LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

- TREE SHEARS & FELLER BUNCHERS -

P.R.2 1977

N.Z. LOGGING INDUSTRY RESEARCH ASSOCIATION (INC.)

P.O. Box 147 Rotorua New Zealand

N.Z.Logging Industry Research Assoc.Inc.

Project Report No.2.
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- TREE SHEARS & FELLER BUNCHERS -

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- SUMMARY -

With a number of felling machines being introduced into New Zealand logging operations recently, the need for logging operators and equipment suppliers to have an indication of the potential of felling machines in New Zealand was seen.

LIRA co-ordinated study data from separate trials, carried out by different industry organisations involving the N.Z. machines, with the objective of providing guidelines on the potential and limitations of felling machines, plus recommending the extent and types suitable to New Zealand. The local machines studied included the Caterpillar D6C-mounted QM tree shear, the Clark-Melroe Bobcat feller-buncher, the Hitachi UH07 feller buncher, and the Drott 40LC feller buncher. The individual trials varied from short studies of four hours up to twelve weeks, average merchantable stem volumes of the stands varied from $0.1m^3$ to $1.8m^3$, and systems of felling machine operation and application varied considerably.

The results of each N.Z. trial are presented separately and are then combined to form an indicative picture of felling machines in New Zealand. This is complemented with a summary of overseas trends with felling machines as extracted from literature.

The study indicates that felling machines cost from $25,000 to $175,000, and the many different styles available can accommodate a variety of different logging situations. Machine felling performance rates are 2 to 5 times that achieved manually and they are capable of working more

productive hours than manual operations. The major constraints on their application are slope and tree size, which restrict them to slopes of less than 20% (11°) and mean stand tree sizes of less than 60cm. DBH x 2.0m^3 merchantable stem volume in order to achieve reasonable production rates. Currently approximately 25% of the total N.Z. exotic felled volume comes from areas considered suited by slope and tree size to felling machine application.

The report details specific conclusions aimed at indicating the potential in New Zealand for felling machines, their effectiveness and influence on costs and productivity, their effects on logging systems, and the types of machine considered suited to New Zealand.

- A C K N O W L E D G E M E N T S -

The N.Z.Logging Industry Research Association (Inc.), (LIRA), as an industry backed research facility, is dependent on industry organisations and personnel to carry out specific trials or studies. LIRA's role is to co-ordinate the independent activities, compile all relevant information on the subject, and distribute the findings to industry.

In this study of Shears and Feller Bunchers, LIRA acknowledges the privilege of being able to use trial data collected by Kaingaroa Logging Company, Tarawera Forests Limited, and the Forest Research Institute's Harvesting Group. LIRA is also grateful for the co-operation received from Carter Oji Kokusaku Pan Pacific Limited, Brian Cochrane, Raeburn Industries Limited, Cable-Price Corporation Limited, and Domtrac Equipment Limited, all of whom assisted in the New Zealand trials.

The Photographs used in this report have been supplied by: Forest Research Institute; Clark Equipment (Aust) Limited; Cable-Price Corporation Limited; and Domtrac Equipment Limited.

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INTRODUCTION

The use of tractor mounted tree shears for felling during early 1970's and the more recent introduction of three feller buncher machines for felling plus bunching indicated the arrival in New Zealand of a new phase in tree felling operations.

With a considerable range of mechanised felling machine types available overseas, and with the New Zealand forests having a number of variable factors affecting performance of such machines, the need for an early indication of the potential and problems involved in utilising mechanised felling machines was seen. This study was commissioned in 1976 to provide early guidelines on the potential of mechanised felling machines in New Zealand and was therefore aimed at, examining the effectiveness of shears in felling, ascertaining their impact on productivity, cost, utilisation, safety, plus recommending the extent and types of machines desirable for importation or development.

Relatively short studies of the New Zealand operated machines were carried out by independent parties, each machine being studied under different influencing factors and circumstances, and four summary reports have been published by LIRA covering these units and their trials individually. This report combines this local information we have on mechanised felling machines in New Zealand with detail and trends indicated in overseas literature covering other machines, and is aimed at comparing felling machine concepts rather than comparing brands of machine. Any comment on a particular brand is therefore aimed at highlighting a feature relative to felling machines overall within the New Zealand logging environment.

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FELLING MACHINE TRIALS IN NEW ZEALAND

2.1 THE MACHINES:

The study trials covered four mechanised felling machines as follows:-

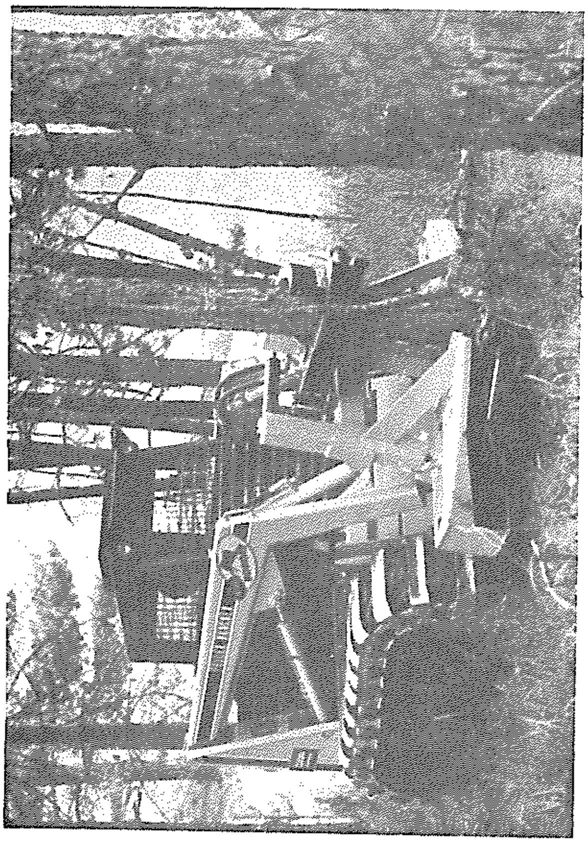
- Caterpillar D6C Crawler Tractor fitted with front-mounted QM shear head.
- Clark Melroe Bobcat feller buncher on tracks over rubber tyres fitted with a front-mounted Morebark feller buncher head.
- Hitachi UH07 crawler-mounted excavator fitted with a boom-mounted Vulcan feller buncher head.
- Drott 40LC crawler-mounted feller buncher fitted with a boom-mounted Drott feller buncher head.

The machines are shown in *Fig.1* and the basic specifications of these units are presented in Appendix I, grouped in terms of base machine detail, felling head detail, controls and ergonomic detail.

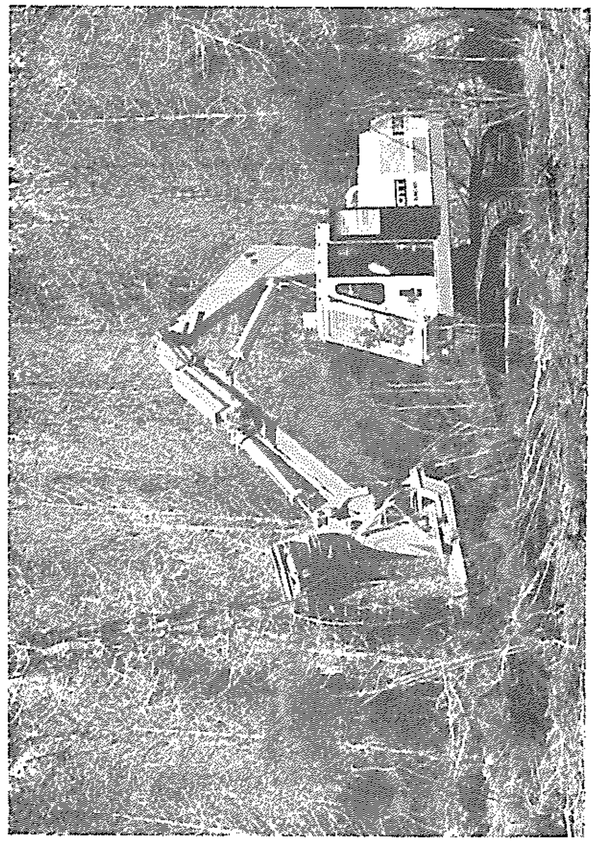
2.1.1. THE BASE MACHINES:

All of these machines are considered to be adaptions of mechanised felling heads to selected base machines basically designed for another purpose, although considerable modifications have been included in the manufacture of the feller buncher units. This use of standard type base machines of course does have a number of advantages in terms of serviceability, parts supply, equipment adaptability, and equipment disposal, which are important considerations due to the remoteness of New Zealand in relation to the major manufacturing areas of the world.

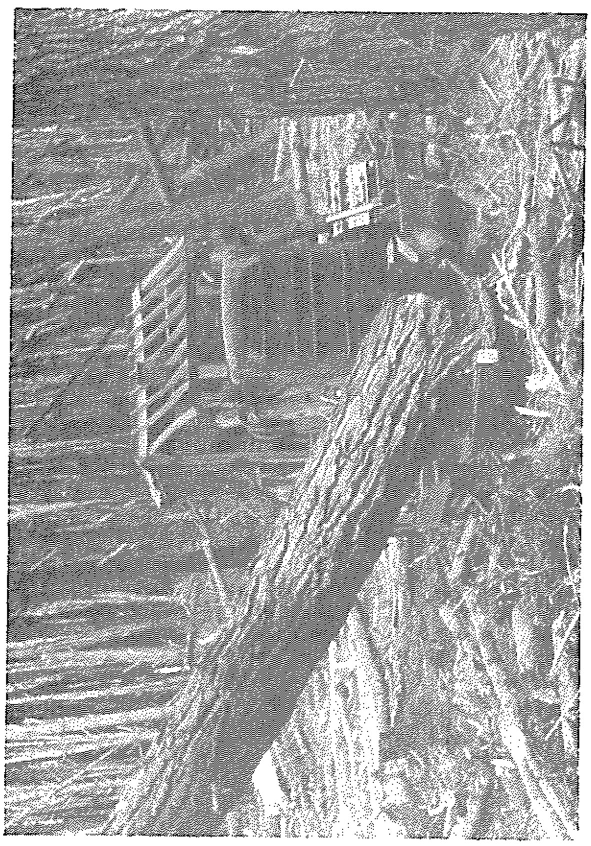
Although all the machines are diesel powered with various sized engines, they are mechanically quite different in drives. The Cat D6C - Q.M. shear machine has the geared direct drive transmission driving through independent clutches to gear type final drives at each track, whilst the three feller bunchers have fully independent hydraulic drives



Bobcat Feller Buncher



Drott 40LC Feller Buncher



Caterpillar D6C with Q.M.Shears

Hitachi UH07 Feller Buncher

Fig.1
Four Separate Photos Showing Each of the N.Z. Machines

driving each track, through an enclosed chain reduction final drive on the Bobcat and enclosed geared final drives on the Hitachi and Drott. The independent hydraulic drives on the three feller bunchers enable them to spin turn, thus being more manoeuvreable than the Cat D6C machines.

In overall dimensions as indicated in *Fig.2* there are some marked differences, and this must be considered for ease of transportation plus workability within stands such as in thinnings operations. The compactness of the Bobcat type layout is thus of potential for thinnings application. All of these machines are of reasonable weight by N.Z. logging equipment standards, however there is some difference in ground pressure figures, significant in comparing ground disturbance. The Caterpillar D6C with standard grousers has a comparatively high ground pressure which when used in this type of operation with pivot turning required, will tend to create more disturbance than the others. On the other hand it is this feature of the Cat D6C that provides a better ability to negotiate steeper slopes.

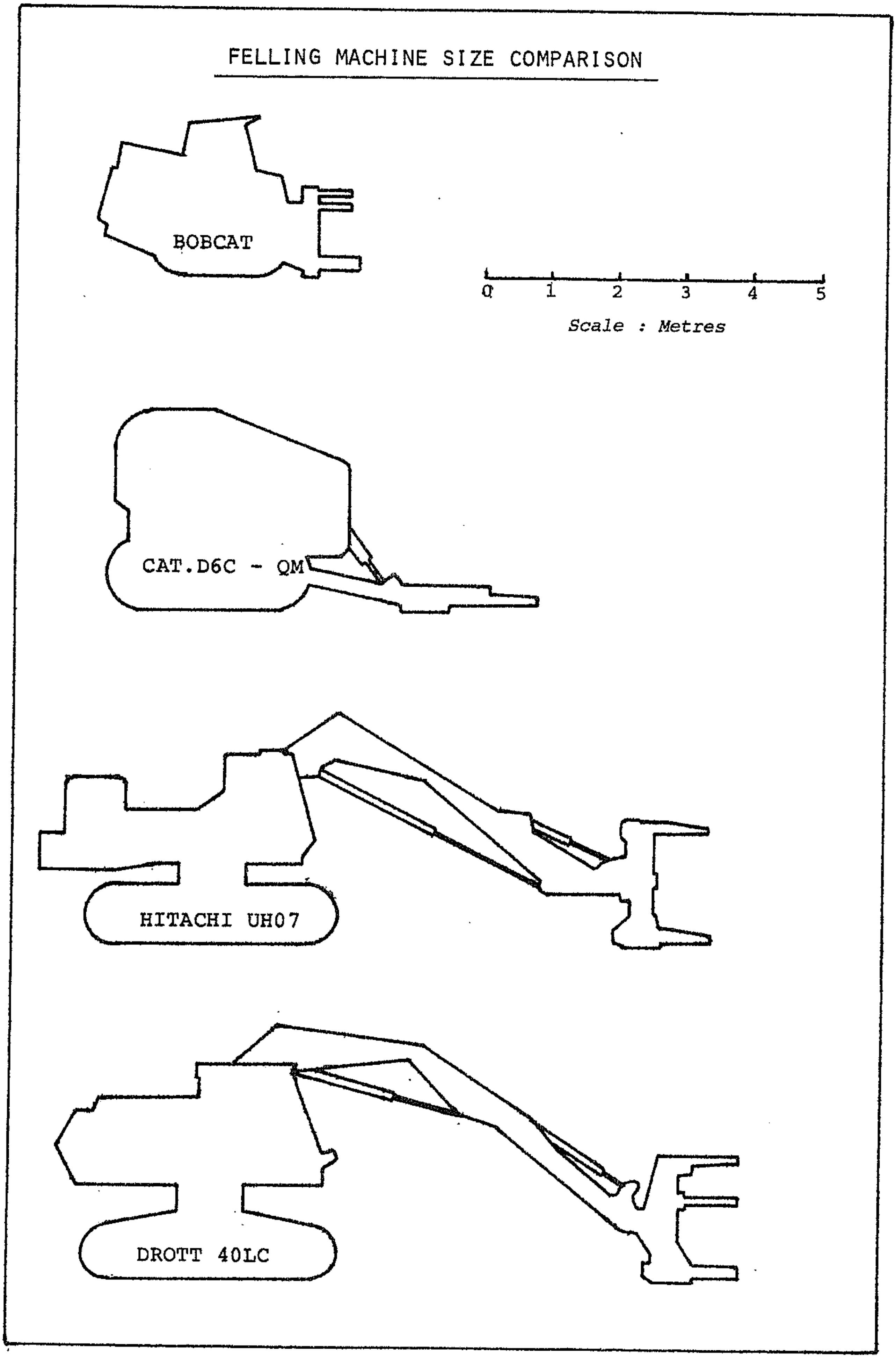
Considering base machine performance, the gradability and travel speed figures shown in Appendix I . primarily reflect the ability of the machines to travel on flat or sloped ground, such as during felling operations which is the primary consideration, plus also between felling face and landing for the likes of refuelling or transporting. The machines without slew concept of operation, such as the Bobcat and Cat D6C, obviously require higher travel speeds to maintain felling performance, and this is the case here.

