LOGGING INDUSTRY RESEARCH ASSOCIATION

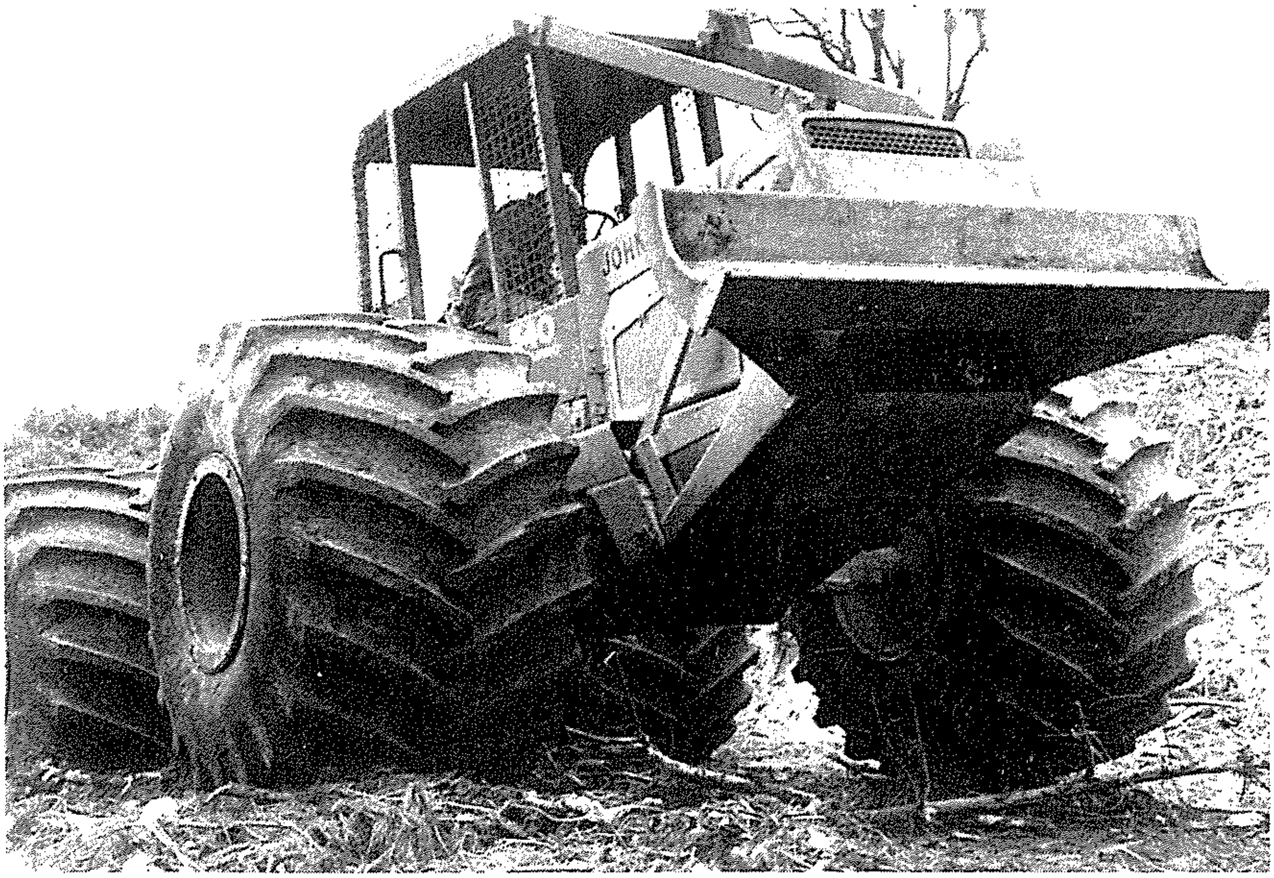
NEW ZEALAND

PROJECT REPORT

RESTRICTED CIRCULATION

A PROJECT TO INVESTIGATE THE USE OF WIDE TYRES ON A SKIDDER IN NEW ZEALAND

R. PREBBLE, W. BLUNDELL, E. ROBERTSON, P. COSSENS.



Project Report

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

A PROJECT TO INVESTIGATE THE USE OF WIDE TYRES ON A SKIDDER IN NEW ZEALAND

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Prepared by:

R. Prebble,
New Zealand Logging Industry
Research Association (Inc.)

W. Blundell,
Forest Research Institute.

E. Robertson,
Forest Research Institute.

P. Cossens,
Forest Research Institute.

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For information address the NZ Logging Industry Research Association (Inc), PO Box 147, Rotorua, New Zealand.

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- *Machine operator Merv Bennett for the skilled and conscientious service he gave during the project.*

SUMMARY

A 75 kW skidder and five 100 cm (43") wide tyres were imported for trials in New Zealand. The machine and tyres were evaluated over a ten-month period in nine forest locations throughout the North Island.

The project was designed to measure the difference between wide and narrow tyres in controlled experiments and in long-term production studies. Tyre wear and damage was also monitored.

The **controlled experimentals** *examined the effects of the two different tyre types on the soils, and the effects of the tyres on various machine activities, e.g. climbing ability, traction, fuel consumption etc.*

Soil compaction *studies were conducted in Maramarua and Mangatu forests. There was very little difference between the compactive effect of wide and narrow tyres in the soil conditions experienced.*

The machine passes done in the compaction tests were also used to measure **surface rutting** *and* **wheel slip**. *Other surface rutting tests were set up in Tarawera Forest. There was little difference in rutting between wide and narrow tyres on flat ground, but wide tyres caused less disturbance when travelling uphill. Wide tyres also caused less rutting on scoria soils with slopes up to 26% and on highly erodible soils at Mangatu. Test results were difficult to interpret because soil moisture was variable.*

The wide tyres had less **wheel slip** *than narrow tyres in most circumstances. This would have influenced the degree of rutting that occurred.*

Tractive capacity *tests were done on a flat gravel surface at Mangatu forest. A crawler tractor, connected to the skidder winch rope through a load cell, was used to apply a pre-determined load. Two different tyre pressures were tried in the wide tyres. The wide tyres had less slippage than the narrow tyres under all loaded conditions. As the load increased, the difference between wides and narrows became greater. The wide tyres inflated to 103 kPa had more traction than they did at 69 kPa.*

Climbing tests *were set up in Kinleith, Kaingaroa, Matahina, Woodhill and Tarawera Forests. Other extraction machines in the vicinity were tested if available. The wide tyred skidder could consistently climb further up the slopes than the other rubber tyred skidders tested. The same skidder on narrow tyres also performed well in the climbing tests. Tracked machines could climb further than the rubber tyred skidders.*

The **stability** *of the skidder on side slopes was recorded in both a structured test and in production situations. The wide tyres made the skidder very stable on steep side slopes, even when travelling over stumps and slash. Wider than normal axles made the test skidder more stable than other skidders of similar capacity i.e., even when on narrow tyres.*

Attempts were made to determine the **stopping ability** *of the skidder on the two different tyre types. The wide tyres did not appear to offer any advantages over the narrows.*

In two forests, Tarawera and Mangatu, **controlled fuel consumption** *tests were run. The wide tyres offered no advantage over narrow tyres in the scoria soils at Tarawera. Heavy rain between tests at Mangatu rendered the results there invalid.*

Tests to determine **functional differences** *between the two tyre types were also conducted. The turning circle of the wide tyres was 30 cm wider than the narrow tyres. Spacers had been installed in the skidder steering rams to prevent the wide tyres from touching during turns. This would have affected the turning circle.*

Machine **stability when winching** *was tested and it was found that the skidder was more stable on wide tyres, although similar line tensions could be achieved with either set of tyres.*

The **long term production studies** *compared the performance of the skidder on the two tyre types. Data was collected in detailed time studies and on a daily basis.*

The intention had been to compare the relative productivity and fuel consumption under similar conditions in each forest. However in most studies there was too much variation in piece size between the wide and narrow tyre studies to make meaningful comparisons. Overall the wide tyres were as productive as the standard size, with higher unloaded travel speeds, particularly on steeper slopes, reflecting improved machine stability. However these advantages were offset by reduced manoeuvreability and increased bladework. The wide tyres showed higher production on clay soils, whereas the narrow tyres performed better on pumice and scoria soils.

Comparing **fuel consumption** *for the whole trial period, the skidder with wide tyres used 8% less fuel per productive machine hour than it did with the narrow tyres. When fuel consumption was related to m^3 produced, the fuel saving was 10%.*

The wide tyred skidder was not considered suitable for **thinning on steep slopes** *because it was difficult to control when travelling over slash and loose tops. Operator safety and damage to residual stems were the main concerns in this application.*

Unusually dry weather conditions *had a detrimental effect on the project. In most situations, ground conditions were more stable and soil was much firmer than expected, particularly in Ngaumu and Mangatu forests. The net result was that the wide tyres offered no advantage over narrow tyres in machine performance, and there was little if any difference in soil disturbance or compaction between the two tyre types.*

Wide tyres on skidders could have application in New Zealand where swampy or consistently wet areas are being logged, e.g. West Coast of the South island and some of the forests in low lying clay areas, such as North Auckland, Masterton and parts of the East Coast where flotation may be as important as traction. Benefits could also be realised using wide tyres in sand forests such as those found in the Northland and Wanganui areas.

One of the most impressive features of the wide tyres in the New Zealand trials, was the stability they gave the machine on side slopes. Where an operation involving large amounts of cross slope *travel is envisaged, wide tyres could offer considerable advantages. It must be remembered however, that their climbing ability, while being superior to narrow tyres, was not as good as track mounted machines, and could be affected by the concentration of slash on the ground.*

Further trials under more adverse conditions would be essential before wider implementation of wide tyres on skidders is considered. Recommendations are made to narrow down the scope of future trials to a smaller number of forests and a more uniform tree size. This would enable a machine better suited to the requirements of the job to be selected. It is suggested that timetables should be flexible to allow for abnormal weather conditions, and that local constraints likely to restrict production be identified and sorted out before the project starts.

The concept of using a working group to control the project, with LIRA as the administrative agent, worked successfully and is recommended for other trials. Employing one operator for the whole project also proved successful in reducing the amount of time lost through training and familiarisation.

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INTRODUCTION

Wide tyres have been used on skidders working in sensitive terrain in the United States and Canada since the late seventies. Considerable research has gone into the use of these tyres and manufacturers have responded by producing a range of different sizes and constructions for a variety of applications. Claims of significant improvements in productivity, combined with reductions in fuel consumption, prompted interested companies in New Zealand to investigate the use of wide tyres in this country.

Three major companies (New Zealand Forest Service, NZ Forest Products Limited and Tasman Forestry Limited) formed a Working Committee using the New Zealand Logging Industry Research Association (LIRA) as the coordinating body. Two other companies, Henderson & Pollard and Dunedin City Council also made a financial contribution towards the trials. The Harvest Planning Group of the Forest Research Institute (FRI) was asked to do the soil impact analysis and the production studies.

A 75 kW (94hp) John Deere cable skidder (equipped with standard 63 x 23.1-26 tyres), and five wide 66 x 43-25 tyres (see footnote) were imported for the trials. Each company was responsible for arranging suitable test sites and the necessary crew and equipment to run their trial. The machine was evaluated in nine forests throughout the North Island of New Zealand with a variety of different ground conditions and soil types. One skidder operator was employed for the 10-month project.

The Project Manager liaised with individual company coordinators to control the day-to-day running of the trials. Wherever possible the wide tyred skidder was used to replace existing machinery in an established operation. It worked in both company and contract crews in the following situations:

(i) Clearfelling radiata old crop.

(ii) Clearfelling thinned Douglas fir.

(iii) Thinning radiata.

(iv) Clearfelling radiata new crop.

Detailed records of terrain types, number of pieces extracted, fuel consumption, tyre damage, hours worked etc., were kept on a daily basis. Where considered necessary, intensive production studies were undertaken to closely monitor performance. The machine was tried on both wide tyres and narrow tyres in each area and in some instances the regular extraction machine was also studied, for comparison.

This Report describes the trials and summarises the results.

BACKGROUND

Research into the use of wide tyres in logging dates back as early as the 1960's. But it was not until 1979 that any real progress was made. The Forest Engineering Research Institute of Canada (FERIC) began an intensive

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Footnote 1.

Tyre sizes expressed as : Outside tyre diameter (in) x Width (in) - Rim diameter (in) e.g. 66 x 43-25.

effort to improve the performance of skidders on soft, sensitive terrain and a four-year research program was undertaken. Mellgren and Heidersdorf (1984) reported on the early trials with Rolligon 54 x 68-18 tyres at Kapuskasing, Ontario. This area falls within the Northern Ontario clay belt which is characterised by deep organic soils, "black muck", overlaid with a thin root mat.

The Rolligons were compared with a set of 65 x 23.5-34 Trelleborg tyres and a set of 68 x 34-26 United tyres. Even with a 24 - 32 cm diameter disadvantage, the Rollingons (on the same machine) still showed a 20 - 25% fuel saving with no appreciable ground disturbance. Practical skidding comparisons set up in the same area recorded 61% higher production per PMH, while fuel consumption was 41% lower with the Rolligon tyres fitted.

Morley (1982) reported on similar experiments in Iroquois Falls, Ontario, with United Super Muskeg tyres. Productivity gains of up to 5.9 m^3 per PMH were recorded, resulting in an overall saving of $US4.34 per m^3. At that stage, (early 1980's), Goodyear and Firestone were also developing "over-width" tyres for logging.

FERIC continued their research with comparisons of conventional 71 x 24.5-32 tyres, Firestone 66 x 43-25's, Rolligon 54 x 68-18's and United's "Swamper" 68 x 50-32 tyres. Once again the Rolligons were superior to the other two. The United tyres required modification before they would perform satisfactorily.

By 1983, FERIC were satisfied that they had progressed as far as they could with improving machine performance in the black spruce swamps, so they turned their attention to other applications for the tyres. Mellgren and Heidersdorf (1984) reported on trials with United "Super Muskeg" 68 x 50-32 tyres which were compared with 67 x 23.1-26 tyres. A 16% increase in speed and associated 18% reduction in fuel usage was recorded on slopes of up to 24%. The soil was wet clay loam, incorporating sand, silt and clay.

Later in the evaluation, some United "Super Swamper" tyres were also tested. The results showed that conventional tyres with chains fitted lost traction when trying to climb up slopes of 28%. The "Super Muskeg" tyres could climb slopes of between 28 and 34% and the "Super Swampers" climbed onto 40% slopes (Note: "Super Muskeg tyres have a shallow lug, designed primarily for swamp work). Sideslope stability was much greater with wide tyres. The "Super Muskeg" and "Super Swamper" tyres handled slopes of 40 and 44% respectively compared to 30% with conventional tyres.

About this time, Weyerhaeuser Company in the US, were trying wide tyres in their operations. Jackson (1982) described trials with Firestone 66 x 43-25's in Arkansas which returned 20% increases in productivity on moderate to wet soils and a 15% improvement on slopes up to 20%. A second trial with United "Super Swampers" in the Twin Harbours region recorded a 31% increase in productivity in wet conditions but a 5% decrease in performance on slopes (up to 20%). Severe ground disturbance, i.e. ruts deeper than 15 cm, was reduced by between 18 and 50%.

Trials in Weyerhaeuser's Oklahoma operations found the Goodyear 66 x 43-25 tyres prone to excessive wear and the evaluation was abandoned, but in North Carolina, these tyres had a 58% higher travel speed than 68 x 34-25's on slopes of 15-26%. The recommendations from these trials were that 66 x 43-25 tyres be used on wet soils and ranging from 15 to 40%.

The impact of rubber tyred skidders on soils has been recorded in many sources, (Mace, 1971; Campbell et al 1973; Dickerson, 1976; Hassan, 1977). These investigations have recorded physical changes in soil properties, e.g.

increases in bulk density and exposed mineral soil, and decreases in macropore space, infiltration rates and organic matter. An increase in bulk density increases the strength of the soil causing increased resistance to root penetration. Studies have shown that tree growth on skid trials is slower than on undisturbed ground (Moerhing and Rawls, 1970; Hatchel et al, 1970; Froehlich, 1979; Murphy, 1983; West and Thomas, 1981).

Field observations have shown that tree root density is reduced in compacted skid trials (Wronski, 1984; Jakobsen, 1983). Highest compaction occurs in the top 30-40 cm of the soil profile which normally contains 70-90% of the root mass of the forest (Wingate-Hill & Jakobsen, 1982). It has been suggested that root penetration can be severely restricted when soil is compacted above 3000 kPa (approximately 30 kg/cm^2) (Sands et al, 1979). Tree growth can also be affected by ground disturbance and skidder operations have been known to displace or remove between 11 and 30% of the organic matter in a logging area (Murphy, 1982 & 1984). Organic matter is important for maintaining favourable soil structure in sandy soils and it also affects the water holding capacity and infiltration of soils.

A reduction in soil infiltration may increase water run-off and result in poor aeration through puddling and waterlogging. The top 30 cm of a soil profile should have a high hydraulic conductivity and high water storage capacity to minimise the effects of short duration high intensity rainstorms (Wingate-Hill & Jakobsen, 1982).

Increasing tyre width has the potential to reduce wheel slip, tyre sinkage and ground compaction and increase travel speeds, operator comfort and safety (Wingate-Hill & Jakobsen, 1982; Radforth, 1978). Models are available to assist in making tyre width versus performance comparisons (Olsen & Gibbons, 1983; Iff et al, 1982; Hassler et al 1983). These models are based on performance equations (Wismer & Luth, 1972) and wheel sinkage predictive equations (Freitag & Richardson, 1967). They all show improved performances using wide tyres on soft or steep ground.

Theoretical equations to calculate the distribution of ground pressure for skidders (Lysne & Burditt, 1983; Froehlich et al, 1980), show that the maximum ground pressure of a loaded skidder is the best indicator for predicting compaction. Other models (Wronski, 1985; Pollock et al, 1984), concluded that the use of wider tyres would help to reduce soil compaction.

A series of studies were conducted at the National Tillage Machinery Laboratory, Alabama, to determine the effects of tyre size, inflation pressure, wheel slip and number of passes on soil compaction. The facility allowed testing of individual wheels in large bins where soil type, moisture content, wheel loads, inflation pressures and wheel slippage could be controlled. It was found that tyre slippage had a greater influence on soil compaction than tyre size (Koger et al, 1982), although higher ply ratings of the larger tyres had influenced the bulk density readings. There was no significant difference in rut depth.

Compaction was greatest at wheel slips of 20-30% (Raghaven et al, 1978). Traction and performance of oversize tyres was improved by operating them at the minimum recommended inflation pressures (Burt et al, 1982), so tyre pressures could be adjusted to suit the soil conditions (Bailey & Burt, 1981). The largest change in bulk density values were found to occur in the first machine pass (Koger et al, 1982), and clay soils were the most susceptible to bulk density increases, followed by sandy loams and loamy sands. Lowering tyre pressures and increasing tyre size (either width or diameter), would decrease the amount of change in bulk density.

Comparisons made in the field have generally recorded reductions in the amount of disturbance to low strength organic soils (Mellgren & Heidersdorf, 1984). On silt loam soil, tyre width and number of passes had the most significant effect on bulk density.

A study conducted in Floyd County, Georgia, in the Southern Appalachians, was set up to determine the effects of tyre width on soil compaction (Green et al, 1983). The soil compaction of a range of tyre configurations was measured, i.e. 16.9-26 Firestones to 68 x 34-26 United tyres. The research was aimed at determining what effect wider tyres with lower ground pressure had. It was found that in dry soils, only limited compaction occurred in three to ten passes and that tyre size had little influence.

When the soils were wetter, i.e. approaching their plastic limit, significant compaction occurred in the first three passes, but again after that further compaction was gradual. Three different machine sizes were tried in this study and it was found that even with a 12.1 kPa increase in ground pressure (due to the heavier machine) no significant difference was apparent when using the same tyres. Using larger width tyres on the same machine did reduce soil compaction on moist soils.

In a Production Information Bulletin, Porter (1983) identified the different applications for wide tyres. The soft "Muskeg" type tyre with minimal lug depth and very flexible carcass was designed for use in swamplands or where minimum ground pressure was critical, e.g. Ontario clay belt. The less flexible carcass with deeper, more aggressive lug was best suited to situations where both flotation and traction were necessary, e.g. South Eastern US. It had been found that on firm dry ground, the wide tyres would take more horsepower to drive than conventional tyres.

Skidder axles also have to be beefed up to withstand the greater stresses imposed on them when using wide tyres. The additional forces that are generated, occur further out from the machine centre which causes increased bending on the axles. In some situations, operators have noticed difficulty turning with wide tyres on.

MacMillan Bloedel Limited carried out some trials on Vancouver Island with Goodyear 66 x 43-25 and 63 x 23.1-26 tyres and Firestone 66 x 43-26's and 66 x 50-26's (Sauder, 1985). The tyres were tested on John Deere 640 cable skidders on four of the sites and on a John Deere 540 in the fifth site. The conditions ranged from flat swampy ground, to slopes of up to 35%. Stand stocking levels varied from 150 to 753 m^3, and skidding distances from 60 to 240 m. While performance differed markedly from site to site, i.e. 9.7 m^3 per PMH to 30.2 m^3 per PMH, predicted shift production was estimated at 125 m^3, or 21 m^3 per productive machine hour.

Tractive capacity tests were also set up to measure the difference in tractive efficiency between wide and narrow tyres. Tyre pressures were varied during these tests to find out what effect tyre pressure had on traction. The results showed that the wide tyres had greater traction than the narrow tyres and that lower pressures (69 kPa) resulted in less slippage. The 127 cm (50") tyres were prone to bouncing and eventually spinning out during the maximum load tests. The Goodyear tyres showed substantial signs of wear after only 1100 hours and it appeared that the 23 degree lug angle of the Firestone tyres gave better traction in slippery conditions.

The evaluation concluded that the wide tyres offered considerable advantages when climbing on slopes and had good side slope stability on slopes as high as 35%. Performance in soft wet ground conditions was far superior to the narrow tyres and the machines were more stable when winching with wide tyres on. One major disadvantage noted was the loss of traction on slash and loose tops due to the fact that the tyres could not penetrate through to firmer ground.

Generally, it was found that the wide tyred machine was hampered by stumps and wet debris on steeper slopes. Where tracking was required, it was necessary to put in wider tracks. Soil bulk density samples were taken during the study, and only one site showed any significant difference, i.e. a 2% increase after 20 passes and a 10% increase after 100 passes.

The Society of Automotive Engineers compared the advantages and disadvantages of wide tyred and dual tyred combinations on log skidders (Jenson and Klaas, 1985). The various tread designs were identified for muskeg swamps, low strength soils, general forestry, and boggy areas where traction is the most important consideration. Dual tyres offer similar advantages to wide tyres and are easier to convert back to the narrow configuration. They do have some drawbacks, such as slash build-up between tyres and the sidewall interaction between the tyres if they are close together. Effective ground pressures for singles, wides and duals had been listed for 75 to 90 kW skidders, and a scoresheet presented to give a guide to optimum productivity and cost according to tyre price, flotation, traction, mobility, requirements etc.

An article about Crown Zellerbach's tree farm operation in Veronia, Oregon (Forest Industries, 1985), reported on the performance of a 518 Cat skidder fitted with a swing-boom grapple working in Douglas fir. The machine had 67.7 x 41.4-26 Goodyear Terragrip tyres and could extract up to 230 pieces in an eight-hour day on wet soils.

