MECHANISED VERSUS MANUAL LOG-MAKING IN TWO CHILEAN *PINUS RADIATA* STANDS

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ABSTRACT

The products and value recovered by two log-making systems — mechanised and manual — were compared in two *Pinus radiata* D. Don stands located at Santa Margarita and Poninquil in the south of Chile. Manual log-making was undertaken by a man marking the position for saw cuts on each stem. Mechanised log-making was carried out with an Ergo HS 16 harvester fitted with an OPTI computerised measuring and log-making system.

At each site both log-making systems were used on the same set of trees. In the manual system, logs were marked for cutting, but the saw cuts were not made. The marks were then removed and the stems converted to logs by the harvester. Forty-three trees were processed at Santa Margarita and 39 trees at Poninquil.

The manual log-making system recovered more volume and value (~ 16%) than the mechanised system at the Santa Margarita site. There was no difference between systems at the Poninquil site.

Keywords: log-making; bucking; value recovery; mechanisation; harvesting; *Pinus radiata.*

INTRODUCTION

Harvesting production from Chilean plantation forests has been increasing rapidly in recent years; 21 million m^3 were harvested from *Pinus radiata* plantations in 2003. To be able to better meet the increase in production, forest companies have introduced highly mechanised harvesting systems.

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Pinus radiata harvesting systems in Chile range from conventional manual-felling and log-making to mechanised cut-to-length systems, with single-grip harvesters that process specified log lengths at the stump. Variations on these systems include mechanised felling and skidding or cable-logging full-tree or tree-length to roadside where log-making can be done manually by chainsaw or by a mechanical processor.

Mechanised systems often achieve higher productivity than manual systems, particularly where tree size is small. Depending on the relationship between labour rates and machinery capital costs, this higher productivity can lead to reduced harvesting costs. A considerable amount of research effort around the world has focused on mechanised harvesting productivity and costs (e.g., Andersson 1993; Tufts 1997).

Many forest companies also require reliable information about the effectiveness of harvesting and processing systems for recovering the maximum value from their forests. The log-making process is an important activity in a harvesting system, because it determines the value of the recoverable products from the logs and is a major factor affecting the value obtained from a stand.

Significant value losses may occur during mechanised processing compared with manual processing. The speed of the mechanised process makes it difficult for the machine operator to accurately assess stems visually for defects and form. Other inaccuracies in the diameter and length measuring system may occur during log-making. Manual log-making with a chainsaw allows a closer visual inspection of the logs and more accurate diameter and length measurement (Young 1998). On the other hand, better value recovery can sometimes be obtained by computerised and mechanised log-making systems where complex product specifications make it difficult for a chainsaw operator to optimise log-making.

Because net revenue is a balance between value recovery and processing costs, more information about the performance of harvesting and processing systems in recovering log value is needed to assist forest companies in the selection of appropriate harvesting systems.

Murphy (2003), in a review of value recovery studies from around the world, noted that manual log-making systems, on average, recover about 10% more value than mechanised systems during the log-making process. Few studies, however, have compared manual and mechanised value recovery in the same stands or on the same trees (Cossens 1991; Young 1998). This study compared the results from mechanised, computer-based, optimal log-making with theoretical values obtained by an experienced log-maker using a chainsaw in two stands in Chile.

STUDY DESIGN AND METHODS

Study Locations and Stand Descriptions

Two *P. radiata* stands were selected from Region IX and Region X in the south of Chile. The Santa Margarita stand was located about 5 km from the city of Temuco. The Poninquil stand was located near the coast and about 30 km from the city of Osorno. The stands were of similar age at harvest but differed in final stocking, average tree size (Table 1), and treatment.

The study areas receive about 1350 mm of precipitation per year in the form of rainfall, most of which falls during a 7-month period (Santibanez 1993). The study was carried out during winter and spring between June and November 2002.

TABLE 1–Stand details as provided by the forest owners

Stand	Year of planting	Stocking (stems/ha)	Average tree size (m^3/stem)	Treatment	
				Thinned	Pruned
Santa Margarita	1981	943	0.6	No	No
Poninquil	1979	459	0.9	Commercial	No

Machinery and Equipment Used in the Study

The same manual log-maker and mechanised harvester and operator were used at both sites.

