas were located in the coastal area from Concepcion and Arauco provinces, between 36° 45' and 37° 15' South. The climate of the area is rainy-temperate with a Mediterranean influence (Fuenzalida, 1965). Average annual rainfall ranges from 1200 to 1500mm, mainly concentrated in autumn (29%) and winter (49%) (Almeyda, 1958). Soils correspond to silty clays derived from geological substratum of metamorphic stones, highly plastic and adhesive in wet conditions, hard and compacted in dry conditions, thin to moderately deep soil profiles with approximately 50% total porosity and 1.2 Mg/m^3 bulk density. Topography is complex with slopes ranging between 20% and greater than 50%.

Stand details

Study stand conditions are summarized in Table 2. Time studies deal with clear felling in mature stands of Pinus radiata and Eucalyptus globulus. Pruned and managed pine stands show stockings of 630 to 768 stems/ha with volumes of 508 to 711 m^3/ha. Fresh pinewood has approx. 1.0 ton/m^3 specific gravity. The brush in the pine stands was light.

The stocking of Eucalyptus stands reached 861 stems/ha with 508 m^3/ha. Specific gravity of eucalyptus wood is 1.3 ton/m^3. In general, eucalyptus stands harvested show a high stocking range between 237 and 508 m^3/ha and average tree size between 0.23 and 1.0 m^3. The brush (stems less than 7 cm), resulting from high regeneration, was cut over with brush saws two months before the felling. This operation improves production

Table 1. Payment systems

Work	Pay System	NZ$/week (*)
Yarder operator Skidder operator Powersaw operator Oxen driver	Base wage + Bonus Base wage + Bonus On piece work On piece work	200 200 200 200
Chokerman	On piece work	130
Stacking Delimbing	On piece work	90

(*) Includes 20% Social Benefits

Table 2. Stand data per case study

Stand data	Case 1	Case 2	Case 3	Case 4	Case 5
Location	Pinares	Ralquecura	Pinares	Pinares	Chivilingo
Species	Pinus r.	Pinus r.	Pinus r.	Pinus r.	Eucalyptus
Age	30	26	30	30	mature
Av dbh (cm)	33.5	28.5	33.5	33.5	25.4
Av tree height (m)	32	(31.5)	32	32	26.7
Stocking (stems/ha)	668	768	668	668	861
Total volume (m3/ha)	711	545	711	640	508
Terrain slope (%)	20-50	21-54	20-50	35-50	steep
Date of study	w. 1988	s. 1987	w. 1989	w.1988	w.1990
Type of cut	clearfell full stem	clearfell full stem	clearfell full stem	clearfell full stem	clearfell full stem and logs of 12.3m

w = winter s = summer
() = estimated values from INFOR(1985) Compendio de Tablas Auxiliares para el Manejo de Plantaciones de Pino Insigne, Manual No. 14, p. 52.

rates and yarding safety.

Equipment details

Two uphill rigging systems were studied: mid-size live and standing skylines (yarding distances up to 500m and maximum payloads between 2.5 and 4 tons). Skyline systems used automatic carriages that allowed lateral skidding. Table 3 shows the data for the yarders.

Felling and delimbing methods

Directional felling was used. For cases 1 to 4 felling was parallel to the direction of the skyline roads. For Case 5, in a eucalyptus stand, felling followed the contour lines and took place two weeks before the yarding. Cases 1,2 and 3 correspond to felling and delimbing with powersaws, case 4 corresponds to felling with powersaws and delimbing by axes.

Study methods, cycle time observations

Conventional stopwatch studies of the hauling phase using continuous timing methods were carried out. Cycle-time observations included the following time elements:

+ Variable times
  - Outhaul time (without load)
  - Inhaul time (with load)
+ Fixed times
  - lateral-out: time required for the rigging crew to pull the skidding line laterally from the skyline to the logs.
  - hook time
  - lateral-in: time required to skid the logs to the skyline.
  - unhook time
+ Nonproductive times
  - fatigue and delays
+ Rigging and yarding road-changing time

Data analysis

Table 4 summarizes the time study data. Although the yarders had the capability of yarding distances up to 400-500m, the high road density in the study areas (between 18 and 20 ha/km or 50 to 55m/ha) meant that the full capability was not required.