A Grande Prairie contractor in Alberta had been using 44" tyres on his Cat 518, and recorded reductions in fuel consumption of up to 20% per m^3 produced (Westergaard, 1985). The usual logging season was extended from just winter months, when the ground was frozen, to all year long. Even with longer cycle times and restricted manoeuvrability, machine productivity with wide tyres was still higher than conventional tyres because the machine could handle a larger drag. Two disadvantages found were the poor performance in snow and the difficulty (and cost) of installing chains.

An unpublished report on experience with wide tyres in the Southern US (Simpson, 1985), documented some of the operational problems users had come up against there. The Firestone 66 x 43-25 12/1 tyres with the 23 degree lug angle was recommended for the New Zealand trials. These tyres were generally used where traction was a higher priority than flotation. Rim slippage and operator abuse were noted as the main cause of failures.

By 1986, the Spruce Falls Power & Paper Co. in Kapuskasing had over 40 units operating with wide (43" plus) tyres (Heidersdorf, 1986). The most recent comparison showed that wide tyres on a machine with 5% less power, produced 15% less wood, but had a cost differential of only 5% more, and a much lower ground disturbance.

It was noted that Canada had over 400 wide tyres working on logging machinery in 1986 and predicted that the population would grow to nearly 1600 by the end of 1987. There was considerable application for the wide tyres on slopes above 40% where they displayed better gradeability than conventional tyres, even with chains on. Slippage on slash was highlighted as a problem.

OBJECTIVES

The objectives of the project can be divided into three categories; Controlled Experiments, Long Term Production Studies, and Tyre Monitoring.

Controlled Experiments

These were designed to measure the capabilities and effect of the wide tyred skidder through controlled tests. The following tests were proposed.

1. *Compaction tests:* to determine the soil compaction caused by the loaded machine. Specific consideration was given to;
   - Soil type;
   - Soil moisture;
   - Number of passes;
   - Direction of travel;
   - Slope.

2. *Wheel rutting:* to measure the amount of ground disturbance caused by successive machine passes, again considering;
   - Soil type;
   - Soil moisture;
   - Number of passes;
   - Slope.

3. *Wheel slip:* to compare wheel slip under varying ground conditions and gradients.

4. *Stopping tests:* to compare the stopping ability of the machine, recording the following;
   - Loaded and unloaded condition;
   - Total distance to stop;
   - Amount of machine slide;
   - Operator control.

5. *Climbing ability (unloaded):* to determine the maximum slope the machine can climb in both forward and reverse directions. The following parameters to be measured;
   - Soil type;
   - Soil moisture;
   - Slope;
   - Limiting factor.

6. *Side slope stability:* to determine stability when travelling loaded and unloaded on side slopes of increasing angles.

Long Term Production Studies

The objective in these studies was to collect data on machine productivity and costs to determine whether the wide tyres offered any advantages over narrow tyres. The information was to be collected in two ways:

1. *Daily Production monitoring:* recorded by the operator at the end of each shift, including;
   - Number of pieces;
   - Number of cycles;
   - Distance travelled;
   - Ground conditions;
   - Soil conditions;
   - Weather conditions;
   - Fuel used.

2. *Detailed production studies* recording;
   - Extracted piece size and haul volume;
   - Average haul distance;
   - Cycle times;
   - Slope and ground conditions.

Tyre Monitoring

Regular inspections for tyre wear and damage, to establish the expected life of the wide tyres. Parameters recorded were;
- Tyre pressure;
- Rim slippage;
- Lug profiles;
- Tyre damage.

MACHINE DESCRIPTION

In November 1984, tenders were called for the supply of a 67 to 75 kW skidder, fitted with 110 cm wide tyres. This particular size of machine was chosen because it was anticipated that it would be capable of handling the expected tree size to be logged and yet still have the versatility to operate in thinnings. Four companies responded with the following machines:

- Timberjack 225A, 64 kW (NZ Motor Holdings Limited)
- John Deere 540D, 75 kW (Lees Industries Limited)
- Caterpillar (Cat) 518, 90 kW (Gough Gough & Hamer Limited)
- Tree Farmer C7, 64 kW (Cable Price Limited)

The John Deere 540D skidder was selected and an order placed with Lees Industries in April 1985. The main reasons for choosing the John Deere skidder were:

- Deere & Co had the most experience with wide tyres on their machines;
- The 540D had heavy duty axles fitted as a standard option;
- The machine could be imported fully built up without incurring heavy import tariffs (imposed by the Government at the time);
- John Deere machines have a manually operated differential lock which is a big advantage when turning with wide tyres on;

Figure 1 : Fitting of the wide 66 x 43-25 tyres to the John Deere skidder, Kinleith

- The 540D model has a direct drive, power shift drive train which is known to offer more efficient transmission of engine power;

- The planetaries are inboard mounted which reduces the amount of heat build-up in the tyres, a common problem with outboard mounted planetaries;

- It was competitively priced.

The John Deere 540D is a 75 kW four cylinder, turbo-charged diesel skidder with eight speed forward and four speed reverse with power shift transmission. Braking is achieved through a wet disc system acting on the front axles and being transferred to the rear axles through the transmission. The machine ordered had S4 (loader type) heavy duty axles fitted which were 300 mm wider than the standard S3 axles.

Equipped with standard 63 x 23.1-26 tyres, the skidder weighed 8.76 tonnes and was 2.93 m wide.

On the wide tyres the skidder weighed 9.00 tonnes and was 3.74 m wide. The winch has a line pull of 118 KN at bare drum, and can take 31 m of 19 mm rope.

One operator was employed for the duration of the trial. He had been driving a 70 kW skidder for the previous three years in both clearfelling and thinning operations and held a Senior Loggers Certificate. (NZ Logging & Forest Industry Training Board Certificate Scheme).

The skidder was fitted with a 24 hour tachograph, and hubodometers were installed on both front and rear axles. A tank-mounted flowmeter was used to monitor fuel usage.

TYRES

Five Firestone 66 x 42-25 Flotation 23 logger tyres, mounted on single piece Webco rims were ordered with the skidder.

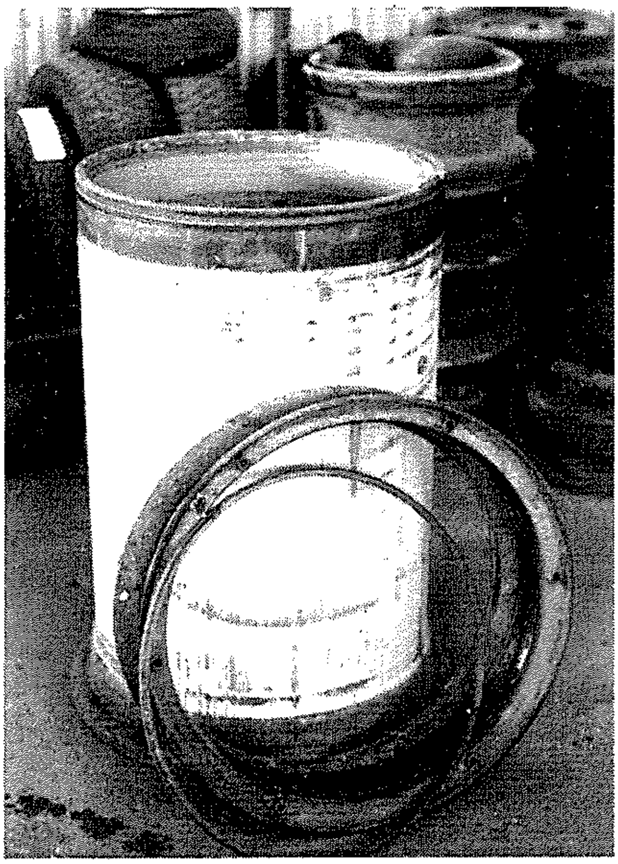

Figure 2 : A Webco single piece rim with bead, locking rim and cover plate

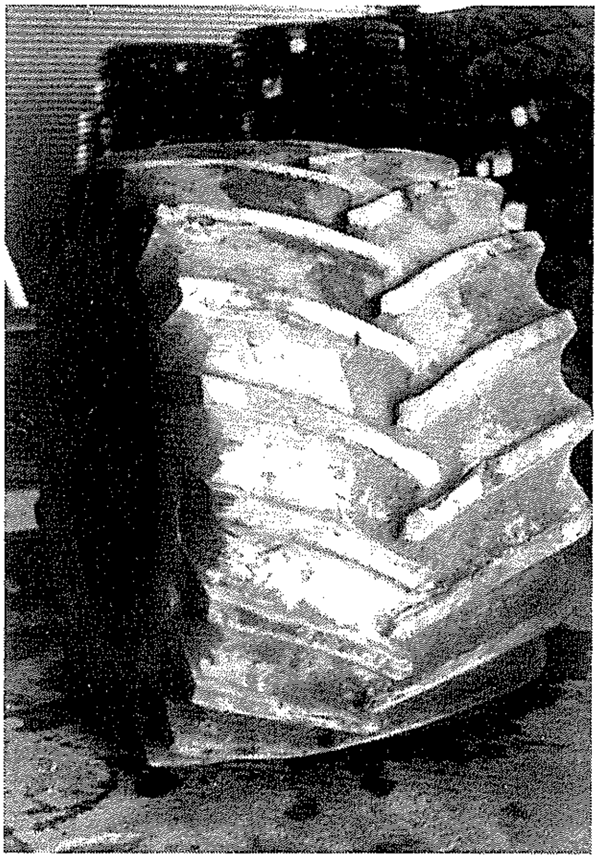

Figure 3 : One of the Firestone 66 x 43-25 tyres

The Firestone 66 x 43-25 is a 109 cm wide steel belted tyre with a 10 ply rating. It is a tubeless tyre which has an overall height of 167.6 cm and an inside rim diameter of 63.5 cm. The lug angle of the tyre is 23° and the tread depth 50 mm.

The recommended operating pressures were; 110 kPa (16 psi) minimum, to 220 kPa (32 psi) maximum.

Before the tyres were installed on the skidder, each rim was marked at the valve stem with a number from one to five. This number was used to note the location of the tyres on the skidder i.e. front or rear. Tyres two and three were mounted on their rims for right hand operation, and tyres one, four and five were mounted for left hand operation.

The cost of the five tyres was $NZ43,495 (August 1985).

CONTROLLED EXPERIMENTS

This section includes the compaction, wheel slip, wheel rutting, stopping, climbing and side slope tests. For these tests, the skidder was taken out of the production situation. The operator was required to assist with the field measurements and data recording.

For the compaction, rutting and wheel slip tests, towing logs, as in a normal extraction operation, would have made identification of the wheel ruts difficult. To simulate a loaded condition for the skidder, concrete and steel weights were constructed and suspended beneath the fairlead, (see Figure 4).

For most of the controlled tests, the differential lock of the skidder was engaged and the appropriate gear for the terrain and conditions selected. Wherever possible, a rolling start was used to begin the tests.

SOIL COMPACTION

Introduction

The purpose of these tests was to investigate the soil compaction caused by wide and narrow tyres on two different soil types. The parameters considered were:

- Slope;
- Direction of travel;
- Number of passes;
- Soil moisture.

The two sites selected, in Maramarua and Mangatu Forests, were considered difficult to log with skidders, mainly due to their susceptibility to compaction (Murphy & Robertson, 1984).

Site Description

The soil type of Maramarua forest is Mangawhean sandy clay loam hill soil (44 cH) (NZ Soil Bureau, 1984), derived from shattered greywacke. The average annual rainfall of 1271 mm (Anon, 1973) contributes to the water-logged conditions experienced for many months of the year.

The Mangatu soil is Wanstead clay loam hill soil (23 aH) (NZ Soil Bureau, 1984), which has been derived from interbedded marine sediments and volcanic ash. The presence of bentonitic clay crush

Figure 4 : The wide tyred skidder with weights attached, on one of the plots at Maramarua Forest

zones increases the susceptibility of this soil to slumping, sheet erosion and slipping. The annual rainfall is 1320 mm.

Gage & Black (1979) devised the following terrain categories for Mangatu Forest, based on slope, stability and geological and geomorphic factors:

- Class 1; Stable surfaces on tertiary rock.
- Class 2; Stable surfaces on cretaceous-to-paleocene rock.
- Class 3; Very deep slumps in tertiary rock.
- Class 4; Older flows and moderately deep slumps in cretaceous-paleocene rock.
- Class 5; Younger flows and moderately deep slumps in cretaceous-paleocene rock.
- Class 6; Active flows, slumps, and eroding gullies.
- Class 7; Debris fans and flood-plain accumulations.
- Class 8; Stream terraces and dissected fans.

Seventy percent of the forest falls into classes 4, 5 and 6 so the study concentrated on those terrain categories.

Experimental Design

Individual test plots were selected on the basis of; soil type or category, slope, direction of run, accessibility, and proximity to other plots set up for the particular tyre type being tested.

The plots were 6 m wide by 10 m long and were cleared of most debris. All trees were directionally felled away from the plots and winched clear, causing no disturbance prior to the test-

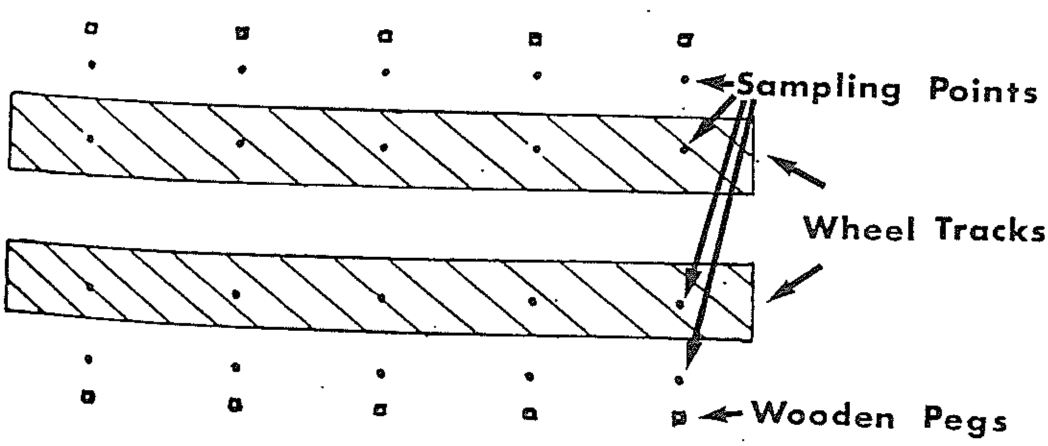

Figure 5 : Plot layout for soil resistance to penetration recordings

ing. The remaining stumps were cut off at ground level.

Both wide and narrow tyres were tested at each site.

The plots in Maramarua were set up for 21% upslope travel, 21% downslope travel and flat, 0-3%. The load applied was a fully suspended, 2.2 tonne concrete weight. Four replications were used.

In Mangatu, the plot slopes ranged from 4% to 11% on classes 4, 5 and 6. The load was a fully suspended, 1.5 tonne concrete weight. Three replications were used.

Due to the difficulty in manoeuvring the skidder between plots, the tyre treatments were not randomly assigned to the plots. This led to difficulties in later interpretation of the results.

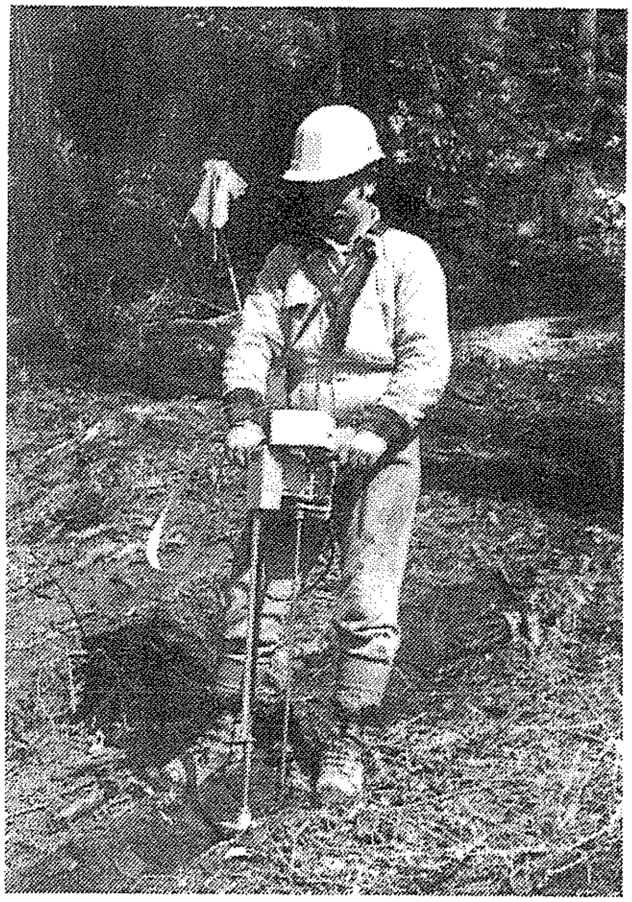

Figure 6 : Positioning the "Bush self-recording soil penetrometer" prior to making a probe

Soil Resistance to Penetration

The skidder made multiple passes over each plot. Soil resistance to penetration was measured prior to the first pass, then after 1, 3, 7, 13 and 21 passes. Twenty probes per plot were collected in a 4 x 5 pattern (see Figure 5), using the "Bush Self-recording Soil Penetrometer". Fifteen readings at 3.5 cm intervals, to a depth of 52.5 cm, were taken at each point.

Soil Moisture

A Troxler Neutron Probe was used to monitor changes in soil moisture during the experiment. Aluminium access tubes were installed at each test site and

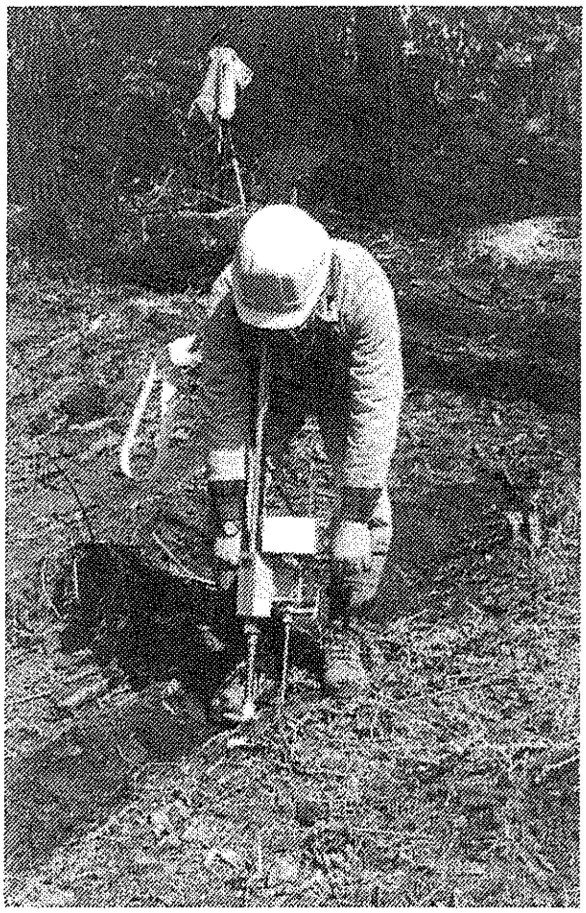

Figure 7 : Taking a probe reading with the penetrometer

measurements taken daily. At Maramarua, it was necessary to cover plots with polythene to prevent substantial changes in moisture content occurring.

The moisture content of the soil influences the resistance to penetration, therefore changes in moisture occurring during the study would affect results making interpretation impossible.

Soil Bulk Density

Bulk density readings were taken before and after the experiment using a "Ronly Depth Density Gauge". Post treatment measurements were done in the ruts left by the tyres.

Results

Soil Resistance to Penetration

An analysis of variance was performed in the soil resistance to penetration results from both sites. They are summarised below.

(i) Maramarua

The soil resistance to penetration results for a selection of treatments are shown in graphical form in Appendix 1.

(a) Soil resistance to penetration was significantly higher on the flat than on the slope before testing began.

(b) After 21 passes there was no significant difference in resistance between the wide and narrow tyre treatments on either slope or flat ground.

(c) After 21 passes soil resistance to penetration increased by 50-100% in the upper 21.0 cm for all treatments.

(ii) Mangatu

Soil resistance to penetration results for a selection of treatments are shown in graphical form in Appendix 2.

(a) Before testing there was a significant difference in soil resistance between Class 4 and 5 and Class 6. Classes 4 and 5 showed a higher resistance to penetration than Class 6 soils.

(b) There was no significant difference between tyre types after 21 passes, except at depth 1 (3.5 cm), i.e. wide tyres did not achieve significantly less compaction than the narrow tyres.

(c) There was a significant difference in soil resistance after 21 passes at all depths. Both tyre types caused significant compaction to the soils tested, to a depth of 21.0 cm.

Soil Moisture

(i) Maramarua

The soil moisture figures from Maramarua showed a 2-3% increase in soil moisture for the top 20 cm of the soil on the slopes, and a 4-5% increase in soil moisture for the top 20 cm of the soil on the flat, over the six days that readings were taken. These changes, however, did not affect the results of the study.

(ii) Mangatu

At Mangatu, there was a small decrease in soil moisture content between the two sets of measurements. Again, these changes did not influence the study results.

Soil Bulk Density

The results from the soil bulk density readings are shown in the following tables.

Table 1 : Bulk density measurements, Maramarua (g/cm^3)

Depth (cm)		*After*	
	Before	*Wides*	*Narrow*
10	*1.06*	*1.09*	*1.10*
20	*1.23*	*1.34*	*1.20*
30	*1.33*	*1.39*	*1.19*
40	*1.35*	*1.38*	*1.17*
50	*1.34*	*1.41*	*1.17*

Table 2 : Bulk density measurements, Mangatu (g/cm^3)

Depth (cm)		*After*	
	Before	*Wides*	*Narrow*
10	*0.96*	*0.97*	*0.83*
20	*1.07*	*0.92*	*1.04*
30	*1.20*	*1.22*	*1.33*
40	*1.30*	*1.34*	*1.36*
50	*1.29*	*1.33*	*1.41*

In both areas, changes in bulk density were small and these differences were not significant.

Conclusion

Maramarua

Even with a difference between slopes and the flat before testing there was no difference in soil resistance between wide and narrow tyre treatments after 21 passes. The presence of litter and slash may have prevented more compaction on the flat as it remained during the experiment.

Although soil moisture conditions were at a moderate level, only a small amount of severe disturbance occurred on the slope.

Mangatu

The large difference between Class 4 and 5 and Class 6 is mainly due to moisture content and soil texture. The soil in Class 6 was very swampy, therefore it had a lower resistance to penetration before testing.

The effect of 21 passes was significant to a depth of 21.0 cm on all terrain classes, indicating that compaction occurs to a greater depth than previously measured on other soil types.

Again there was no difference to soil resistance after 21 passes between the tyre types.

The overall conclusion from the soil compaction tests was that in both Maramarua and Mangatu Forests, there was very little difference in compactive effect between the wide and narrow tyres, for the soil conditions experienced.