In the manual system, a professional chainsaw operator was employed. The operator selected for the study was experienced (> 5years) and usually worked with the mechanised system referred to below, processing trees which were too big for the harvester or which were located on slopes that were too steep. He normally used a chainsaw to cut the stems into logs.

In the mechanised system, a Ponsse Ergo HS 16 harvester with a Ponsse HS 73 processing head was used (Ponsse 2000a). The harvester has a maximum reach of 10 m and the processing head could handle a maximum diameter of 64 cm. The harvester was fitted with an OPTI 3G system for measuring lengths and diameters and for presenting an "optimal" log-making solution via a computer graphic to the machine operator (Ponsse 2000b). "Optimal" log-making was based on measurement of a portion of the stem and forecasting of taper for the remaining portion of the stem. The operator could accept the OPTI solution or provide an alternative solution if he believed that other stem characteristics, such as nodal swelling, sweep, or branch size, needed to be considered. Most of the OPTI solutions were accepted by the operator.

The length and diameter measurement systems were calibrated before the trials were undertaken. Log volumes and values could have been calculated in up to 12 different ways on the harvester (the authors are unsure which method was used).

The harvester operator had been trained by a Finnish contractor and had 8 years' experience working on mechanised harvesting equipment in Chile.

Log Products

Seven log-products were cut at both the Santa Margarita site and the Poninquil site — five saw-log lengths and two pulp-log lengths. In addition, two peeler lengths were cut at the Poninquil site, making nine products in total for the Poninquil site. The product specifications and values are shown in Table 2.

TABLE 2–Product specifications and prices used at each site

Product	Lengths (m)	Diameters (cm over bark)		US$/m^3 JAS	Stands
		Min.	Max.		
Peeler	2.90	38	+	70	Poninquil only
	2.65	28	+	65	
Saw log Margarita	4.50	46	+	50	Both Santa
	4.30	38	44	45	and Poninquil
	4.10	30	36	40	
	3.70	24	28	35	
	3.30	18	22	30	
Pulp log	3.50	10	40	25	
	2.44	10	46	20	

Assessment of Log Product Yields and Value Recovery

At both the Santa Margarita site and the Poninquil site the trees selected for the study were larger on average than indicated by the forest company's stand records. A pre-sample of stem volumes indicated that sample sizes of about 32 stems would be sufficient for the study. Other value-recovery studies have usually indicated that 30 to 50 stems provide a good measure of value-recovery performance (Cossens & Murphy 1988).

At the Santa Margarita site, 43 trees were felled and laid out parallel to each other. Overbark diameter, changes in stem quality and form, and distance along the stem were measured with a tape and calliper, and then manually recorded. Diameters recorded were the average of the largest and smallest diameter at the measurement point. Butt diameters ranged from 20 to 53 cm, with an average of 38 cm. Tree sizes included in the study ranged from 0.46 m^3 to 2.72 m^3, with an average of 1.32 m^3. The average stem length to a 10-cm top was 21.6 m.

Each stem was evaluated, measured, and marked by the chainsaw operator in the manual system for cutting into logs. The log lengths, diameters, and the type of product that would have been cut, were measured and recorded by the study team and the marks were removed.

Each stem was then processed into logs using the mechanised harvester system. Log lengths, diameters, and products were again measured and recorded by the study team.

The forest company that owned the two sites where the studies were undertaken sold log products according to the Japanese Agricultural Standard (JAS). Log lengths and diameters were therefore converted to JAS volume using the function below:

$$V = D^2 \times L \times (1/10000)$$

where V = volume (m^3)
D = small-end diameter overbark (cm) rounded down to the nearest 2-cm class
L = length (m)

A few saw logs cut by the mechanised system did not meet specification due to shape issues. These were downgraded to pulp logs. Log volumes were then converted to log values using the prices shown in Table 2.

At the Poninquil site, 39 trees were included in the study. Measurements by the study team, marking of the logs by the manual chainsaw operator, processing of the logs by the mechanised harvester, and calculations of volumes and values were carried out in a similar manner to those at the Santa Margarita site. Butt diameters ranged from 20 to 61 cm, with an average of 36 cm. Tree sizes included in the study ranged from 0.28 m^3 to 3.36 m^3, with an average of 1.12 m^3.

