LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

SOUTH-EAST U.S.A. TOUR NOTES

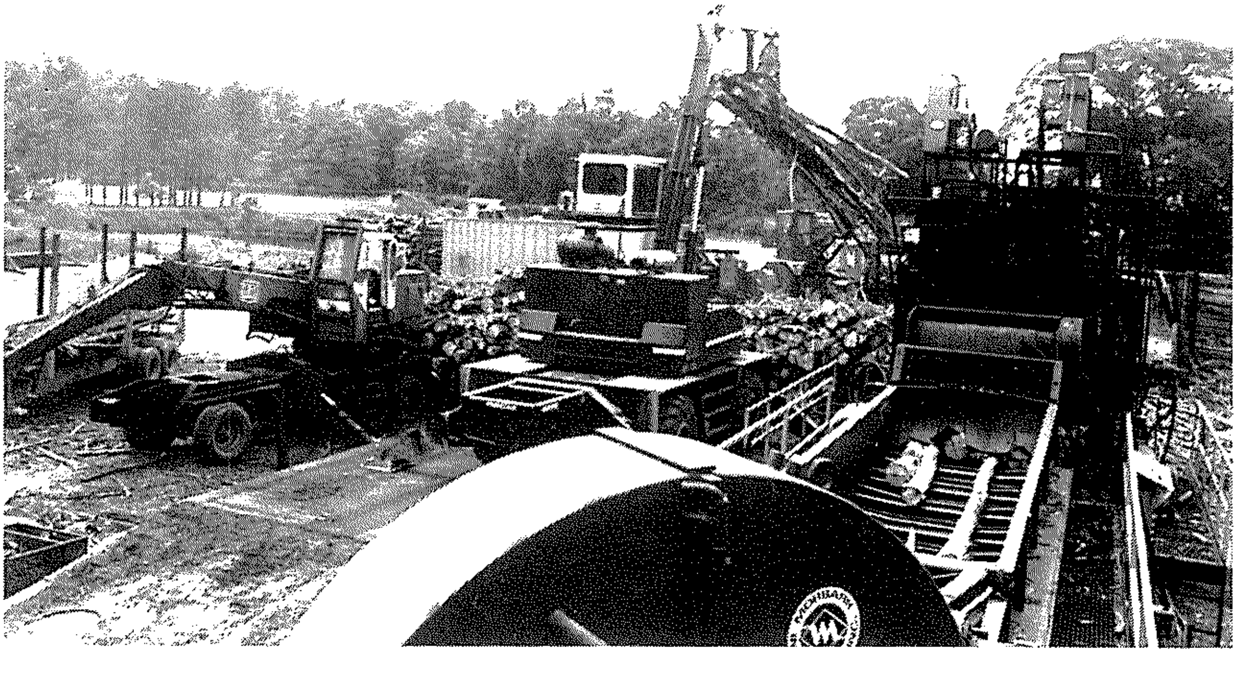
JUNE 1988

IEA Harvesting Early Thinnings Conference

IEA Harvesting Machinery and Systems Evaluation Workshop

Field Trip Notes

LINDSAY VAUGHAN



Project Report

P.R. 40

New Zealand Logging Industry Research
Association (Inc.)
P.O. Box 147,
ROTORUA,
NEW ZEALAND.

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SUMMARY

IEA - Harvesting Early Thinnings Conference

The HETS Conference provided a forum for the nine participating countries to present their national research programmes into early thinnings. The developments of most interest were:

- the development of machinery to carry out pre-commercial strip thinning in young dense naturally-regenerated stands in Canada,
- the work in the U.S.A. with central tyre inflation, the use of thinning residues as temporary roadfill, and development with the steep country feller-buncher.

The results of the HETS sub-projects were presented; most had little application in New Zealand because of differences in:

- tree size
- branching characteristics
- terrain characteristics
- harvesting systems
- relative costs of machinery, labour and energy.

There were some interesting results from the U.S.A. relating to the high costs of production thinning with small machinery (compared with larger machinery) and the higher levels of stand and site damage as a result of the greater number of trips along the extraction trails.

Despite the opportunities offered by energy markets, thinning problems were widespread, harvesting costs were high and prices were low. There was no new technology on the scene and the best short-term solution lay in seeking out higher-value markets for thinnings.

IEA - Harvesting Machinery and Systems Workshop

This workshop focused on identifying the broader forces that influenced harvesting systems - these included traditional practices, the existing infrastructure of forests, roads, workforce and processing plants, and the local cultural, social and economic factors. As an example of different responses to changing conditions in countries with similar tree sizes, terrain and climatic characteristics, the Swedish move from tree-length systems to shortwood systems in the 1970's and 1980's occurred at the same time the Canadians were moving from shortwood to tree-length to whole-tree systems.

The workshop focused on the greater role for contractors, the increased requirements for capital and the influence of changes in markets. It provided a much broader economic perspective of the role of forestry in the industrial marketplace, and one that has not been addressed in previous IEA work.

Field trip notes

The Weyerhaeuser intensive stand management practices in the South-east U.S. were impressive, although it was not possible to determine how widespread these were. The move away from motor-manual harvesting practices has undoubtedly been accelerated by physical and social factors as much as by economic factors.

The characteristics of the forest industry in the South-east U.S. have encouraged the development of a highly competitive market-driven harvesting industry. These characteristics include multiple forest ownership and a multitude of wood buyers for a range of products.

The multi-stem processing capability of the Weyerhaeuser horizontal chain flail delimber/debarker was also impressive, as was its delimbing/debarking quality. It provides another possible option for both pine and eucalypt debarking and for minor species delimbing.

INTRODUCTION

TRIP OBJECTIVES

Participation in an IEA Conference on "Harvesting Early Thinnings" by:

- presentation of current NZ developments in thinning practices
- presentation of recent LIRA work on crawler tractor thinning.

Participation in an IEA Conference on "Harvesting Machinery and Systems Evaluation" by:

- presentation of recent LIRA/FRI work on the NZ logging workforce.

BACKGROUND

LIRA has participated in two major international cooperative projects since 1982. This work has been carried out under the auspices of the International Energy Agency, an organisation set up in the early 1970's by the OECD countries following the dramatic rise in oil prices. Developed countries with significant forestry resources signed a Forest Energy Agreement to work together on research and development into growing, harvesting and processing forest products with energy wood as a potential end product. An executive committee was set up to coordinate this R & D work. John Tustin, Director of the Forest Management and Resources Division of the Forest Research Institute, has been the New Zealand representative on this committee.

LIRA's participation in this cooperative research commenced in 1982 with its involvement in a project titled "Felling and Bunching Small Trees from Thinning on Gentle Terrain with Small Scale Equipment". This project ran until 1985 with financial assistance from the Forest Research Institute and the Liquid Fuels Trust Board.

This project was divided into a number of subprojects, each to be led by a different country. New Zealand agreed to lead a subproject on "Bunching with Winches" and later a second subproject on "Motor Manual Felling". It participated actively in subprojects on "Bunching with Grapples" and "Chokering Methods and Equipment". Reportage by LIRA staff has included Vaughan (1982, 1983, 1984), Prebble (1984a, 1984b) and Gaskin (1984). This project work was summarised by Kofman (1985). The benefits of NZ participation was seen to be:

- development of personal contacts with leading overseas researchers
- opportunities to visit other countries and better understand the factors influencing the development of harvesting systems
- opportunities to review New Zealand smallwood harvesting work
- opportunities to monitor developments in harvesting energy wood.

In 1986, LIRA agreed to participate in a second IEA project on "Harvesting Early Thinnings". It was difficult to define areas of research in New Zealand that were relevant to the aims of this project with its strong emphasis on energy. LIRA offered to lead a project on "Crawler Tractor Thinning on Steep Terrain".

The results of this work were presented at a conference in Richmond, Virginia, in June 1988 (Vaughan 1988a, b, c). Participants presented the results of their subprojects and provided an overview of relevant developments in thinning R & D in their own country. A summary of relevant sections of their presentations is included in this report.

Following the post-conference field trip, an IEA workshop was held at the Virginia Polytechnic and State University in Blacksburg on "Harvesting Machinery and Systems Evaluation". LIRA was invited to present a paper on the joint LIRA/FRI work on the logging workforce (Vaughan 1988d).

IEA HARVESTING EARLY THINNINGS CONFERENCE

The objective of this project is to encourage the development of harvesting systems in early thinnings to benefit self-sufficiency in energy. The project has been led by Per Brenoe of the Danish Institute of Forest Technology who opened the conference. He noted the potential resource in the participating countries was approximately 100 million m³ of first thinnings, the energy equivalent of 18 million tonnes of oil. Stem diameters range from 5 to 25cm. Forests have a silvicultural need for this treatment but production thinning is uneconomic with the present markets and techniques. Energy requirements provide opportunities to develop new markets for thinnings. However, the development of harvesting systems are very complex and depend on many factors.