SURFACE RUTTING

Site Selection

The effects of wide and narrow tyres on surface rutting was measured on three sites :

- Mangawheau Sandy Clay Loam Hill soil, (Maramarua Forest)
- Tarawera Gravel, (Tarawera Forest)
- Wanstead Clay Loam, (Mangatu Forest).

The Maramarua and Mangatu sites were on the same plot used for the compaction studies, described in "Soil Compaction". In Tarawera, 6 m x 10 m plots were established on; flat ground and 12 to 26%, and 26 to 40% slopes. Machine passes were made in both uphill and downhill directions in the two slope categories. The physical properties of the soils and their moisture content are contained in Appendix 3.

Test Method

Each plot was divided up into 5 transects and measurements taken along these transects at 25 cm intervals. A string line was pulled taut between two reference points at either end of the transects and this provided a common height from which to measure the profile. Measurements were taken before any passes were made, then after 1, 3, 7, 13 and 21 passes. At Tarawera and Mangatu a 1.5 tonne weight was used as a load and at Maramarua a 2.2 tonne weight was used. Tyre pressures in the wide tyres were 110 kPa at Maramarua and Tarawera, and 96 kPa at Mangatu. The narrow tyres were inflated to 138 kPa for all tests.

The deepest points in each tyre rut across the five transects were used to calculate the mean rut depth for each plot.

A study of wheel slippage was carried out at the same time as the surface rutting trials. The number of wheel revolutions taken to travel over the 10 m plots were counted, and each run was recorded on a video camera. Both front and rear wheels were observed.

Figure 8 : Ground disturbance to two flat plots (end to end), at Maramarua. Note the string profiles, the unused plot covered with polythene on the right, and the penetrometer readings being taken.

Results

Surface Rutting

The results of the rutting tests are shown in the tables in Appendix 4. To determine whether the probability of the means were the same, Analyses of Variance (ANOVA) were conducted on the different slope classes and directions of travel (see Appendix 4.).

(i) Maramarua

There was evidence of an overall difference between tyres (significant at the 5% level), on the first pass and after 13 passes.

Narrow tyres had deeper ruts when all slope and direction measurements were combined.

Downhill travel resulted in the deepest rutting, but there was no difference between tyres.

Flat ground had the least rutting and again there was little difference between wide and narrow tyres. Both sets of tyres failed to climb the 26-40% uphill plots. Failure was rapid once the ruts penetrated through to the mineral soil and considerable soil disturbance resulted. Narrow tyres caused deeper rutting than wide tyres on uphill plots.

(ii) Tarawera

In the scoria soils the wide tyres caused less rutting than narrow tyres. On uphill plots of 12-26%, detectable differences were recorded after all passes. A large difference between wide and narrow tyres showed up after 13 passes. Both sets of tyres failed to climb the uphill plots of 26-40%. On the 12-26% downhill plots the wide tyres caused less rutting. There was also less rutting with wide tyres after the first pass on the 26-40% downhill plots but there was no noticeable difference after successive passes.

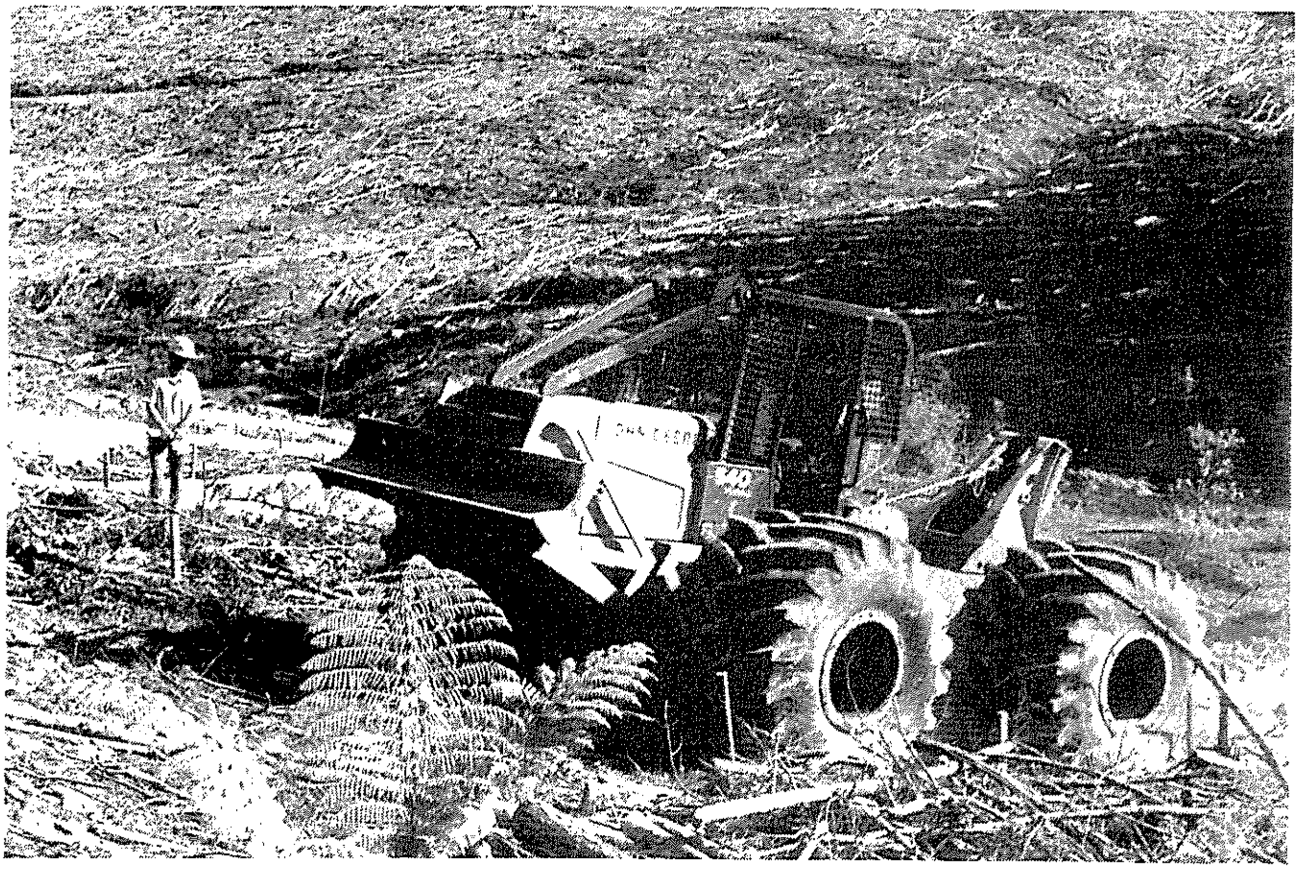

Figure 9 : Counting wheel revolutions on an uphill plot

(iii) *Mangatu*

There was a significant difference between the three terrain classes at Mangatu. The narrow tyres produced much deeper ruts on Class 6 terrain, which was evident from the first pass. On class 5 there was no difference between tyre types.

Wheelslip

(i) *Maramarua*

The results of the wheelslip measurements taken have been averaged to give an overall wheelslip comparison.

The wide tyres had less wheel

Table 3 : Wheelslip comparison - Maramarua

Plot Type	% Wheelslip	
	Wide Tyres	Narrow Tyres
All slopes	8.43	9.46
Flat	9.19	8.94
Uphill	14.60	23.70
Downhill	-8.49	-5.90

slippage than narrow tyres when travelling uphill. On flat ground and downhill plots there was little difference between the two tyre types. The negative wheelslip shown in the downhill tests indicates the wheels were sliding under engine braking. There was no difference between front and rear wheelslip.

(ii) Mangatu

The table below shows the wheelslip recorded in the Mangatu tests. The average of both front and rear wheel revolutions has been used to give an overall wheelslip figure.

All plots were approached from the uphill side so direction of travel was downhill. There was a slight difference in wheelslip between wide and narrow tyres on class 5 terrain. Wide tyres had less wheelslip than narrow tyres on class 6 terrain. The negative value for the wides on class 6 terrain suggests that there was some slippage with the direction of travel on the plot. The slopes were not steep (8-17%) but the wetness of the soil in class 6 plots reduced the tractive ability of the tyres.

Conclusion

Both sets of tyres caused surface rutting in the plots. The depth of rut using the wide tyres was signficantly less when travelling uphill in most situations. Wide tyres also caused less rutting on loose scoria soils (up to 25% slope) and on class 6 soils in Mangatu. There was little or no difference between the rutting caused by wide and narrow tyres on flat ground and when travelling downhill. The trial results were difficult to interpret because soil moisture, which has a direct bearing on soil strength, was variable, particularly at Mangatu.

The wide tyres showed less wheelslip than the narrow tyres under most circumstances. When complete failure did occur, damage to the soil was considerable. The reduced wheelslip with the wide tyres would have influenced the degree of surface rutting that occurred.

TRACTIVE CAPACITY

Introduction

To evaluate the tractive efficiency of the wide tyres compared to narrow tyres, a series of tests were designed to measure the difference in performance under controlled conditions.

A flat, compacted gravel surface at the Mangatu Forest headquarters was used for the tests. The area was part of a vehicle compound, and had a regular flow of forest traffic over it.

Table 4 : Wheelslip comparison - Mangatu

	% Wheelslip	
Plot Type	Wide Tyres	Narrow Tyres
All Classes	4.29	7.84
Class 5	5.92	8.46
Class 6	-2.16	4.15

Figure 10 : Counting wheel revolutions during tractive capacity tests, Mangatu

Test Method

The length of each test track was determined by measuring the circumference of the tyres and multiplying by ten. Start and finish points were identified by two pegs at each end of the track. Both front and rear right hand tyres were marked at the valve stems to enable the revolutions to be counted during the tests. A minimum of two unloaded runs were done with each set of tyres before any loaded testing was done.

To apply the appropriate load, the winchrope of the skidder was anchored to the drawbar of D4D Cat tractor. The connection between the skidder winchrope and tractor drawbar was through a Daytronics 9000 series loadcell installed to measure the load being pulled. By applying his brakes, and reading the loadcell printout, the tractor operator could regulate the load and skidder was pulling.

For each run, the skidder was driven at maximum revs in second gear, with the differential lock engaged. When evaluating the wide tyres, two series of tests were done, firstly with pressures set at 103 kPa, and the second with pressures at 69 kPa. The narrow tyres were evaluated at 138 kPa. (At these pressures, both tyre types were below their recommended minimum).

When conducting the tests, two observers recorded the location of the mark on the tyre at the start peg, then counted the number of revolutions completed before passing the finish peg. The percent slippage was found by dividing the number of loaded revolutions by the number of unloaded revolutions taken to run the length of the test track.

Results

The results of the tractive capacity tests are shown in Figure 11, and tables showing the recorded data are included in Appendix 5.

Conclusions

The wide tyres had less slippage than the narrow tyres under all

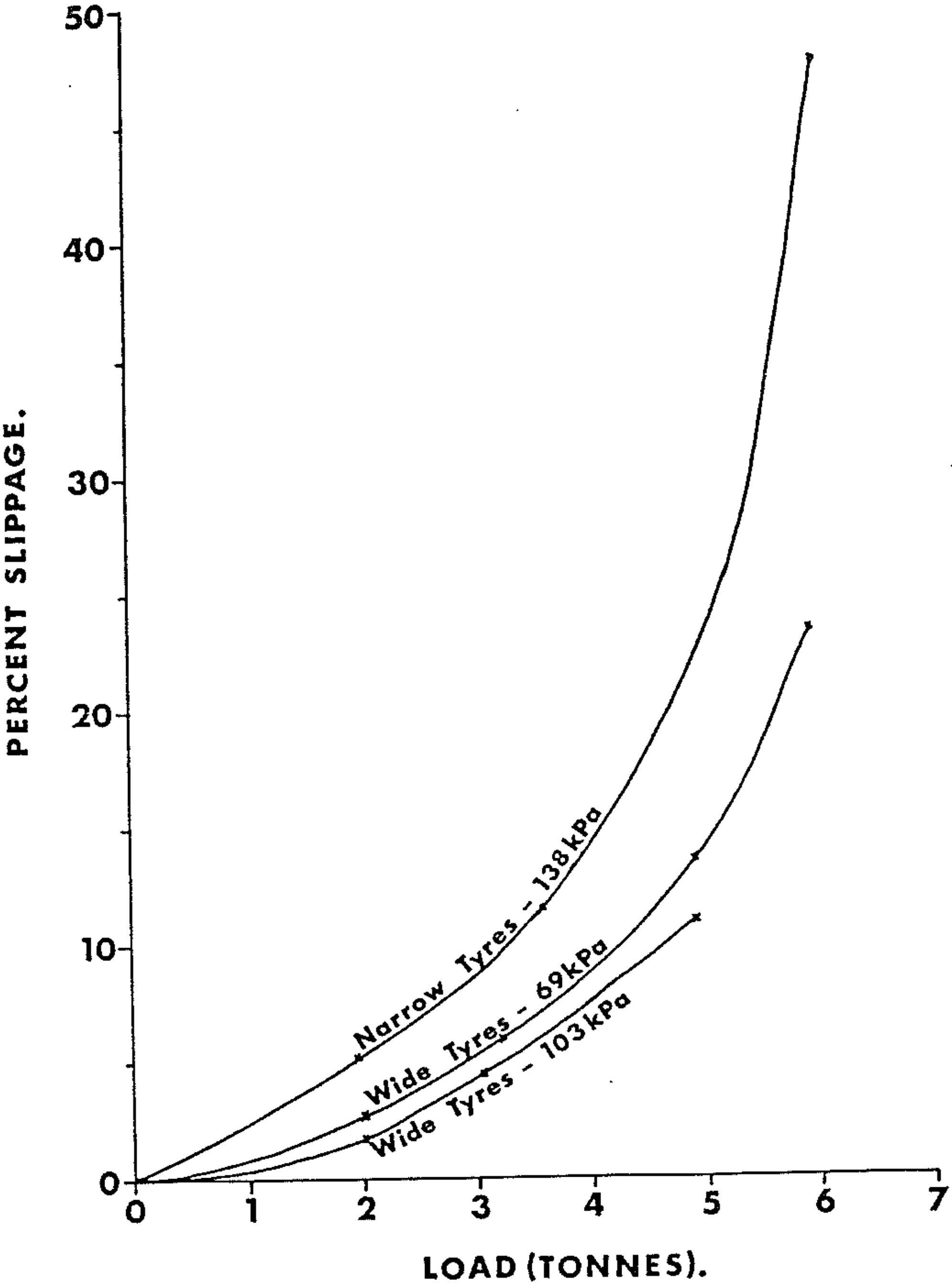

Figure 11 : Tractive capacity test results

loaded conditions. As the load increased, the difference between wides and narrows became greater. The wide tyres inflated to 103 kPa pressures had more tractive capacity than they did at 69 kPa.

CLIMBING ABILITY

Introduction

Climbing tests were set up to determine the climbing ability of the skidder on both wide and narrow tyres. During the procedure at least one other skidder was tested on the same site. These tests were done on a range of soil types within the trial areas.

Test Method

The test track consisted of a 10 m wide strip marked out on slopes of increasing gradient, up to a point beyond the predicted climbing ability of the machines tested. These strips were divided into 10 m sections with a slope change at

Figure 12 : Using stumps for traction when climbing up a 45% slope with a D7 Cat tractor

each 10 m interval. All stumps were cut off at ground level, and any heavy slash likely to impede traction was removed or cut up with a chainsaw. The operator of each machine was instructed to climb as far up the slope as he could in both forward and reverse directions. He was encouraged to select a different route with every attempt to avoid previously disturbed ground from affecting the run.

The attempt was deemed to have reached its maximum distance when the forward momentum of the machine had stopped and the wheels or tracks were slipping. Operators were allowed to articulate their machines to gain additional traction, but once forward movement ceased, the run was stopped because further slipping would have disturbed the test track too much for later runs. The distance reached was measured at the centre point of the uppermost axle when climbing forwards. When the FMC was evaluated, measurement was taken from the uppermost sprocket.

Generally these tests were coincided with a scheduled tyre change so that ground conditions were consistent for both configurations. Once all machines had been tested, (both wide and narrow tyres), the operators were invited to have further attempts at climbing the slopes without being restricted by the requirements of the test procedures.

The climbing tests were done at four different forests, three of them having a different soil type. The forests were :

- Kaingaroa : Otanewainuku steep-land pumice derived from Rhyolite ash and Rhyolite.

- Matahina : Tarawera scoria gravel from Tarawera basalt lapilli.

Figure 13 : Example of the heavy slash concentration in the upper section of the Kaingaroa test track

- Woodhill : Podzolic soils from Aeolian sand.
- Tarawera : Tarawera gravel from Tarawera basalt lapilli.

The condition of the skidders tested was varied. Basic machine specifications and the condition of each skidder tested are shown in Appendix 6.

The machines tested were :

- The John Deere on wide tyres;
- The John Deere on narrow tyres;
- A Cat D7 tractor;
- A Timberjack 207 skidder, fitted with tyre chains.

Results

Kinleith

The Cat D7 tractor could climb considerably further than the wide tyred skidder. The cleared tracks enabled the tractor to gain traction from slash and stumps which were a hindrance to the rubber tyred skidders. Heavy slash had more of a detrimental effect on the performance of wide tyres than it did on the narrow tyres, although the wides could still climb further up the slope. When partially filled with water, the climbing ability of the narrow tyres improved but the difference in performance was not measured.

The John Deere 540 on wide tyres could climb further than the Timberjack 207 in both directions.

The chains on the front tyres of the Timberjack caused considerable ground disturbance when the machine lost traction.

Kaingaroa

Three machines were tested at Kaingaroa, the John Deere 540D, a Cat 518 and a Clark 666C. The John Deere was tested on wide tyres, on narrow tyres and on narrow tyres with water in them. The proportion of water in the tyres was 25% in the front and 75% in the rear. The Clark 666 also had 75% water in all of its tyres. The test track had a light coverage of slash on the easier slopes and a high concentration of undergrowth in the top section. The results from the tests are shown in Figure 14.

Matahina

Three machines were tested at Matahina, the John Deere 540D on wide and narrow tyres, a Tree Farmer C7, and an FMC 220CA. The slash on the test track was medium to heavy. Results from the climbing tests are shown in Figure 16.

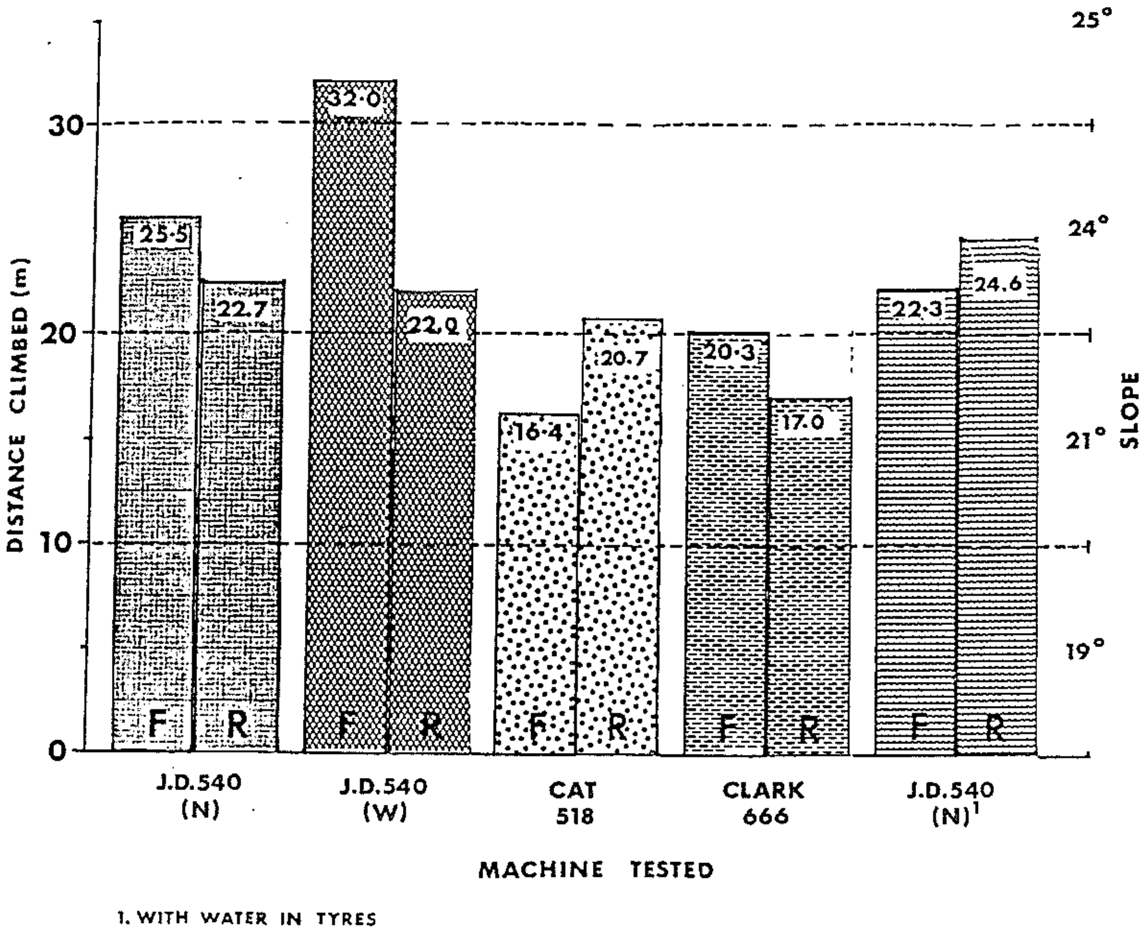

Figure 14 : Results of forward (F) and reverse (R) climbing tests, Kaingaroa

Figure 15 : The three machines tested in the Kaingaroa climbing tests

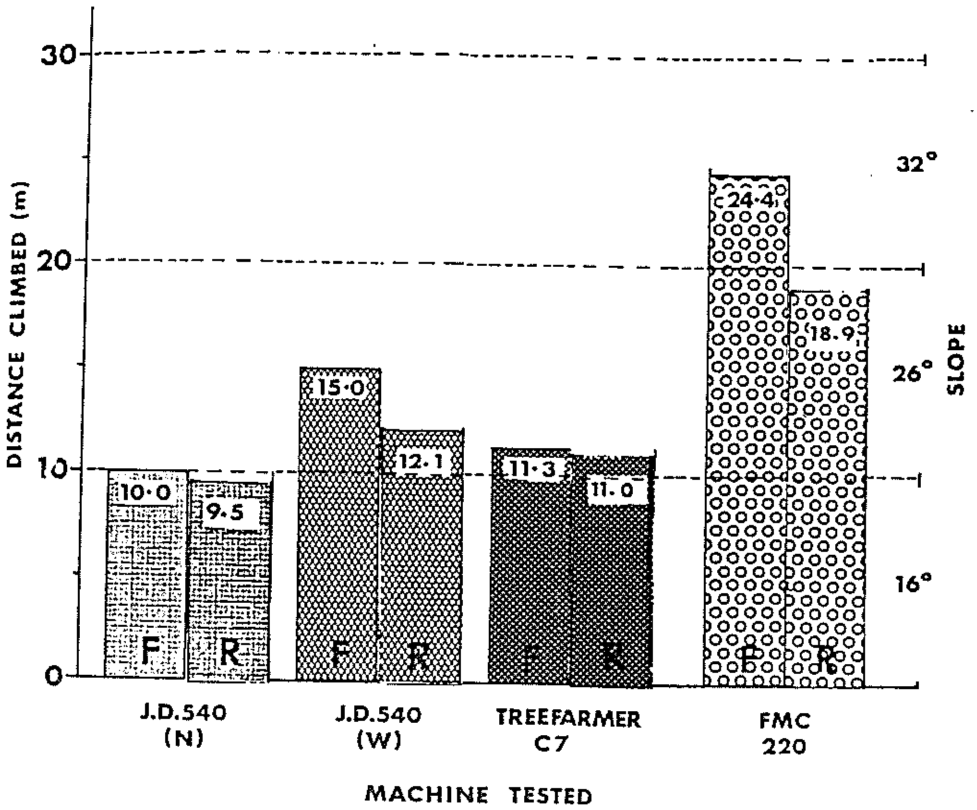

Figure 16 : Results of climbing tests, Matahina

Woodhill

Two machines were tested at Woodhill, the John Deere on wide and narrow tyres and a Clark Ranger 666C. As a measure of the consistency of the tests, the Clark was tried on both occasions that the tests were run. The soil type was fine sand with a light grass cover. Results from the Woodhill tests are shown in Figure 18.