No information was available to quantitatively compare machine stability, however, the effect of slope on performance is discussed in a later section.

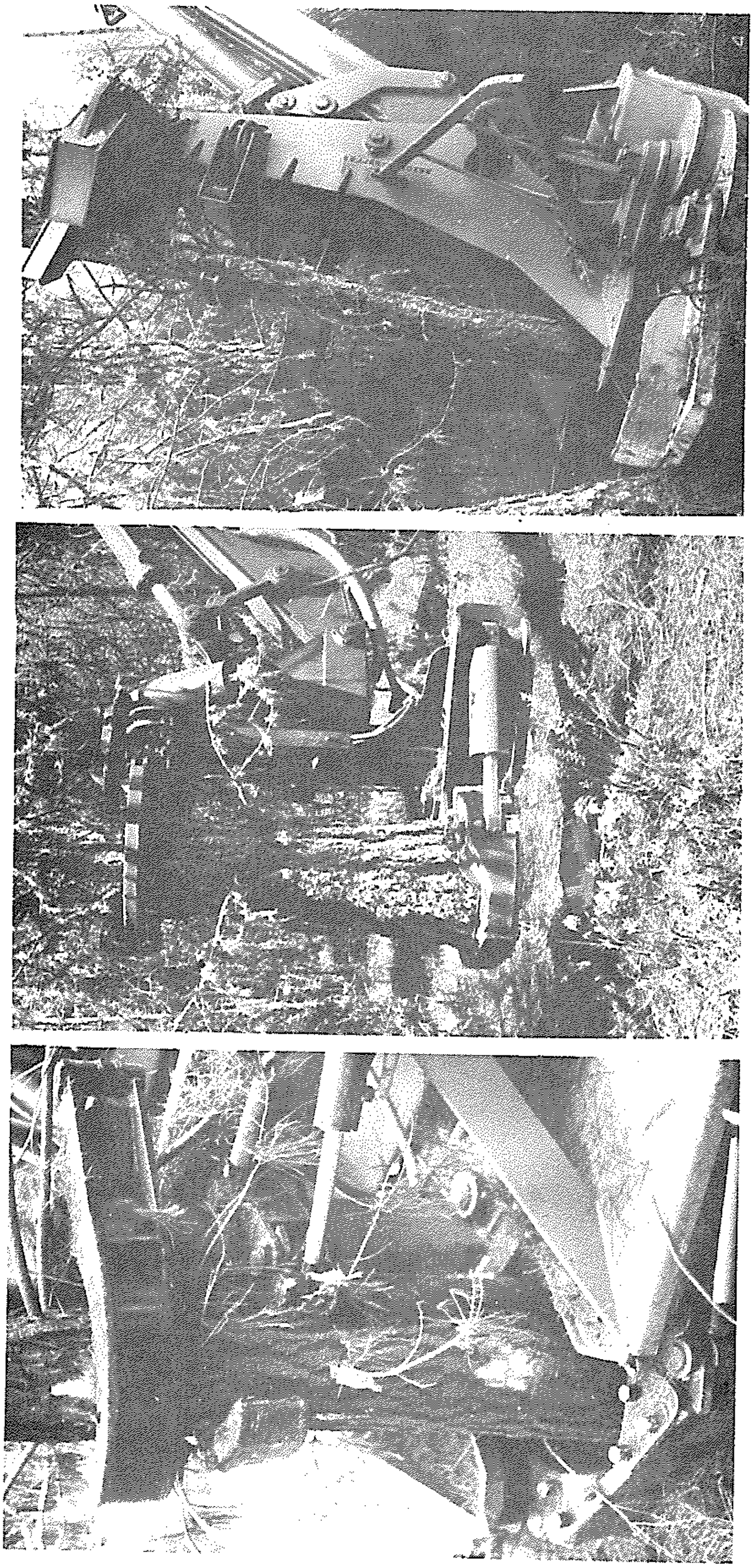
2.1.2. THE FELLING HEADS:

The four felling heads were all different and the specifications of each are shown in Appendix I.

The QM head is a shear only with single knife blade cutting against a fixed anvil. The feller-buncher heads are shown in *Fig.3* indicating their basic differences. The Morebark on the Bobcat is a feller buncher head with two knives each pivoting on separate pivots, and each operated by a separate front-mounted hydraulic


FELLING MACHINE SIZE COMPARISON
BOBCAT
0
1
2
3
4
5
Scale : Metres
CAT.D6C - QM
HITACHI UH07
DROTT 40LC

(Fig.2)



Drott 40LC

Hitachi UH07

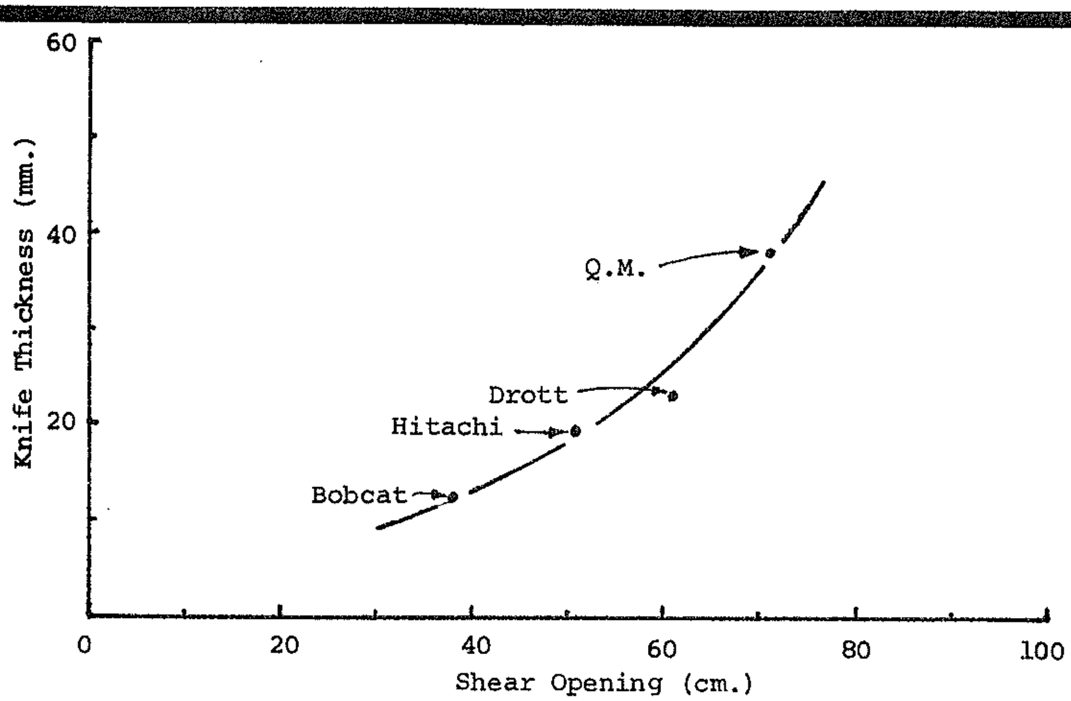
Bobcat

Fig.3

Feller Buncher Heads on N.Z.Machines

ram, plus a staggered two-finger clamp arrangement and accumulator arm. The Vulcan on the Hitachi is similarly a feller buncher head with two knives both on a common pivot but each operated by separate front-mounted rams. It has a slightly different three finger overlapping clamp arrangement which gave good stem control, plus provision for side or transverse rotation of the head to compensate for slope or leaning trees. The Drott feller buncher head, like the previous two, also has two knives but both activated by a single rear-mounted hydraulic ram which provides some protection for it, and this head with a staggered 2-finger clamp arrangement was fitted with the optional extra accumulator arm. There is no side rotation provision at the Drott head, the Drott base machine itself having a turntable leveller to cope with leaning trees and slope differences.

The differences in knife thickness between heads varies mainly due to the extra knife strength required for greater shear openings. *Fig.4* indicates how this varied with these four machines. None of the shear heads in use report knife blade problems, although the three feller bunchers have not as yet done much work, however, the Hitachi-Vulcan head single knife pivot has worn slightly resulting in unclean cutting. Another aspect of knife thickness and knife design is butt splitting, and although detailed trials were not done with these machines, reports from two users indicate butt splitting restricted to approximately



VARIATION OF KNIFE THICKNESS WITH SHEAR OPENING

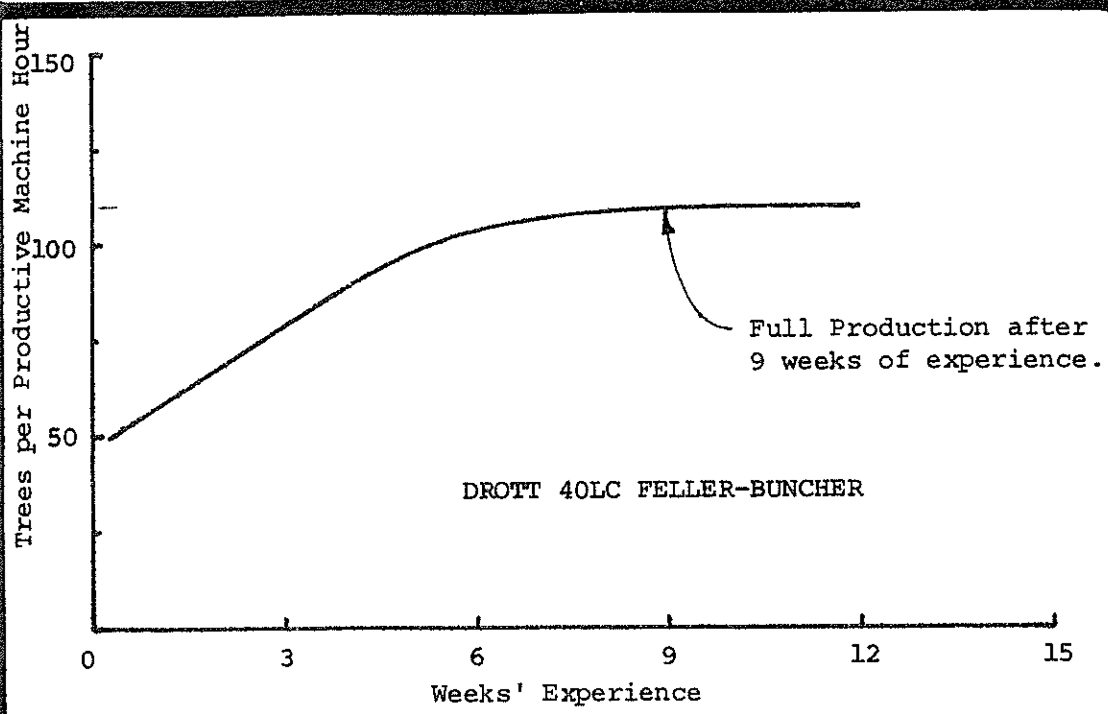
(Fig.4)

7.5cm. This must be taken into account where the butt is used in a sawlog or peeler log. Butt splitting in New Zealand is not as severe a problem as in some overseas countries, it being significantly increased by freezing temperatures during logging. Overseas developments in knife designs, which reduce butt splitting are discussed in Section 3.2.

The two boom mounted feller buncher heads had provision for side tilt at the machine or head. This is a particularly useful feature in compensating for side slope or leaning trees where the felling head is located at a distance from the base machine as on the Drott and Hitachi. The Bobcat and Cat D6C without this feature did not seem restricted by it due to the fact that they position at the base of each tree to be felled.