Each country was required to report on relevant developments in early thinnings. These are summarised by country of origin.

A. National Projects

1. Canada (Heidersdorf)

Canada has no national programme for energy and no national programme for first thinnings. Energy-related work is primarily aimed at utilising existing sources : stands of mixed hardwoods, logging residues, and sawmill residues.

He described current research areas of interest to participants.

1. Pre-commercial thinning - Studies were being undertaken in heavily stocked stands of natural regeneration. Strip thinning was being used to open up the stands once tree height reached 1.6m. Equipment used included:

   a) Beater bars (pivoted) mounted on a rotating disk and carried on a variety of low ground-pressure carriers.

   b) A large circular saw on a hydraulic boom.

   c) A heavy-duty "weed-eater" using steel wire.

   d) A heavy-duty rotating disk-saw mounted on a pipeline maintenance machine, similar to an articulated loader.

   e) The Canadian Forest Service Tranfor, similar to the Pallari. This was designed to process thinnings into chips but proved too slow, mechanically unsuitable and its energy usage greatly exceeded its energy production. The cutting mechanism involved 2 counter-rotating disks, cutting on an anvil.

2. Commercial thinning -Feller-buncher heads, mounted on carriers such as the Morbell and the Hydro-ax, are under evaluation. Production levels appear to be around 1500 trees per shift, similar to those achieved in the South-east U.S.

3. Delimbing and Debarking Technology -
There is interest in developing satellite chipping stations, forest-based units that could satisfy the seasonal demand for chips. The Manitowoc chain flail was capable of removing limbs and bark in the summer and could produce clean pulp chips. In the wintertime, it would be difficult to remove frozen bark and a market for energy chips would be needed.

   A large trailer-mounted debarking and delimbing drum, ranging in length from 10 to 20m was being built and marketed in Maine as the Price drum. They considered that this heavy-duty unit was better utilised as a fixed unit because of its size, weight and power requirements.

4. Micro Tractors -
A Canadian manufacturer was producing a local version of the Goliath, a small tracked carrier, steered by the operator walking in front.

5. All Terrain Vehicles -
FERIC were undertaking extensive testing on a number of 4WD motorbikes. They were looking at replacing wheels with skis to improve its mobility on snow.

6. Chipping Technology -
FERIC had undertaken a systematic study of existing chippers to look at performance and potential, and at fitting them into existing harvesting systems.

2. Denmark (Kofman)

Forest stands in Denmark receive five to six multiple thinnings, commencing about age 20, and at five yearly intervals thereafter. These provide whole-tree chips for district heating plants. Future use includes electricity generation.

Development of this work has included:

a. early felling of thinnings to reduce the moisture content from 60% to 40% (dependent on having a good summer),

b. evaluating grapple processors.

c. Modifying agricultural tractors to provide farmers with a low-cost forwarder, similar to the Matthews mini-skidders.

He noted that all Danish pulp wood was exported to Sweden and Norway; there is no domestic processing.

3. UK (Hudson)

Forests in Britain currently cover 2 million hectares and could possibly reach 3 million hectares in future. However, severe constraints have been imposed on future expansion - no further planting with conifers is permitted in England or Wales! Most of the energy work has been funded by the UK Dept of Energy and the EEC. The work of this group at Aberdeen University has focused on developing systems for fuel wood harvesting and for integrated harvesting, building up a database on machine productivity and costs. To date, 27 trials have been undertaken, covering both motor-manual and mechanised systems. The work with whole-tree forwarding has run into problems with chipper damage and chip contamination, as a result of stones and other material being picked during extraction. A number of chippers have been studied, mostly small- or medium-size machines, which proved to have very low levels of productivity.

They have also undertaken studies of chip storage and chunk-wood storage, looking particularly at changes in moisture content. Results have been variable.

A trial at Keilder Forest (Scotland) on harvesting of 28 year old unthinned Sitka spruce increased the yield from 200m³/ha of stemwood to 380m³/ha of biomass using a Brunett forwarder fitted with band tracks for extraction and a roadside chipper. Chips were stored by the roadside and (optimistically) stacked for drying. As a result of a wet Scottish summer, the moisture content <u>increased</u> by 16% (from 58% to 74%). Chipping productivity varied from five to ten green tonnes per hour.

A copy of the UK National Report is held in the LIRA Library.

4. Norway (Stenhammer)

Forest area - 6.4 million hectares of production forest.
Round wood production - 13 million m³ (10 million m³ for industrial use, 3 million m³ for domestic use).
Species composition - 50% Norway spruce, 30% Scots pine, 20% Birch.
Ownership - 75% private, 25% state.
Average forest size - 40 hectares (mostly farmer owned).
Thinning programme - 8000 hectares thinned in 1986, 50% mechanically. The high level of private (farm) ownership of forests (woodlots) encourages motor-manual felling and tractor-mounted equipment for processing and chipping. Some 5000 firewood processors were sold in 1986, mostly tractor-mounted units driving off the power take-off.

5. Sweden (Knuttel)

Total forest area - 23.5 million hectares (50% of land area).
Current Annual Increment (CAI) 90 million m³.
Annual cut - 60 million m³ (25% from thinnings, expected to reach 35% in five years time).
Desired annual cut - 75 million m³.

<u>Systems for Harvesting Small Thinnings</u>

Stocking reduction - from 3000 to 2000 s/ha.
Thinning size - 10 to 13 cm dbh.
Motor-manual felling, micro-tractor extraction to roadside, MB Trac processor to delimb, debark and chip.
Productivity - 10 to 40 m³/PMH for diameter range of 6 to 14cms.
Harvesting and processing costs - U.S.$50 to $22/m³.
Trials are underway with a harvester mounted on a Mini-Brunett which can fell, extract, delimb, debark and chip. Capital cost U.S.$300,000 (in Sweden).

6. Finland (Heikka)

Finland exports 40 to 50% of its forest produce. Future expansion has been achieved by moving capital into countries like Sweden (Kockums takeover). There has been extensive development of tractor-based attachments. This has required redesign of the tractor cab to allow two-way operation and better instrumentation. An alternative approach they considered was a fully-rotating cab. Safety bars on rear windows has been part of this development.

A number of all-terrain

vehicles (ATV) have been evaluated. These include the Honda 4WD (equipped with a trailer or skidding pan) as well as a number of microtractors ("moose carriers") and motorised felling benches.

A copy of the Finnish National Report is held in the LIRA Library (Heikka, 1988).

7. U.S.A (Stuart)

Bill Stuart reviewed the changing scene in thinning operations in the south-east U.S. The original philosophy was:

Small areas and small trees = small contractors plus small machines.

This led to many frustrations, bankrupt contractors and unthinned stands. He noted the changes in silvicultural constraints (timing and regimes), non-silvicultural constraints (taxation, cash-flow, pulping technology, pulp log specifications and energy costs), the development of new harvesting systems (feller-bunchers, grapple skidders, gate delimbers), and changes in technology (tree length transportation and drum debarking to provide pulp chips and energy chips). The benefits of the newer mechanised harvesting systems were seen in lower unit costs, lower labour requirements, an acceptable level of stem damage and the achievement of silvicultural objectives.

Stand Damage

Stuart described a recent VPI production thinning trial on the coastal plain which compared the effect of two sizes of grapple skidder on soil compaction and stand damage. The results are summarised (Table 1) and challenge the assumption that small skidders always produce lower levels of damage and lower unit costs.

The differences in measured compaction was related to the fewer trips made by the larger skidder to extract the same volume of wood.

Table 1 : Comparison of Thinning with a small and a large skidder in a pine plantation on the coastal plain, south-east U.S.

	Small Thinning Skidder	*Large Grapple Skidder*
Make and Model	*Franklin 105*	*Franklin 170*
Horsepower	*87*	*185*
Cost (U.S.$000)	*76*	*94*
Ownership	*Dealer*	*Contractor*
Tyre width (in.)	*23*	*28*
Average turn size (tonnes)	*2.2*	*4.0*
Maximum turn size (tonnes)	*4.5*	*9.1*
Stand damage (%)	*4.2*	*5.6*
Soil compaction	*High*	*Low*
Ground pressure (lbs/sq in.)	*8.2*	*13.8*
Extraction costs (U.S.$/tonne)	*1.40*	*1.10*

A similar trial compared a skidder and a crawler tractor (with ground pressure one quarter that of a skidder). There was no difference in the degree of compaction because of the dynamic forces (vibration) and the uneven weight distribution of the loaded crawler tractor.

8. U.S.A (Sturos)

The USDA Forest Service manages 76 million hectares of national forest. He described some of the research work being undertaken in different centres.