Figure 17 : Testing the climbing ability of the wide tyres on scoria soils, Matahina

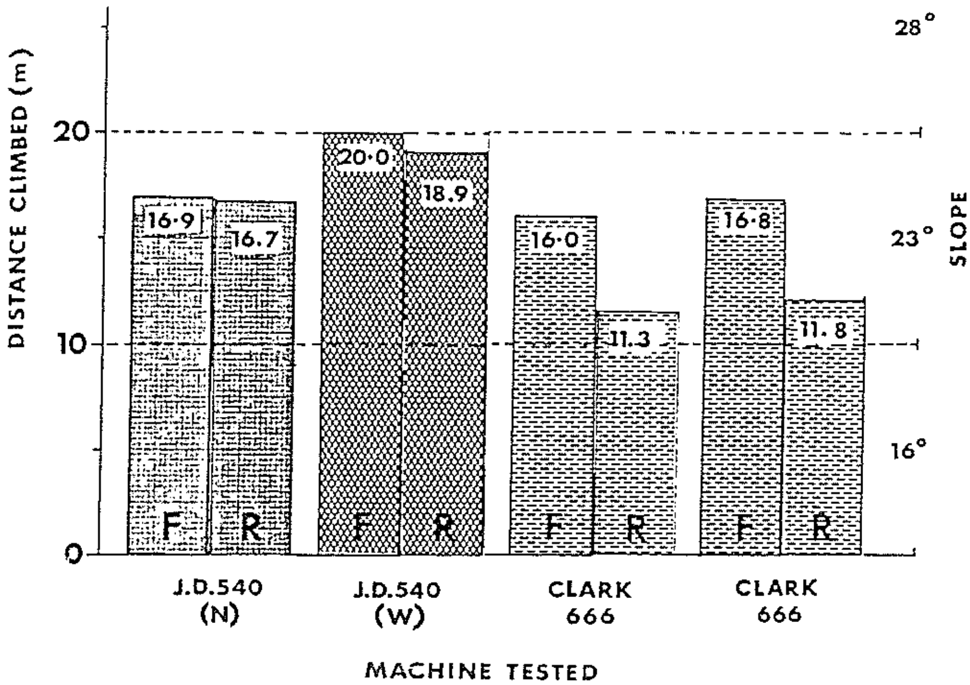

Figure 18 : Results of climbing tests, Woodhill

Tarawera

A Cat 518 was tested along with the John Deere (on wide and narrow tyres), in the Tarawera tests. There was a very light ground cover of pine needles and undergrowth. Results from the Tarawera tests are shown in Figure 20.

Figure 19 : Testing the narrow tyres for climbing ability in the sandy soils at Woodhill

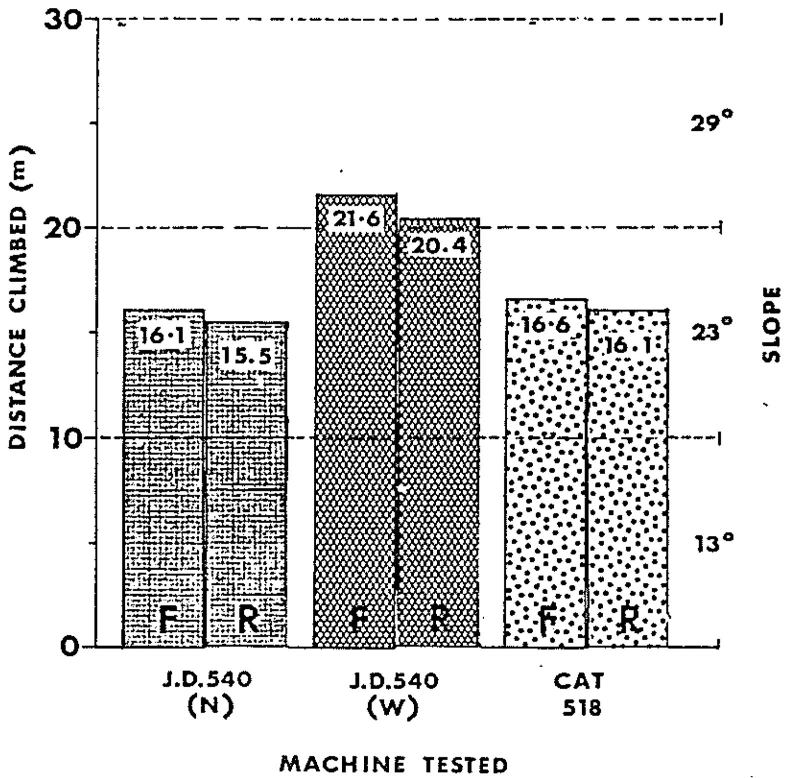

Figure 20 : Results of climbing tests, Tarawera

Figure 21 : Tracked machines could climb further than the rubber tyred skidders

Conclusions

The wide tyred skidder could consistently climb further up the slopes, both forwards and reverse, than the other rubber tyred skidders tested. The John Deere on narrow tyres also performed well in the climbing tests, and on some soil types, could out-climb the wide tyres in reverse, e.g. Kaingaroa. Tracked machines could climb further than any of the rubber tyred skidders tested.

SIDESLOPE STABILITY

Introduction

One of the advantages of wide tyres noted in other reports (Mellgren & Heidersdorf, 1984; Porter, 1983; Heidersdorf, 1986; Heidersdorf & Ryan, 1986; Sauder, 1985), has been the improved side slope stability of the skidder. A test was devised to measure the difference between the wide and narrow tyres on side slopes.

Test Method

The test track was located along the side of a short spur in Kinleith Forest. The side slope of the spur increased from 19% at the foot of the spur, to 55% where it ran into an adjoining ridge. At the very top of the spur, the side slope was 60%. Access to the track was from either the top or bottom of the spur. The test track was 6 m wide and 20 m long and divided into four 5 m sections (see Figure 22). The track was cleared of all slash larger than 5 cm in diameter.

The skidder operator was instructed to drive along the test track in second gear. Researchers visually assessed the effect of the slope on the machine at each 5 m interval. Both wide and narrow tyres were evaluated. A security rope was available to prevent the skidder from tipping over.

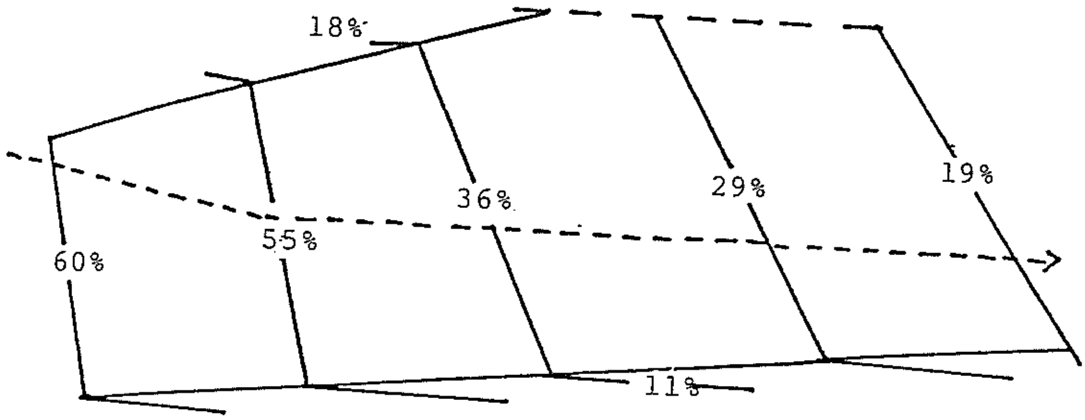

Figure 22 : Diagram of side slope test track

Figure 23 : Side slope stability tests with the wide tyred skidder, Kinleith Forest

Table 5 : Results from sideslope stability tests

Side Slope %	*Wide Tyres*	*Narrow Tyres*
19	*Stable*	*Stable*
28	*Stable*	*Slight slippage*
36	*Slight slippage*	*Slipped sideways*
55	*Slipped sideways*	*Skidded off track*

Periodic side slope measurements were taken during production runs throughout the trials. Both loaded and unloaded situations were observed.

Results

The results from the side slope stability tests are shown in Table 5.

The narrow tyres slipped at an earlier stage along the test track than the wide tyres did. At no stage did either machine appear to be unstable but the operator had to exercise more caution on the narrow tyres.

In Ngaumu Forest the wide tyred skidder was observed travelling loaded across a 53% side slope with apparent ease. In Kaingaroa the machine comfortably went unloaded across a 48% side slope over stumps and debris. At Matahina the wide tyred skidder successfully travelled empty across a 60% side slope until the rear of the machine slipped downhill. The operator was able to turn the skidder around on the side slope.

Figure 24 : The wide tyred skidder operating on 40% side slopes, Ngaumu

Figure 25 : The John Deere parked alongside the Cat 518 at Kaingaroa Forest. Note the additional width provided by the S4 axles. The John Deere would normally be 20 mm narrower than the Cat.

In Tarawera Forest, the skidder worked a steep, 60% slope by climbing as far as it could up the ridge, then turning sideways and going across slope until it was above the wood.

Even with narrow tyres fitted, the John Deere 540D skidder was very stable. It was observed working on side slopes of up to 42% with relative ease.

Rollovers

In the hauler thinning area at Kinleith, the wide tyred skidder rolled over while trying to negotiate a 65% slope. The incident occurred when the front left hand wheel came up against an old stump which gave way, slewing the machine sideways. At the same time, the rear right hand wheel rode up onto two logs in the outrow. No injury resulted from the rollover and the skidder was undamaged.

A second rollover happened in the tractor thinning area with the narrow tyres fitted. This time an old rotting log caused the skidder to slide into a standing tree on the edge of the extraction strip. The tree uprooted, tipping the machine over with it. Again no damage or injury resulted.

Conclusions

The John Deere 540D on narrow tyres appeared to be more stable on side slopes than other skidders of similar capacity. It was believed that the 300 mm wider S4 axles contributed to this.

The wide tyres made the skidder very stable on steep side slopes, even travelling over stumps and slash. The machine tended to slip sideways rather than tip up.

WARNING - While this report cites examples of the wide tyred skidder negotiating slopes in excess of 57%, it should not be interpreted as an endorsement of working such slopes with skidders.

STOPPING TESTS

Introduction

To determine whether the wide tyres improved the control and the performance of braking, stopping tests were set up to measure the difference between wide and narrow tyres. The tests were to evaluate controlled and lock-up braking situations, both with and without a load attached.

Test Method

The test tracks were located along a well used extraction track in the Kinleith clearfell trial. The beginning of each track was marked, and the distance travelled was measured from there. Two different slope classes were tested, 15% and 32%. The soil was a pumice/clay combination and ground conditions at the time of testing were dry.

All tests were done with the skidder in fifth gear at maximum revs. When the machine reached the start mark, the operator would start braking. Visual observations were made on the way in which the skidder stopped and the number of wheel revolutions recorded. The front axle was used as the machine reference point.

Two methods of braking were tried, one with full pressure being applied to the brake pedal, in a lock up situation, and the other in a controlled stop allowing the wheels to turn. The operator was asked to try and keep the pressure on the brake pedal consistent for all tests.

For the loaded tests a 2.19 tonne log was towed behind the machine.

Results

The results of the stopping tests are shown in Table 6. Due to the difficulty in counting wheel revolutions, they were not recorded after the wide tyres testing.

In almost all tests the wide tyres travelled further under braking than the narrow tyres did. Apart from the controlled braking on 32% slopes, the differences between the two tyre types was not significant.

Conclusions

The data collected showed that the wide tyres offered no apparent advantages over narrow tyres in stopping ability on the slopes and soil types tested.

FUEL CONSUMPTION TESTS

Introduction

Two fuel consumption tests designed specifically to measure fuel usage were set up. Each test involved towing a drag of logs of known dimensions and weight, around a measured circuit. The results of the two tests are represented by forest, as both circuits were completely different.

Tarawera

Track Description

An old, unused road called Gully Road was used as a test track in Tarawera. The circuit was 2 km long and had a range of adverse and favourable grades from -30% to +14%. The soil type was Tarawera scoria gravel, and a short 150 m section of the track was dissected by deep ruts.

Table 6 : Results of Stopping Test

Tyres	*Slope %*	*Type of Braking*	*Number of Wheel Revs*	*Distance Travelled*	*Comment*
Wides	*15*	*controlled*	*.75*	*3.4 m*	*no slippage*
Narrows	*15*	*controlled*	*-*	*3.0 m*	*no slippage*
Wides	*15*	*lock-up*	*.25*	*1.3 m*	*minor slippage*
Narrows	*15*	*lock-up*	*-*	*1.2 m*	*minor slippage*
Wides	*15*	*with log*	*.50*	*2.6 m*	*some slippage*
Narrows	*15*	*with log*	*-*	*3.1 m*	*some slippage*
Wides	*32*	*controlled*	*1.25*	*4.3 m*	*minor slippage*
Narrows	*32*	*controlled*	*-*	*3.5 m*	*some slippage*
Wides	*32*	*lock-up*	*.75*	*2.0 m*	*some slippage*
Narrows	*32*	*lock-up*	*-*	*1.8 m*	*slippage*
Wides	*32*	*with log*	*1.25*	*4.1 m*	*some slippage*
Narrows	*32*	*with log*	*-*	*3.6 m*	*some slippage*

Test Method

Three machines were tested in Tarawera, the John Deere on wide tyres, the John Deere on narrow tyres and a Cat 518 skidder. The regular operator of the Cat drove his machine during the tests. The test drag consisted of four logs with a total weight of 3.03 tonnes and an average length of 5.94 m.

Each test started from the start/ stop point on the skid. The operators were instructed to tow the logs with the butts suspended for part of the circuit to avoid excessive disturbance to the road surface. For the remainder of the circuit, the logs were dragged with their full length on the ground. Each machine started with a full fuel tank and did five circuits of the track before refuelling. Immediately before the test with the John Deere on narrow tyres, 43 mm of rain fell.

Mangatu Forest

Track Description

The test track at Mangatu was on a no exit track adjacent to the logging trial site. Total round trip length was 1.75 km. The soil type was Wanstead clay loam and gradients ranged from 3% to 19%.

Test Method

Both narrow and wide tyres were evaluated at Mangatu. Four logs with a total weight of 2.18 tonnes and an average length of 8.28 m were used as a test drag. The machine started with a full tank of fuel and was refuelled after each run. The time taken and distance travelled were also recorded.

The evening before the tests with the narrow tyres 46 mm of rain fell, completely saturating the test track. This made it difficult to draw comparisons between the two tyre types.

Results

Tarawera

The results of the fuel comparison done at Tarawera are shown in Table 7.

The John Deere skidder operated in third and fourth gears on the uphill section of the track and up to sixth gear on the downhill section. The Cat remained in second gear for most of the circuit. The drag size was considered optimum for the test conditions that prevailed. All machines suffered some traction loss when negotiating the section of the track dissected with ruts.

Mangatu

The results from the Mangatu fuel consumption tests are shown in Table 8.

The ground conditions for the two tests were vastly different. Visual observations clearly showed that site disturbance was much greater with the narrow tyres and more slippage was evident, hence the longer distance recorded by the hubodometers (see Table 8).

Table 7 : Fuel consumption tests - Tarawera

Machine	Tyres	Fuel Used
John Deere 540D	66 x 43-25	33.0 L
John Deere 540D	63 x 23.1-26	31.3 L
Cat 518	63 x 23.1-26	29.0 L

Table 8 : Fuel consumption tests - Mangatu

Run No	Tyres	Time	Hubodometer Distance	Litres Used
1	66 x 43-25	18.0 min	1.9 km	5.90 L
2	66 x 43-25	19.0 min	1.9 km	5.80 L
3	66 x 43-25	18.0 min	1.9 km	5.70 L
4	66 x 43-25	19.0 min	1.9 km	6.00 L
	Average	18.5 min	1.9 km	5.85 L
1	63 x 23.1-26	21.0 min	2.1 km	7.60 L
2	63 x 23.1-26	21.0 min	2.1 km	7.80 L
3	63 x 23.1-26	22.0 min	2.1 km	7.80 L
	Average	21.3 min	2.1 km	7.73 L

Conclusions

The wide tyres offered no advantage over narrow tyres in the conditions at Tarawera. The rain that fell on the loose Tarawera soils did not appear to affect the test with the narrow tyres. The higher powered Cat machine used less fuel under the test conditions.

No valid conclusions could be drawn from the tests at Mangatu, due to the wide variation in ground conditions.

OTHER MACHINE TESTS

A number of other tests were conducted on the wide tyred skidder to simply measure physical differences, i.e. what effect the larger width (and diameter) tyres had on basic machine functions. These tests are divided into subsections for convenience.

Turning Circle Tests

Introduction

These tests were designed to measure the difference in manoeuvrability between the wide and narrow tyres. Unfortunately the centres of the Webco rims were 100 mm closer to the inner edge of the rim than expected. This, when combined with the wider S4 axles, meant that it was necessary to install spacers in the steering rams to stop the wide tyres from touching when turning on full lock. These spacers remained in the rams for the whole trial.

Test Method

To measure turning circle, the skidder was run onto an undisturbed skidsite and turned onto full lock. Both left and right hand locks were tested. All tests were done in fifth gear with diff lock engaged.

The imprint on the outside tyre tread was used as a measure of turning cycle and this was noted for two circle diameters, perpendicular to each other, across the imprint left by the tyre.

Results

The results of the turning circle tests are shown in Table 9.

The difference in turning circle was the same for both locks. The turning circle of the machine on narrow tyres, without spacers in the rams, was not tested.

Conclusions

The larger turning circle of the wide tyred skidder was not proportional to the extra width of the tyres. It is unlikely that altering the travel of the steering rams would significantly change this difference. Moving the rim centres of the wide tyres further in would change the difference between the two types of tyre.

Table 9 : Turning Circle Test Results

Turn Direction	*Wide Tyres*	*Narrow Tyres*	*Difference*
Left hand turn	*12.95 m*	*12.65 m*	*.30 m*
Right hand turn	*13.15 m*	*12.85 m*	*.30 m*

Table 10 : Results from Blade Travel Tests

Wide Tyres	Narrow Tyres	Difference
170 mm	200 mm	30 mm

Blade Travel Measurement

Introduction

The larger diameter of the wide tyres increased the height of the skidder and consequently reduced the effectiveness of the blade. This test was set up to measure the difference between wide and narrow tyres.

Test Method

The difference in blade travel was measured by running the skidder up onto a concrete loading ramp and lowering the blade to its maximum depth. A spirit level was used to mark the location of the bottom of the blade against the front of the ramp. The distance between the mark, and the top of the ramp was recorded.

Results

The result of the blade travel tests are shown in Table 10.

Conclusions

The depth of travel of the skidder's blade was reduced by 30 mm when the wide tyres were fitted. This is equivalent to 42% of the difference in tyre diameter.

Winching Tests

Introduction

The purpose of this test was to establish whether the wide tyres offered any advantage over narrow tyres when winching. These tests were done at Mangatu at the same time as the tractive capacity tests.

Test Method

The skidder winchrope was anchored to the D4 Cat tractor through a loadcell. For each test, the skidder was positioned 8 m from the tractor. To avoid shock loading, the winchrope was tensioned to about .5 tonne before the test began. Two types of test were done with each tyre configuration, one with the skidder in a straight line with the tractor, and the other with the skidder at a 45 degree angle to the tractor (see Figure 26).

At least three replications were done with each test. Visual observations were made of how the skidder reacted when maximum tension was reached. The ground conditions were the same for each test, a compacted gravel surface.

Results

Table 11 shows the results of the winching tests.

For both tyre configurations, the skidder reared up when winching in a straight line with the tractor. In the tests with the wide tyred skidder at a 45 degree angle, the rear tyre closest to the tractor deformed and looked as though it was going to peel off the rim but the machine remained relatively stable. When the narrow tyres were tested at a 45 degree angle, the skidder lifted up onto one wheel and would have tipped over had the winching continued.

Conclusions

While the skidder on narrow tyres appeared to have greater winchline pull than it did on wide tyres, it was a lot less stable when winching at a 45° angle. Both machines had similar winching capabilities in a straight line. This test procedure did not consider soft or unstable ground conditions where the flotation effect of the wide tyres would have been an advantage.

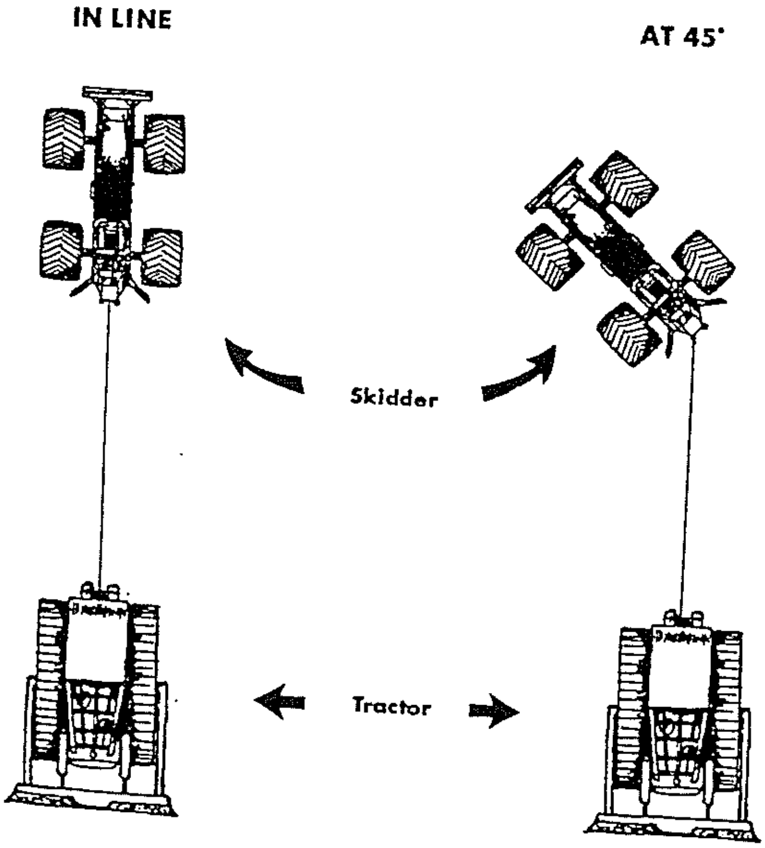

Figure 26 : Diagram of skidder location during winching tests

Table 11 : Winching Test Results, Tonnes Tension

Machine Position	*Wide Tyres*	*Narrow Tyres*
In line with tractor	*6.30 t*	*6.82 t*
At 45 ° angle to tractor	*2.29 t*	*2.30 t*

PERFORMANCE MONITORING

INTRODUCTION

At each forest, the John Deere skidder was put into operation in place of the logging crew's regular extraction machine. Apart from Mangatu Forest, no attempts were made to alter the logging system although the method of extraction was sometimes adjusted to suit the wide tyres. Both wide and narrow tyres were evaluated at each site.