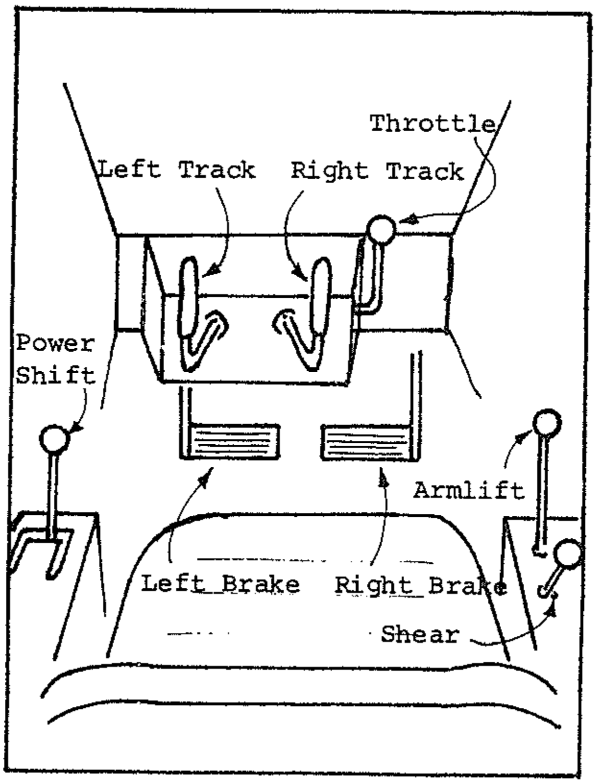
2.1.3 MACHINE CONTROLS AND ERGONOMICS:

Between these four machines there was a considerable variation in controls layout and this is outlined in *Fig.6*. It is interesting to note that the only real common control position was the right foot operation of forward head tilt to bunch on the three feller bunchers, the Q.M. shear not having a bunching ability. This control layout variation and complexity is significant from the point of view of productivity during operator training, and *Fig.5* from

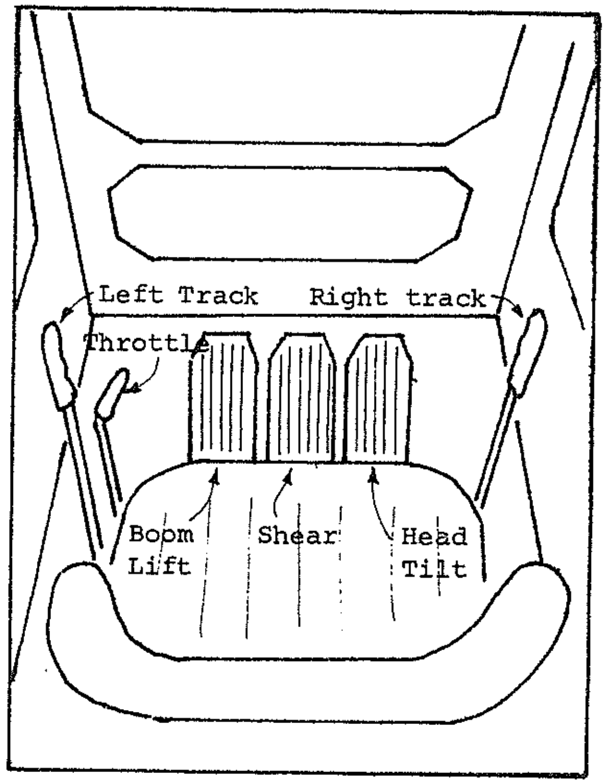


PRODUCTION TREND WITH LEARNER OPERATOR

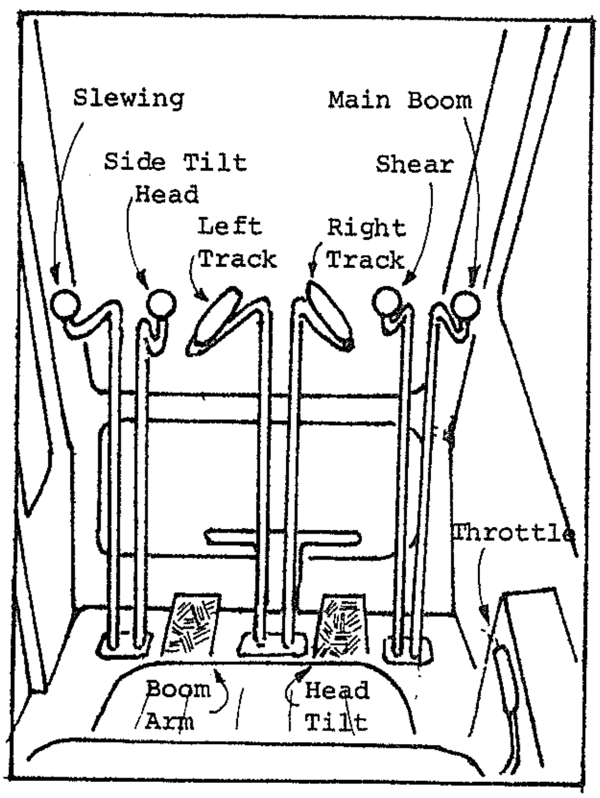
(Fig.5)



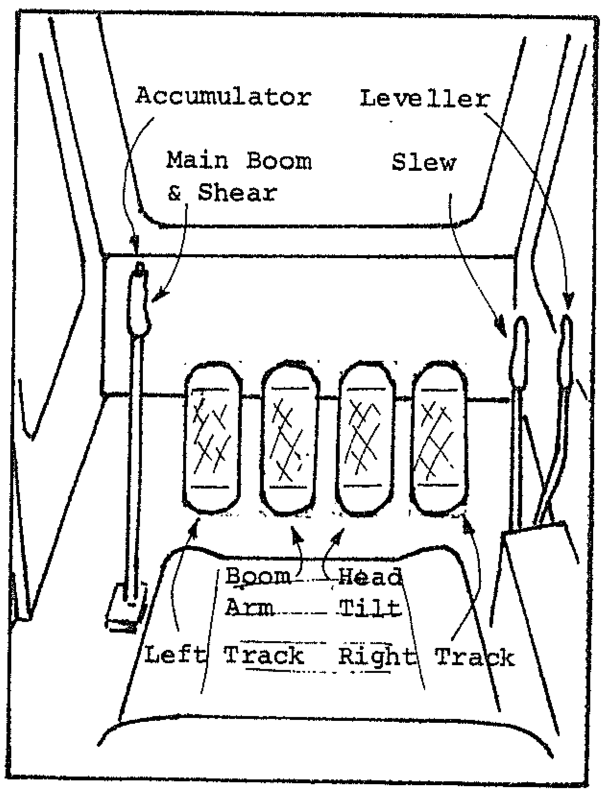
CAT D6C - QM SHEARS



BOBCAT



HITACHI UH07



DROTT 40LC

FELLING MACHINE CONTROL LAYOUTS

(Fig.6)

the Drott trials illustrates how an operation took approximately two months to reach full production. Simplicity of control layout would seem to be the most important factor here, and the Bobcat control layout is a good example of simplicity where a commonly used machine such as the Cat D6C is not used.

Ergonomic measurements were not taken however operator reports indicated one other prominent restrictive factor apart from controls layout. This was visability limitations on all machines, either upward for identifying forked trees or dead tops, to the rear for the machines required to manoeuvre during operations, or wet weather windscreen restrictions. In terms of operator comfort, the two excavator based machines with limited travel requirements in operation result in a comparatively comfortable ride. The Cat D6C and Bobcat machines which travel a larger portion of their operating cycles, produce considerably more operator "bouncing around" which, in the case of the smaller Bobcat with shorter wheel base, is a significant aspect to operator acceptance and performance.

One of the major advantages of mechanised felling machines over the manual chainsaw, is the ability to work productively and safely in conditions not normally used by power saw operators, such as wet, cold, windy, and dark conditions. The mechanised felling machine can put the feller in a completely different environment, in terms of comfort plus safety and although the return is not immediately measurable, it could be significant in the long term through improved working conditions.

2.2 THE TRIALS:

As this study covered three different types of felling machine layout, the operating methods of each at the felling face was different, as was the operation of the other components within each tree harvesting system.

The trials covered operation of all four machines in clearfelling operations, and also the Bobcat in thinnings operations, the time studies covered however, were all relatively short, thus the results of individual machines can only be taken as indicative of their capabilities. As outlined in the introduction however, the aim is to present results which provide guidelines on the application of mechanised felling machines to New Zealand logging operations.

2.2.1. THE MACHINE OPERATING METHODS:

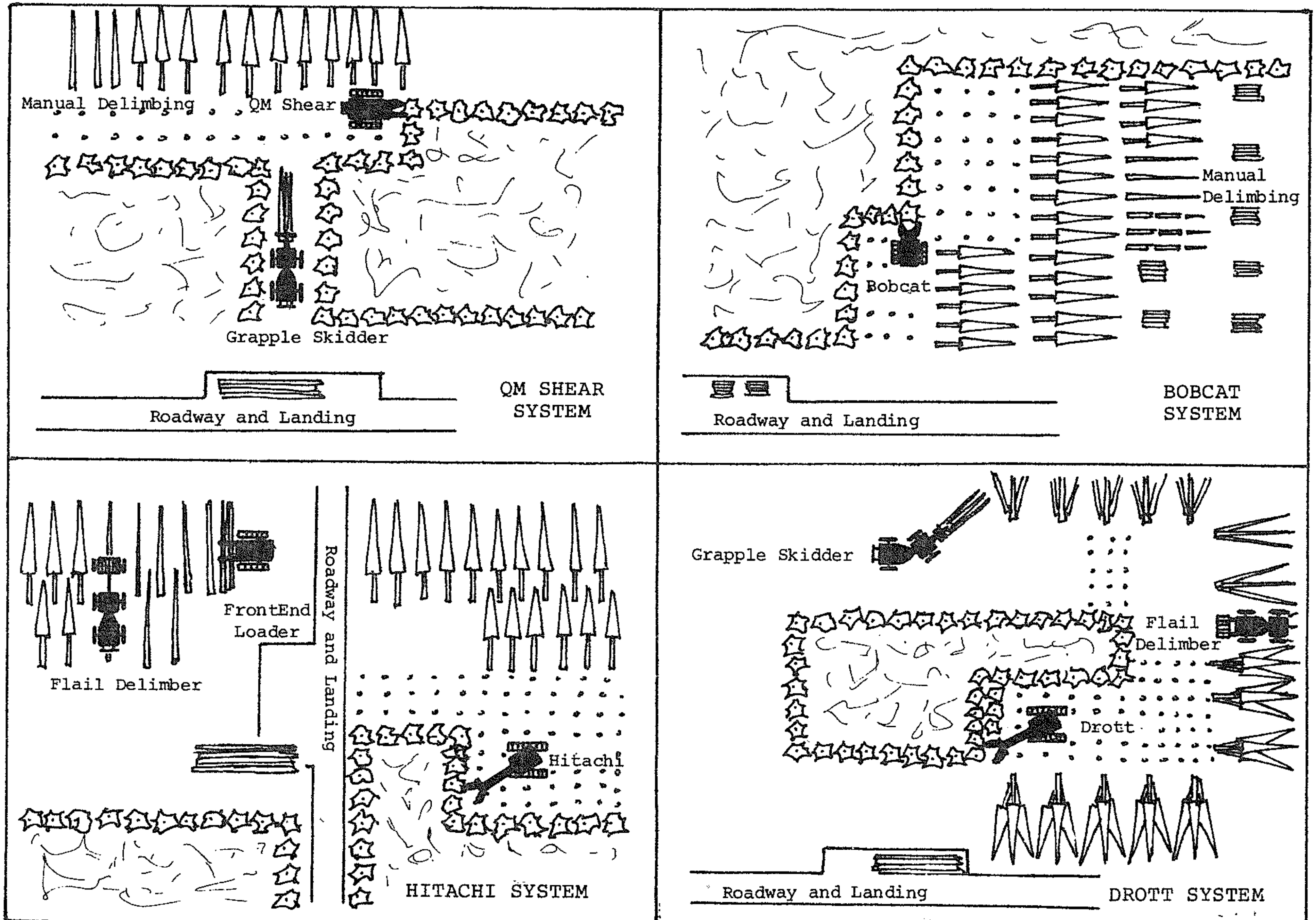
Both the QM and the Bobcat machines must physically manoeuvre to the base of each tree for felling. The Bobcat however being a feller buncher, carries the sheared tree stem and bunches stems for further processing, while the QM shear is limited to only felling trees at the stump with a limited ability to control direction of fall of felled trees. During trials the tendency at the felling face was thus for the QM to fell two rows on a long face (10 - 15 chains) while the Bobcat aimed for 3 - 5 rows per swathe. The Hitachi and Drott machines being slew type units travel down the centre of a 5-row swathe shearing trees and swinging them for bunching alongside the swathe. The method of laying out the felled trees in each case, aimed at suiting the following operations, which for the QM and the Bobcat involved hand trimming by powersaws, and for the Hitachi and Drott involved mechanised trimming by chain flail delimbers.

In the thinnings trial with the Bobcat, the machine cut a 5 - 6 metre (2 row) access path, bunching the trees herringboned to the path and later thinning the area of 16 - 20 metres between access paths. This trial however, was particularly short, and the application of felling machines to thinnings operations requires further investigation.

2.2.2. THE HARVESTING SYSTEMS:

The complete harvesting system used in each case is illustrated in *Fig.7* and involved the equipment shown.

During the trials the Cat/QM harvesting system in P.radiata had the felling machine operating between the two double tractor gangs on full time felling. At each gang the shear operated well ahead of the following operations which involved manual trimming with chainsaw and tractor or grapple skidder extraction to landing. The shear aimed to position felled trees at an angle away from the felling face line to assist both the following operations.



HARVESTING SYSTEMS USED WITH N.Z. FELLING MACHINE TRIALS

(Fig.7)

The Bobcat clearfelling and thinnings trials had the felled trees being delimbed manually with powersaw. Different following extraction methods were used. Delimbing operations with chainsaws were reported to be quicker on prebunched trees and the Bobcat aimed to assist this. Where skidder extraction was used the bunching also assisted stropping. In the thinnings trials where manoeuvreing was more difficult, it was considered best for the operator to select trees for thinning.

Both the Hitachi and Drott harvesting systems had the felling machines laying out the felled stems to suit chainflail delimbing. The Hitachi system then had a tracked front-end loader forwarding to a roadside chipper, while the Drott system had two grapple skidders skidding to roadside landings for loadout.

2.2.3. THE FOREST STAND FACTORS:

Over the four machines, a total of ten trial results are detailed in this report, five of these being Ponderosa clearfelling trials involving all four machines, two being Radiata clearfelling trials with the QM shear, two being Radiata thinning trials with the Bobcat, and one being a Corsican clearfelling trial with the Bobcat.

The stand factors of each trial are shown in *Fig.8* and while identical conditions are not obtained between individual trials, the Ponderosa trials in Compartments 243, 348, and 670, are relatively close for comparison. Because of the nature in which these short trials were implemented and studied, range and deviation figures are not considered relevant to this study involving three completely different concepts of mechanised felling.

Further descriptions of the trial stands are as follows:-

- Compartment 1159 contained the B.C. variety of Ponderosa.
- Compartment 880 was an uncrushed Radiata stand in which 22% of stems felled were classified as dead.
- Compartments 806/874 were precrushed Radiata stands. The presence of the precrushed stems about the standing trees however, impeded positioning of the shear during felling operations, thus reducing performance rates.