The average daily yarding production values are lower than expected, and lower than current production rates. In general, for clear felling in pine stands, the production reaches about 100 to 110 m^3/day. In eucalyptus stands, yarding ranges between 70 and 107 m^3/day corresponding to the tree size between 0.23 and 1.0 m^3/each.

However, the production rates for the case studies range between 68 and 78 m^3/day because of high fixed times (mainly hook times), low average turn volumes, high rigging times (cases 1, 2 and 3), low yarding areas for rigging units and high delay times in others (1, 2, 4).

Fixed Time - analysis per turn shows that hook time is the most time consuming and represented about 35 - 63% of the total fixed time including delays, Table 5. This is a consequence of the directional felling quality, brush density, terrain and slope conditions, besides volume per turn, number and size of stems hooked on, number of chokermen and chokers, etc. Unhook times

Table 3. Machine data

Machine data	Case 1	Case 2	Case 3	Case 4	Case 5(*)
Hauler	Koller	Koller	Koller	Christy	Cypress
Model	K-600	K-600	K-501		1400
Motor	Cummins	Cummins	Cummins	Cummins	Cummins
Power kw (HP)	140 (170)	140 (170)	84 (112)	90 (120)	110 (152)
Tower height (m)	11	11	10	9	14
Carriage model	SK 2.5	SK 2.5	SK 2.5	Christy	
payload (kN)	38	38	-	40	60
Interlock	Hydrostat.	Hydrostat.	Hydrostat.	w.i	Hydraulic
Skyline capacity (m)	550	550	500	w.i	500
line size (mm)	24	22	20	w.i	w.i
Main line capacity (m)	650	650	650	w.i	800
line size (mm)	12	12	12	w.i	w.i
Haulback capacity (m)	1000	1000	-	-	w.i
line size (mm)	12	12	-	-	w.i
Yarding system used	standing	standing	standing	live	live
Direction	uphill	uphill	uphill	uphill	uphill
Span	multiple	multiple	multiple	single	single
Equipment to clear deck	F. loader	F. loader	Skidder	Skidder	M.crane

(*) and Case 5b = butt rigging system without carriage and without lateral skidding
multiple = normally one intermediate support
F.loader = front loader like Volvo 4300
M.crane = Prentice 210 C
w.i = without information

Table 4. Time study data

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 5b
Line slope (%)	w.i.	36	w.i.	38.5	w.i.	w.i.
Slope yard. distance (m)	50-415	50-270	285	50-250	15-110	15-140
Corridor width (m)	40	40	30	w.i	w.i	w.i.
Crew members (i.f)	11	9	10	12	9	9
Stems per turn	2.09	3.22	w.i	1.78	w.i	w.i
Volume per turn (m3)	3.08	2.35	2.01	2.37	1.57	1.17
Rigging time (minutes)	347	326	352	113	173	58
Fixed time per turn (min)	5.17	8.20	4.93	1.89	4.34	2.38
DPT (%)	63.6	65.1	58.3	54.4	63.9	65.7
Delays (%)	11.8	10.6	7.9	19.4	10.0	9.3
Utilization (%) ET	75.4	75.7	66.3	73.8	73.9	75.0
Total number of turns	238	117	w.i	211	313	547
Ave. daily prod. (m3)	73.6	68	71.6	w.i	78	89

DPT = directly productive time (based on delay free time)
ET = effective time
i.f. = includes fallers
w.i. = without information

Source:

Case 1. Forestal Mininco S.A. 1989. Madereo con cables. Informe Tecnico. 31p.

Case 2. Henriquez, R. 1992. Estudio de rendimiento en el madereo con torre. Tes. Ing. For. Universidad Austral de Chile. 65p.

Case 3. Forestal Mininco S.A. 1990. Informe proyecto tala rasa con torre Koller K-501. Desarrollo en Cosecha y Transporte. 25p.

Case 4. Becker, J., Silva, J., Rojas, J., Vicencio, R. 1989. Tala rasa con torre de madereo. Programa de invessigacion y desarrollo en cosecha y transporte. Forestal Mininco S.A. 31p.

Case 5. Lineros, M., Guajarco, C., Cabezas, W. 1990. Informe proyecto evaluacion tecnica torre de madereo Cypress 1400. Depto. Explotacion Forestal Colcura S.A. 37p.