Detailed daily records of weather, ground conditions, supplies used, activity times and production data were kept throughout the ten-month trial. The operator was responsible for collecting this information.

Time studies were carried out at each site once the operator had established a working pattern with the rest of the crew. Scaled log volumes were used to measure production.

DATA COLLECTION

Time Studies

Time studies were undertaken when a reasonable flow of work could be observed. A minimum sample size of 100 cycles was considered desirable but not always obtainable. Each cycle was divided into basic elements described in Appendix 8.

Log volumes were derived from a volume table constructed by the study team for the specific site being observed. Each piece extracted was measured for length and diameter.

Each individual haul path was measured for length and divided up into slope categories as follows:

- 8% to + 8%
+ 10% to + 17%
+ 19% to + 26%
above + 28%
- 10% to - 17%
- 19% to - 26%
- 28% and below

Actual times for both loaded and unloaded conditions were recorded for these haul paths and the data used to calculate travel times for a constant 150 m distance. These times were based on the following assumptions :

45% unloaded travel on slope class -8% to +8%
25% unloaded travel on slope class +10% to +17%
25% unloaded travel on slope class +19% to +26%
5% unloaded travel on slopes above +28%

45% loaded travel on slope class +8% to -8%
25% loaded travel on slope class -10% to -17%
25% loaded travel on slope class -19% to -26%
5% loaded travel on slope class steeper than -28%

Hook on and unhook times were standardised to a mean time per piece for each study.

Daily Records

The method of collecting daily records was based on the "Evaluation Methods Data Manual" (Sobhany 1984). This format is being considered as a universal classification system for logging studies by Bio-energy participants of Task 3 in the IEA (International Energy Agency). At the end of each day the machine operator filled in the seven forms as shown in Appendix 7.

Figure 27 : A production study of the skidder fitted with narrow tyres at Woodhill

The ground and wind conditions were generally based on a visual assessment made during the day. Temperature and rainfall were recorded from a portable weather station set up on site.

Consumable supplies (excluding wire rope) were measured at the end of the shift, usually the end of the day.

Production was recorded by the number of logs pulled per drag. Log size was assessed by averaging the volumes of the logs extracted during the production studies.

Daily machine activities were recorded by the tachograph and the distances travelled measured by the hubodometers. The operator marked on the recorder disks reasons for delays and any extraordinary activities he was required to do. Times for the activities were measured from the disks and transferred to the shift record analysis form. The information was stored in a computer data base designed for the collection manual.

The results of the performance monitoring and the production studies are summarised by forest.

KINLEITH CLEARFELL

Trial Description

Kinleith forest is a privately owned exotic forest located on the western side of the Volcanic Plateau in the central North Island. The trial site at Kinleith was in a designated tractor area on the corner of Duncan and Waioraka roads. The soil type was pumice ash clay loam. The terrain was flat to undulating at the front of the setting climbing up to a 78% slope at the back. Some tracking was necessary for access to the logs from these areas. The road leading in to the block was bounded by a swamp which ran across one corner of the logging area.

The logging system was a hot deck operation with tree length extraction in a downhill direction to two separate landings. One or two men assisted with the breaking out on the steeper slopes. Five wire rope strops were used on the machine. The skidder was required to do some fleeting on the skids.

The stand was 36 year old P. radiata with some smaller 30-33 year old trees at one end.

A six-man crew (excluding the skidder operator) did the logging and an RB30 cable crane was used as a loader.

Production Study Results

A total of 158 cycles of operation on the wide tyres and 161 cycles on the narrow tyres were recorded. The study period was from August to September, 1985. Table 12 summarises the results.

Both landings were situated on dried up watercourses and when worked in the rain, they cut up badly. A large hollow developed in one of the skidsites which restricted skidder access. The wide tyres caused considerably less disturbance to the skid surface than the narrow tyres did. The slower skid travel times for wide tyres could be attributed to the congested landing area and the fact that the machine had less manoeuvrability on wide tyres.

Table 12 : Production Study Results, Kinleith

Element	*Wide Tyres*	*Narrow Tyres*
Run Empty (Skid)	*0.51*	*0.40*
TRAVEL EMPTY (Bush)	*1.41 (150 m)*	*1.54 (150 m)*
Blade logs	*0.13*	*0.25*
POSITION	*0.62*	*0.80*
Breakout	*3.56 (3.57 pcs)*	*3.70 (3.71 pcs)*
TRAVEL LOADED (Bush)	*1.48 (150 m)*	*1.56 (150 m)*
Run loaded skid)	*0.81*	*0.60*
Drop on skid	*0.85*	*0.88*
Other blade work	*1.04*	*0.78*
Total Cycle	*10.47*	*10.51*
Average piece size (m^3)	*1.25*	*1.46*
Average drag size (m^3)	*4.46*	*5.43*
Production per PMH (m^3)	*25.7*	*31.8*

Figure 28 : The wide tyred skidder operating on the badly cut up skid

Heavy slash was a hindrance to the wide tyres, particularly when trying to climb empty up the slopes. A D7 Cat tractor was observed climbing the same slopes with relative ease.

Daily Records

The daily records at Kinleith covered 14 days on wide tyres and 10 days on narrow tyres. Initially the wide tyres were inflated to 172 kPa but after only a few hours of operation, the pressures were reduced to 124 kPa. The narrow tyres were kept at the recommended 172 kPa.

Water was added to the narrow tyres to improve machine stability when reversing. The proportions of water were : 25% in the front, and 75% in the rear. A summary of the daily information collected is shown in Table 13.

Conclusions

The production study results showed that the skidder on narrow tyres was more productive than on wide tyres. Daily records, however, indicated that there was no significant difference between the two tyre types. Average haul distances from the daily records show that the wide tyred skidder was hauling over longer distances.

Productivity and fuel consumption may have been influenced by these differences. Both tyre configurations spent a similar amount of time on each slope class except on the steeper slopes.

Heavy slash and stumps hindered the performance of the skidder on wide tyres. The efficiency of the machine on wides was also affected by tyre inflation pressures.

Table 13 : Summary of Daily Records, Kinleith

		Wide Tyres	Narrow Tyres
Productive Machine Hours		79.10	63.10
Machine availability		93.1%	93.2%
Total Cycles		471.0	413.0
Pieces per cycle		3.08	2.73
Average Piece Size* (m^3)		1.36	1.36
Average haul distance (m)		103.0	84.0
Slope classes	0-10%	14.0%	30.0%
	11-20%	56.0%	40.0%
	21-32%	14.0%	30.0%
	32-50%	14.0%	-
Rainfall recorded (mm)		0.0	25.0
Fuel used per PMH (lit)		11.4	11.2
Fuel used per m^3 (lit)		0.46	0.45
Production per PMH (m^3)		32.1	31.3

* Weighted average from Production studies

NGAUMU CLEARFELL

Trial Description

Ngaumu forest is located in the lower South Eastern region of the North Island. The trial site was in Compartment 13 which had been planned for a fast-track skidder. The soil type was fine sandy loam and hill soil derived from sandstone. In wet conditions, it turned to mud, making it difficult for rubber tyred machines to operate. Part of the area had previously been post thinned off tracks with an agricultural tractor. The site spanned two catchment areas drained by seasonally flowing streams in the gullies.

Slopes in the lower reaches of the settings were variable with some short steep side slopes around the dry streams. Towards the back of both settings the slope exceeded 62%. Two landings were used and one had an access track formed through a stand of young trees to the logging area.

The normal operation was based on a five man crew with an FMC 220 CA extraction machine pulling tree length logs to a Hitachi UH083 hydraulic loader in a hot deck situation. Five strops were used on the John Deere skidder and the operator did his own breaking out.

The stand was a 40 year old block of P. radiata, stocked at 227 stems per hectare. The recoverable tree size was estimated to be 2.45 m^3.

Production Study Results

The study at Ngaumu took place in September and October of 1985 and included 108 cycles with the wide tyres and 71 cycles with the narrow tyres. The results are summarised in Table 14.

When travelling empty, the wide tyred skidder was faster than the narrow tyred skidder. This was particularly evident when negotiating slopes between -10% and +26%. Actual gains were as follows:

Table 14 : Production Study Results, Ngaumu

Element	*Wide Tyres*	*Narrow Tyres*
Run empty (skid)	*0.39*	*0.26*
TRAVEL EMPTY (Bush)	*1.00 (150 m)*	*1.85 (150 m)*
Blade logs	*0.18*	*0.23*
POSITION	*0.77*	*0.45*
Breakout	*3.48 (2.62 pcs)*	*3.47 (2.61 pcs)*
TRAVEL LOADED (Bush)	*1.65 (150 m)*	*1.43 (150 m)*
Run loaded skid)	*0.63*	*0.49*
Drop on skid	*0.44*	*0.44*
Other blade work	*0.16*	*0.10*
Total Cycle	*8.65*	*8.80*
Average piece size (m^3)	*2.16*	*2.14*
Average drag size (m^3)	*5.66*	*5.59*
Production per PMH (m^3)	*39.3*	*38.1*

-8% to +9% - wides were 59% faster;
+10% to +17% - wides were 103% faster;
+18% to +27% - wides were 104% faster.

The Ngaumu trial was stopped prematurely because of an over supply of wood and the unseasonally dry conditions.

On one occasion the skidder on wide tyres slid into a standing tree, wedging the tree between the front and rear wheels. The tree had to be felled to release the skidder.

Performance Monitoring

Seventeen days of operation on wide tyres and two days on the narrow tyres were recorded at Ngaumu. The wide tyres were inflated to 110 kPa during this period and the narrows remained the same as they were at Kinleith. The water was still in the narrow tyres. A summary of the daily records collected at Ngaumu is contained in Table 15.

Conclusions

The difference between wide and narrow tyres in Ngaumu was marginal. The machine on narrow tyres used more fuel per PMH than it did on the wide tyres, but it was hauling over longer distances, and actually used less fuel per m^3 produced.

The production studies showed the wide tyres to be more productive than the narrow tyres which is a contradiction to the results from the daily records. Note though that the sample of daily records on the narrow tyres was small.

Travel empty times were significantly less for the wide tyres and there could be significant gains made with using wide tyres over longer haul distances.

The wide tyres could be a disadvantage when operating on side slopes amongst standing trees.

The unusually dry weather conditions had a detrimental effect on the trial result.

Table 15 : Summary of Daily Records, Ngaumu

	Wide Tyres	Narrow Tyres
Productive Machine Hours	110.80	13.48
Machine availability	93.7%	94.7%
Total Cycles	519.0	71.0
Pieces per cycle	3.17	3.22
Average Piece Size* (m^3)	2.15	2.15
Average haul distance (m)	182.0	225.0
Slope classes 11-20%	23.5%	-
21-32%	23.5%	50.0%
32-50%	53.0%	50.0%
Rainfall recorded (mm)	5.0	5.0
Fuel used per PMH (lit)	12.2	13.6
Fuel used per m^3 (lit)	0.38	0.37
Production per PMH (m^3)	31.9	36.5

* Weighted average from Production studies

Figure 29 : Significant gains could be made with using the wide tyres over longer haul distances. The skidder on a formed skid trial at Ngaumu.

KAINGAROA CLEARFELL

Trial Description

Kaingaroa is the largest plantation of exotic trees in New Zealand. It is a State owned forest, located on the Volcanic Plateau in the centre of the North Island. The trial was in Compartment 1123, which had been previously thinned using a crawler tractor working contour tracks. Heavy understory and native shrubs covered the ground. The soil type was Otanewainuku steepland soil derived from Rhyolite ash and Rhyolite.

The trial area comprised two settings, each with a separate landing. One was located in the bottom of a dry gully and the other was in the foot of a basin. Slopes ranged from moderate to flat around the landing areas to over 55% towards the back of each setting.

Extraction was predominantly downhill although a corner of one unit had to be pulled uphill. It had been planned as a hot deck treelength operation based on a Cat 518. The normal crew size was five men with a rubber tyred Cat 950 front end loader to fleet the logs. The skidder was fitted with five strops, and a breaker-out assisted the operator during breakout. Occasional fleeting was necessary with the skidder at the landing.

The stand was 64 year old Douglas fir stocked at 158 stems per hectare. The calculated recoverable piece size was 2.82 m³.

Production Study Results

The skidder was observed for 50 cycles on wide tyres and 41 cycles on narrow tyres. There was a large variation in piece size between the two study areas. The study period was October to November 1985. The results from the studies are shown in Table 16.

Table 16 : Production Study Results, Kaingaroa

Element	*Wide Tyres*	*Narrow Tyres*
Run empty (skid)	*0.37*	*0.37*
TRAVEL EMPTY (Bush)	*1.09 (150 m)*	*1.36 (150 m)*
Blade logs	*0.33*	*0.10*
POSITION	*0.52*	*0.46*
Breakout	*4.92 (4.30 pcs)*	*3.32 (2.90 pcs)*
TRAVEL LOADED (Bush)	*2.04 (150 m)*	*2.07 (150 m)*
Run loaded skid)	*0.29*	*0.30*
Drop on skid	*0.96*	*0.65*
Other blade work	*0.09*	*0.00*
Total Cycle	*10.61*	*8.63*
Average piece size (m³)	*1.41*	*2.77*
Average drag size (m³)	*6.06*	*8.03*
Production per PMH (m³)	*34.3*	*55.8*

The average drag size for the narrow tyres was much larger than for the wide tyres. With the smaller piece size in the wide tyred area, the operator spent much more time blading logs.

A small sample of travel times on a formed road with a 7% downhill slope indicated that the wide tyres were 57% faster. A second incident where the skidder got stuck with a tree lodged between the front and rear wide tyres, occurred in Kaingaroa.

The (89Kw) Cat 518 skidder was also studied in this operation. The travel empty times for the Cat were slower (over the 150 m haul), but travelling loaded it was faster. Overall productivity was measured at 38.9 m³ per PMH.

Performance Monitoring

The daily records collected in the Kaingaroa trial covered 13 days on the wide tyres and four days on narrow tyres. Tyre pressures were kept the same as for Ngaumu although the water was removed from the narrow tyres after climbing tests had been done. The information is summarised in Table 17.

Conclusions

The logging conditions in Kaingaroa were too variable for realistic comparisons to be made. The larger piece size and unusually short haul distances in the narrow tyred area resulted in artificially high production figures.

The fuel consumption on wide tyres was less per machine hour but when the larger piece size in the narrow tyred area is taken into account, fuel used per m³ was less than the narrows.

The wide tyred skidder proved to be very stable on side slopes and when crossing over unused contour tracks.

Table 17 : Daily Records, Kaingaroa

	Wide Tyres	Narrow Tyres
Productive Machine Hours	77.25	21.96
Machine availability	87.9%	93.5%
Total Cycles	465.0	138.0
Pieces per cycle	4.10	3.50
Average Piece Size* (m³)	1.61	2.29
Average haul distance (m)	101.0	85.0
Slope classes 11-20%	53.9%	75.0%
21-32%	46.1%	25.0%
Rainfall recorded (mm)	2.0	0.0
Fuel used per PMH (lit)	10.9	11.7
Fuel used per m³ (lit)	0.27	0.23
Production per PMH (m³)	39.7	50.4

**Note : The two production studies were carried out in separate parts of the compartment. Average piece sizes were derived from the means of the studies done in the respective areas.*

MATAHINA CLEARFELL

Trial Description

Matahina Forest is a privately-owned plantation forest located in the Eastern Bay of Plenty. The John Deere was put into a double skidder operation, replacing a 668 Clark Ranger. The logging area was in a forked gully system at the end of Tutu Road. The soil type was Tarawera Gravel from Tarawera basalt Lapilli. Slopes in the gully were easy with short steep pitches (over 60%) in the heads of the forks and along the ridges.

A Treefarmer C7 skidder was the other extraction machine being used. Most logs on the slopes could be reached from the gullies, but to make breaking out easier, both skidder operators preferred to climb up the ridge and come down over the top of the logs.

The logging system was tree length to a hot deck situation. Crew size, excluding the John Deere operator, was seven men. A Volvo rubber tyred front end loader was used to fleet and load the logs. Three strops were used with each tyre configuration and the operator did his own breaking out. The stand was 37 year old P. radiata with an average extracted piece size of 1.73 m^3.

For the last four days of the Matahina trial, the John Deere skidder was put into an area that was being logged with an FMC skidder. No studies were carried out but visual observations of machine performance were made.

Production Study Results

A total of 42 cycles on wide tyres and 62 cycles on narrow tyres were studied at Matahina in November 1985. The results are shown in Table 18.

Table 18 : Production Study Results, Matahina

Element	*Wide Tyres*	*Narrow Tyres*
Run empty (skid)	*0.27*	*0.31*
TRAVEL EMPTY (Bush)	*1.11 (150 m)*	*1.24 (150 m)*
Blade logs	*0.23*	*0.39*
POSITION	*0.47*	*0.58*
Breakout	*3.32 (2.60 pcs)*	*3.96 (3.10 pcs)*
TRAVEL LOADED (Bush)	*1.46 (150 m)*	*1.52 (150 m)*
Run loaded skid)	*0.46*	*0.47*
Drop on skid	*0.77*	*0.92*
Other blade work	*0.67*	*0.47*
Total Cycle	*8.76*	*9.86*
Average piece size (m^3)	*1.83*	*1.68*
Average drag size (m^3)	*4.75*	*5.21*
Production per PMH (m^3)	*32.5*	*31.7*

Table 19 : Daily Records, Matahina

	Wide Tyres	Narrow Tyres
Productive Machine Hours	39.84	11.25
Machine availability	96.0%	93.1%
Total Cycles	249.0	58.0
Pieces per cycle	2.51	3.26
Average Piece Size* (m^3)	1.76	1.76
Average haul distance (m)	143.0	202.0
Slope classes 0-10%	17.0%	-
21-32%	83.0%	100.0%
Rainfall recorded (mm)	0.0	0.0
Fuel used per PMH (lit)	10.1	11.0
Fuel used per m^3 (lit)	0.37	0.37
Production per PMH (m^3)	27.6	29.6

* Weighted average from production studies

The John Deere on narrow tyres and the Treefarmer C7 could both climb the ridges quicker than the wide tyres because it was harder to manoeuvre between the stumps on the ridge with the wides on. All the machines could handle the short steep slopes provided the direction of travel was straight down the slope. In this situation, the longer wheelbase of the Treefarmer made it more stable than the John Deere on either set of tyres. Travel speeds were again higher with wide tyres on and the position element was shorter. There was also less log blading done prior to breakout.

In the FMC area the wide tyres did not perform well after heavy rain (not recorded by the weather station). The machine was limited to about 20% slopes because the combination of wet soils and moderate slash cover caused excessive wheelslip. Access tracking was necessary to keep the machine working. The FMC had little difficulty working the same area in similar conditions.

Performance Monitoring

Six days of operation on wide tyres and two days on narrow tyres were recorded. Tyre pressures were the same as for Kaingaroa. The information collected at Matahina is summarised in Table 19.

Conclusions

Production study results showed that the wide tyres were more productive than the narrow, but this is not reflected in the daily records. The extra width of the wides was sometimes a hindrance, particularly when trying to negotiate a path along the top of a ridge. Both tyre configurations were capable of working on the steeper slopes, but more caution was necessary when going across the slope with narrow tyres on.

The wet scoria appeared to have more effect on the performance of the wide tyres than it did on the narrow tyres. The FMC had a far greater capacity to climb up the scoria slopes but it lacked the stability of the wide tyres on side slopes.

Only a small sample of daily records were collected on narrow tyres.

KINLEITH THINNING

The wide tyred skidder was trialled in both hauler thinning and tractor thinning areas in Kinleith.

Hauler Thinning

The hauler thinning area was in the Waikato block along Jack Henry Road. The soil type was pumice ash on clay. The setting was on a steep hillside with flat areas at the top and bottom. Slopes on the hillside were consistently around 60-65%.

The trial was arranged to assess outrow extraction using the skidder on both wide and narrow tyres. Five corridors were marked in and the following systems tried:

1. Trees in the corridors only were felled and extracted.

2. Bay trees in the same corridors were felled and extracted in a second series of machine passes.

3. Corridor and bay trees were felled and extracted concurrently.

The theory was that the wide tyred skidder would reverse up the corridors and get the bulk of the wood from the bottom. Slope length was between 80 and 140 m. The flat area at the top was extracted down a 182 m long, 23% track, which was also used for access to the top of the block.

The operation was based on a four man crew (excluding the skidder operator) with the fallers assisting in the breakout phase. The skidder was required to fleet the logs on the landing. The stand was 15 year old P. radiata with an average piece size of .26 m^3.

Production Study Results

The wide tyres were studied for 42 cycles and the narrow tyres for 30 cycles during December of 1985. The results are shown in Table 20.

Table 20 : Results from Studies in Hauler Thinning Area

Element	*Wide Tyres*	*Narrow Tyres*
Run empty (skid)	*0.31*	*0.29*
TRAVEL EMPTY (Bush)	*1.86 (150 m)*	*1.77 (150 m)*
Blade logs	*0.15*	*0.17*
POSITION	*0.74*	*0.98*
Breakout	*6.74 (7.60 pcs)*	*7.00 (7.90 pcs)*
TRAVEL LOADED (Bush)	*1.59 (150 m)*	*1.20 (150 m)*
Run loaded skid)	*0.31*	*0.30*
Drop on skid	*1.51*	*1.57*
Other blade work	*0.35*	*0.55*
Total Cycle	*13.56*	*13.83*
Average piece size (m^3)	*0.28*	*0.25*
Average drag size (m^3)	*2.13*	*1.98*
Production per PMH (m^3)	*9.4*	*8.6*

Figure 30 : The wide tyred skidder was difficult to control on the steep slopes in the hauler thinnings area

The skidder on wide tyres was virtually uncontrollable when travelling over logs on the steep slopes. Occasionally it would lose traction on top of the slash and spin a complete circle.

The operator found the blade of the wide tyred skidder of little use when trying to position logs for breakout, or as a means of support on steep descents.

The narrow tyres penetrated through the slash and logs lying in the outrow which gave better traction and stability.

Performance Monitoring

A total of three days of operation on wide tyres and two days on narrow tyres were documented in the hauler thinning area. No changes were made to tyre inflation pressures from the Matahina trail. The information collected is summarised in Table 21.

The corridors in the Hauler thinning area were widened from four metres to five to six metres for the wide tyres. Some large gaps were created when the machine skidded off the outrow into standing trees. Residual stocking was kept at the prescribed level by leaving extra trees in the bays.