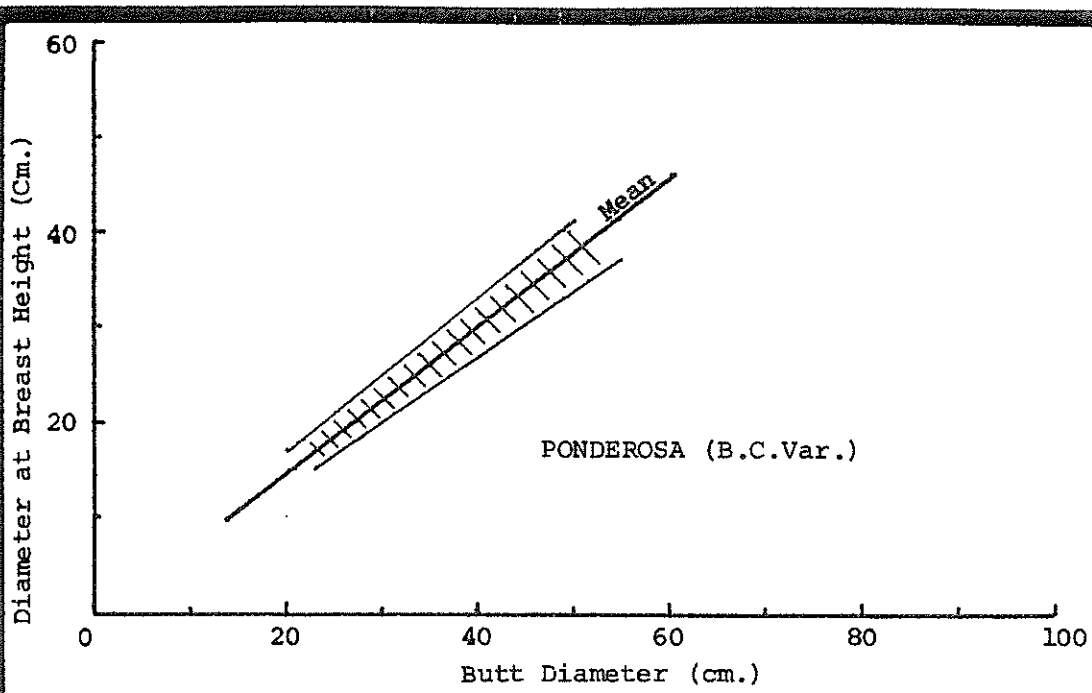
MACHINE:	CAT D6 & QM SHEAR			BOBCAT			BOBCAT		HITACHI	DROTT
FOREST & TRIAL COMPARTMENT:	Kaingaroa 1159	Kaingaroa 880	Kaingaroa 806/874	Kaingaroa 243	Kaingaroa 1087	Kaingaroa 1070	Tarawera 9yr.old	Tarawera 13yr.old	Kaingaroa 348	Waimihia 670
SPECIES:	Ponderosa (BC)	Radiata	Radiata	Ponderosa (BC)	Corsican	Ponderosa (BC)	Radiata	Radiata	Ponderosa (BC)	Ponderosa (BC)
OPERATION:	Clearfell	Clearfell	Clearfell	Clearfell	Clearfell	Clearfell	Thinning	Thinning	Clearfell	Clearfell
STOCKING: *(s.p.Ha)*	512	972	832	1089	745	353		1000	930	1245
MEAN DBH *(cm)* :	27.9	40.6	43.2/39.4	20.8	26.4		15.4		25.4	19.0
MEAN BUTT DIAM: *(cm)*				24.9	31.0	31.8	17.0	24.6	33.4	
MEAN HEIGHT *(m)* :	18.3	36.6	38.1	13.4	16.8	13.4	12.8	21.3	14.3	15.3
MEAN STEM VOLUME: (m^3)	0.39	1.63	1.76	0.13	0.57	0.26	0.07	0.26	0.215	0.17
TERRAIN:	rolling	flat	flat	flat	predom. flat	flat	predom. flat.	2° slope	flat	flat

TABLE OF STAND FACTORS

(Fig.8)

- Compartment 243 was flat with stunted B.C.Ponderosa in relatively light underbrush which did not impede travel of the Bobcat or operator visibility.
- Compartment 1087 in Corsican on semi-flat terrain had larger diameter stems for the Bobcat which had to bypass approximately 10% of these. The operator also had more difficulty in moving the Bobcat to bunch the stems.
- Compartment 1070 contained 50% of unmerchantable dead stems plus many tall pungas often growing as suckers on the B.C. Var Ponderosa stems. These restricted visibility and tended to increase the stem diameter at the shear point. Shearing the clean stems up to 35cm. diameter at the butt was done with ease but several passes were often necessary to fell the bigger trees up to 41cm. diameter around the suckers. Bypassed stems totalled 8%.
- The 13yr.old Tarawera Radiata stand was thinned from approximately 1000 stems per hectare to 450 stems per hectare. Due to original mechanical planting and subsequent thinning to waste, no definite row pattern was obvious. Slope varied from 2° to 7° in very loose scoria soils and this combination restricted mobility of the Bobcat.
- Compartment 348 was originally planted 1.8m x 1.8m and had a current stocking of 930 B.C.Ponderosa stems per hectare. The area included a full range of tree diameters from 8cm.DBH to 46cm.DBH, and estimated slopes up to 10°. This stand contained 18% dead or cull stems, these being machine felled. Larger trees within this trial area were sheared above ground level to reduce hand felling.
- Compartment 670 was generally flat with light vegetation, and contained approximately 20% dead stems in the trial area. All sound dead material was included in the merchantable category, and the machine had the capacity to easily fell and bunch all of the Ponderosa (B.C.Var.) trees encountered.

Significant untabulated New Zealand tree characteristics which affect felling machine operation are butt diameter, tree weight distribution, tree form, and wood resistance to shearing. Butt diameters were recorded in six of the ten trials, and the relationship between butt diameter and DBH was studied more fully in the Hitachi Ponderosa trial in Compartment 348. The results are shown in *Fig.9* and indicate that for Ponderosa (B.C.Var.), butt diameter was on the average, 33% greater than DBH. Tree weight distribution and form, and wood resistance to shearing were not studied during these trials.



RELATIONSHIP BETWEEN BUTT DIA. & DBH

(Fig.9)

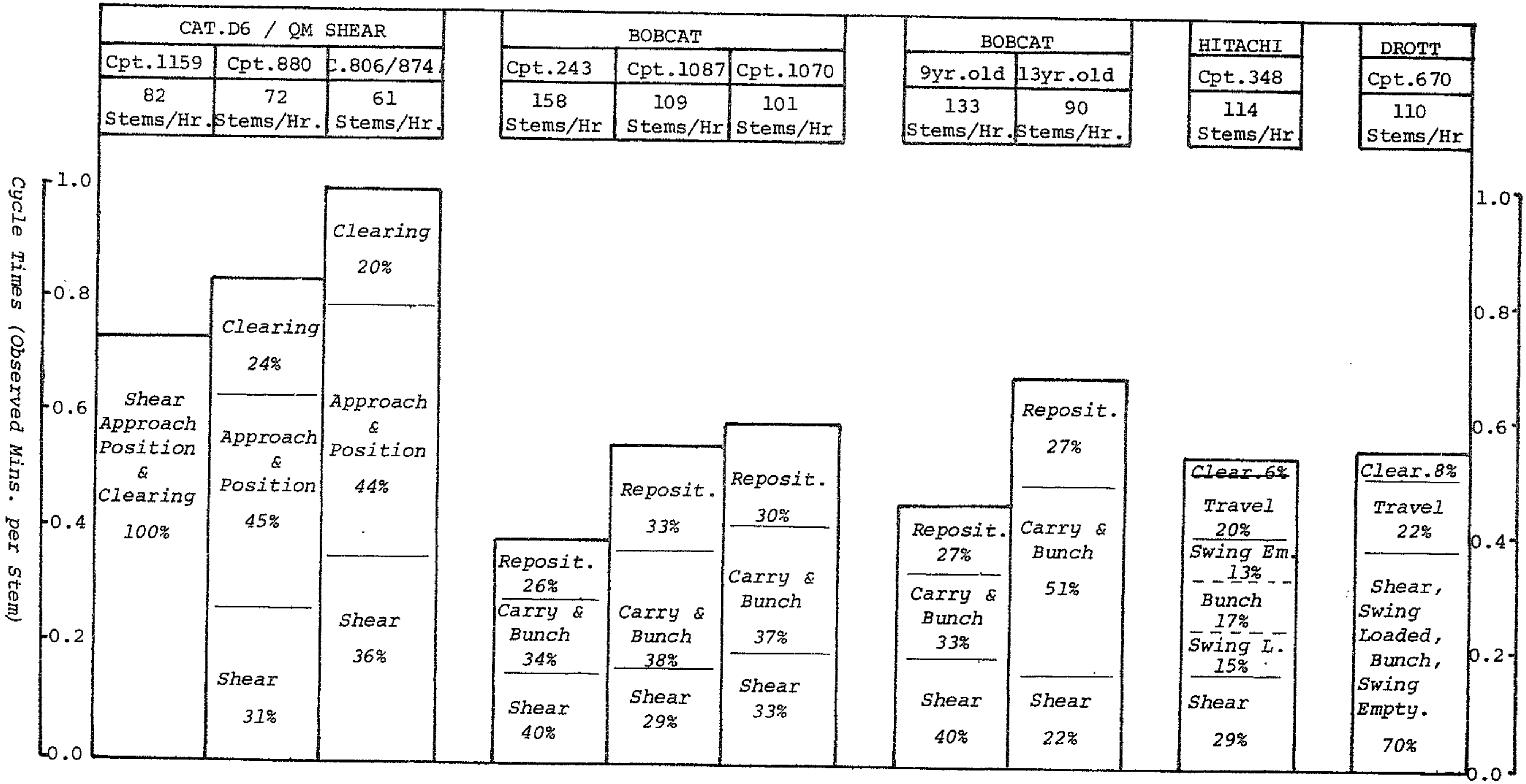
2.3 THE RESULTS:

The relatively short studies carried out to date give indicative results of felling performance and productivity, plus identifies some of the major factors influencing such, and these are presented. Comments based on observations are also made covering the aspects of ergonomics, safety, operating costs, timber utilisation, which were not measured.

2.3.1. FELLING PERFORMANCE:

Observed felling performance times and rates for each trial are shown in *Fig.10* along with a breakdown of the cycle times into respective time elements. The identity of each time element is described in Appendix II.

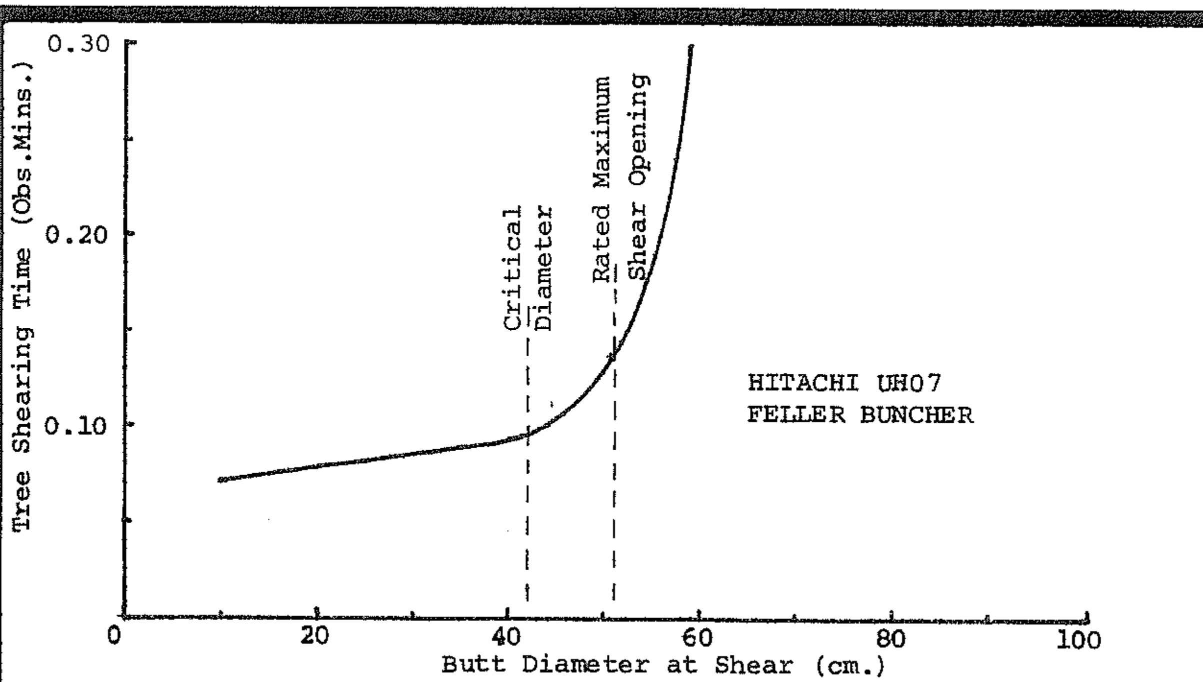
As can be seen for all the machine types, the clear-felling trials showed from 20% - 40% of each cycle time is involved in the shearing element. In thinnings however, the proportion of shearing time is to a large extent dependent on the operational method used, and thus varies more widely. The variation of this shear time element in a particular machine, with tree diameters was studied in the Hitachi trial, and



FELLING MACHINE PERFORMANCE RATES AND TIME ELEMENTS

(Fig.10)

this is indicated in *Fig.11*. Shear time increases markedly as the tree butt diameter approaches the maximum shear opening due to the extra care required in positioning the shear head. It is thus important to select a shear head size which is capable of handling the bulk of tree butt diameters expected. As outlined in Section 2.2.3., there is a significant difference between DBH and Butt Diameter, this should also be taken into account.