Seattle - continuous line system (ex Japan), steep slope feller-buncher (Allied Harvester Quad Track, previously Washington).

Davis - Cable-supported feller buncher for steep terrain work, chutes for firewood.

Idaho - residue recovery, shearing or chunking for firewood.

Auburn and Mississippi - chainflail delimber/debarker.

TVA - roller crushing.

Purdue - thinning and chipping hardwoods.

Morgantown - cable yarding with the Bitteroot Mini-yarder extracting hardwoods off steep terrain.

Maine - thinning small coniferous stands.

Houghton - thinning hardwood stands, chunk wood (for both energy use and as a temporary roadfill covered with gravel and fabric), central tyre inflation (long-term studies on tyres and road surface), intermediate supports on easy terrain with an Urus hauler (up to 200 metres with a single support).

9. New Zealand (Vaughan)

Production thinning operations in New Zealand were only a minor component of roundwood production (less than 10%). Nearly all thinning operations utilised motor-manual methods of felling and delimbing and used cable skidders or tractors for extraction of tree length material. There was considerable interest in the recent developments in mechanisation.

Developments in mechanised felling had included a variety of carriers - crawler tractors, skidders, front-end loaders and hydraulic excavators. The excavators had provided good operator capability, good reliability, and the ability to handle easy terrain. Recent developments included the use of a Bell logger fitted with a Hultdins F45 felling grapple and the introduction of the Bell Super T feller-buncher.

Developments in mechanised delimbing was utilising the Australian experience with delimbers. Two Canadian-made stroke delimbers, the Harricana and the Denis, both mounted on hydraulic excavator bases, have been operating at roadside. A New Zealand-made Waratah grapple processor, mounted on a rubber-tyred excavator base, was also operating at roadside.

Developments in mechanised harvesting had seen the introduction of a LAKO grapple harvester mounted on a skidder base in a combined fifth-row outrow and selection thinning operation in Kaingaroa Forest.

B. Sub Project Reports

The project on harvesting early thinnings was divided into eight subprojects. These will be brought together into a major report. Summaries of the individual subprojects are listed below.

1. Felling Methods and Technology (Heidersdorf, Canada)

He summarised the information from different countries on the results of motor-manual and mechanised felling studies in young stands. It is generally of limited application to New Zealand because of the very small size of trees.

2. Chipping Technology (Kofman, Denmark)

The main developments in chipping technology are in whole tree chipping of young stands, either at stump, at roadside, or in central processing yards. Danish costs of chips at mill were approximately twice that of U.S. costs, primarily a function of the very small piece size and subsequent low machine productivity.

3. Integrated Harvesting (Hudson, UK)

Hudson noted that the problem with using thinnings for energy wood was a result of thinnings being only one of a number of sources of woody residue available for processing, and only one of a large number of energy sources. The uncertain future for energy wood markets has led to a reluctance by contractors to invest heavily in specialised harvesting and processing facilities.

He asked why the tree-section method of thinning in Sweden, having been shown to be economically attractive, is used in less than 1% of the thinning operations. The ensuing discussion suggested that traditional methods using existing harvesting systems and a reluctance to change were the main factors in this. Group members considered there was limited application in the U.S. and none in Canada. It also supported the need to identify the broader socio-economic forces that influence harvesting operations, as discussed later in the Harvesting Systems Evaluation Workshop.

4. Thinning with Small Crawler Tractors (Vaughan, NZ)

Vaughan spoke to two papers, one covering a survey of operators and the other the preliminary results from some work with whole tree extraction at NZFP (Vaughan, 1988b, 1988c). The second paper suggested that some improvements in daily machine production could arise with whole-tree extraction. Twaddle noted that his studies at NZFP had recorded little difference in machine productivity between trimmed and untrimmed thinnings in a side-by-side comparison, but with a different gang structure.

5. Micro-tractors (Stenhammer, Norway).

These were defined as tractors up to 20kw, with payloads up to 1.5 tonnes. They all showed low levels of productivity relative to total cost and were limited by both terrain and high stumps.

6. Bunch Delimbing (Knuttel, Sweden)

He reported on Swedish studies of 4 systems:

1. the KMW drum delimber, capital cost U.S.$1.5 million, productivity 50m³/PMH, unit cost U.S.$3-4/m³ (biomass).

2. Cabro mobile drum delimber, capital cost U.S.$450,000, productivity 30m³/PMH, unit cost $3.50-4.50/m³ (biomass).

3. Manitowoc Flail - U.S.$1.5 million, 80 tonne/PMH, $5.30/tonne.

4. Turpeinen Flail Delimber/ Debarker - a 20 foot exposed shaft, containing 15 to 40 chain flails, attached to a power source. A grapple skidder runs a load over the flails, then backs the load under the flails. The operation is considered dangerous because of the exposed flails.

7. <u>Forest Transport of energy wood on soft terrain</u> (Heikka, Finland)

In Finland, 35% of the forests are growing on peat and half of these were drained before planting. Harvesting problems arise from small stems, low volumes and long haul distances. Heating plants provide opportunities for energy chips. He described the development of lighter forwarders which used more wheels or flexible rubber tracks (Figure 1, 2).

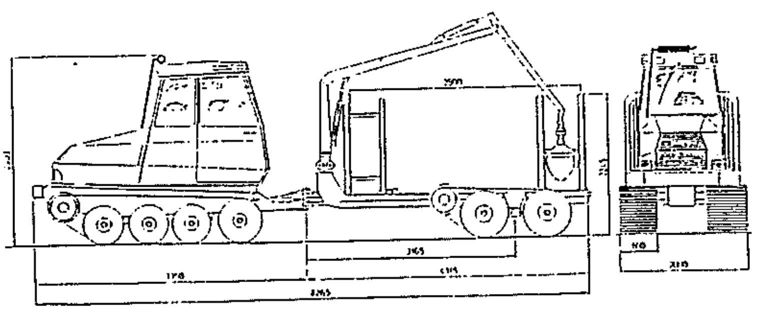

Figure 1 : Construction of a Farmi Trac 5000 rubber-tracked forwarder. (from Heikka, 1988a)

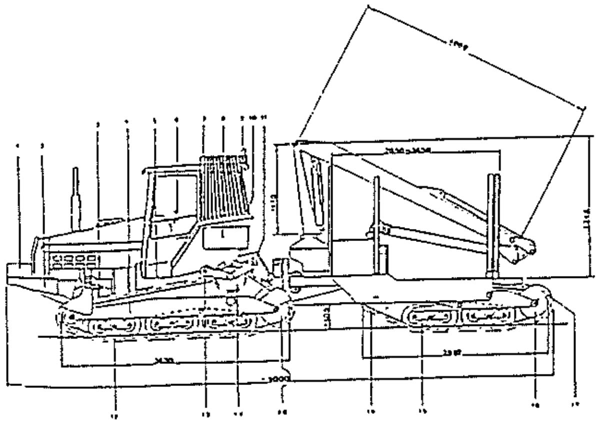

Figure 2 : Construction of a tracked forward, based on a Valmet 805 farm tractor fitted with bolt-on track.

8. <u>Small scale harvesting of hardwoods</u> (Sturos, U.S.A)

He described a cooperative project between the U.S. Forest Service and the manufacturer to produce a 28 hp mini-skidder (Clark VTR 2000) with a hydro-static transmission, overall dimensions of 5 ft by 5 ft by 6 ft and a capital cost of $18,000. Results from a time study (average haul distance of 120m, piece size of .24m³, payload of .6m³) gave an overall productivity of 3m³/PMH. Fixed machine costs of $4.40/PMH and operating costs of $3.06/PMH gave an overall extraction cost of $2.49/m³, considerably higher than with conventional-sized machines.

Trials with a Holder A 55 (36KW), fitted with an Igland Primo single drum winch in a small hardwood stand (.24m³ piece size, .84m³ payload) resulted in productivity of 4.5m³/PMH. Other trials by Hofman with a variety of small machines suggested that harvesting costs with small machines greatly exceeded those of conventional machines.

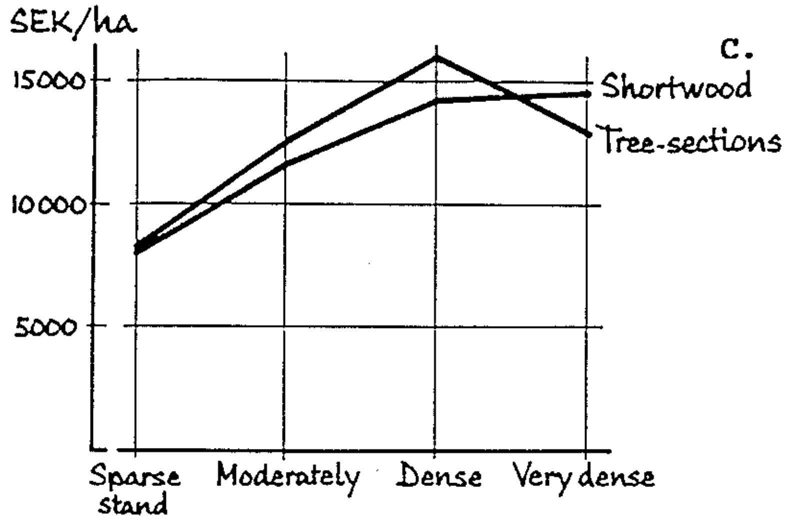

Figure 3 : Value of thinnings (Swedish kroner per hectare) as fuelwood from shortwood and tree-section methods.