Table 5. Fixed time in minutes per cycle

Time	Case 1	Case 2	Case 3	Case 4	Case 5	Case 5b
Hook	2.98	5.74	1.91	1.18	2.62	1.56
Unhook	1.26	1.38	1.36	0.50	1.72	0.82
Lateral - Out/in	0.93	1.08	1.66	0.21	-	-
Delays	2.19	2.07	0.50	1.25	0.82	0.50
Total	7.36	10.27	5.43	3.14	5.16	2.88

Table 6. Production equations (Total time)

Case study	Regression equation (1)
Case 1	TT(w) = 7.85 + 0.0105 D
	TT(s) = 9.19 + 0.0109 D
Case 2	TT(s) = 8.33 + 0.0115 D + 0.2238 V
Case 3	TT(w) = 5.10 + 0.0132 D
Case 4	TT(w) = 4.14 + 0.0124 D + 0.074 V
Case 5	TT(w) = 4.96 + 0.0057 D
Case 5b	TT(w) = 2.97 + 0.0077 D

(1) Based on delay free time
TT = total time (var + fix)
w = winter yarding s = summer yarding
D = logging distance
V = volume per turn
Case 5b = Cypress 1400 Butt rigging system (like highlead).

are influenced by the number of logs, equipment that services the log deck, volume per turn. Lateral-out and -in times depend on brush, terrain roughness and terrain slope. Delays mainly happen in the lateral-in phase because of tangling with other stems and as interference on the logdeck while waiting for clearing up.

Variable Time - All the regression equations for variable time (outhaul plus inhaul time) are based on delay free time and include the yarding distance. As well, Cases 2 and 4 include the volume per turn.

Total Time - Table 6 shows the regression equations for the different case studies for total time. The regressions for total time are composites - made up of the regressions of variable times plus the average fixed time per turn. The regression coefficients for variable time were significant at the 0.05 probability level or less.

PRODUCTIVITY AND COSTS FOR NEW ZEALAND CONDITIONS

To better evaluate the suitability of these type of machines and systems for application in New Zealand forests data from selected Chilean case studies were applied to New Zealand stand conditions and daily costs.

Production equations for the Koller K600, Koller K501 and Christy yarders were chosen since they were from studies on multispan and single span operations and on two machine sizes. Based on the comments above that there have been improvements in hook time, rigging shift times and turn volumes since the studies were carried out in the late 1980's (and based on personal comments from logging managers in Chile) the equations were modified appropriately.

Five stands, with average stem sizes ranging from 1.1 to 1.9 m^3, from North Island forests were selected for analysis.

Figure 3. shows that, for an average piece size of 1.5 m^3, daily production for a Christy yarder operating over a single span would be about 15 m^3 higher than for a commparable sized machine (Koller K501) operating over a multi-span - due primarily to the greater rigging time associated with the multi-span. Figure 3. also shows that the larger (and also more versatile) Koller K600 would produce 5 to 10 m^3 per day more than the Koller K501 over similar ground conditions - because of the larger payloads.

Figure 4. shows the effect of tree size on the daily productivity of the Koller K600.

The LIRO costing format was used to calculate indicative daily costs for the Koller K600 and Koller K501 machines with 8 man crews (8 men would be more suitable for New Zealand) and a Bell 120 or Bell Super Logger loader. Based on these costings and the production levels shown in Figures 3 and 4 unit costs would range from $19 to $23.50 per cubic metre for the Koller K501 (1.5 m^3 tree size, average yarding distances from 150 to 350m)