VARIATION OF SHEAR TIME ELEMENT WITH TREE BUTT DIAMETER

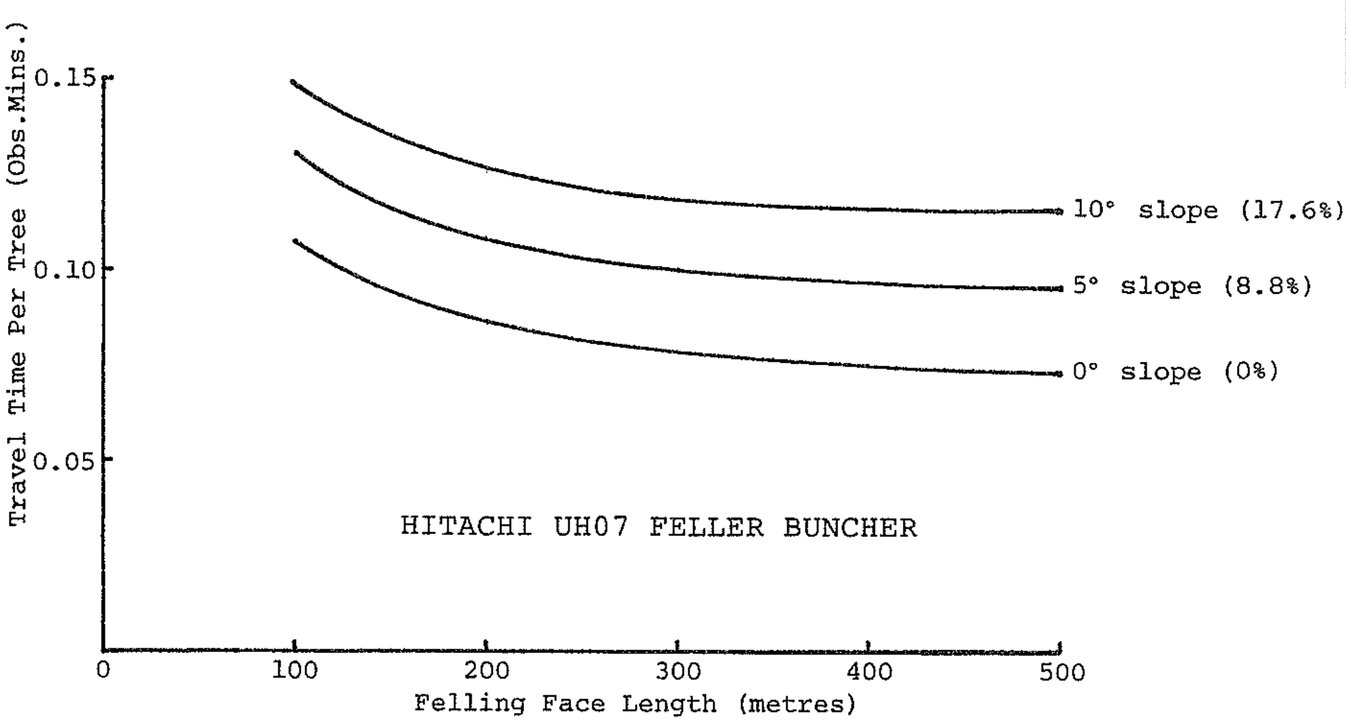
(Fig.11)

The use of the Bobcat in thinnings confirmed the extra time per felling cycle was in the main due to the extra carry-and-bunch work required in this particular operation. Felling performance by this style machine in thinnings is still comparable to that in clearfelling and is therefore a feature in the utilisation of such a unit within New Zealand.

The two swinging boom machines (Hitachi and Drott) showed very similar cycle times and even very similar element times. When comparing the swing boom type machines to the small front-end loader type Bobcat in Compartment 243, a similar stand, the difference in cycle elements indicates that the time taken to actually travel the crane boom type units is responsible for a longer cycle time. The Bobcat type machine achieves its travel within its carry-bunch time element, however, this would be affected markedly by the nature of the localised ground surface or terrain.

The effect of accumulator attachment use was measured in the Drott trial, and indications were, that in this type of stand (Compartment 670), little return from the accumulator use was achieved, and similar levels of production could be achieved felling one tree at a time.

During the Hitachi study slope was assessed into three categories (0°, 5°, 10°) during each reposition activity. The results were indicative of the effect of slope on travel time as shown in *Fig.12*, however it was considered that localised slope fluctuations were of greater influence in reducing performance rate rather



VARIATION OF TRAVEL TIME ELEMENT WITH FELLING FACE LENGTH AND SLOPE

(Fig.12)

than steady slope changes within the limits measured. In applying these results of *Fig.12* to the Hitachi felling performance rates shown in *Fig.10*, the result indicates that a 5° slope reduces maximum felling performance rate by 6%, and a 10° slope reduces maximum felling performance rate by 12%. This effect of slope on the performance rates of other machines was not measured however a similar result is expected for the Drott whilst the effect on the Bobcat and Cat QM shears type machines, in which the travel element plays a greater part (three times as much as Drott and Hitachi) would be more marked. The effect of slope on a Drott 40 feller buncher operating in North America is referred to in Section 3.3, the result being very similar to that obtained for the Hitachi trial.

As these felling machines are all capable of higher felling performance rates, and are comparatively high capital cost units compared to manual chainsaw felling, much more attention is required in planning the system under which they operate. *Fig.12* illustrates how the Hitachi travel time element was also affected by the operation setting or backline length in this case. This is a systems analysis factor which will not be expanded here, however the systems under which these felling machines operate, and the complementary machines within the system all require comparable performance rates and integration.

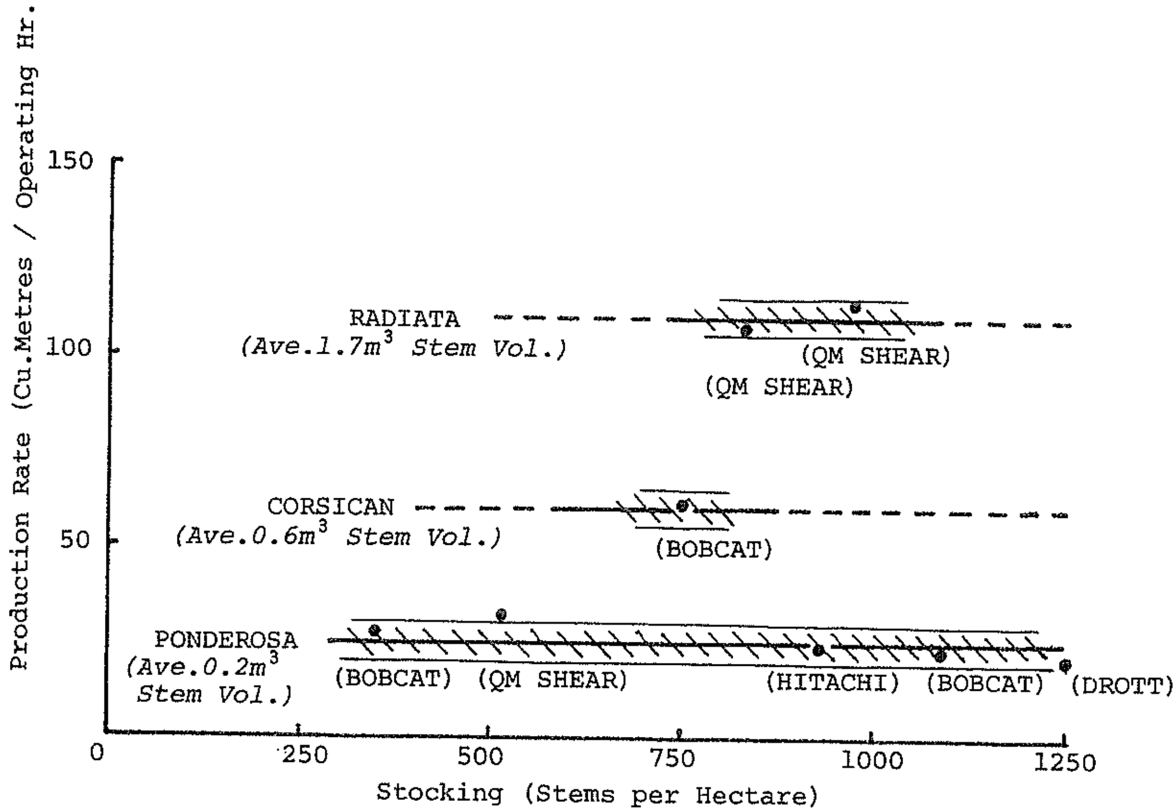
2.3.2. PRODUCTIVITY:

Because of the large variations in stand factors, and the small number of trial results available, productivity of these mechanised felling machines is compared using volume production as the basis. The results shown in *Figs.13 & 14* indicate the following for the four machines in clearfelling operations.

(a) Stocking variation for similar volume trees had negligible influence on volume production rate, in cubic metres per hour. Felling performance rate in trees per hour was influenced by stocking however this characteristic is not expanded in this study involving large variations in stand data.

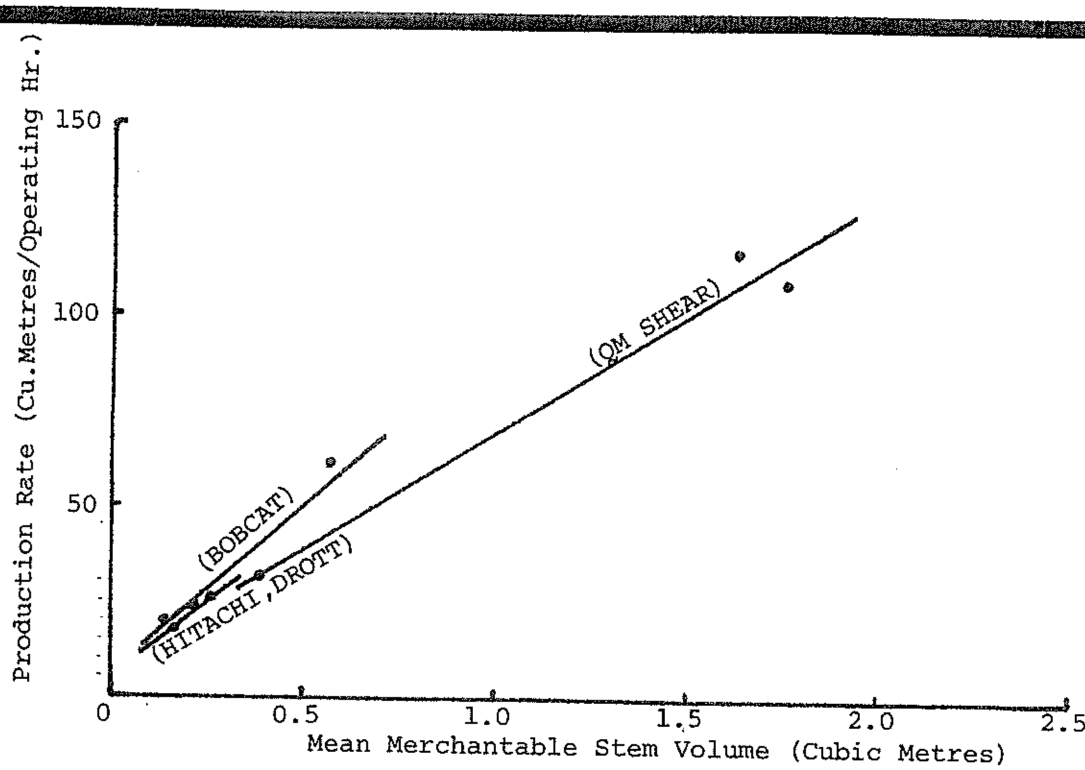
(b) Stem volume variation significantly affected volume production rate irrespective of stocking level. A 100% increase in stem volume, increasing volume production rate by approximately 100%.

(c) Tree species choice (between Radiata, Corsican, Ponderosa) influenced volume production rate due primarily to the difference in stem volumes.



VARIATION OF PRODUCTION WITH STOCKING

(Fig.13)



VARIATION OF PRODUCTION WITH STEM VOLUME

(Fig.14)

The most significant stand factor effecting volume production of these mechanised felling machines is thus stem volume and the stem size capable of being handled is determined by the design and size of felling machine considered.

2.3.3. COMMENTS ON OTHER FACTORS:

Although not measured, normal stump heights left in powersaw felling vary from approximately 7.5cm. to 22.5cm. and depend largely on the felling standards required, tree size, and ground conditions. Shear felling stump heights are very close to ground level and using this as a basis, the extra timber yield achieved by shear felling lies in the range 2.5% to 7.5% in Ponderosa at $0.20m^3$ per stem, and 1% to 3% in Radiata at $3.0m^3$ per stem. To a certain degree this is offset in saw logs by the small butt shatter outlined in Section 2.1.2. however the ground level sheared stumps will result in reduced wear and tear on machines subsequently used in the harvest, and will also add to ease of forest re-establishment.

Although not measured, the maximum tree size capable of being handled by the felling machines is indicated in the shear size and manufacturer's maximum tree weight rating where supplied. The only restriction on the QM shear which does not physically handle trees is given by its maximum shear opening. The Hitachi UH-07 feller buncher has a maximum tree weight manufacturer's rating of 1.6 tonnes which indicates a limiting merchantable stem volume of the order of $1.0m^3$ per stem. The Drott 40LC is rated at 3.2 tonnes maximum tree weight indicating a limiting stem volume of approximately $2.0m^3$. Ideal stem volumes for maximum productivity will however be somewhat lower than these figures, being influenced by butt diameter, mean stem size, variance of size within stand, tree form, tree species, and tree weight distribution. Butt diameter was the major restrictive factor for the feller bunchers operating in Ponderosa, however the tree weight distribution could be significant in other species such as Corsican or Radiata. More trials in other species are required to establish results.

- 3 -

OVERSEAS TRENDS WITH FELLING MACHINES

The mechanisation of tree felling originated by adapting machines originally designed for other purposes by fitting felling heads. Current developments however show many machines specifically designed for use as feller bunchers, and others with extensive modifications to layout. This section is aimed at outlining the types of felling machine available, their features, and any information indicating their application. All detail was obtained through a search of relevant literature plus correspondence.

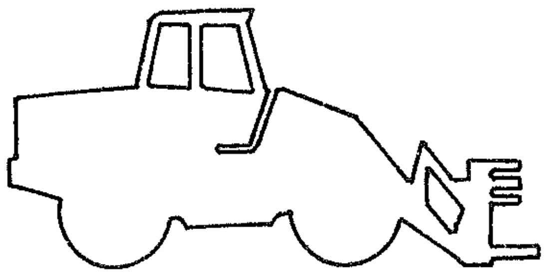
3.1 MACHINE LAYOUTS:

There are currently five basic types of machine layout in common use, as follows:-

(a) Front-end wheeled loader type machines, where the bucket has been replaced by a front-mounted felling head as shown in *Fig.15a.* Machines in this category include the Clark-Melroe Bobcat, the Caterpillars 910 to 950, the Clark 45, the Timberjack 1700, and the John Deere 544, all of which stem from USA/ Canada.

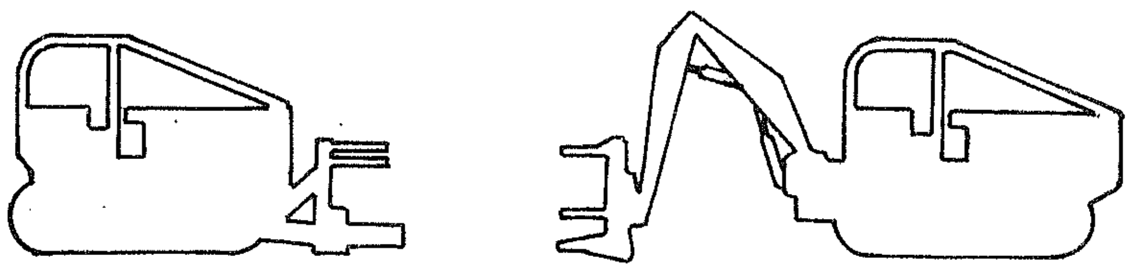
These machines are generally limited to slopes less than 20% (11.3°) for effective production, and rely on machine mobility and speed for felling performance. As a mechanical falling machine a minimum of base machine modifications are required, the feller buncher head generally being an attachment.