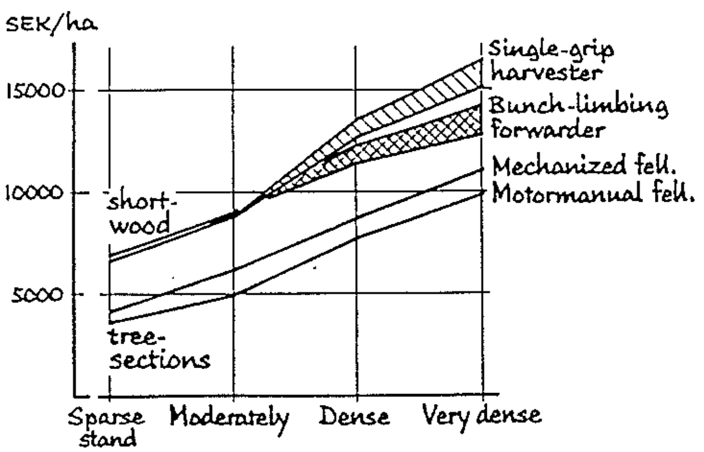

Figure 4 : Logging costs (Swedish kroner per hectare) for selected tree-section and shortwood systems.

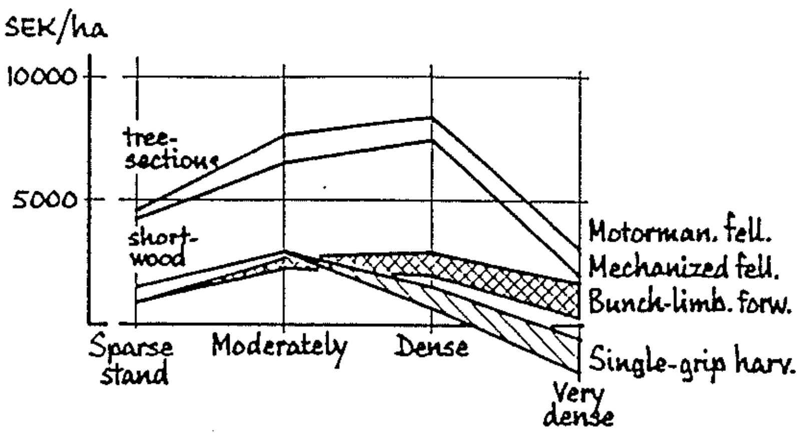

Figure 5 : Revenue from thinning for selected tree-section and shortwood systems.

C. **Associated Papers**

Analysis of Tree Section and Shortwood Systems in First Thinnings in Sweden

Brunberg presented a paper which looked at different harvesting systems for 1st thinnings. It noted that big increases in efficiency could be achieved through the development of machinery for multi-tree handling, felling and processing. It also noted that if there is a favourable demand for fuelwood, the tree section method offers the greatest gains (Figure 3). The systems included both motor-manual and mechanised felling and varied from "no processing at the stump" to "full processing at the stump". All options involving motor-manual felling were cheaper, except in heavy snow conditions (Figure 4). Single-grip harvesters were better suited to the larger-dimension material, with multi-tree harvesters better in smaller dimension material (Brunberg, 1988) (Figure 5).

D. **Summary**

Brenoe noted that thinning problems were widespread, markets were depressed, prices were low and harvesting costs were high. There was no new technology on the scene. He concluded that the best short-term solution was to seek out higher-value markets for thinnings. One example was using thinning to supply the large demand for garden mulch in the high population centres in the States.

Benefits of participation in IEA-HETS

The benefits of NZ participation in the IEA Harvesting Early Thinnings project have been limited in comparison with the previous work in the CPC7 "Felling and Bunching of Small Trees from Thinnings" Project. This was mainly a result of a strong emphasis on energy and selection of subprojects which involved systems, machinery, tree size and end products that had little relevance to New Zealand, a country where pre-commercial thinning is common and where energy wood markets are largely limited to firewood. As a result, our contributions to these sub-projects were also limited.

The main benefits of participation in HETS were in developing and maintaining contacts with leading overseas researchers and organisations, and providing the opportunity to fast-track information.

Future participation in such co-operative projects will depend on the relevance of this work to current NZ R & D. The invitation to participate in a project on harvesting small trees under the leadership of Dr Bryce Stokes based in Alburn, Alabama, could offer considerable benefits if this will allow access to better information on the productivity of mechanised thinning systems in the south-east U.S.

IEA HARVESTING MACHINERY AND SYSTEMS EVALUATION WORKSHOP

Dr W B Stuart defined the workshop objective as being **"to assess the forces that shape the development of harvesting systems"**. He suggested the harvesting environment should be considered in terms of three overlapping environments - biological, social and economic - which impinged on the physical and mechanical aspects of an operation.

The workshop was divided into four sessions:

- entrepreneurial evolution and input,
- capital and capital formation,
- market stability and market alternatives,
- resource types and land use policies.

Papers will be reproduced in Proceedings (available in 1989), but a summary of the papers is contained below.

Keynote Address

Laestadius (Swedish University of Agricultural Sciences) highlighted the different trends that had evolved with handling small trees on easy terrain in Sweden and Canada. Sweden had seen the phasing out of full-tree and full-stem logging in the 1970's with the introduction of the shortwood system (Figure 6). By comparison, Canada had phased out its shortwood system in the late 70's and early 80's, moving into tree length harvesting and more recently into full tree systems.

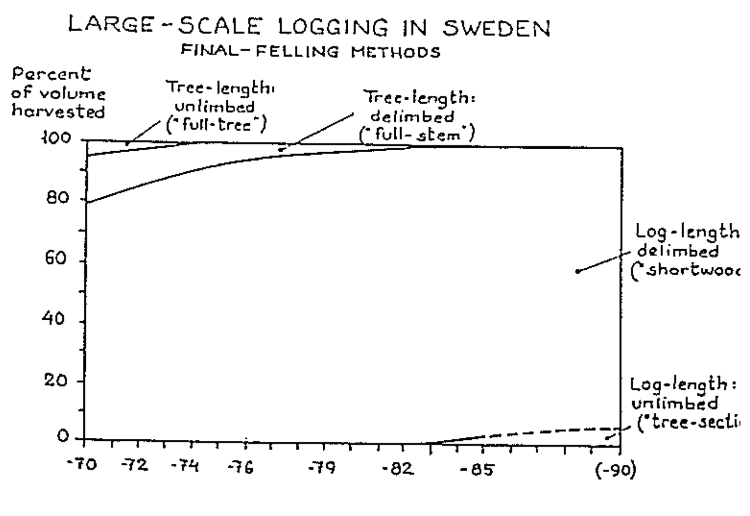

Figure 6 : Changes in clearfelling methods in Sweden, 1970 to 1990. (from Laestadius, 1988)

Why had this occurred in two countries with similar climates, similar tree size and similar attitudes towards mechanisation? The additional criteria to be considered are infra-structure, traditional practice, industrial structure and a range of social, economic and cultural factors (Laestadius, 1988).

Session I - Entrepreneurial Evolution and Input

Curtin (Tennessee Valley Authority) provided a thoughtful presentation which looked at the major factors contributing to changes in harvesting systems in the South-east U.S. over the last 60 years. He emphasised there were major differences between different states in the U.S. and these were related to a number of factors (demographic, structural, economic and resource).

He saw the 1930's as a period when there was a strong rural economic base, local communities were strong, there was a tradition of barter and a versatile multi-skilled work-force. Many small enterprises involved fathers and sons, harvesting operations were labour-intensive and had low capital requirements.

Between 1930 and the mid-1950's, there was an industrial revolution in rural areas. Agriculture was mechanised, there was specialisation of skills, widespread migration to the city, a loss of the stewardship ethic and the development of absentee landowners.

The period from 1950 to the 1970's was characterised by the postwar baby boom, continuing industrial expansion, the development of manufactured products and the onset of mechanisation in the harvesting field.

Some companies set up their own gangs to work the new systems, others provided a stable business environment (guaranteed financing for machinery, medium-term contracts) and encouraged the development of small independent producers.