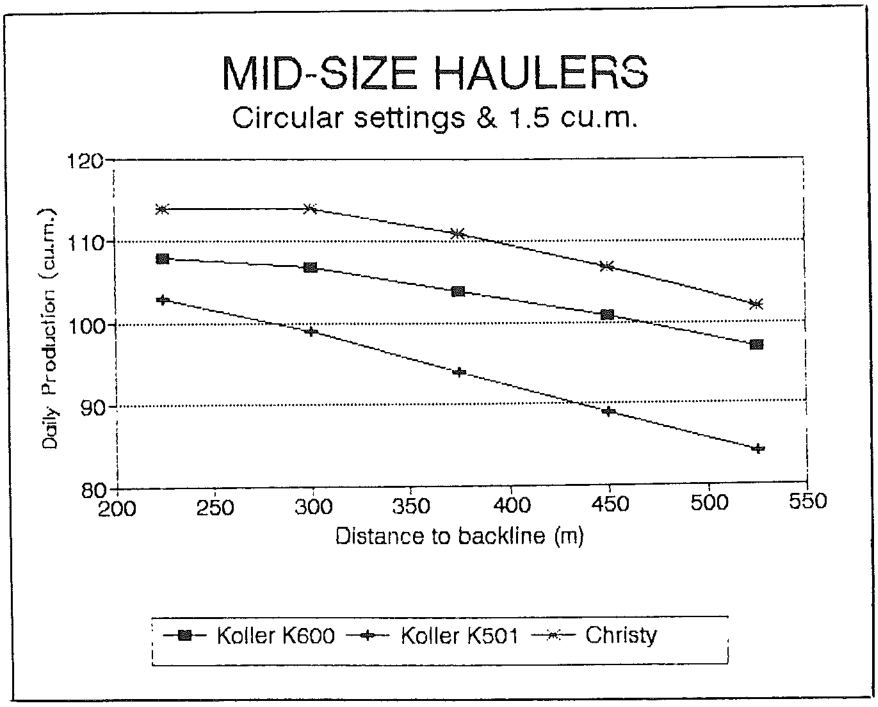

Figure 3. Predicted daily production for three mid-size haulers in a stand with an average piece size of 1.5 m^3.

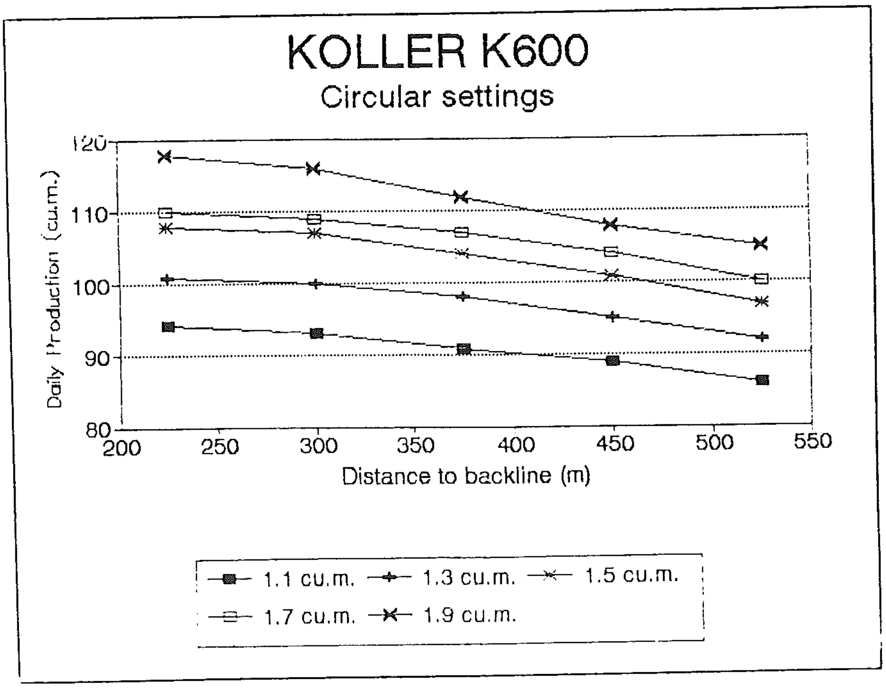

Figure 4. Effect of piece size on the productivity of the Koller K600. Piece sizes range between 1.1m^3 and 1.9m^3.

and from $19.50 to $26.50 per cubic metre for the Koller K600 (1.1 to 1.9 m^3 tree size, average yarding distances from 150 to 350m). It must be stressed that these costs apply to multi-span configurations.

How do these costs compare ? They are considerably higher (50 to 100%) than those reported recently by Prebble (1989a and 1989b) and Robinson (1992) for Madill 171 and Thunderbird TY90 operations. Prebble's and Robinson's studies related to larger machines with bigger payload capability operating in single-span mode, however.

CONCLUSIONS

Chilean labour costs are much lower than New Zealand costs and tree sizes tend to be smaller. They, therefore, tend to use smaller machines than we do. In addition, convex terrain has forced them into frequently using multi-span systems and, as a result, the Chileans have a larger experience-base with this technology and machine size than New Zealand does. Using the best information that Chile can supply and applying it to New Zealand cost structures and forest stand types indicates that unit costs ($\$/m^3$) would be considerably higher than our industry is currently facing for cable logging in most cases.

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