(b) Crawler-tractor type machines where the blade or bucket has been replaced with a front-mounted felling head, or alternatively a felling head fitted to a hydraulic knuckle-boom mounted at the rear of the tractor *(Fig.15b)*. Typical base machines in use include Caterpillar D3 to D6's, Case 450, and the Muskeg, these stemming from North America, however Russia has also developed their machines along these lines making use of their tracked



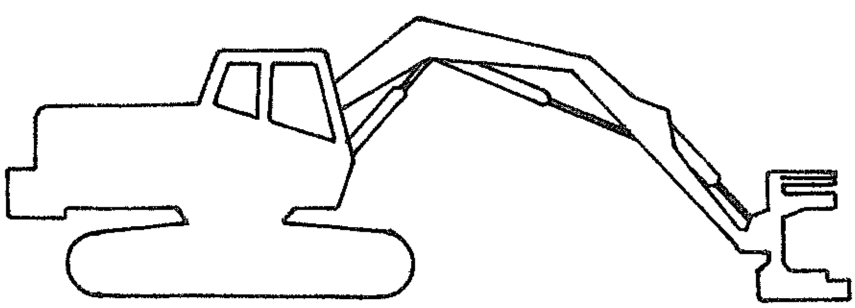
FRONT-END WHEELED LOADER TYPE FELLING MACHINE

Fig.15a.



CRAWLER TRACTOR TYPE FELLING MACHINES

Fig.15b.



EXCAVATOR TYPE FELLING MACHINE

Fig.15c.

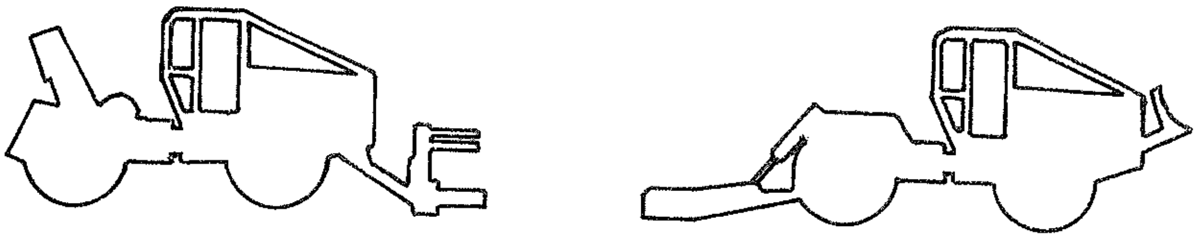
skidders. While the front-mounted head type machine retains the felling attachment concept, the rear crane-mounted head machines have undergone considerable modification. This crane-mounted head gives the crawler-tractor based unit more versatility in handling trees and is aimed at improving felling performance rate due to the slower travel speeds of most crawler machines. The crawler tractor based machine however is capable of working on slopes to 45% (24.2°) and is generally not limited with traction. Performance on slopes of this nature however becomes very inefficient and dangerous.

(c) Track laying excavator type units with boom-mounted felling heads in place of buckets, *(Fig.15c)* machines such as the Drott 40LC, Hitachi UH07 (now known as the UH 750), International 3966, Warner & Swasey 522, Caterpillar 225, Poclain LC80, are in use along with many others.

These machines rely in the main on their swing and reach operation of the hydraulic boom for their cycle times. While some early machines used standard excavator booms many now have a special main boom and arm plus incorporate other features such as modified boom mounts, heavier undercarriage, and modified turntable, etc. Travel speeds of these machines are slow (up to 5 km/h maximum) and they are generally limited to slopes less than 30% (16.7°) for reasonable production.

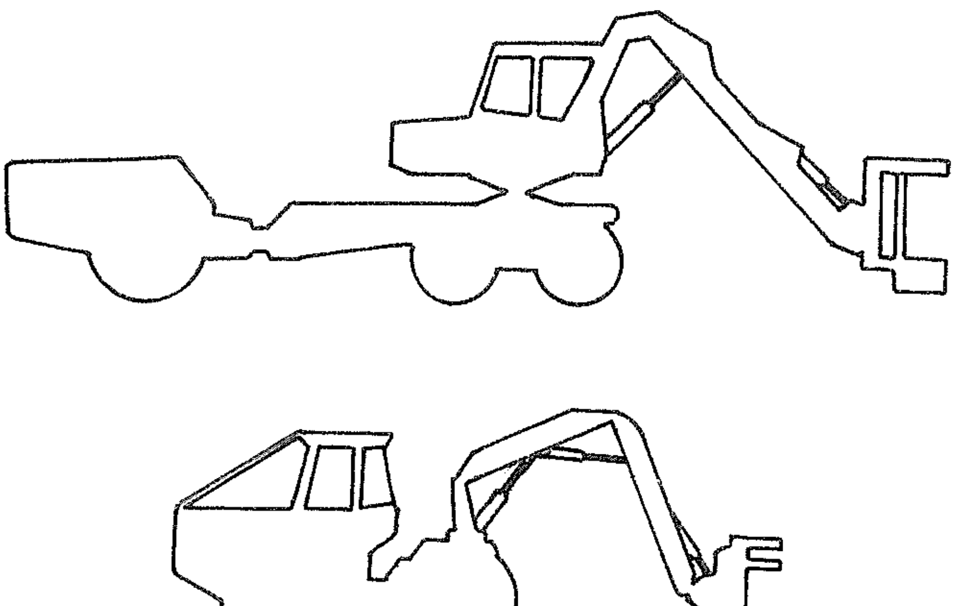
(d) Rubber tyred skidder based machines with felling heads fitted directly either front or rear as shown in *Fig.16a* such as on the John Deere, Clark Ranger, Caterpillar 518 or 528, and Tree Farmer C5 to C8 machines. The rubber-tyred skidder based machines which use the felling head attachment concept mounted front or rear, use the skidders speed, mobility, and manoeuvreability for felling performance and are a similar category to the front-end loader types. They are however more suited to slopes up to 30% (16.7°) and can handle localised ground roughness more readily, plus can be adapted to feller-skidding with the appropriate felling head rear mounted.

(e) Machines designed and build entirely as felling machines. The OSA 670, Volvo 995, Cemet, fall into this bracket, as do the Lokomo 950, Kockum 880, Forano BJ20, and Can Car Clipper, which although initially rubber tyred forwarder and



RUBBER TYRED SKIDDER BASED FELLING MACHINES

Fig.16a.



SPECIALIST FELLING MACHINE LAYOUTS

Fig.16b.

skidder based machines, have undergone such extensive alterations and development that they now cannot be readily re-converted. They are function designed machines on which much development has gone into operator considerations, and are aimed at attaining high performance rates on most ground conditions and slopes up to 35% (19.3°). Consequently, they are the most expensive type of felling machine.

Other variations in felling machine layout occur, but mainly with multiple function machine layouts such as feller skidders, feller delimbers, feller forwarders, etc.

3.2 FELLING HEADS AVAILABLE:

In the main the felling heads are manufactured by separate companies to the base machine manufacturers, and the heads are available for fitment to any suitable base machine, with usually the approval of both manufacturers being required.

There are three main varieties of felling head produced, the felling shear as used on the Cat-QM combination, the feller buncher as on the Bobcat, Hitachi, and Drott machines, and the feller delimber head which we will not cover in this report.

(a) A comparison of known felling shears is tabled in *Fig.17* along with examples of typical base machine mountings. All the felling shears use a single blade which closes against an anvil, with either a scissor or guillotine action.

(b) A similar comparison of known feller-buncher heads is shown in *Fig.18*, and the bulk of these use two shear blades closing with a scissor action. Attachment type accumulator arms are available on some, whilst others are designed with accumulator arms standard.

MAKE	RATED SIZE (cm.)	WEIGHT (kg)	BLADE THICKNESS (mm.)	TYPICAL BASE MACHINES & TYPES
FLECO:	46	770	25	Cat.D3 tractor, Cat 931 tractor.
FULGUM:	51	910	25	Int.TD7 tractor, Can Car C5 skidder.
FOR-MAC:	51	910	16	Ford 4500 tractor.
ESCO:	51	1110	22	Allis Chalmers HD6 tractor.
ROME:	51	1500	25	Cat.920 loader, John Deere 440 skid.
ROANOKE:	56	910	25	Cat D3 tractor, Case W14 loader.
ROANOKE:	61	950	25	Timberjack 230 skid. Cat D4 tractor.
FLECO:	66	1550	32	Cat D4 tractor.
QM:	66	1910	38	Cat D4 tractor, Cat D6 tractor.
ROANOKE:	71	1050	32	Franklin 132 skidder Cat 930 loader.
FLECO:	76	1640	32	Cat D6 tractor, Cat 951 tractor.
FULGUM:	76	1950	32	International TD15 tractor.

TABLE OF KNOWN FELLING SHEARS

(Fig.17)

MAKE	RATED SIZE (cm.)	WEIGHT (kg.)	BLADE THICKNESS (mm.)	TYPICAL BASE MACHINES & TYPES
Allen	30	320	13	Case Uniloader, Melroe Bobcat.
Allen	38	730	13	Cat 910 loader, John Deere 450 tractor.
Roanoke	38	680	13	Inter.TD7 tractor, John Deere 450 tractor.
Fleco	38	730	16	Cat 910 loader, Cat 931 tractor.
Crawford	41	730	13	
Morebark	41	950	13	Melroe Bobcat, Timber-jack 1500 loader.
Drott	41	1000	13	Drott 40 Excav., Case 1150 tractor.
Vulcan	41	1140	13	Inter.125 tractor, Hitachi 440 Excav.
Timmins	41	1360	19	Poclain LC80 Excav.
Poclain	41	1500	16	Poclain LC80 Excav.
Lemco	46	730	13	Cat 941 tractor, John Deere 450 tractor.
Earls	46	1590	13	Terex 82-30 tractor.
Can Car	46			Can Car Clipper special.
Brundell	51	950	13	Kockum 880 special.
Forano	51	1180		Forano BJ20 special.
Crawford	51	1000	13	John Deere 544 loader, Drott 40 Excav.
Allen	51	1410	16	Clark 45 load.,Cat 920 l.
Roanoke	51	1410	16	Liebherr 925 Excav.
Clark	51	1860		Clark 45FB loader.
Harricana	51	1450	16	Cat 225 Excav.
Vulcan	51	2000	19	Hitachi 750 Excav., Inter.3966 Excav.
Rome	51	2180	25	Cat 930 loader, Cat 225 Excav.
Drott	51	2090	16	Drott 40 Excav.
Timmins	51	2050	19	Liebherr 925 Excav.
Morebark	51	2500	19	Timberjack 1700 loader.
OSA	56	900	13 (chainsaw)	OSA 670 special.
QM	56	2950	22	Cat 225 Excav.
OSA	56	600	19 (chainsaw)	Valmet 882KK special.
Drott	61	2730	22	Drott 965 Excav.
Vulcan	63	3320	19	Hitachi 965 Excav., Poclain SC 150 Excav.
Volvo	65		19 (chainsaw)	Volvo 995 special.
Poclain	71	3680	25	Poclain SC 150 Excav.
QM	76	3860	25	Cat 235 Excav.
RMS	76			Cat 235 Excav.

TABLE OF KNOWN FELLER BUNCHER HEADS

(Fig.18)

3.3 PERFORMANCE AND COSTS:

The productive use of shears and feller bunchers in particular, has been confined mainly to the 1970's and comprehensive data sources on felling machines are thus few in number. Some North American and Scandinavian publications however give significant information that is referred to here, to confirm plus add to some of our local findings.

Canadian reports of the late 1960's[1] indicate production rates of 60 and 180 cu.metres/hour achieved in trials of crawler-tractor mounted tree shears, felling tree sizes 21cm. mean DBH x 0.37 cu.metres mean stem volume, and 38cm. mean DBH x 1.55 cu.metres mean stem volume, respectively. Shear machine felling rates were considered to be four or five times that achieved manually with power saw, and a 40% savings in felling costs was reported. Tree volume was considered as the prime factor governing volume production rate, whilst stand stocking was considered to affect felling performance rate (trees per hour) rather than tree volume. The crawler tractor with front mounted shear showed a 96% machine availability and was studied in operations on slopes up to 30%.

A 1973/74 North American book[2] indicates that maximum achievable productivity of an excavator based feller buncher was reduced 5% by a 10% (4.7°) slope, 20% by a 20% (11.3°) slope, and 50% by a 35% (19.3°) slope.

A more recent 1976 Canadian study of multifunction harvesting machines[3] indicates feller bunchers productivity as 24 cu.metres per hour in trees with mean volume 0.155 cu.metres. The machine cost was $140,000, total operating cost was $31.50 per productive machine hour, and an average machine availability of 87.5% was expressed.