In the late 1970's, harvesting was a growth industry. A number of federal agencies (Revenue Service, Accident and Safety groups, Pension funds) had closely examined the relationship between companies and contractors (dependent or independent contractors). The results of these surveys forced a hands-off attitude by company management. Problems arising from this were the issues of responsibility for training and safety.

A recent survey in the Mississippi area by Watson had identified major changes in the harvesting workforce in terms of higher levels of education, higher average age and higher levels of production per gang. There were fewer small (farmer type) units.

The downturn in the 1980's led to the introduction of quota systems and the working of three- or four-day weeks. Compounding this was increased productivity, resulting in a continuing surplus capacity with the end result being diminishing profits. Surviving contractors have had to travel greater distances and have had to be able to switch quickly from pulp wood to sawlog production or find niche markets.

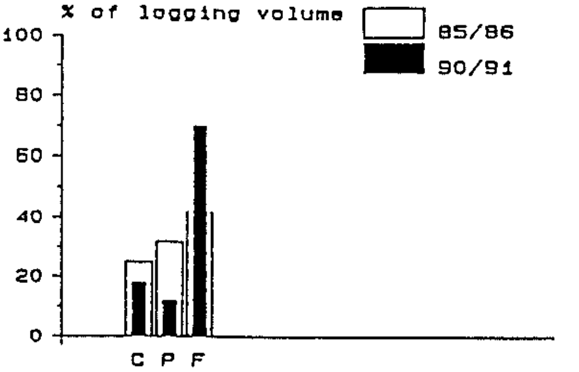

Figure 7 : Logging Systems used in Sweden in 1985/86 and predicted for 1990/91.

C = chainsaw felling
P = partly mechanised system
F = fully mechanised system

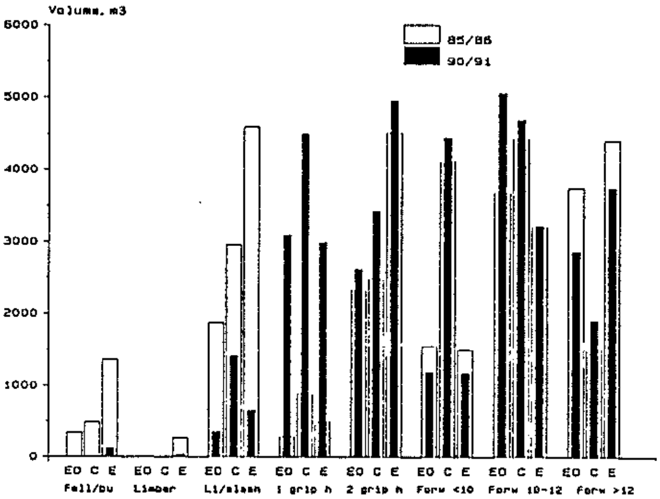

Figure 8 : Logging machines used in Sweden in 1985/86 and predicted for 1985/86.

EO = *employed owner (under long-term contracts)*
C = *contractor (under short-term contracts)*
E = *owned by forestry organisation.*
Fell/bu = *feller-buncher*
Limber = *delimber*
Li/slash = *delimbing and cutting into shortwood*
1 grip h = *single-grip harvester*
2 grip h = *two-grip harvester*
Forw<10 = *forwarder with less than 10 tonne payload*
Forw 10-12= *forwarder with 10-12 tonne payload*
Forw>12 = *forwarder with >12 tonne payload*

Liden (Swedish University of Agricultural Sciences) described the results of a survey of forest machinery in Sweden in 1985/86. The data indicated a substantial increase in fully mechanised systems at the expense of motor-manual and partly mechanised systems (Figure 7). Increasing machine productivity also meant a reduction in the number of machines (13% over the next five years). Single-grip harvesters will increase substantially while feller-bunchers and delimbers will almost disappear (Figure 8). Machine ownership has changed from around 1980, when there were similar proportions of contractor, company and enterprise-owned machines, to having much fewer company-owned machines and a higher proportion of contractor-owned machines (Figure 9) (Liden, 1988a).

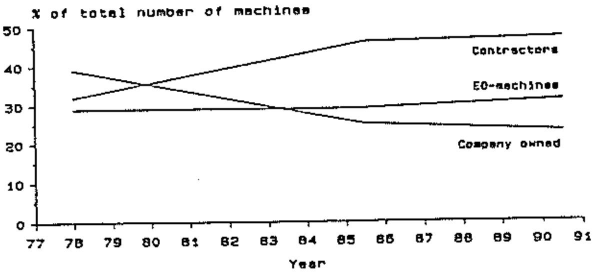

Figure 9 : Changes in machine-ownership in Sweden 1978 to 1990.

The discussion suggested that since the survey in 1986, there had been continuing development of more efficient feller-bunchers and this could change the predictions of future machinery requirements.

Informal discussion indicated that Swedish at-mill prices were approximately twice that of U.S. prices. It was suggested that mill prices were set by the cost of imported roundwood.

Session II - Capital Formation and Capital Requirement

McNeel (University of Georgia) looked at the capital costs of typical harvesting units for the four major harvesting regions in the States. These costs were derived using 1988 prices. These range from $0.71 million for the South (one feller buncher, two grapple skidders, one loader and four trucks) to $1.25 million for the Pacific Northwest (feller-buncher, hauler, loader and four trucks). He then related these costs and the life of the machinery to output and looked at capitalisation per unit of production. As expected, the southern states had much lower levels compared with the PNW.

He then listed the major sources of contractor finance that were currently available in Georgia and the prevailing interest rates.

Local Banks (limited involvement)	12-15%
Finance Companies (major source)	12-15%
Equipment Companies (higher risk ventures)	8-16%

Other sources included insurance companies, wood producing companies, wood dealers and government agencies. Start-up finance was usually available from local banks, providing a guarantor could be found. Relatively few finance and equipment companies were involved and it was extremely difficult to get finance from insurance companies.

Quotas were now applied to about 80% of loggers in the south-east. This increased unit costs and changed the emphasis from increasing productivity to reducing costs through improved fuel efficiency, improved ergonomics and the use of smaller equipment.

Liden (Swedish University of Agricultural Sciences) presented the results of a study of contract chippers in Dalarna County. She provided some nomograms which made it relatively easy to move from the capital investment, interest rate and chip price to get the volume per year required for the contractor to remain viable.

Results of her survey of 17 contractors showed that most contractors worked between 45 and 90 hours per week with one exceeding 105 hours (Figure 10).

A breakdown of this time suggested 68% was spent on chipping and the remainder on travelling, maintenance, administration and other tasks. The paper included a number of suggestions to reduce the uncertainty of contractors and improve the financial environment in which they operate (Liden, 1988b).

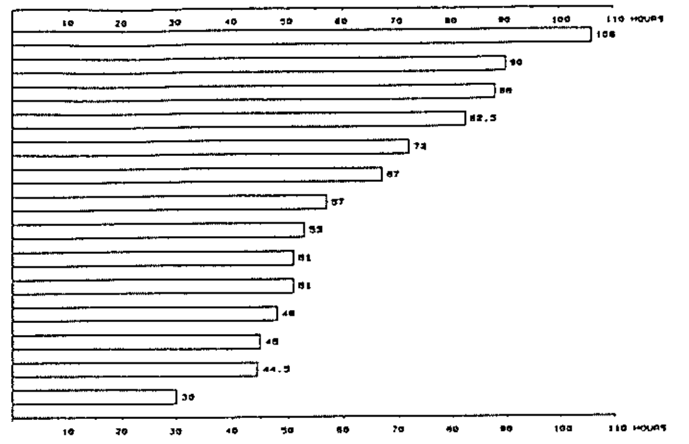

Figure 10 : Weekly working hours for chipping contractors in Sweden.

Twaddle (NZ Forest Research Institute) spoke to a paper by Walker & Terlesk on changes in capital requirements. It noted the three-fold increase in capital cost for a clearfell skidder gang (from $190,000 in 1977 to $530,000 in 1987). During this time, interest rates had more than doubled from 12% to 27%), and the proportion of turnover needed to cover interest charges had increased from 13% to 24%. The major hurdle that had limited the entry of new contractors was the four-fold increase in the cost of entry, up from 30% to 50% of the capital investment (from $57,000 to $265,000).

The challenges in the future for contractors will be refinancing the current generation of equipment, the move towards mechanisation and the financing of new cable systems.

Session III - Markets, Market Stability and Market Alternatives

Grace (Virginia Polytechnic) described the market potential for sawdust. It is a low-value waste product available at a nominal rate of $5-$7 per tonne with moisture content between 50% and 100% and a variety of particle sizes making it difficult to handle. In its wet form, it is highly susceptible to fungal infection (moulds). Once dried, the fines can be screened out, the larger sizes can be used for poultry and the smaller material can be mixed with flour to produce briquettes or heated to produce charcoal. It can also be used as a mulch for gardens and other uses include pathways, as a material for controlling and cleaning up oil pollution, and as a packing medium. For a successful operation, it would be necessary to have a variety of markets for the end product.