Bark damage on the slopes was high along the edges of the corridors (5-10%). Irregular slopes and logs lying in the outrow would cause the skidder on wide tyres to slide sideways into standing trees.

Table 21 : Daily Records in the Hauler Thinning Area

	Wide Tyres	Narrow Tyres
Productive Machine Hours	15.85	8.92
Machine availability	91.9%	96.0%
Total Cycles	59.0	35.0
Pieces per cycle	6.83	7.74
Average Piece Size* (m^3)	0.27	0.27
Average haul distance (m)	300.0	233.0
Slope classes 0-10%	33.3%	50.0%
21-32%	66.7%	50.0%
Rainfall recorded (mm)	0.0	0.0
Fuel used per PMH (lit)	8.2	11.0
Fuel used per m^3 (lit)	1.19	1.34
Production per PMH (m^3)	6.9	8.2

** Weighted average from production studies*

Conclusions

The wide tyres showed a marginal advantage over the narrow tyres in the production studies but not in the daily records. The daily records however, were considered a truer indication of machine productivity in this situation. Because of the difficulties in controlling the machine when travelling over slash on steep slopes, the wide tyres were considered to be unsuitable in the hauler thinning area. The flotation effect of the wides would not allow the wheels to penetrate through the slash and logs in the outrows. This resulted in uncontrollable manoeuvres and a roll-over.

The larger diameter of the wides combined with their flotation effect rendered the blade useless when working on top of logs and slash.

Tractor Thinning

The tractor thinning area was along Barnett Road on a Taupo ash soil type. The setting was designed for downhill extraction of tree length logs in a selective thinning operation. Slopes in the block ranged from 19% at the foot of the hill to between 46% and 65% above that. The stand was 17 year old P. radiata.

The regular extraction machine for this operation was a Cat D4 tractor which also did the fleeting at the landing. The crew size was four men (excluding the John Deere operator), and two were assigned to breaking out during the study. The logging system was a cold deck operation with intermittent load out.

Production Study Results

Due to problems with dirty fuel, only 29 cycles on the wide tyres were studied in the tractor thinning area. The narrow tyres were studied for 75 cycles. Study period was late December 1985. The results are shown in Table 22.

No extra tracking was necessary to operate the wide tyred skidder in the selection thinning although the machine did use a climbing track on both wide and narrow tyres. Once again control of the skidder was difficult when operating on wide tyres. A second roll

Table 22 : Time Study Results in Tractor Thinning Area

Element	*Wide Tyres*	*Narrow Tyres*
Run empty (skid)	*0.31*	*0.29*
TRAVEL EMPTY (Bush)	*2.07 (150 m)*	*1.64 (150 m)*
Blade logs	*0.10*	*0.13*
POSITION	*0.87*	*0.77*
Breakout	*5.16 (6.31 pcs)*	*5.34 (6.52 pcs)*
TRAVEL LOADED (Bush)	*1.53 (150 m)*	*1.81 (150 m)*
Run loaded skid)	*0.46*	*0.63*
Drop on skid	*1.12*	*1.16*
Other blade work	*0.48*	*1.66*
Total Cycle	*12.10*	*13.43*
Average piece size (m^3)	*0.37*	*0.41*
Average drag size (m^3)	*2.33*	*2.67*
Production per PMH (m^3)	*11.6*	*11.9*

over incident occurred in the tractor thinning area, this time on the narrow tyres.

The skidder had fuel problems during the trials with the wide tyres and consequently the study was cut short.

Performance Monitoring

Only two days of operation on wide tyres and three days of operation on the narrow tyres were recorded. Tyre pressures remain at 110 kPa for the wide tyres and 172 kPa for the narrow tyres. A summary of the daily records for the tractor thinning area is shown in Table 23.

Conclusions

The narrow tyres again proved to be more productive in the tractor thinning area. No extra tracking was necessary to operate the wides. The operator had lost some confidence in the wide tyres in thinnings and this was reflected in his operation of the machine.

The wide tyres were not suited to the thinning operation. Slopes of 60%+ were considered too steep for safe skidder operation. Narrow tyres were more controllable than wide tyres when travelling over logs and slash, but that did not prevent a second roll over accident from occurring.

Travel empty times on the steep slopes were significantly longer with the wide tyres. The narrow tyred machine used more fuel per machine hour and per m^3 than the wide tyred machine.

WOODHILL CLEARFELL

Trial Description

Woodhill forest is a sand dune stabilisation forest on the north

Table 23 : Daily Records for Tractor Thinning Area - Kinleith Forest

	Wide Tyres	Narrow Tyres
Productive Machine Hours	5.76	15.37
Machine availability	84.2%	90.1%
Total Cycles	27.0	74.0
Pieces per cycle	5.92	6.04
Average Piece Size* (m^3)	0.39	0.39
Average haul distance (m)	119.0	134.0
Slope classes 0-10%	100.0%	33.3%
21-32%	-	-
Rainfall recorded (mm)	0.0	8.0
Fuel used per PMH (lit)	10.4	9.0
Fuel used per m^3 (lit)	0.96	0.79
Production per PMH (m^3)	10.8	11.3

* Weighted average from production studies

western coast of the North Island. The soil type in Compartment 71 was of Podzolic origin from Aeolian sand.

Terrain in the area was typical of sand dune type forests with undulating hills and gradual slopes. The logging crew was six men with a Clark Ranger 666C skidder and a Clark Michigan 55B rubber tyred front end loader.

The system used was tree length extraction to a hot deck landing. A certain amount of uphill travel loaded was necessary for most of the trial area. It was common practice for the skidder to butt the logs up at the end of each cycle. Logs were dropped onto runner logs at the landing. The weather prior to the study had been unusually wet for that time of the year. Some light showers fell during the trial.

The stand was 43 year old P. radiata stocked at 280 stems per hectare. The recoverable tree size was estimated to be 2.15 m^3.

Production Study Results

A total of 99 cycles on wide tyres and 88 cycles on narrow tyres were studied at Woodhill in January 1986. Results from the study are summarised in Table 24.

On some occasions, congestion at the skid resulted in a smaller than optimum drag being extracted.

A 40 m section of 12% uphill grade in the travel loaded element enticed the operator to attach one less log per drag to avoid having to winch. This applied to both tyre types.

On the abovementioned incline, no winching was necessary with the wide tyres in 99 cycles. In the study with narrow tyres, the operator had to winch in five out of 88 cycles. Overall travel speed for that section, including winching, was 10% faster with narrow tyres.

Daily Records

Eight days of data on the wide

Table 24 : Production Study Results, Woodhill

Element	Wide Tyres	Narrow Tyres
Run empty (skid)	0.31	0.29
TRAVEL EMPTY (Bush)	2.07 (150 m)	1.64 (150 m)
Blade logs	0.10	0.13
POSITION	0.87	0.77
Breakout	5.16 (6.31 pcs)	5.34 (6.52 pcs)
TRAVEL LOADED (Bush)	1.53 (150 m)	1.81 (150 m)
Run loaded skid)	0.46	0.63
Drop on skid	1.12	1.16
Other blade work	0.48	1.66
Total Cycle	12.10	13.43
Average piece size (m^3)	0.37	0.41
Average drag size (m^3)	2.33	2.67
Production per PMH (m^3)	11.6	11.9

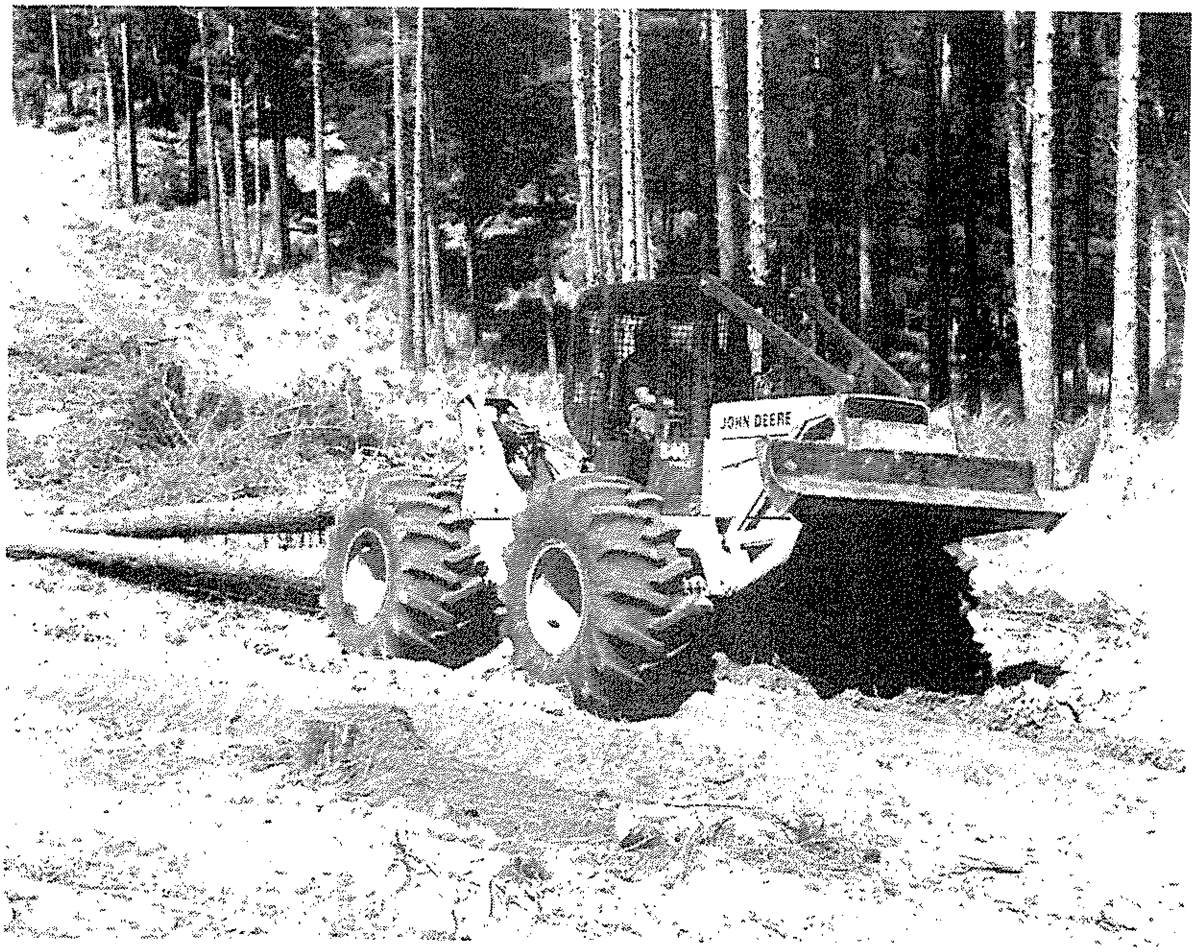

Figure 31 : The skidder on narrow tyres hauling up the +12% incline to the skid at Woodhill

Table 25 : Summary of Daily Records, Woodhill

	Wide Tyres	Narrow Tyres
Productive Machine Hours	39.17	18.21
Machine availability	88.6%	91.0%
Total Cycles	281.0	124.0
Pieces per cycle	2.46	2.40
Average Piece Size* (m^3)	1.52	1.52
Average haul distance (m)	133.0	166.0
Slope classes 0-10%	12.5%	-
21-32%	87.5%	100.0%
Rainfall recorded (mm)	9.0	-
Fuel used per PMH (lit)	12.5	14.9
Fuel used per m^3 (lit)	0.46	0.60
Production per PMH (m^3)	26.8	24.8

* Weighted average from production studies

tyres and four days of data on the narrow tyres was collected. The pressures in the wide tyres were reduced to 103 kPa during the Woodhill trial. The narrow tyres were left at 172 kPa. A summary of the daily records are shown in Table 25.

The wide tyres appeared to have more traction than the narrow tyres in the sand. Disturbance to the extraction track was considerably less with the wide tyres. The sand was relatively wet under the top 10 cm of the surface.

A sample of cycles with the Clark Ranger were observed but no times collected. Drag sizes were smaller with the Clark and it seemed to have more difficulty with traction when travelling loaded up the 12% grade to the skid.

Conclusions

The estimated production from both sets of tyres was almost the same.

Fuel usage on narrow tyres was higher per machine hour and per cubic metre produced, but average haul distance was longer for the narrow tyres.

The difference in performance between the two sets of tyres may have been greater if the sand had been drier.

TARAWERA CLEARFELL

Trial Description

Tarawera Forest is located on the eastern edge of the Volcanic Plateau in the central North Island. The soil type was a scoria type gravel from Tarawera basalt lapilli. The trial was the first clearfelling operation undertaken in the forest. A six-man crew with a Cat 518 skidder and Cat 950 rubber tyred loader were imported from Kaingaroa to do the logging.

The setting was bounded by a ridge on one side and a road in the gully bottom on the other. Two landings had been established for the operation. Slopes on the side of the ridge ranged from 42 to 65%

Table 26 : Production Study Results, Tarawera

Element	*Wide Tyres*	*Narrow Tyres*
Run empty (skid)	*0.37*	*0.35*
TRAVEL EMPTY (Bush)	*1.37 (150 m)*	*1.61 (150 m)*
Blade logs	*0.49*	*0.47*
POSITION	*0.39*	*0.32*
Breakout	*3.48 (3.96 pcs)*	*4.61 (5.24 pcs)*
TRAVEL LOADED (Bush)	*0.85 (150 m)*	*2.01 (150 m)*
Run loaded skid)	*0.36*	*0.56*
Drop on skid	*0.50*	*0.71*
Other blade work	*0.46*	*0.26*
Total Cycle	*9.27*	*10.90*
Average piece size (m^3)	*0.98*	*0.86*
Average drag size (m^3)	*3.88*	*4.51*
Production per PMH (m^3)	*25.1*	*24.8*

with intermediate ridges dissecting the main ridge.

The basic logging system was downhill, tree length extraction with the operator breaking out his own wood and a minimal amount of fleeting on the landing. Six chain strops were used in place of the normal wire rope strops.

The stand was 23 year old P. radiata stocked at 376 stems per hectare with a recoverable piece size of 1.24 m^3.

Production Study Results

A total of 83 cycles on wide tyres and 93 cycles on narrow tyres were studied. The study period was between February and April. The results are shown in Table 26.

The Cat 518 was also studied during the Tarawera trial. It had a quicker cycle time of 9.21 minutes and a smaller piece size of 0.84 m^3 but production per PMH was higher at 26.9 m^3. The Cat was head-pulling 100% of the time, whereas the wide tyres were head-pulling only 30% of the time and the narrow 55% of the time.

Daily Records

Daily records were kept for 12 days of operation on wide tyres and 10 days on narrow tyres. Part way through the trial with wide tyres in Tarawera, tyre pressures were reduced from 103 kPa to 83 kPa. The narrow tyres were also reduced in pressure from 172 kPa to 138 kPa. A summary of the records are shown in Table 27. Six days of machine-related downtime have not been included in these records.

On one intermediate hill a 42% adverse grade access track was planned to get to wood on the top of the main ridge. Attempts to climb the ridge on both wide and narrow tyres and with the Cat 518 were unsuccessful. By lowering pressures from 103 kPa to 83 kPa in the wide tyres, the John Deere was able to climb most of the way up the ridge but not to the top.

Table 27 : Summary of Daily Records, Tarawera

	Wide Tyres	Narrow Tyres
Productive Machine Hours	58.26	52.44
Machine availability	87.7%	92.1%
Total Cycles	410.0	277.0
Pieces per cycle	4.27	5.29
Average Piece Size* (m^3)	0.89	0.89
Average haul distance (m)	100.0	162.0
Slope classes 0-10%	9.0%	10.0%
11-20%	36.0%	20.0%
21-32%	27.5%	20.0%
33-50%	27.5%	50.0%
Rainfall recorded (mm)	51.0	-
Fuel used per PMH (lit)	9.1	11.3
Fuel used per m^3 (lit)	0.34	0.45
Production per PMH (m^3)	26.7	24.9

* *Weighted average from production studies*

Logs on the slope were picked up by the skidder turning and driving across a 60% side slope and coming down over the top of the logs. Eventually, access to logs at the back of the setting was gained via a track running the length of the main ridge. Lowering the pressures in the narrow tyres did not appear to improve the skidder's performance when climbing on the loose scoria.

Conclusions

There was little difference in productivity between the wide and narrow tyres. Variations in the extracted piece size made it difficult to draw comparisons between the three machines. The wide tyres again proved to be very stable when travelling across steep side slopes.

Reducing tyre pressures improved the climbing ability of the wide tyred skidder in the scoria soils.

Production was higher when the machines were head-pulling i.e. the more head-pulling the skidders were doing, the more productive they were.

The wide tyred skidder used less fuel per PMH and per m³ produced but the narrow tyred machine was hauling over longer distances.

MANGATU CLEARFELL

Trial Description

Mangatu is a protection forest situated on unstable, erosion prone terrain on the East Coast of the North Island. The soil type was Gisborne sandy loam derived from Gisborne ash. Slopes ranged from flat to 23% with some pitches of over 44%. The logging area was located on either side of Whetarau Road.

As there was no regular logging being done at Mangatu, a seven-man crew and a Mitsubishi MS 180 hydraulic loader were brought in from Patunamu forest. The logging system was experimental with short

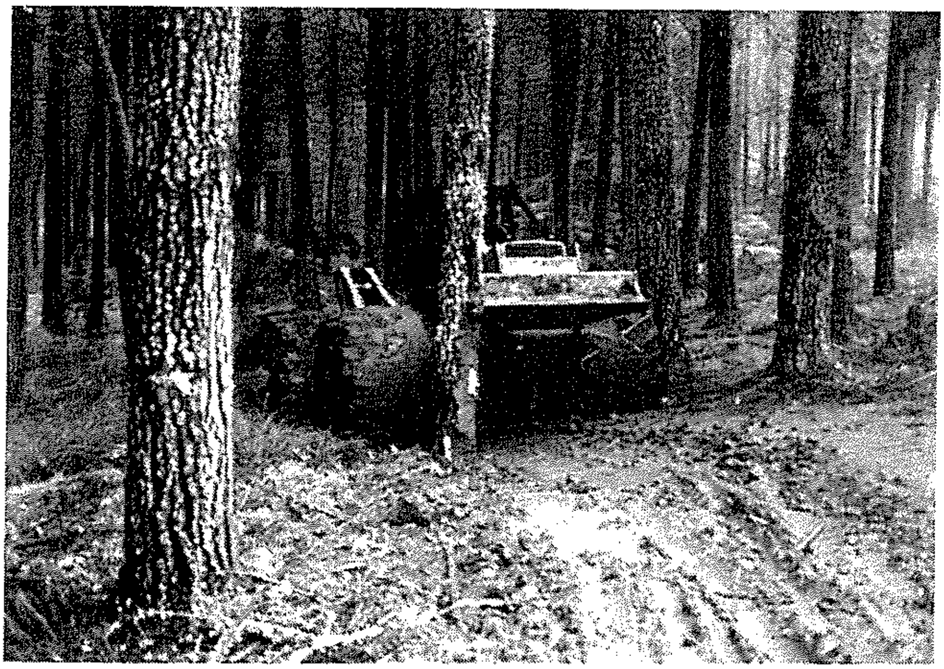

Figure 32 : The skidder on wide tyres having difficulty negotiating a greasy track during the Mangatu trial

and long log length extraction to the road edge in a hot deck operation. Both uphill and downhill extraction was tried on the wide tyres, and only a brief spell of uphill extraction tried with the narrow tyres on. An FMC 220 CA tracked skidder was also studied in the same area.

At the beginning of the trial, the short logs were cut to actual sawlog specifications (2.4 m to 6.3 m) in the bush. Due to operational difficulties in extracting this wood the pattern was changed to a semi-random cut approximately midway up the stem. A breaker-out assisted the skidder operator during the log attachment phase.

The stand was 35 year old P. radiata stocked at 285 stems per hectare. The recoverable tree size was 1.87 m^3.

Production Study Results

A total of 79 cycles of wide tyre operations were studied at Mangatu, 20 when extracting short logs and 59 when extracting semi-processed wood. The narrow tyres were not studied at Mangatu. The study period was April-May 1986. Results are shown in Table 28.

Weather prior to the study had been dry and ground conditions were described as unusually firm. Some rain did fall when the skidder was extracting uphill and the tread on the wide tyres quickly became clogged, resulting in virtually no traction. The rain was insufficient to saturate the soil.

Some bunching of the short logs had been done before the study. A brief evaluation of the FMC showed that it was much more productive than the rubber tyred skidder, especially pulling logs uphill.

Daily Records

Daily records were kept for 27 days of operation on the wide tyres and two days on the narrow tyres. The pressures in the wide tyres were left at 83 kPa and the narrow tyres remained at 138 kPa. Five days of machine downtime has been disregarded in these records

Table 28 : Production Study Results, Mangatu

Element	Short Logs	Long Logs	Combined
Run empty (skid)	0.21	0.35	0.24
TRAVEL EMPTY (Bush)	1.37 (150 m)	1.43 (150 m)	1.42 (150 m)
Blade logs	-	0.07	0.05
POSITION	0.31	0.26	0.27
Breakout	2.68 (5.10 pcs)	2.36 (3.92 pcs)	2.41 (4.22 pcs)
TRAVEL LOADED (Bush)	1.92 (150 m)	2.05 (150 m)	2.00 (150 m)
Run loaded (skid)	0.36	0.49	0.46
Drop on skid	0.75	0.61	0.65
Other blade work	0.25	0.47	0.41
Total Cycle	7.86	8.00	7.01
Average piece size (m^3)	0.96	1.21	1.13
Average drag size (m^3)	4.90	4.74	4.78
Production per PMH (m^3)	37.4	35.6	36.3

as it was not related to either set of tyres. A summary of the daily records from Mangatu are shown in Table 29.

Table 29 : Daily Records, Mangatu

	Wide Tyres	Narrow Tyres
Productive Machine Hours	130.00	6.58
Machine availability	86.2%	98.2%
Total Cycles	881.0	50.0
Pieces per cycle	3.71	2.50
Average Piece Size* (m^3)	1.09	1.21
Average haul distance (m)	141.0	103.0
Slope classes 11-20%	100.0%	100.0%
Rainfall recorded (mm)	34.0	41.0
Fuel used per PMH (lit)	11.4	12.5
Fuel used per m^3 (lit)	0.42	0.54
Production per PMH (m^3)	27.4	23.0

* Weighted average from production studies

Heavy rain fell on the last two days of the trial. At that stage the wide tyres were having considerable difficulty climbing up the 16% incline. The tyres were changed and performance improved immediately. It was noticeable that the narrow tyres were biting through the soft surface to firmer ground underneath, whereas the wide tyres were not penetrating through the surface and the treads were clogging up.

In the initial stages of the trial, the skidder was travelling through standing trees to get to the road edge. This limited the choice of haul paths that could be taken and meant that when it rained and the track got muddy, the operator could not easily select a new route.

Conclusions

Dry weather conditions before and during the trial at Mangatu had a large bearing on the somewhat doubtful results. Even with the rain falling at the end of the trial, ground conditions were not considered normal.

The system of extracting logs to the road edge worked successfully although the skidder had some difficulty with the uphill extraction. Efficient truck scheduling was essential where there was limited room to stockpile the logs.