Sweden's Logging Research Foundation, Skogsarbeten, followed Swedish feller buncher developments during 1972/3/4, and indicated the following as applicable to the specialist type felling machine layouts referred to in section 3.1 (e) of this report[4]. Volume production rates of these type of feller

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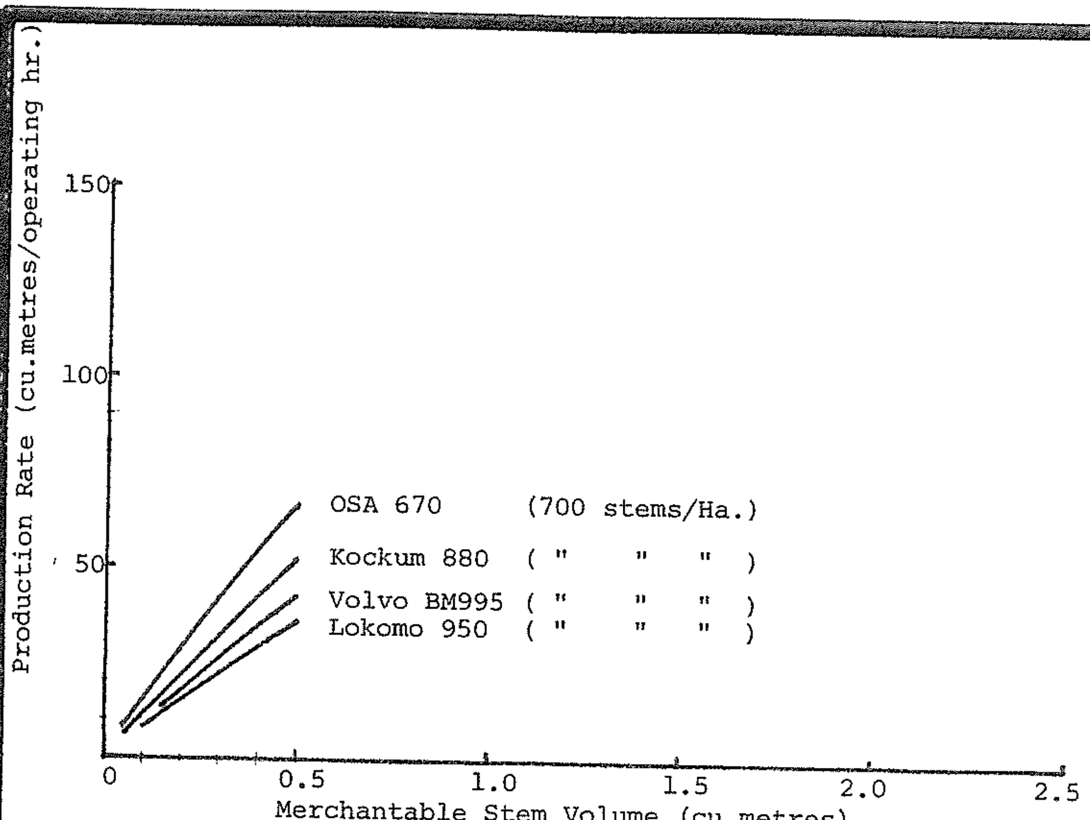
1 "Tree Shears Reduce Felling Costs, Offer Other Savings" by J.A.McIntosh and E.C.Kerbes. A reprint from Canadian Forest Industries, 1968.

2 "Timber Cutting Practices" by Steve Conway. A Forest Industries Book, 1974.

3 "Economics and Productivity: Multifunction Forest Harvesting Machines" by John Kurelek. A Pulp & Paper, Canada, article, 1976.

4 "Logging With Feller Bunchers" by Hans Berg, Tord G.Lindberg, Jan Sondell. A Skogsarbeten report, 1974.

bunchers varies as shown in *Fig.19*, this ranging from approximately two times the volume production rate achieved manually with power saws in the smaller 15cm. DBH stems to approximately four times the manual rate in 25cm. DBH stems. They indicate that tree size has little influence on felling performance in trees per hour, and that felling performance is affected by stocking, and also understory growth, ground roughness, and darkness. They use a general conclusion that stump diameters are 20% greater than DBH. Specialist type feller buncher machines as covered in the study vary from $25,000 for a 40kW powered unit to $175,000 for a 160kW powered unit. Total operating costs of these sized machines with operators, ranged from approximately $15 per hour to $55 per hour as shown in *Fig.20*. They indicate a minimum machine availability of 80% as being desirable by 1980 in these machine types.



PRODUCTION RATES OF FELLER BUNCHERS

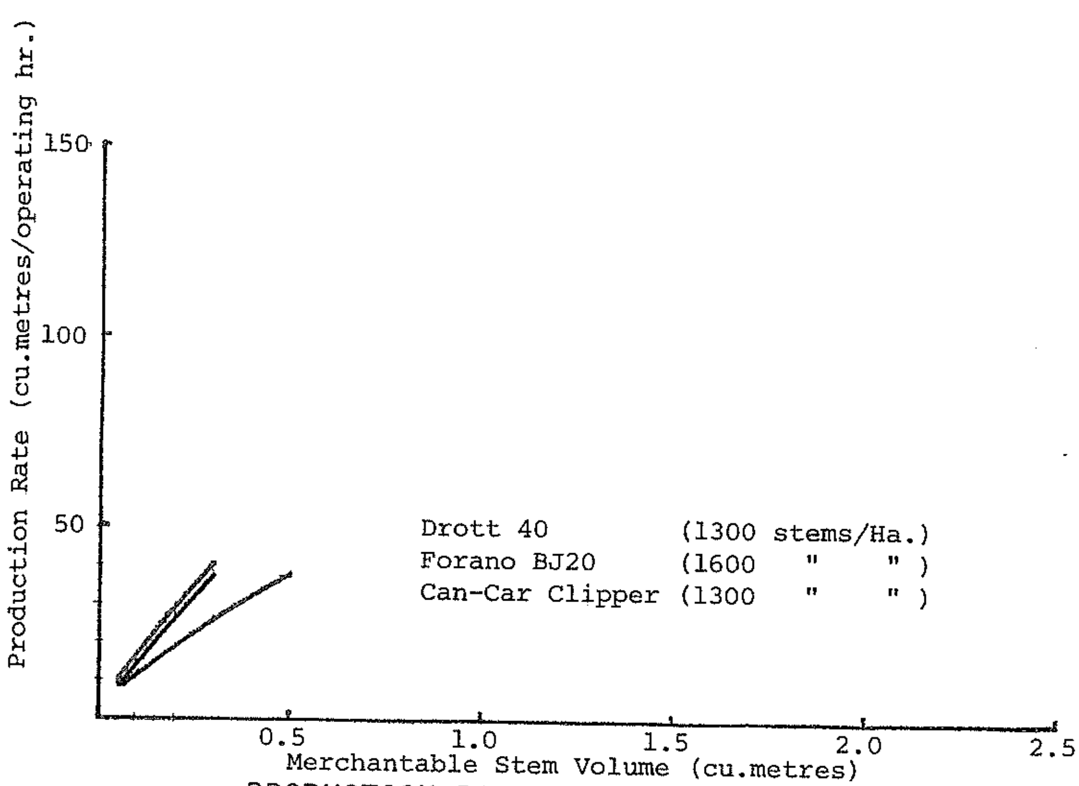
(Skogsarbeten)

(Fig.19)

Initial Machine Cost $	Power Rating kW	Total Machine Operating Cost $ per hour
25,000	40	15
75,000	80	29
125,000	120	41
175,000	160	54

CAPITAL AND OPERATING COSTS OF SWEDISH FELLER BUNCHERS

(Fig.20)



PRODUCTION RATES OF FELLER BUNCHERS

(Metsateho)

(Fig.21)

In a separate study by Skogsarbeten they produced a report outlining an "Ergonomic Checklist for Transport and Materials Handling Machinery"[1]. This checklist is relevant to felling machines, and covers thirteen different aspects ranging from mounting the machine, operator seating, controls, lighting, noise, etc., through to exhaust emission and maintenance. It is a recommended reference.

In a 1975 study of feller bunchers for Finnish conditions, Metsateho summarised the above Swedish study and extended this to cover North American and Russian felling machines of the excavator machine types[2]. They indicate volume production rates from 20 cu.metres per hour to 50 cu.metres per hour being achievable depending on tree size and conditions of operation, with machine prices varying from $37,500 to $87,500. *(Refer Fig.21.)*

The American Pulpwood Association (A.P.A.) have in recent years produced a large number of summary reports covering different felling machines[3]. *Fig.22* summarises the information presented in them indicating machine types, costs, and performances.

Recent comparative logging equipment operating cost figures published in Canada[4] indicate for machines in the 75kW to 100kW range, that skidders operate at $0.15 to $0.20 per kW-hr., front-end loaders operate at $0.20 to $0.25 per kW-hr., crawler tractors operate at $0.20 to $0.30 per kW-hr., and excavators operate at $0.30 to $0.35 per kW-hr. Although N.Z. costs will be different these figures provide a comparison between different base machine types.

A further North American, 1973 report[5] indicates the effective application area for accumulator attachments being in the very small tree sizes up to approximately 20cm. DBH x 0.2 cu.metres per stem where volume production rates can be doubled. In trees exceeding this size the accumulator use becomes ineffective and above trees of 25cm. DBH x 0.4 cu.metres size, single stem felling is best.

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1 "Ergonomic Checklist for Transport and Materials Handling Machinery" by Aminoff, Hansson & Pettersson. Revised by Skogsarbeten 1974.

2 "Feller Bunchers and Their Use in Finnish Conditions" by Esko Mikkonen. A Metsateho Review article, 1975.

3 Miscellaneous items from the American Pulpwood Association Technical Release Series.

4 "Interlog" February 1977. The British Columbia Independent Logging Association's journal.

5 "Rome Shear Head Application on 80 to 100 h.p. Wheel Loaders" a 1973 Rome Job Report.

YEAR OF APA REPORT	FELLING MACHINE TYPES	FELLING HEAD SIZE RANGE	COST RANGE	FELLING PERFORMANCE TREES/HR.	CU.METRES/HOUR
1970	3 front-end loader types 1 skidder type 1 excavator type	30cm.-51cm.	$2,250 - $4,950 attachment cost	40 - 100	5 - 10
1971	1 front-end loader type 2 crawler tractor types 1 excavator type 1 specialist felling machine	30cm.-61cm.	$1,200 - $7,000 attachment cost	40 - 100	8.5 - 25
1972	1 crawler tractor type 1 specialist felling machine	46cm.-127cm. (saw)			
1973	3 front-end loader types 2 crawler tractor types	41cm.-53cm.	$21,000 - $60,000 complete machine	- 35	10 - 20
1974	1 excavator type	51cm.	$63,000 complete machine	45 - 70	
1975	1 front-end loader type	30cm.	$8,000 attachment cost		10
1976	2 specialist felling machines	51cm.-56cm.	$130,000 complete machine	180	
1977	1 front-end loader type 1 skidder type	51cm.	$20,800 attachment cost		9 - 63

TABLE SUMMARISING A.P.A. FELLING MACHINE REPORTS

(Fig.22)

- 4 -

CONCLUSIONS & DISCUSSION

4.1 POTENTIAL IN NEW ZEALAND FOR FELLING MACHINES:

All types of felling machine are restricted to generally flat terrain of less than 20% (11.3°) slope in order to achieve reasonable performance levels. The New Zealand exotic forest areas possess a wide range of terrain and topography types, however there are some extensive areas of generally flat terrain suited to felling machine operations. Assessing these suitable felling machine areas in N.Z., the current production levels from them indicate that approximately 25% of the total N.Z. exotic felled volume is suited to felling machine application. The bulk of this potential felling machine production (93% of it) lies in the Kaingaroa and Waimihia State Forests[1,2]. See Appendix III.

The felling machines currently available indicate the felling shears as being suited to producing in trees up to approximately 55cm. mean stand DBH and 2.0 cu.metres mean stem volume, while the feller bunchers are more restricted to the smaller trees up to approximately 35cm. mean stand DBH and 1.0 cu.metres mean stem volume depending on machine size. The 1974 survey of the logging industry by F.R.I.[3] indicates that the mean piece sizes extracted in exotic clear-felling operations averaged 1.78 cu.metres for all extraction systems, and 1.67 cu.metres for extraction by skidder and crawler tractor only which is more indicative of the flatter country. This lies within the capacity of felling machines.

If felling machines were to be applied solely to clearfelling the estimated current New Zealand exotic roundwood production levels from felling machine suited areas would support between 16 and

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1 "Statistics of the Forest Industries of N.Z. to 1974" N.Z.Forest Service Information Series.

2 "Report of the Director-General of Forests' Annual Report for the year Ended 31st March 1976"

3 "A Survey of the Logging Industry for the Year Ended 31st March 1974" by Fraser, Murphy and Terlesk. An FRI Economics of Silviculture Report, 1976.

50 felling machines if used to replace all manual felling operations. See Appendix IV. These figures are based on estimated factors and are presented solely to indicate the order of the number of felling machines New Zealand could support.

The immediate application areas with greatest potential are in the felling of the poorer species such as Ponderosa, where labour availability, cost, and safety aspects present current difficulties.

Felling machines, and more particularly the feller buncher type, possibly have some application potential in the harvesting of windthrow due to the dangers that exist in manual breaking out and cutting of windthrown trees. This however requires evaluation. The application of feller buncher type machines to whole tree pulling including stump uprooting before shearing, is also being evaluated overseas, particularly where the cost of wood within the stumps can justify this approach.

4.2 THE EFFECTIVENESS OF SHEARS & FELLER BUNCHERS:

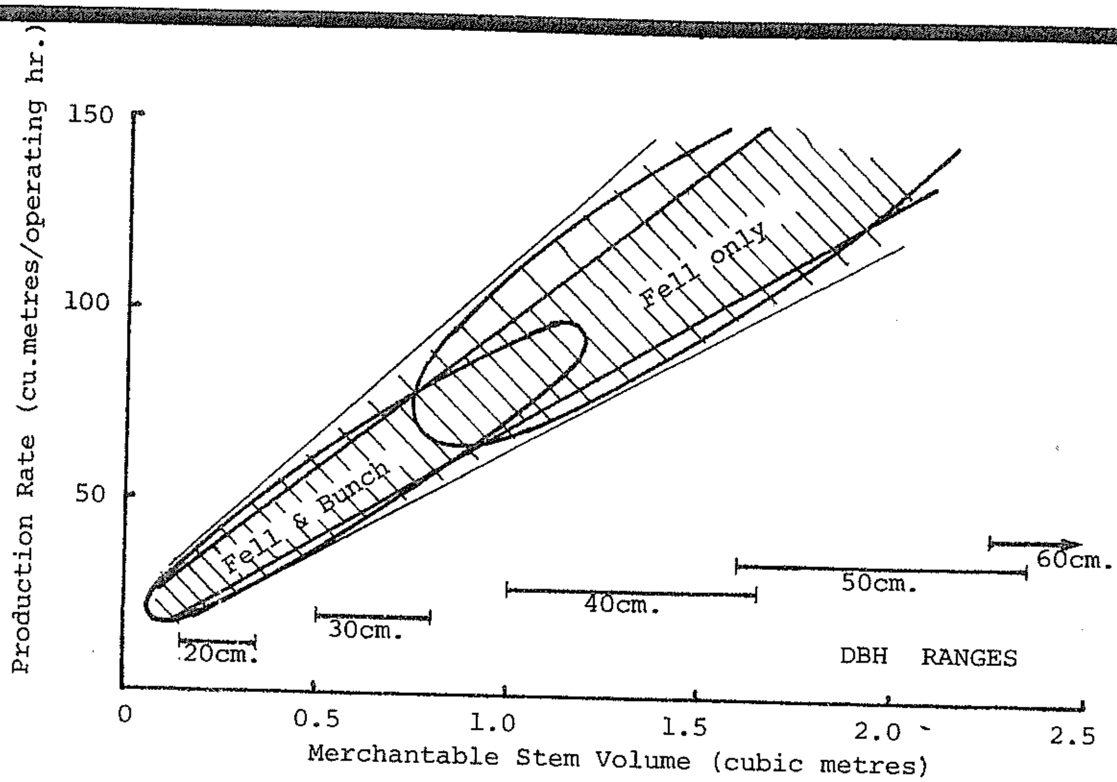
Felling machines produce lower stumps resulting in better volume recovery, and a cleaner forest floor.