Grimm (Virginia Dept of Forestry) described the results of a survey into the use of wood and wood residues for energy in Virginia. From a total area of 6.2 million hectares, there was 16 million m^3 of roundwood produced, mostly hardwood. Markets were lumber (42%), paper (33%) and fuelwood (25%). There were 8 pulp mills and 450 sawmills although sawmill numbers were declining. Two major bark processing plants were recently set up to produce screened bark to be sold (very profitably) as mulch. Planer shavings were being used in particle board and pulp and as poultry litter. Three power co-generation plants had recently been established (typically around 30 Mw) and required 300 tonnes per day of residues. Firewood markets had continued to expand at around 12% per annum over the last five years.

Owens (Canada) described the situation in New Brunswick. The total forest area is 7.2 million hectares producing around 9 million m^3 of roundwood, mostly softwood, going in equal proportions to pulpmills and sawmills. The Crown owned 50% of the forest with ownership of the remainder being divided equally between companies and private ownership. A new 25 Mw power plant had been set up to utilise surplus residues and this would provide an outlet for smallwood from thinnings.

Hudson (UK) noted that forests in Great Britain covered approximately 10% of the land area (2 million hectares) and produced around 5 million m^3 of roundwood. With constraints on future forest expansion, it was unlikely that the country would ever produce more than 25% of its wood requirements. They had done some systems analysis to look at harvesting of forest residues. To estimate wood values, they had used an energy value of U.S.$2.70 per gigajoule (GJ). The energy potential of forest residues depended largely on moisture content; energy values range from 6 to 80 GJ per green tonne depending on moisture content (60% to 15%). In total, they had modelled 30 different systems using economic analyses. Sensitivity analyses had included risk factors because of the competing sources of energy (gas, coal, oil, nuclear hydro).

Their results were similar to those for Scandinavia - delivered costs of residue were around U.S.$25 per green tonne, approximately twice the U.S. price. To harvest all the available resource would require between 100 and 150 Bruks chippers.

Their work included a survey of the investment criteria used by chipping entrepreneurs. One rule of thumb, was a return of approximately twice the true cost of borrowed capital; this dramatically reduced the attractiveness of many energy wood projects. Other entrepreneurs used a payback period of around 50% of the depreciation period. If a machine had a life of 5 years, the payback period would be 2.5 years.

Curtin (TVA) described a sophisticated regional energy model developed by the USDA Forest Service called IFCHIPS$. It took the information on the availability of chips, cost of harvesting, transportation, handling and conversion, and matched this with a sophisticated GIS (geographical information system) to tie in inventory data, cutting plans and land use data to provide information county by county on the volume and costs. A curvilinear function was used to adjust data for economies of scale. Selection and evaluation of harvesting and chipping systems was done using a Delphi approach with a questionnaire distributed to a large group of logging managers.

The system could be used to identify areas of relative desirability for building a wood-fired energy plant. It was ironical that the least desirable areas were those regions with large areas of hardwood forests. The lack of existing markets for this material meant there were no harvesting operations and no high-value products to carry harvesting costs.

The model was validated on pulp log production and prices and gave reasonably good correlation.

Session IV - Resource Types and Land Use Policies

McCormack (CSIRO Australia) described some of his work on eucalypt logging and conversion. He described the problems of restocking logged eucalypt forest where total stem volume (before logging) may exceed 2000m^3/ha and residues (after logging) exceed 500m^3/ha, including some large rotten butt logs. Their normal practice has been to log, burn and then aerial seed with pelletised seed.

Their eucalypt programme for managed stands was targeted at the high-yield areas in south-east Australia (Victoria and Tasmania) with fertile well-drained soils, moderate rainfall and MAI's of 25-35m^3/ha.

The CSIRO Young Eucalypt Programme was a cooperative research programme. The seven research areas were:

- Resource
- Growth and Yield
- Thinning and Harvesting
- Debarking
- Sawing
- Pulping
- Stand Damage

The challenge for the thinning and harvesting team was to develop effective thinning treatments for natural regeneration. The methods tested included:

[1] spraying (age 1-3 years)
[2] stem poisoning (3-6 years)
[3] chainsaw thinning (3-6 years)
[4] stem injection (6-15 years)
[5] conventional thinning programmes (15 years +).

Machines used included; the OSA 250 with grapple saw, feller-bunchers and grapple skidders, the Lako with modified flat bars on the rollers to replace the spikes, feller-bunchers and a Logma processor.

FIELD TRIP NOTES

1. Weyerhaueser Operations, North Carolina

Weyerhaueser's plantation operations in the South-east U.S. started with the establishment of around 6000 hectares per year of loblolly pine (P.taeda) in the 1960's. Much of the work in the early 1970's involved deciding whether or not to production thin and which systems should be considered.

John Lilley, Logging Manager, is responsible for providing their Kraft mill with 48,000 tonnes per week of roundwood and chips. The mill supplies five paper mills and processes a variety of hardwood and softwood chips. There are five chip lines; hardwood, high density pine, low density pine, juvenile pine and whole tree chips (used for hog fuel for power co-generation).

Logging operations are almost exclusively contract; company operations produce less than 3% of their roundwood requirements. About 40% of their requirements for pulp and sawlogs come from company land and 60% from privately owned land.

Company crews are paid on an hourly rate and receive separate bonuses for safety, production, and quality. Supervisors undertake quality control checks to monitor selection quality.

Clear felling is strongly market-driven and clearfell gangs are moved regularly around the forests to meet changes in market demand. This requires advance roading to provide access to areas designated for logging over the next 5 years.

Thinning Operations

Their thinning system has evolved from a selection thinning operation to a fifth-row outrow system with selection thinning in the two rows each side. Wide-tyred skidders allow them to operate all year round on the coastal plains with its high water table. The first thinning operations take place between age 12 and 16 with a tree height of 12-14 m, diameter of 15 cms and piece size of around .15 m^3. They are currently using a Morbell 121 feller-buncher and a Hydro-ax 411 feller-buncher, both 3-wheeled vehicles with low ground pressure, high level of fuel efficiency and simple maintenance requirements. The Hydro-ax was row thinning and the Morbell was selection thinning two rows each side. Both machines have felling heads fitted with twin-action shears and accumulating arms.

In a thinning operation in a 14 year old stand (1600s/ha, tree size .14 m^3), two feller-bunchers were selecting, cutting, accumulating three trees (range 2-4) and bunching. Production was around 150 trees per hour, (1200 trees per shift). Extraction of bunches was done out-of-phase using a John Deere 640 grapple skidder fitted with a standard grapple, differential lock, wide tyres (43 inches wide) and heavy duty axles.

The bunches were hauled to roadside where a Case 1080 hydraulic loader pulled small bunches (4-8 trees) through a vertical double flail delimber prior to loading onto stakeout trailers. A prime mover hauled the trailers to a nearby truck road. Delimbing quality was poor but adequate for "touching up" the bunches for trucking on public road systems. It also reduced the amount of small diameter material going to the mill and minimised a processing bottle-neck. Approximately 12% (mostly branches) of the biomass was taken off in the field and a further 17% was removed in a second chain flail delimber/debarker at the mill, mostly as bark.

Daily throughput from this system (two feller-bunchers, two grapple skidders, one hydraulic loader, one flail delimber and one prime mover) was around 370 m^3 per day. Stumpage costs were around U.S.$4/m^3$, harvesting costs $9/m^3$ and transportation $6/m^3$.

Prior to the development of the flail delimber, delimbing was carried out using either gate delimbers or teeth fixed on the underside of the skidder blades.

A second thinning is carried out on these stands 7 years later (age 21 years), using a Rottne-Blondin grapple harvester. Clear felling was at age 30 using disk saws (Koehring and the modified Weyerhaeuser version). Hydraulic and electrical chainsaws were considered unsuitable for mechanised felling in these conditions.

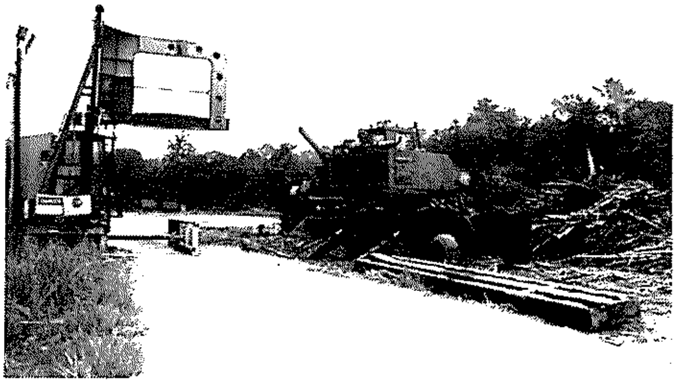

Figure 11 : Hydraulic chainsaw for bucking overhanging tops of tree-length thinnings (untrimmed) at Weyerhaeuser's Plymouth pulpmill, North Carolina.