An additional feature of the study at the Poninquil site was that both the manual system operator and the mechanised system operator were required to "process" the stems at near-to-normal production speeds. Times for processing were recorded. At the Santa Margarita site no production pressure was put on the log-makers.

RESULTS

Utilisation and Log Product Yields

At the Santa Margarita site, on average slightly more stem length was converted into logs with the manual system (19.9 m; standard error 0.56 m) than with the mechanised system (19.7 m; standard error 0.59 m). The difference was not statistically significant at the α=0.05 level. There was no difference between systems at the Poninquil site (18.6 m).

At both sites, fewer logs in total were cut by the manual system than by the mechanised system (Table 3). When specific log products are considered, it can be seen that more saw logs and fewer pulp logs were cut at both sites with the manual system. At the Poninquil site more peeler logs were cut with the mechanised system than with the manual system.

TABLE 3–Number of logs, product yields, and value by log-type

Products	Measurement units	Santa Margarita		Poninquil	
		Manual	Mechanised	Manual	Mechanised
Peeler	Logs	–	–	14 [7]*	22 [10]
Saw logs		176 [72]	174 [69]	149 [70]	136 [62]
Pulp logs		68 [28]	80 [31]	49 [23]	60 [28]
Total		244 [100]	254 [100]	212 [100]	218 [100]
Peeler	Volume (m^3)	–	–	4.7 [11]	6.9 [16]
Saw logs		49.8 [87]	43.6 [88]	35.2 [80]	31.1 [73]
Pulp logs		7.1 [13]	5.9 [12]	3.9 [9]	4.5 [11]
Total		57.0 [100]	49.5 [100]	43.8 [100]	42.5 [100]
Peeler	Value (US$)	–	–	304 [19]	456 [28]
Saw logs		1798 [92]	1543 [92]	1245 [75]	1081 [66]
Pulp logs		163 [8]	128 [8]	90 [6]	105 [6]
Total		1962 [100]	1671 [100]	1639 [100]	1642 [100]

* Figures in parentheses are percentages.

The mechanised harvester operator tended to cut more short saw logs (3.30 m) and pulp logs (2.44 m) than the manual operator at both sites (Fig. 1 and 2). The manual operator also cut more long saw logs at both sites.

Poninquil was the only site where peeler logs were cut. It is notable that the mechanised system found more peeler logs than the manual system.

The manual system recovered more total log volume from the stems at both sites — 15% more at the Santa Margarita site and 3% more at the Poninquil site (Table 3). The distribution of log product volumes was similar for both log-making systems at the Santa Margarita site. At the Poninquil site, more volume was in saw logs and less in peeler logs for the manual system.

Measurement Errors

An assessment of length measurement accuracy was carried out at only the Santa Margarita site. When compared with the nominal lengths specified by the forest company, the average errors were similar for the two log-making systems: +2 cm

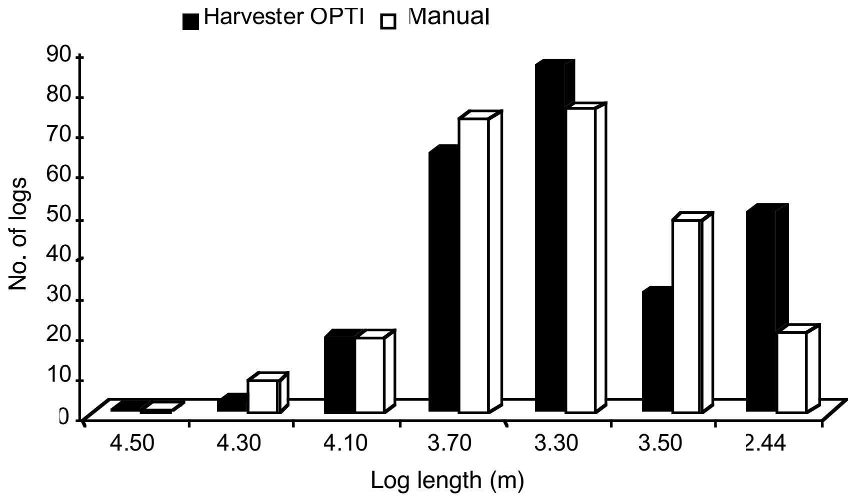

FIG. 1–Distribution of log lengths for the Santa Margarita site. Note the first five lengths are saw logs and the next two lengths are pulp.