The better volume recovery in pulp and chip logs is of the order of 5%, however in saw and peeler logs it is probably offset by the small amount of butt shatter occurring. The extensive butt shatter as occurs overseas in frozen wood operations should not occur in the major New Zealand felling machine application areas. The extra volume recovery at the stump however, results in logs with a greater degree of butt swell and the use plus processing of this by following equipment should be considered.

Although not studied in detail, the cleaner forest floor from machine felling will result in less wear and tear on machines used in the following operations of log extraction and forest re-establishment.

4.3 INFLUENCE ON PRODUCTIVITY & COSTS OF FELLING:

Felling machine volume production rates are higher than manual power saw rates by approximately two times in the smaller 20cm. to 30cm. DBH trees, and by approximately five times in the larger 45cm. to 55cm. DBH trees. The major factor determining felling machine volume production rate capacity is tree volume as illustrated in *Fig.23.*



FELLING MACHINE PRODUCTIVITY

(Fig.23)

Although felling machine costs are high compared with manually operated chainsaws, their current utilisation can be justified through their higher production rates, suitability to use in conditions restricting manual chainsaw felling (darkness, wind, rain, etc.) and improved working conditions for felling personnel. Felling machines cost from $25,000 to $175,000 at purchase and cost from $10 per hour to $60 per hour to operate, dependent on the size and layout type of machine. Skidder based units will be cheapest to operate, followed by front end loader and crawler tractor based units, then excavator based units, and the specialist felling machine units.

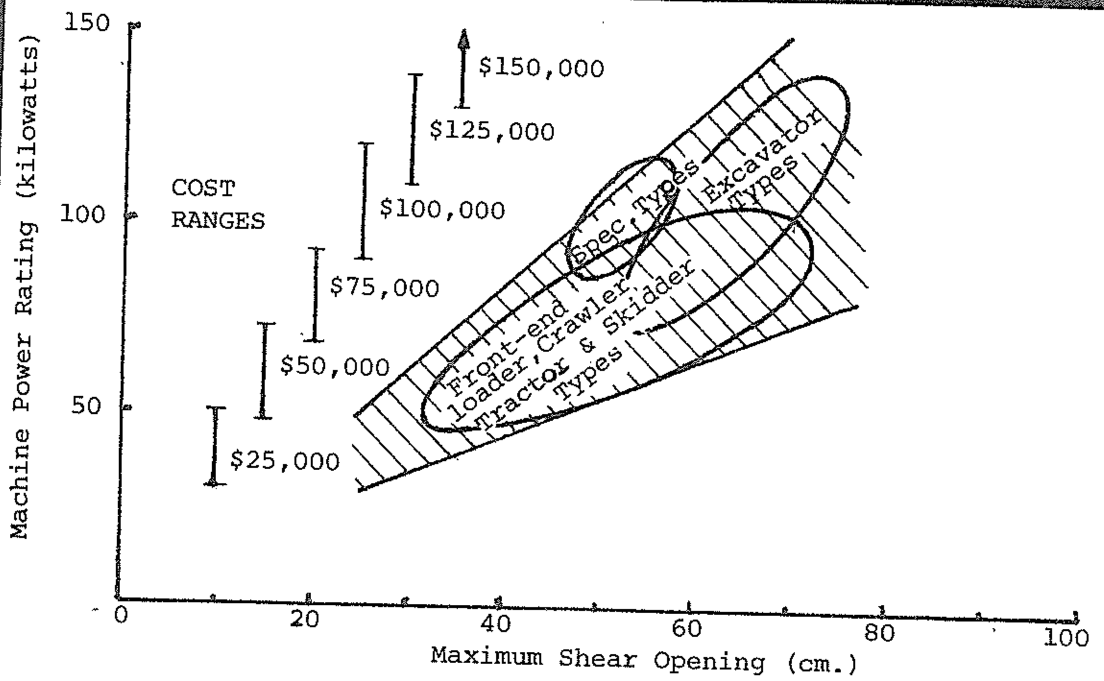
4.4 THE EFFECT OF FELLING MACHINES ON LOGGING SYSTEMS:

An important aspect in felling machine application is that other activities in the whole forest harvesting system, such as trimming, extracting, loading, transporting, etc., must be capable of matching the higher performance rates, and larger productive shift-hours where achieved.

While the productivity of felling machines is not greatly influenced by whether a felling head or a feller buncher head is used, the productivity of the following system operations is affected. The feller buncher felling machine has the ability to place felled trees in positions that can improve the performance rates of following operations, whether manual or mechanised.

4.5 FELLING MACHINES SUITED TO N.Z. APPLICATION:

Basically five different layout types of felling machine are available including the front end wheeled loader type, the crawler tractor type, the excavator type, the rubber-tyred skidder type and the specialist type. Both the layout type and sizing of machine used play a large part in determining initial cost, as indicated in *Fig.24*, and machine performance.



FELLING MACHINE SIZES AND COSTS

(Fig.24)

The New Zealand situation puts our industry remote from the equipment manufacturers and a top rated spares supply, we also require equipment with versatility in logging operations and we have a limited resale potential of specialist equipment. These aspects indicate a preference for a standard type base machine such as the crawler tractor, front-end loader, excavator, and skidder, using an attachment felling head. Selection of base machine type however should depend on a combination of factors such as terrain, tree crop factors, cost, current equipment fleet standards, ease of operator training, machine versatility, etc. The crawler tractor type will be more suited to steeper slopes, is a versatile machine for other applications, and is certainly in common use throughout the New Zealand logging and construction industry. The excavator type however results in a minimum of ground disturbance, and currently provides the best operator comforts, in particular, ride. The rubber tyred front-end loader and skidder types will be the lower costing units and the most mobile when off the job.

The actual machine size selected should be based on expected tree size to be handled and this can be indicated by comparing *Fig.23* and *Fig.24*.

A large variety of felling head types and sizes are available, and those where committed to particular base machine brands will influence choice. Current felling shears are sized up to approximately 75cm. capacity and are suited to felling all tree sizes up to approximately 60cm. DBH. Feller buncher shear heads, are more common up to approximately 55cm. capacity (some models are available up to 75cm. capacity) and are more commonly used in tree sizes up to approximately 30cm. DBH. The size of felling head should be based on tree stump diameters which can be up to 30% greater than tree DBH plus the expected stand tree size variation. Too large a felling head adds to machine costs, on the other hand too small a felling head can slow felling performance rates considerably thus particular attention should be paid to sizing.

COMPARISON OF FELLING MACHINE SPECIFICATIONS

FELLING MACHINE:	*CAT D6C MOUNTED QM SHEARS*	*BOBCAT 1075 F/B*	*HITACHI UH07 F/B*	*DROTT 40LC F/B*
Undercarriage:	Crawler	Tracks over rubber	Crawler	Crawler
Engine Power:	104 kW	61 kW	69 kW	117 kW
Felling Machine Weight:	15 tonnes	6.9 tonnes	19.0 tonnes	24.2 tonnes
Overall length (shortest)	6.0m.	3.8m.	6.5m.	7.2m.
Overall width	2.4m.	2.3m.	2.8m.	3.4m.
Height (top of cab)	2.8m.	2.4m.	3.0m.	3.2m.
Turning Description	pivot turns	spin turns	spin turns	spin turns
Slewing description	Nil	Nil	360° slew	360° slew
Max.reach from machine.	4.2m.	2.0m.	7.3m.	7.6m.
Ground pressure	0.70 kg/cm^2	0.40 kg/cm^2	0.46 kg/cm^2	0.48 kg/cm^2
Grade Ability	100%		58%	60%
Max.Travel Speed	11.0 km/h	10.0 km/h	2.6 km/h	2.3 km/h
Felling Head Type:	Q.M.	Morebark	Vulcan	Drott
Shear opening	66cm.	38cm.	51cm.	61cm.
Knife configuration	single	twin	twin	twin
Knife thickness	38mm.	13mm.	19mm.	22mm.
Limiting hydraulic pressure	155 bars.	155 bars.	172 bars.	172 bars.
Felling head weight.	1.9 tonnes	1.0 tonnes	1.6 tonnes	2.6 tonnes
Head tilt forward	Nil.	87°	90°	) - 100°
Head tilt rearward	Set by adjustment	11°	10°	)
head tilt each side	Nil.	Nil.	20°	8½°
Optional accumulator	Nil.	Fitted	Not fitted	Fitted
Operator's Cab:	Open Bush Canopy	Unglazed cab.	Fully enclosed.	Fully enclosed.
Cab Access:	side	front	side	side
Operator position with respect to tree:	4.3m.directly behind	1.8m.directly behind	6.8m.behind to left.	7.0m.behind to left.
Hand control levers	4	2	6	3
Foot Control pedals	2	3	2	4

APPENDIX II

DESCRIPTION OF TIME ELEMENTS

QM SHEAR ELEMENTS:

Shear - starts with shear head in position at tree
- finishes as tree hits ground after falling.

Approach & Position- starts when moving from felled tree to next.
- finishes with shear positioned at next tree, ready to fell.

Clearing - starts at any point in cycle with the aim of clearing cull trees and undergrowth.
- finishes when the machine is ready to proceed with other elements.

BOBCAT ELEMENTS:

Shear - starts with shear head in position at tree.
- finishes with completion of shearing through stem.

Carry & bunch - starts at completion of stem shearing.
- finishes as tree hits ground after felling and bunching.

Reposition - starts when moving from felled tree to next.
- finishes with shear positioned at next tree ready to shear.

HITACHI ELEMENTS:

Shear - starts with shear head in position at tree.
- finishes with completion of shearing through stem.

Swing Loaded - starts at completion of stem shearing.
- finishes at completion of swing with tree upright ready to fell and bunch.

Bunch - starts with tree upright ready to be bunched by machine.
- finishes as tree hits ground after felling and bunching.

Swing empty - starts when swing from felled tree begins.
- finishes with shear positioned at next tree ready to shear.

Travel - starts with movement of tracks to reposition machine
- finishes with completion of track movement.

Clearing - starts at any point in cycle with the aim of clearing cull trees and undergrowth.
- finishes when machine is ready to proceed with other elements.

DROTT ELEMENTS:

Shear, swing loaded, bunch, swing empty - starts with shear head in position at tree.
- finishes with shear positioned at next tree ready to shear.

Travel - starts with movement of tracks to reposition machine
- finishes with completion of track movement.

Clearing - starts at any point in cycle with the aim of clearing cull trees or undergrowth.
- finishes when machine is ready to proceed with other elements.

APPENDIX III

CURRENT NEW ZEALAND PRODUCTION SUITED TO FELLING MACHINE APPLICATION

The exotic forest areas in New Zealand that have a major portion of their area considered suitable by slope for felling machine application, are listed below. (It is appreciated that there will be areas within these listed forests that will be too steep for felling machines, and we have assumed that this will be offset by those suitable flat areas that occur in the private and state exotic forest areas not listed.) The production figures from these areas are listed as extracted from references [1] and [2], page 35 of this Project Report.

Forest Considered Suited	Clearfelled Area in 1974/75 with Yield (Ha)	Exotic Roundwood Production in $1000m^3$			
		1974/75			1973/74
		Clearfell	Thinning	Total	Total
Aupouri	9	2.5	2.6	5.1	3.9
Woodhill	63	17.9	45.4	63.3	74.0
Kaingaroa	2506	2037.1	311.1	2348.2	2097.1
Lake Taupo	0	0.0	0.0	0.0	0.0
Waimihia	409	105.5	0.0	105.5	195.1
Santoft	3	0.1	4.5	4.6	6.0
Waitarere	52	35.0	0.4	35.4	30.6
Balmoral	103	41.4	1.9	43.3	41.7
Eyrewell	9	1.8	0.4	2.2	24.8
TOTALS:	3154	2241.3	366.3	2607.6	2473.2
Estimated Total NZ Roundwood Production from State and Private:				8500-9500	8000-9000

The portion of N.Z.'s total exotic roundwood production that could be felled by felling machine, assuming clearfelling application only, and suitable stem sizes, is between:

$$\frac{2241.3}{9500} \text{ and } \frac{2241.3}{8500} = 23.6\% \text{ and } 26.4\%$$

i.e. approximately 25% of total exotic roundwood production.

The Kaingaroa and Waimihia Forests form approximately 93% of the potential felling machine application whether considering area,

$$\left(\frac{2506 + 409}{3154} = 92.4\% \right)$$

or production,

$$\left(\frac{2348.2 + 105.5}{2607.6} = 94.1\% \right)$$

MARKET POTENTIAL FOR FELLING MACHINES IN N.Z.

A general indication of the number of felling machines that N.Z. exotic forest production levels could support is achieved by considering the production suited to felling machines as outlined in Appendix III, the mean stem sizes from the suitable forest areas, and the possible felling machine production rates under these conditions *(see Fig.23)*.

Total 1974/75	production	suited	to	felling	machines	is	2.24 million
Estim. current	"	"	"	"	"	"	2.5 "
Estim. 1980	"	"	"	"	"	"	3.1 "

The Kaingaroa-Waimihia forests form over 90% of potential applicatio[n] area for felling machines, and it is considered that the mean stem size of harvest trees lies in the range $0.5m^3$ to $1.75m^3$ per stem.

Felling machine production rates with stems of this size will lie in the range $40m^3$ to $125m^3$ per operating hour. Assuming 65% felling machine utilisation on single 8-hour shifts over 240 days per year, the annual production per felling machine will lie in the range:

$$40 \times 0.65 \times 8 \times 240m^3 \text{ to } 125 \times 0.65 \times 8 \times 240m^3$$

i.e. $50,000m^3$ to $156,000m^3$ per machine per year.

The 1974/75 potential felling machine production would thus support between 14 and 45 felling machines dependent on stem volumes.

The current potential felling machine production would thus support between 16 and 50 felling machines dependent on stem volumes.

The estimated 1980 potential felling machine production would thus support between 20 and 62 felling machines dependent on stem volumes.

This analysis is presented purely to indicate the order of the number of felling machines New Zealand could support. Very important aspects such as capital availability, machine utilisation, fitting machines into harvesting systems, cost of production, and actual forest stem sizes, were not taken into account.