The FMC tracked skidder could handle the logging conditions much better than the rubber tyred machine. Considering the power difference, though, no realistic comparison could be drawn. It is unlikely that a larger rubber tyred skidder would have matched the performance of the tracked skidder.

MARAMARUA CLEARFELL

Maramarua forest is a State-owned forest situated South-east of Auckland. The logging was normally done by cable systems because in wet weather conditions were unsuitable for ground-based machines. The Maramarua soils were Mangawheau sandy loam and clay derived from shattered greywacke. Generally, the terrain was flat to gently rolling, but dissected by two small drainages between two and three metres deep. In one part of the setting, the slopes were up to 25%. A local crew, selected from the forest workforce, made up the logging gang.

The logging system was tree length extraction to a hot deck situation at the landing. Runner logs were laid out across the skid to drop the logs on and at the end of each cycle the skidder butted the logs up. A Fiat Allis 645 rubber tyred front end loader was used for fleeting and loading. Five strops were used on the machine and the operator had an assistant for breaking out.

The stand was a 34 year old block of P. radiata stocked at 368 stems per hectare. The recoverable tree size was calculated to be 1.53 m^3.

Because of the abnormally dry weather conditions, part of the logging area was artificially dampened with a sprinkler system. A total of 44 mm of rain fell during the study period.

Production Study Results

A total of 80 cycles on wide tyres and 72 cycles on narrow tyres were studied at Maramarua during May and June of 1986. The results are shown in Table 30.

Two different tyre pressures were tried in the wide tyres at Maramarua - 69 kPa and 55 kPa. The travel loaded speeds appeared to be 10% higher with the lower pressures on slopes ranging from +8% to -17%. Insufficient data was collected however to substantiate this indication.

Performance Monitoring

Seven days of operations on wide tyres and four days on narrow

Table 30 : Production Study Results, Maramarua

Element	Wide Tyres	Narrow Tyres
Run empty (skid)	0.25	0.24
TRAVEL EMPTY (Bush)	1.15 (150 m)	1.21 (150 m)
Blade logs	0.58	0.89
POSITION	0.25	0.26
Breakout	2.89 (3.26 pcs)	2.65 (2.99 pcs)
TRAVEL LOADED (Bush)	1.68 (150 m)	1.73 (150 m)
Run loaded skid)	0.40	0.49
Drop on skid	0.46	0.42
Other blade work	0.26	0.21
Total Cycle	7.92	8.10
Average piece size (m^3)	1.71	1.70
Average drag size (m^3)	5.57	5.08
Production per PMH (m^3)	42.2	37.6

tyres, were recorded at Maramarua. The pressures in the narrow tyres were left at 138 kPa. The information from the daily recording is summarised in Table 31.

Conclusions

There was virtually no difference between the performance of wide and narrow tyres at Maramarua. On a PMH basis the narrow tyres actually used less fuel but average haul distances were shorter. The production studies indicated that there was more of an advantage using the wide tyres but the long term monitoring did not support this. The wide tyres did not sink as far into the soft ground as the narrow tyres did when crossing the drainages.

Table 31 : Daily Records, Maramarua

	Wide Tyres	Narrow Tyres
Productive Machine Hours	31.36	14.43
Machine availability	79.7%	91.6%
Total Cycles	210.0	109.0
Pieces per cycle	3.24	2.91
Average Piece Size* (m^3)	1.71	1.71
Average haul distance (m)	135.0	108.0
Slope classes 0-10%	100.0%	100.0%
Rainfall recorded (mm)	44.0	-
Fuel used per PMH (lit)	10.9	10.5
Fuel used per m^3 (lit)	0.29	0.28
Production per PMH (m^3)	37.1	37.6

SUMMARY OF PERFORMANCE MONITORING RESULTS

Table 32 summarises the production study results from the clearfelling trials, by forest.

In most forests, paired comparisons of wide tyres versus narrow tyres were not possible because of variations in piece size and number of pieces hooked on.

Figures 33 and 34 summarise productivity versus piece size and drag volume.

Table 32 : Summary of Production Study Results for Clearfell Trials

Forest	*Wide Tyres*			*Narrow Tyres*		
	Av. Cycle Time, mins	*Av. Drag Volume, m³*	*Production Per PMH, m³*	*Av. Cycle Time, mins*	*Av. Drag Volume, m³*	*Production Per PMH, m³*
Kinleith	*10.41*	*4.46*	*25.7*	*10.51*	*5.43*	*31.8*
Ngaumu	*8.65*	*5.66*	*39.3*	*8.80*	*5.59*	*38.1*
Kaingaroa	*10.61*	*6.06*	*34.3*	*8.63*	*8.03*	*55.8*
Matahina	*8.76*	*4.75*	*32.5*	*9.86*	*5.21*	*31.7*
Woodhill	*8.24*	*3.67*	*26.7*	*7.72*	*3.49*	*27.1*
Tarawera	*9.27*	*3.88*	*25.1*	*10.90*	*4.51*	*24.8*
*Mangatu**	*7.01*	*4.78*	*36.3*	-	-	-
Maramarua	*7.92*	*5.57*	*42.2*	*8.10*	*5.08*	*37.6*

** No production studies were done on the narrow tyres at Mangatu*

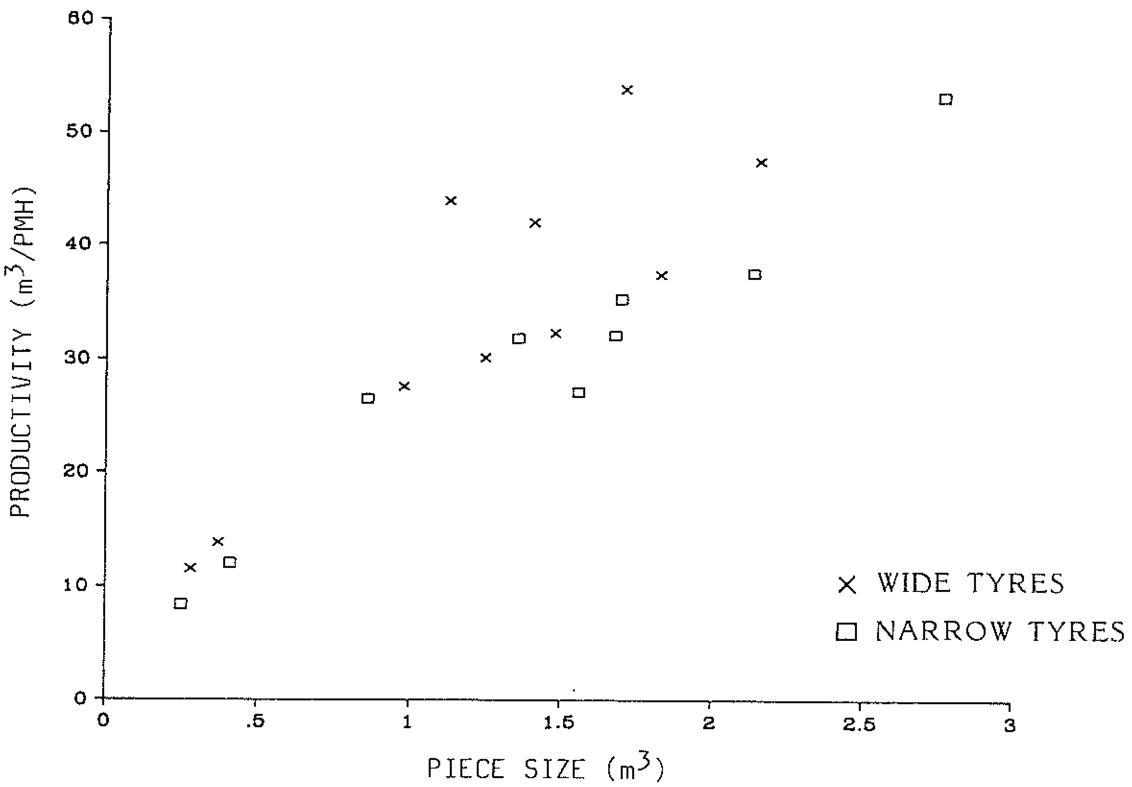

Figure 33 : Productivity versus Piece Size

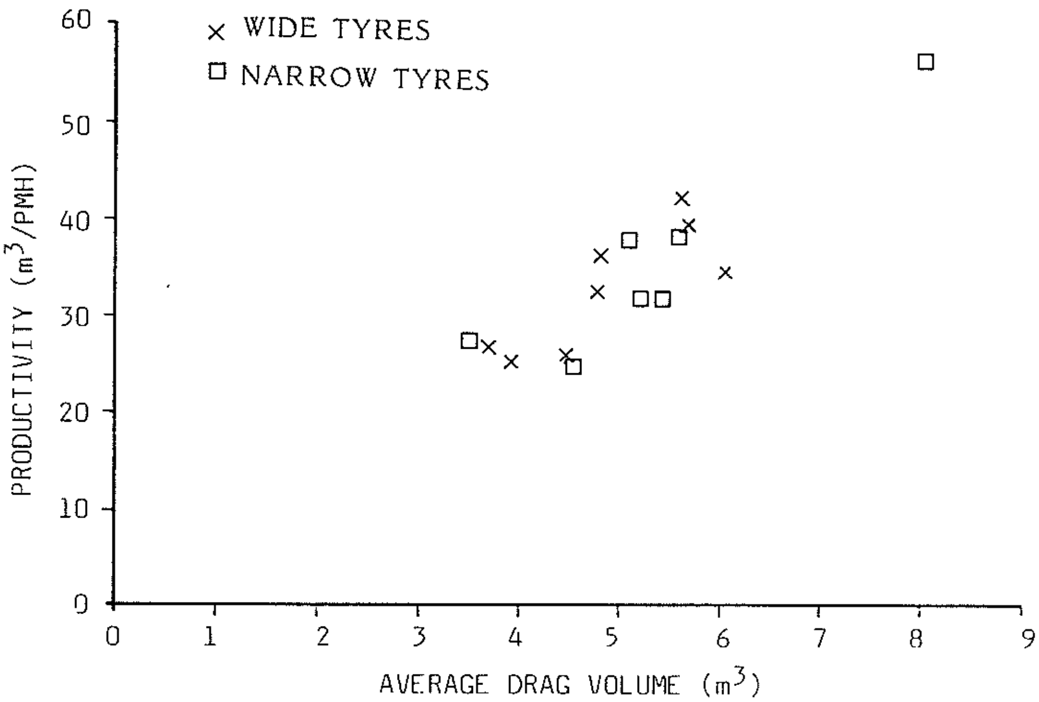

Figure 34 : Productivity versus drag volume

Figure 33 suggests that, for a given tree size, productivity on wide tyres was higher than on narrow tyres but when this is related to average drag size (see Figure 34) the difference is not significant.

The following are conclusions drawn from comparing the different element times between the trials.

(i) **Manoeuvrability on the landing:** The wide tyres were generally slower to manoeuvre, loaded or unloaded, on the landings. Congestion was an influencing factor - especially on smaller narrow landings. In some cases the skidder on wide tyres had to do a 3-point turn to manoeuvre off the landing after unhooking.

(ii) **Travel speeds:** In all but two forests (Ngaumu and Woodhill) the travel loaded speeds were up to 8% higher with the wide tyres. In Ngaumu forest the wide tyres were 15% slower with a similar drag size. Travel loaded was also slower in Woodhill (by 13%) although drag sizes were larger. In all forests the wide tyres were faster unloaded than the narrow tyres. Differences ranged from 5% quicker in Maramarua to 46% quicker in Ngaumu.

Figures 35 and 36 illustrate travel speeds, loaded and unloaded, versus slope. Travel speeds were affected by the increases in slope, both favourable and adverse. The generally higher unloaded speeds on wide tyres reflect their relative stability on steeper slopes and improved traction.

(iii) **Blading logs:** Blading logs in preparation for break-out is common practise in New Zealand skidder operations. Apart from two forests, Kaingaroa and Tarawera, the wide tyred skidder spent less time blading logs prior to breakout. The main reason was that precise blade control was more difficult on the wide tyres because:

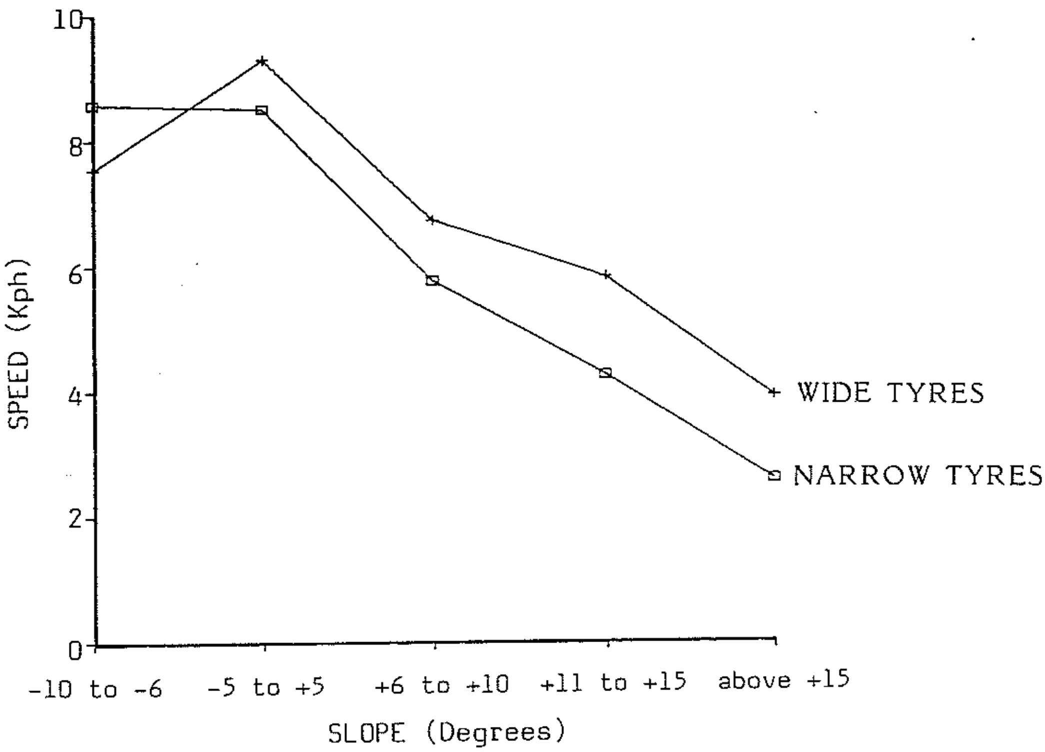

Figure 35 : Travel Empty Speeds versus Slope

- their larger diameter reduced effective blade travel
- their extra width extended beyond the outside edge of the blade
- their flotation effect made it hard to get the machine level.

When using wide tyres the operator was consistently doing more blade work either on the skids or along the haul path to remove obstacles.

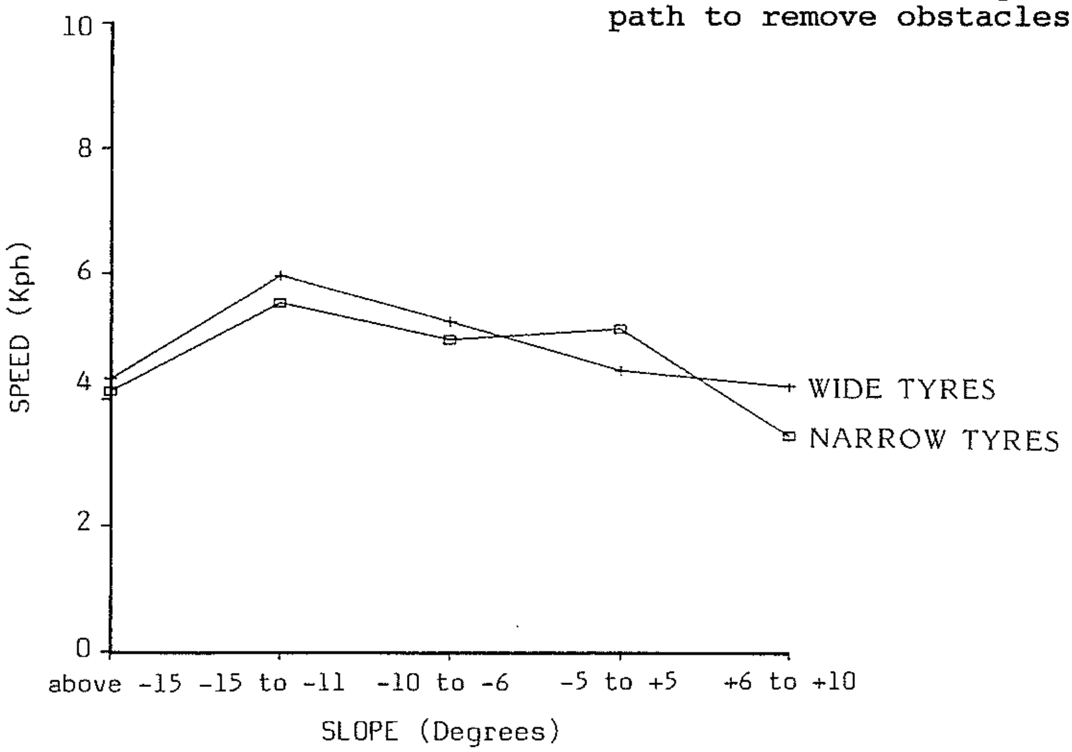

Figure 36 : Travel Loaded Speeds versus Slope

Table 33 : Fuel Consumption and Production Levels Recorded from Daily Records

	Wide Tyres			Narrow Tyres		
Forest	Fuel Used per PMH	Litres per m^3	Production per PMH, m^3	Fuel Used per PMH	Litres per m^3	Production per PMH, m^3
Kinleith	11.4	0.46	32.1	11.2	0.45	31.3
Ngaumu	12.2	0.38	31.9	13.6	0.37	36.5
Kaingaroa	10.9	0.27	39.7	11.7	0.23	50.5*
Matahina	10.1	0.37	27.6	11.0	0.37	29.6
Woodhill	12.4	0.46	26.8	14.9	0.60	24.8
Tarawera	9.1	0.34	26.7	11.3	0.45	24.9
Mangatu	11.4	0.42	27.4	12.5	0.54	23.0
Maramarua	10.9	0.29	37.1	10.5	0.28	37.6

* *There was such a large difference in piece size between the two areas logged in Kaingaroa that a weighted average per piece could not be used.*

Daily Records

Information from the daily records are summarised in Table 33. Production per PMH is calculated by taking the weighted average of piece size recorded in the production studies, multiplying it by the number of pieces pulled and dividing by PMH. Fuel usage is calculated by dividing fuel used by PMH and by cubic metres produced.

The skidder on wide tyres used an average of 8% less fuel per PMH and 10% less fuel per m³ produced.

Total hours worked and mechanical availability are summarised in Table 34.

Note that the lower availability of the machine on wide tyres was not due to the tyres.

Table 34 : Hours Worked and Mechanical Availability

	Wide Tyres	Narrow Tyres
Hours worked	565.9	201.5
Mechanical availability	89.1%	93.4%

Using the LIRA Costing Format (Wells, 1981) the cost of owning and operating the two different tyre configurations can be compared. These costs are based on 1986 machine, tyre and fuel costs and use actual fuel and oil consumption figures, a predicted tyre life of 4000 hours and 50% of depreciation for repairs and maintenance. Table 35 shows the cost per hour and relates it to the production figures from the daily records (excluding Kaingaroa).

The skidder on wide tyres cost \$6.32 per hour more than it did on narrow tyres. Data from the production studies and performance monitoring indicated that this additional cost is not offset by the reduced fuel consumption in these studies.

Table 35 : Cost Comparison of Wide Tyres vs Narrow Tyres

	Wide Tyres	Narrow Tyres
	\$	\$
Owning costs/hr	23.92	22.54
Operating costs/hr	29.05	24.11
Total cost/hr	52.97	46.65
Cost/m^3 (based on 30 m^3/hr)	1.78	1.56

Production Increase required for break-even 3.6 m^3/hr (+13%)

TYRE DAMAGE AND WEAR

INTRODUCTION

Overseas experience (Simpson, 1985) indicated that tyre failures were usually the result of operator abuse, e.g. running over loader stabilisers, incorrect pressures, staking etc. To monitor and record the wear and damage occurring to the tyres used in the New Zealand trials, periodic inspections were carried out. The procedures and results were documented under the following headings; Tyre Wear and Tyre Damage.

TYRE WEAR

An assessment form was devised to record tyre wear (see Appendix 10). A hardboard template, (made up when the tyres were new), was used to measure the lug profile in three places along the length of the lug (see Fig 37). The outer and inner lug closest to the valve stem on all tyres was measured each time. The location of the tyre on the machine was also recorded.

RESULTS

The results of the tyre wear assessment are shown in Fig 38. More detailed summaries of individual wear in relation to use are shown in Appendix 10.

The variation in operating hours for tyres one, four and five was a function of the tyre rotation procedure being used. The number of hours worked and position on the machine for each forest is summarised in Table 36.

The amount of time each tyre spent on the front or rear of the machine is shown in Table 37.