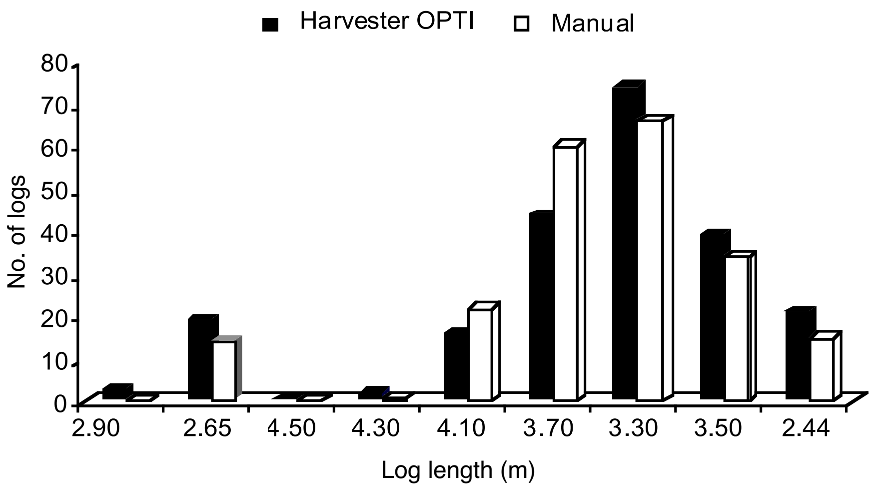

FIG. 2–Distribution of log lengths for the Poninquil site. Note the first two lengths are peeler logs, the next five lengths are saw logs, and the last two lengths are pulp.

for the manual system (standard error 0.2 cm) and +1 cm for the mechanised system (standard error 0.1 cm). Both systems produced approximately 98% of the logs within ±5 cm of the nominal lengths. Only a few logs were outside these bounds, the range of errors being –17 to +9 cm for the manual system and –3 to +26 cm for the mechanised system.

Value Recovered

The mechanised system obtained 14.8% less and 0.2% more value in total than the manual log-making system at the Santa Margarita and Poninquil sites, respectively (Table 3). A paired *t*-test of stems at the Santa Margarita site indicated that the difference between systems was statistically significant (Table 4).

TABLE 4–*t*-test of paired two sample value recovery means — Santa Margarita

	Mechanised		Manual
Mean ($/stem)	38.86		45.62
Variance	489.05		595.51
Observations	43		43
Pearson correlation		0.981	
Hypothesised mean difference		0	
Degrees of freedom		42	
t statistic		–8.805	
P(T<=t) one-tail		0.000	
t Critical one-tail		1.682	
P(T<=t) two-tail		0.000	
t Critical two-tail		2.018	

Some researchers have found that below a certain tree size mechanised systems recover as much value as manual systems; however, more value in percentage terms was lost with larger trees (Young 1998). More detailed analyses of the Santa Margarita and Poniquil data indicated that there was no clear trend between tree size and percentage value recovery differences between log-making systems for either site.

An average time of 0.80 minutes was spent measuring and marking each stem at the Poninquil site by the manual system. Saw cuts were not made with the manual system since the same stems were later processed by the mechanised system. The time per stem for measuring and processing each stem by the mechanised system was 0.22 minutes. As noted above, the reason for recording processing times was so that both the manual and mechanised operators felt that they were working under near-normal production pressures.

DISCUSSION AND CONCLUSIONS

Murphy (2003) noted a wide variation in percentage value recovery reported from studies around the world for both mechanised and manual systems. On average, manual systems recovered about 10% more value than mechanised systems. Few of the reported studies were carried out in the same stands, however. In 1996 the

Forest Engineering Research Institute (FERIC) compared the values of logs manufactured by various systems at two sites in coastal second-growth forests in British Columbia. They found that the mechanical log-making systems had problems with maximising the total prime lengths cut and difficulty with sensing smaller diameters (Young 1998). They also found that manual log-makers recovered more volume and value than operators of mechanised systems.

The two studies reported in this paper provide conflicting evidence for a hypothesis that value recovery is greater for manual log-making systems than mechanised log-making systems. The Santa Margarita study supports the hypothesis. The Poninquil study does not. We can only conjecture as to why there are differences between the two studies.