Silviculture

The Weyerhaeuser intensive stand management is impressive. Cutover sites have been slashed, chopped, bedded and fertilised. They used to plant 1600 s/ha using a rectangular spacing of 3.5m by 1.8m. Foliage sampling is done regularly and the normal fertiliser is DAP (di-ammonium phosphate) for N and P. Following production thinning, they fertilise with nitrogen. Prescription burning is a common practice and is now done after thinning to control fuel build-up. The timing of the thinning is based on stand basal area, a function of site and stocking. Although these stands on the coastal plains appear to be on uniform sites, their origins (a series of buried beaches overlaid with sand and silt) make them highly variable and so silvicultural treatment is very site-specific.

Current regimes involve planting only 650 s/ha, thinning to 350 s/ha at age 14, rethinning to 200 s/ha at age 20 and clear felling at age 30 (50 cm dbh). Some areas on the coastal plains are old swamps and their peaty soils are highly susceptible to fire. They regulate water levels in these areas to minimise fire danger. Roading is a challenge in this situation. In the absence of local sources of metal, ditching is standard practice and this material is used to elevate roads. Water table level is controlled by damming the drainage ditches to provide water for firefighting and to meet forest growth requirements.

Double Flail Delimber/Debarker

At the Weyerhaeuser mill in Plymouth, trucks carrying loads of partially delimbed trees went past a giant (4 m long) chainsaw which trimmed the overhanging ends (Figure 11). These tops were chipped separately to produce hog fuel to reduce a bottleneck in the main system. The truckloads of topped whole trees were placed in a stockpile

Figure 12 : Topped thinnings (untrimmed) being unloaded at chain flail delimber/debarker - Weyerhaeuser's Plymouth pulpmill.

and fed through the horizontal double flail delimber/debarker (Figure 12). This uses two horizontal rollers fitted with flails of half inch chain. The last six links are attached to a specially designed U-shaped link for easy replacement. The bark, broken tops and branches were chipped for hog fuel (Figure 13) and the remaining stem section went for pulp chips. Weekly production was around 3000 tonnes of clean chip and 700 tonnes of hog fuel.

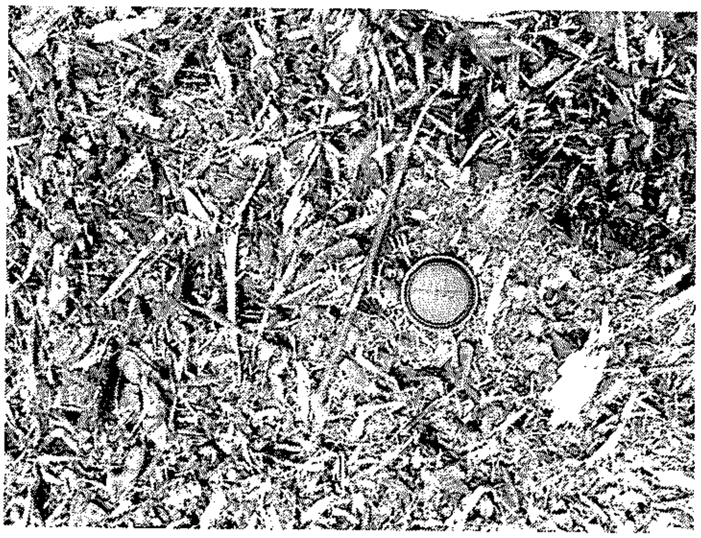

Figure 13 : Hogfuel produced by the chainflail from branches and bark.

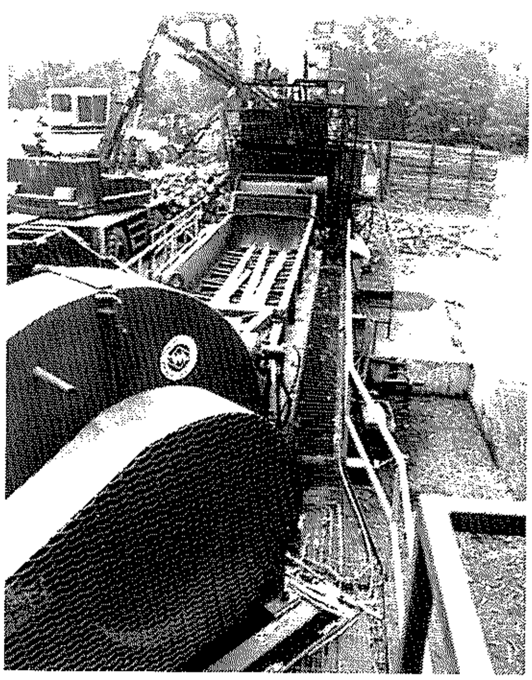

Figure 14 : Delimbed and debarked stems moving from chain flail to chipper.

Debarking quality was high and this system could have some potential for eucalypts and minor species.

Trucking

The use of stakeout trailers was common practice. A single contractor may have 3-4 trailers for each truck and he would supply sawlogs to sawmills during the day and pulp logs to pulp mills at night. Most trucks did two shifts and were commonly family owned.

Market-Orientation

The rapid response of the whole wood supply system to changing market demand was impressive. This was assisted by a large number of forest owners, a large number of independent contract loggers and truckers and a large number of wood purchasing points. This market philosophy extended into land ownership. Land tax is levied on the value of the land and as real estate values crept up, forest companies would minimise their investment by selling higher value land and replacing it with lower value land. Much of the land currently in forest may have gone in and out of a forest cover five or six times over the last 200 years, as a consequence of competing land uses.

Local Factors affecting harvesting systems

Climatic conditions vary seasonally; summer conditions reach 30-35°C for four to five months, while winter temperatures, usually near zero, can drop to -10°C to -15°C at times. Growth rates are high with MAI's of 15-20 m^3/ha. Hardwood regrowth is prolific and can swamp the young trees during the first few years. The pines subsequently emerge and become dominant but after age 40-60, the shade-tolerant hardwoods can come through and overtop the pines again.

Slight variations in topography on these coastal plains (changes in elevation of only 20-30 centimetres) can provide significant changes in vegetation type. Wide tyres are necessary on these soft soils and a small rise in the water table can render an area inaccessible in winter.

It is easy to see why motor-manual systems have rapidly gone out of favour. The heavy scrub understory, the presence of many vines and briars with long thorns, a variety of insects that bite or sting (red bugs, fire ants, mites and ticks), the presence of snakes and the high summer and low winter temperatures make manual work in the forest an unpleasant and demanding task. The banning of the herbicide 2,4-D made hardwood control more difficult, and controlled burning has been used to reduce fuel levels and improve access into the stand.

2. <u>Franklin Equipment Company, Virginia</u>

The Franklin Equipment Company manufacture a range of skidders and also fit feller-buncher heads to the bigger units (Figure 15).

Keane, Senior Vice-President (Manufacturing), took the party around their factory. They buy in Detroit engines, manufacture winches and castings in Oregon, and do the machine work in Franklin on the bodies, axles, transmissions and rams. They employ a total of 300 people. They build their own transmissions as most truck transmissions are designed for operating in fourth and fifth gear whereas most skidders operate in the lower gear ratios.

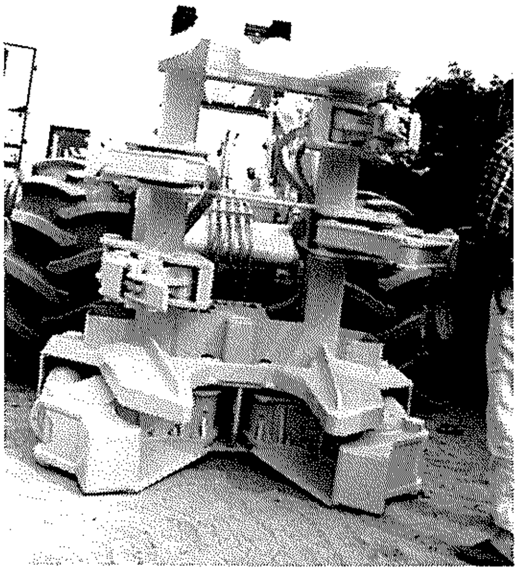

Figure 15 :
Franklin 5001 Feller-buncher.

Felling head with accumulating arms and double-action shears, on twin-shear head, mounted on a modified Franklin 170 skidder.