Since the same manual and mechanised operators were used at both sites, and both operators had considerable experience, operator effects can possibly be ruled out; daily variation in human performance precludes us from eliminating operator effect completely. The three main differences between the Santa Margarita and Poninquil studies were stand type, cutting pattern complexity, and time pressure. The Santa Margarita site had smaller and poorer quality trees; the mechanised operator found that estimation of quality breaks was difficult at fast operating speeds. No time pressure and a simple cutting pattern may have allowed the manual log-maker to make better decisions than the mechanised system operator. The more complex cutting pattern and the production pressure at the Poninquil site may have made it more difficult for the manual operator to "compete" with the decisions of the computer-assisted mechanised operator.

The only consistent trend between the two sites was that the manual operator cut fewer and longer logs than the mechanised operator from the same trees. A 2001 study of five harvesters in Sweden, one of which was a Ponsse H73 harvester, found that there was a tendency for all machines to produce more and shorter logs than the simulated optimum solution (Sondell *et al.* 2002). The Ponsse harvester was also found by Sondell *et al.* (2002) to be unsatisfactory as far as accuracy of length and diameter measurements was concerned.

There are, of course, limitations with this study. The results relate to one manual operator, one mechanised-system operator, and one machine. Study of a wider range of machines and operators is warranted, particularly given the growing importance of mechanised processing in many countries around the world.

Most harvesting operations can be improved when it comes to value recovery, whether the operations are manual or mechanised. Improvements can occur in such areas as operating procedures, operating conditions, measurement systems, decision support systems, and execution of decisions. Provision of the best equipment, tools, training, and operators will help harvesting managers to capture maximum value recovery. Further research we hope will clarify whether there are differences in value recovery between mechanised and manual log-making systems. If the differences are not consistent then a better understanding of what factors affect mechanised and manual value recovery will help harvesting managers to specify the most appropriate systems for their companies.

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REFERENCES

ANDERSSON, B. 1993: "Mechanical Thinning Operations in Sweden, Some Observations". Forest Engineering Research Institute of Canada, Vancouver, B.C., Canada. 26 p.

COSSENS, P. 1991: Operator log making ability on a mechanized processor. *Logging Industry Research Association, Rotorua. New Zealand, LIRA Technical Report 16(14).*

COSSENS, P.; MURPHY, G.E. 1988: Human variation in optimal log-making: a pilot study. Pp. 76–81 *in* Proceedings of the International Mountain Logging and Pacific Northwest Skyline Symposium, December, Portland, Oregon, USA. Forest Engineering Department, Oregon State University, Corvallis, Oregon.

MURPHY, G.E. 2003: Worldwide experiences with mechanisation and value recovery. Pp. 23–32 *in* Proceedings of the Wood for Africa 2002 Conference, July 2002, Pietermaritzburg, South Africa. College of Forestry, Forest Engineering Department, Oregon State University, Corvallis, Oregon.

PONSSE 2000a: Catalogo cabezales Ponsse H53, H60, H73 [Catalogue for Ponsse H53, H60, and H73 heads]. Panamericana Norte 18900. Santiago, Chile. 5 p.

———2000b: Sistema de optimización de trozados OPTI [OPTI system for optimal log making]. Panamericana Norte 18900. Santiago, Chile. 5 p.

SANTIBÁÑEZ, F.O. 1993: Atlas agro climático de Chile. Regiones Sexta, Séptima, Octava y Novena. Santiago, Universidad de Chile, Fac. de Cs. Agrarias y Forestales, Laboratorio de agro climatología. Esc. 1:250.000

SONDELL, J.; MOLLER, J.J.; ARLINGER, J. 2002: Third-generation merchandising computers. *Skogforsk Results No. 2*. 6 p.

TUFTS, R. 1997: Productivity and cost of the Ponsse 15-series, cut-to-length harvesting system in southern pine plantations. *Forest Products Journal 47(10)*: 39–46.

YOUNG, G. 1998: Mechanical and manual log manufacturing in coastal second-growth forest: a comparison of recovered value. *Forest Engineering Research Institute of Canada, Vancouver, Wood Harvesting, Technical Note-267*. 12 p.