They manufacture 45 units per month, mostly for local use, but export some to France, Africa and South-east Asia. They have concentrated on building simple robust machines and survive in the market because of price and servicing. FERIC are monitoring the performance of 10 of their largest (320hp) skidders on site preparation work in Canada.

The factory has a somewhat family atmosphere about it, employing non-union labour and having a profit-sharing agreement. All of the senior management have come up through the ranks and are capable of getting alongside the workforce on lathes and assembly lines. It is a no-frills operation - air temperature was 35° C when we were there and there was no air-conditioning in the factory.

3. Westvaco Pulp Mill, Covington, Virginia

The mill is located in the Appalachian Mountains near Jefferson National Forest. It is a large well-run mill in the process of replacing its shortwood system with a longwood one, utilising a large drum debarker (length 36 metres, diameter 4.3 metres) for hardwoods and softwoods (Figure 16).

Mill requirements are 5,800 tonnes per day of pulp wood (80% hardwood, 20% softwood) fed through a drum debarker into a 2500hp chipper. Additional supplies of chips are bought in, particularly in wintertime. Energy requirements are supplied by burning bark, sawdust, gas and coal ($40 per tonne at mill). This produces 60 MW of electricity a further 10 MW is bought in. Hog fuel is too expensive!

Pulp output is 2000 tonnes/day, going to 5 paper mills. The mill is a major producer of "food board", the material used in food packaging (e.g. cereal boxes). The mill also produces activated charcoal, from woody residues, mostly sawdust.

Mill upgrading has cost $385 million which includes a $90 million recovery boiler. The main thrust in upgrading has been to dramatically reduce manning levels and maintenance requirements (from 60 down to 25 people in the wood yard and only 4 people in the paper plant). All external steel work is galvanised and epoxy paint has been used on all exterior buildings. The wood yard operates two shifts for 5 days a week.

Inventory levels are high by NZ standards - 15 days supply of hardwoods, 20 days of pine. They are looking at reducing this to 6 to 7 days but need to build up their levels in winter because snow can affect delivery.

4. Virginia Polytechnic and State University Research

Sawdust Utilisation

The sawdust is screened to take out the stringy portions from the head rig mix (Figure 17). This produces a uniform

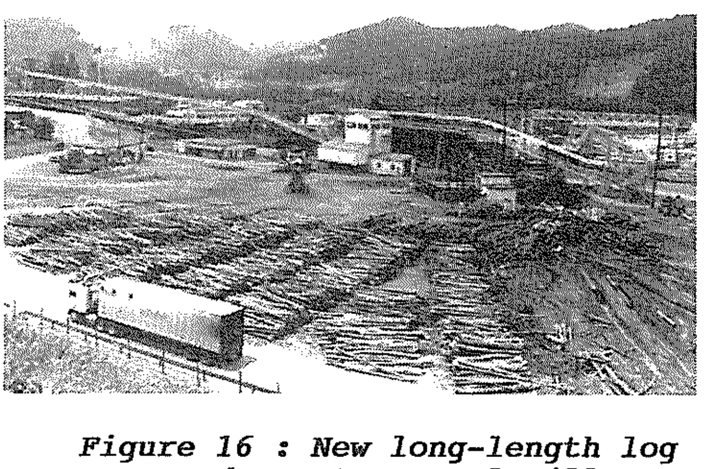

Figure 16 : New long-length log yard, Westvaco pulpmill, Covington, Virginia, replacing a shortwood system.

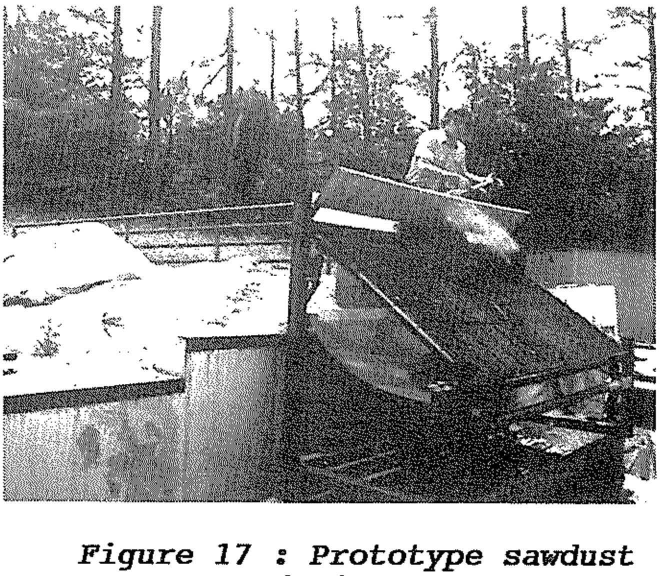

Figure 17 : Prototype sawdust screener, designed to remove stringy and oversize material from headrig sawdust.

Figure 18 : Pilot plant sawdust drier

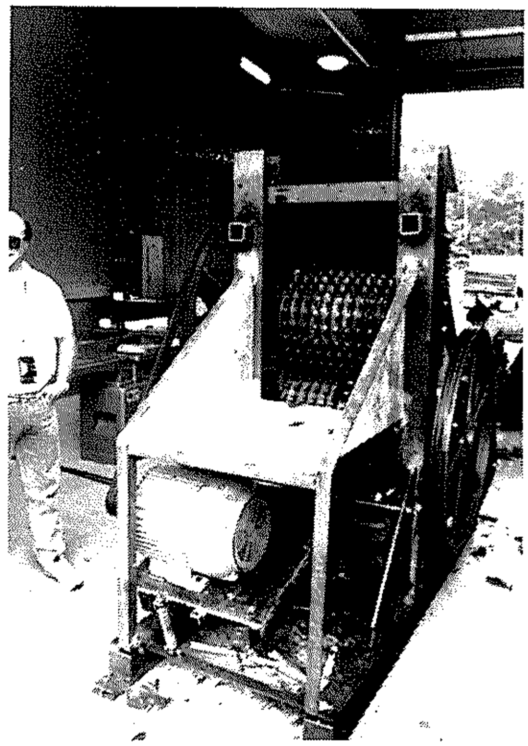

Figure 19 : Prototype biomass roller-crusher under development in VPI Forestry Engineering Laboratory.

particle size and allows a uniform rate of drying which increases energy potential, the number of possible end users and the value of the end product. A pilot plant sawdust dryer (Figure 18) was built with a number of secondhand components. It utilises an old oil burner to dry the screened sawdust by using a variable speed drive on the auger feed mechanism. Screening out the fines means the dried sawdust can also be used for animal and bird litter, a major potential market in the bigger centres.

Drying reduces the moisture content from 95% (poplar) and 55% (oak) down to around 15%.

Roller Crusher

The VPI prototype roller crusher (Figure 19) incorporates an old secondhand stone crusher and has been designed to process woody biomass (tops and branches) in the 4 to 10 cm diameter range. using this as an infield crusher would leave the crushed material in a form better suited to bulk handling. The crusher is effective in removing much of the bark and has a very high feed speed.

The prototype is still at the developmental stage and would need substantial rebuilding to operate in a production situation.

The Brooks Forest Products Centre

Dr Mark White took the party around the Centre. One of their major areas of research was the design of pallets. He noted that the States used 480 million pallets per year manufactured by 2500 producers; 68% of all hardwood is used in pallets. They have done a lot of work in looking at structure, dimensions and fasteners and species using CAD/CAM software. Pallets made out of substitutes (cardboard, panelboard) have also been evaluated.

Other areas of research include solar drying, laser incising of hardwoods (to improve their capacity for drying and to take chemical treatment), a pilot-scale sawmill and a waferboard machine.

IMPLICATIONS FOR LIRA

There are a number of areas which are worthy of further attention. LIRA should continue to:

1. Monitor the ongoing development of mechanised harvesting systems in the south-east and compare their productivity with New Zealand systems.

2. Monitor the ongoing development of chain flail delimber/ debarkers and examine their potential for debarking eucalypts and delimbing minor species.

3. Note the climatic, biological and social factors that have hastened the development of mechanised thinning systems in plantations in the south-east U.S.

4. Recognise the local factors that have encouraged the development of a highly competitive market-driven harvesting industry in the south-east U.S. These include a large number of forest owners, a large number of purchasers, a number of different product types and surplus harvesting capacity.

5. Note the results of trials which confirm the high cost of harvesting smallwood using small machinery and the benefit that can be obtained from using larger machines and properly designed systems.

6. Monitor the USDA Forest Service work on central tyre inflation and on the use of wood residues as temporary road fill.

7. Monitor developments with the steep country feller-buncher.

8. Monitor FERIC trials with mechanised strip thinning in naturally regenerated stands on easy terrain and examine their potential for handling radiata regeneration.

9. Note the rapid development and widespread use of tractor-mounted firewood processors in Norway.

10. Recognise the variety of factors that influence the development of harvesting systems in different countries.

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