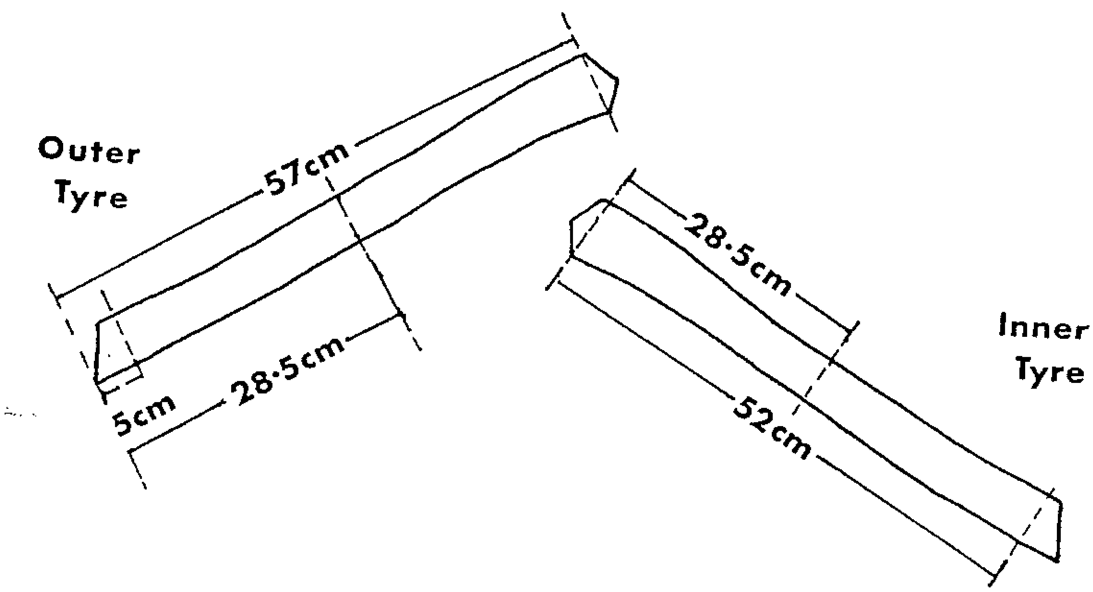

Figure 37 : Location of lug profile measurements

TYRE WEAR

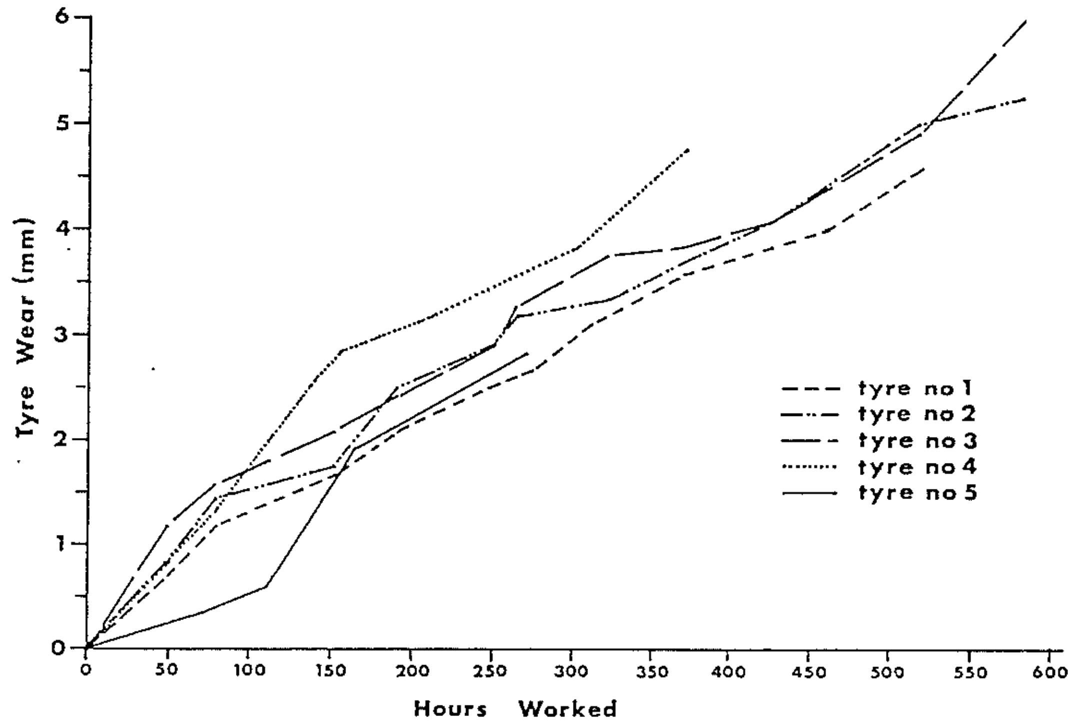

Figure 38 : Tyre wear according to hours worked

Table 36 : Hours worked and tyre position on skidder for each forest

	Tyre No.									
	1 (LHS)		2 (RHS)		3 (RHS)		4 (LHS)		5 (LHS)	
Forest	Front	Back	Front	Back	Front	Back	Front	Back	Front	Back
Kinleith	79.2	-	79.2	-	-	79.2	-	79.2	Spare	
Ngaumu	-	110.8	-	110.8	110.8	-	Spare		110.8	-
Kaingaroa	77.3	-	77.3	-	-	77.3	-	77.3	Spare	
Matahina	Spare		-	39.8	39.8	-	39.8	-	-	39.8
Kinleith (thn)	Spare		-	21.6	21.6	-	21.6	-	-	21.6
Woodhill	-	39.2	39.2	-	-	39.2	Spare		39.2	-
Tarawera	58.3	-	-	48.3	48.3	-	Spare		-	58.3
Mangatu	-	130.0	-	130.0	130.0	-	130.0	-	Spare	
Maramarua	31.4	-	31.4	-	-	31.4	-	31.4	Spare	
Totals	246.2	280.0	227.1	360.5	360.5	227.1	191.4	187.9	150.0	119.3
Total Tyre Hrs	526.2		587.6		587.6		379.3		269.3	

Table 37 : The percentage of time spent on the front and rear of the skidder

Tyre No	Side	Front	Rear
1	LHS	47%	53%
2	RHS	39%	61%
3	RHS	61%	39%
4	LHS	51%	49%
5	LHS	56%	44%

By relating the tyre use from Table 35 to the wear patterns in Figure 34, tyre wear for the different soil types can be traced. In the earlier stages of the trial, wear was greater in the pumice/clay and pumice/ash type soils of the Volcanic Plateau than it was in the clay at Ngaumu. The rate of wear, however, tapered off as the number of hours increased. This could be due to the shape of the lugs and the fact that lug width increases as height decreases.

The tyres were inspected by a specialist from Firestone Tyre Company Limited at the end of the trials. The specialist considered that wear was normal for the use they had been put to. It was noted that physical damage such as chunks torn out and other deterioration was possibly higher than would be expected on conventional tyres but this could be related to the area of tyre actually in contact with the ground.

Some signs of heat stress were evident on the inside of one of the tyres inspected by Firestone. This was attributed to running them at lower than recommended pressures but the damage was not considered serious. With tyre pressures set at 62 kPa, (Maramarua Forest), the rear wide tyres deformed considerably during breakout and when winching off to one side. This deformation was not so evident when travelling loaded over stumps or logs (see Fig. 39).

A total of 29 tyre changes were completed during the course of the trials. These changes were done either in the field or at a workshop.

The field changes usually took two to three hours provided a suitable loader was available to lift the wheels into place. It was easiest to sling the tyres in a loop of chain when trying to locate them on the rims.

Removable alignment studs were necessary because the John Deere did not have fixed studs on the wheel hubs. The thread in the hubs on the front axle stripped after 23 tyre changes.

With the availability of air guns and an overhead gantry, workshop changes could be done in less than an hour.

CONCLUSIONS

The wide tyres did not appear to wear any quicker than conventional tyres according to specialist opinion. The increased width of the wides could have been the reason for the larger number of cuts and chunks torn out of the lugs and outer casing.

Tyre changes were relatively easy to perform in the field provided the necessary support equipment was available. Using air guns to tighten the wheel bolts could have contributed to the stripping of the front wheel studs.

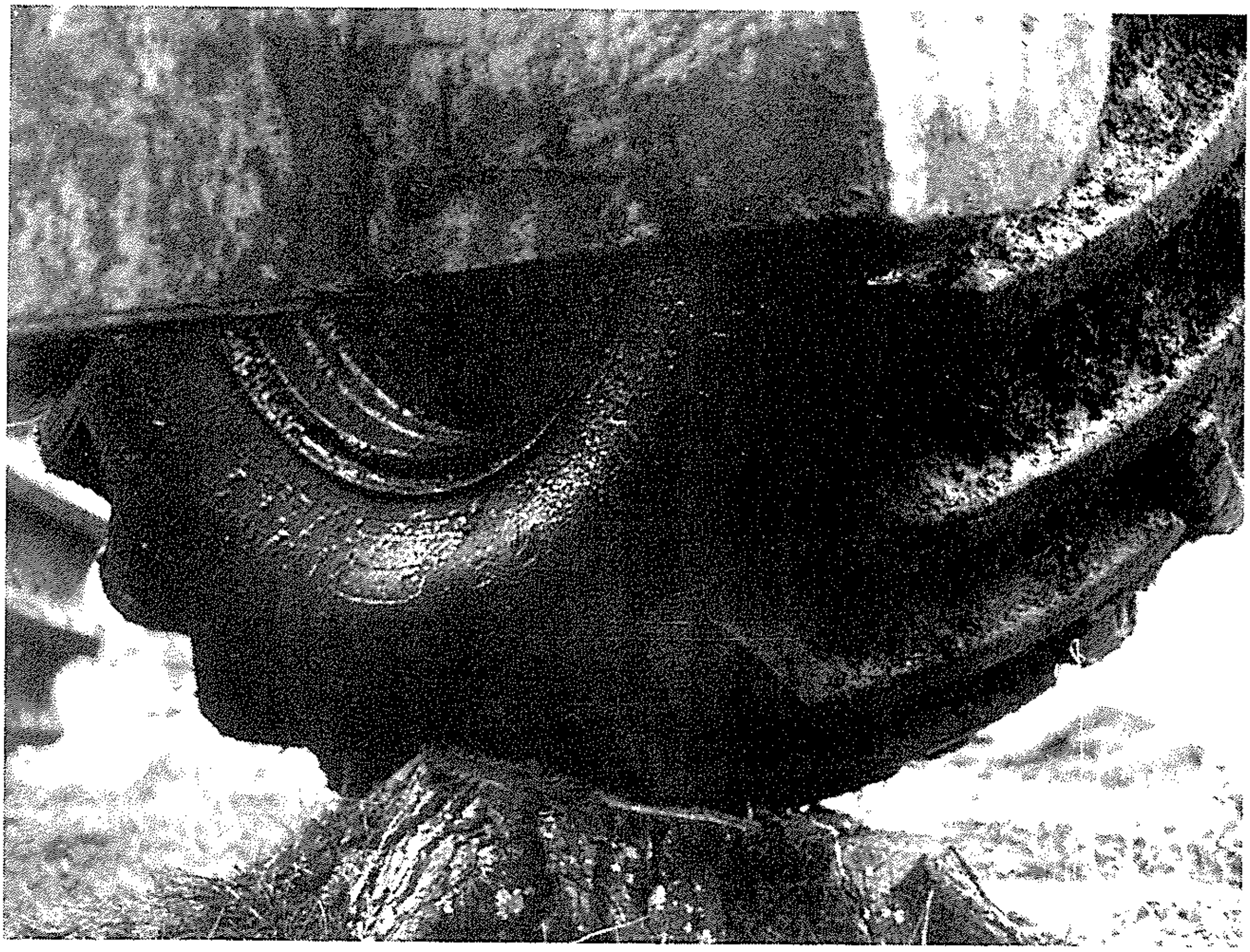

Figure 39 : The wide tyres did not deform as much as expected when travelling loaded. The photo shows the RHS rear tyre (with a load on), passing over a stump at Maramarua. Pressures were set at 62 kPa

TYRE DAMAGE

A separate form was designed to collect information on tyre damage (see Appendix 11). It was part of the operators daily routine to inspect for tyre damage to remove any debris from between the tyres and rims. Initially it was easy to record the nature and location of the damage but as the tyres aged, it became increasingly difficult to determine whether a cut or rip was old or new. The tyre damage records were therefore discarded in favour of photography.

A sequence of figures to show tyre damage follows.

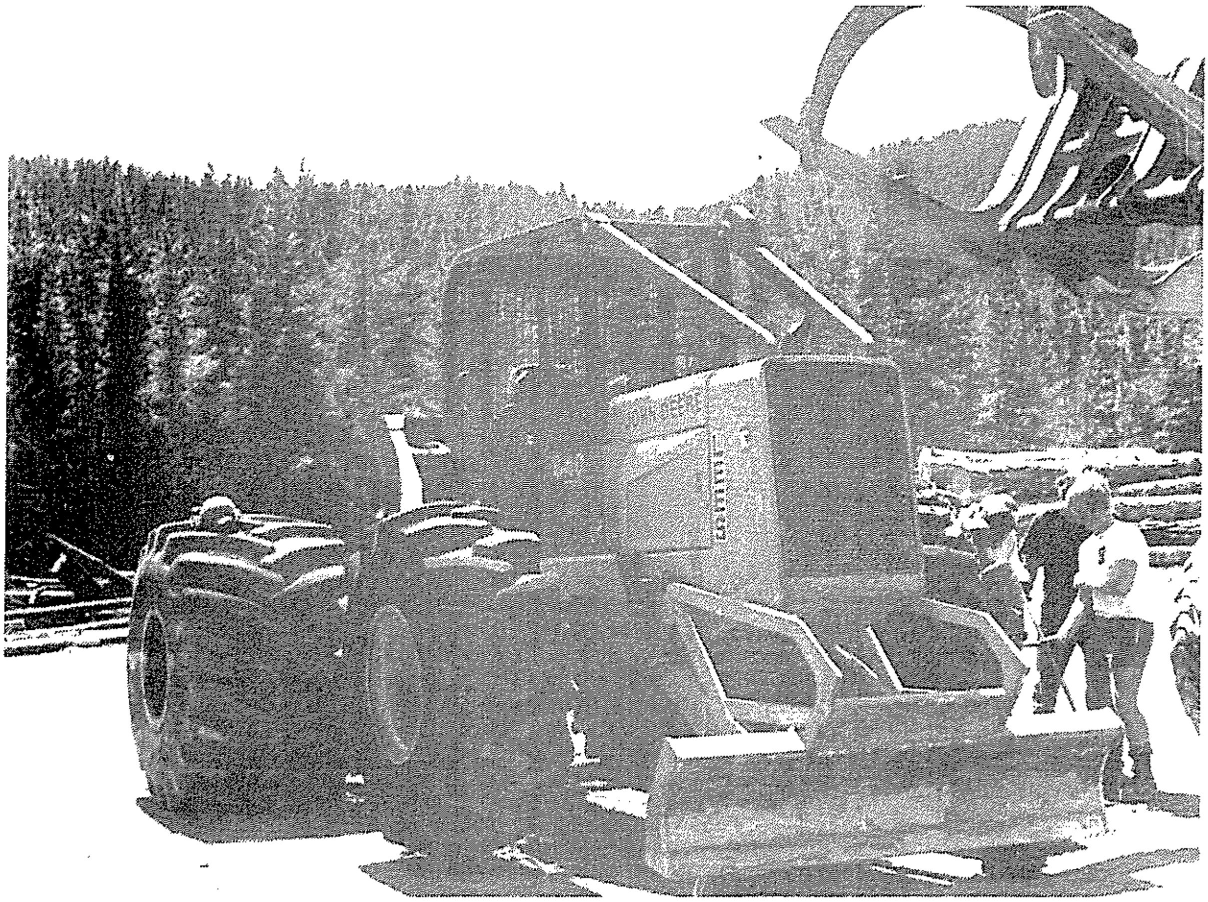

Figure 40 : Using a front end loader to suspend the tyres during a change

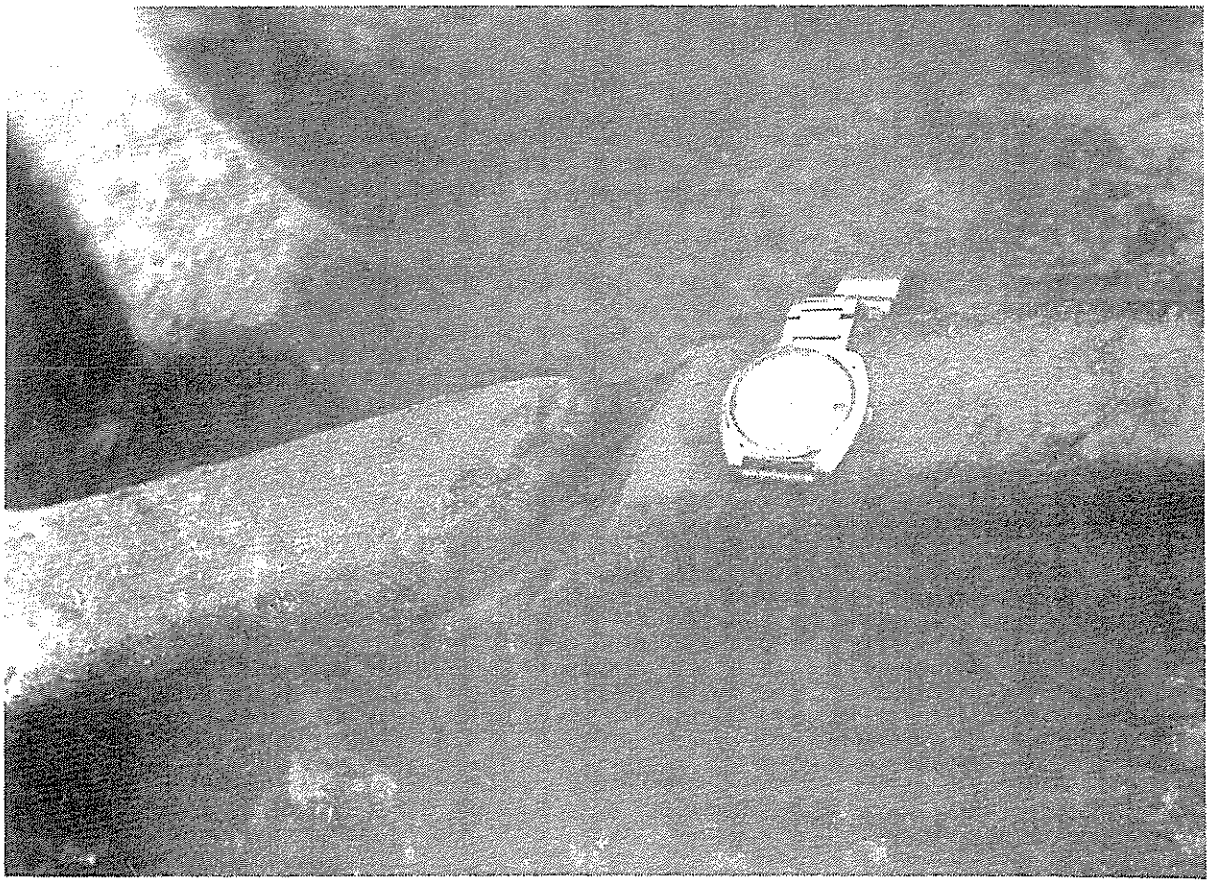

Figure 41 : Early damage to tyre lug, noted during the Kinleith clearfell trial

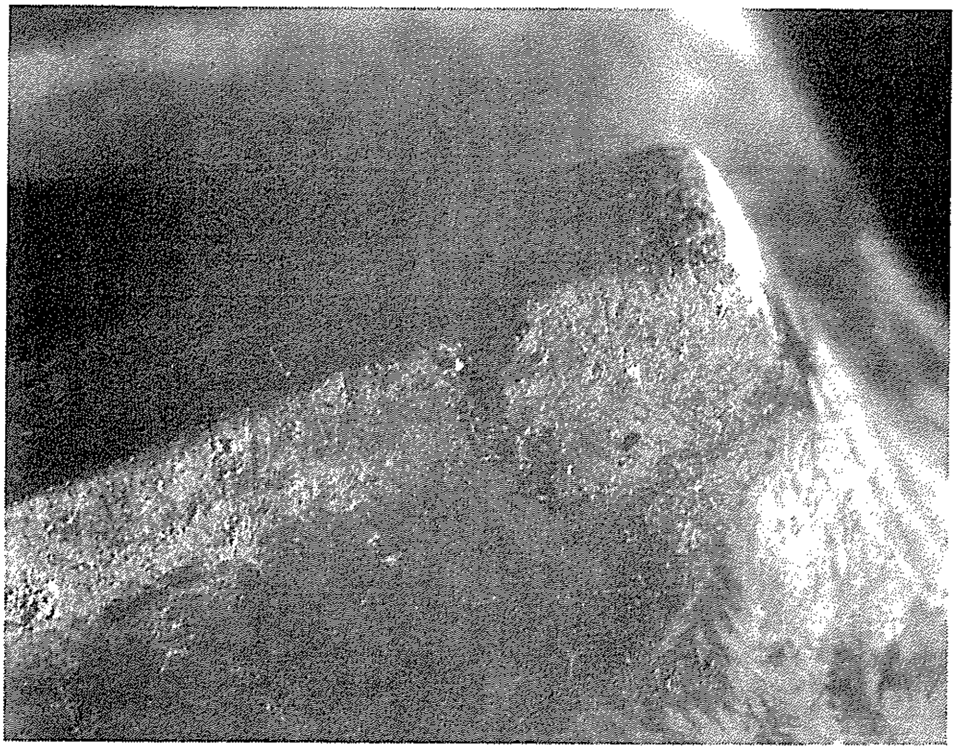

Figure 42 : A deeply incised rip in the outer edge of a lug. This damage was noticed at Ngaumu Forest and it did not deteriorate any further throughout the rest of the trials.

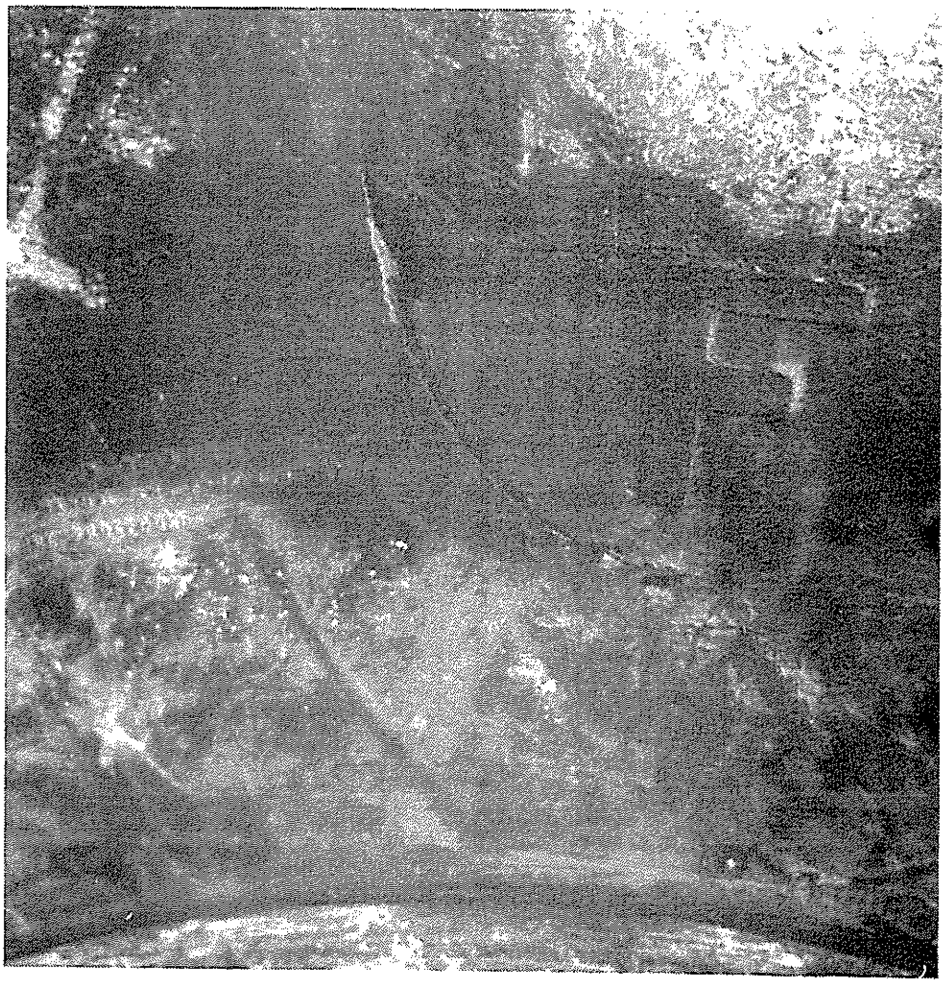

Figure 43 : A split along the seam between the tyre casing and the tread cap. Inspection by Firestone reps revealed that it was a common occurrence and appeared on most tyres.

Figure 44 : The outer casing (between the lugs) was penetrated by a sharp stick. The damage was confined to the outer surface layer of the tyre and did not cause any loss or pressure. Eventually the stick worked its way out but several other instances of sticks penetrating the tyre occurred and on at least one of them, the stick remained in the tyre for a long period.

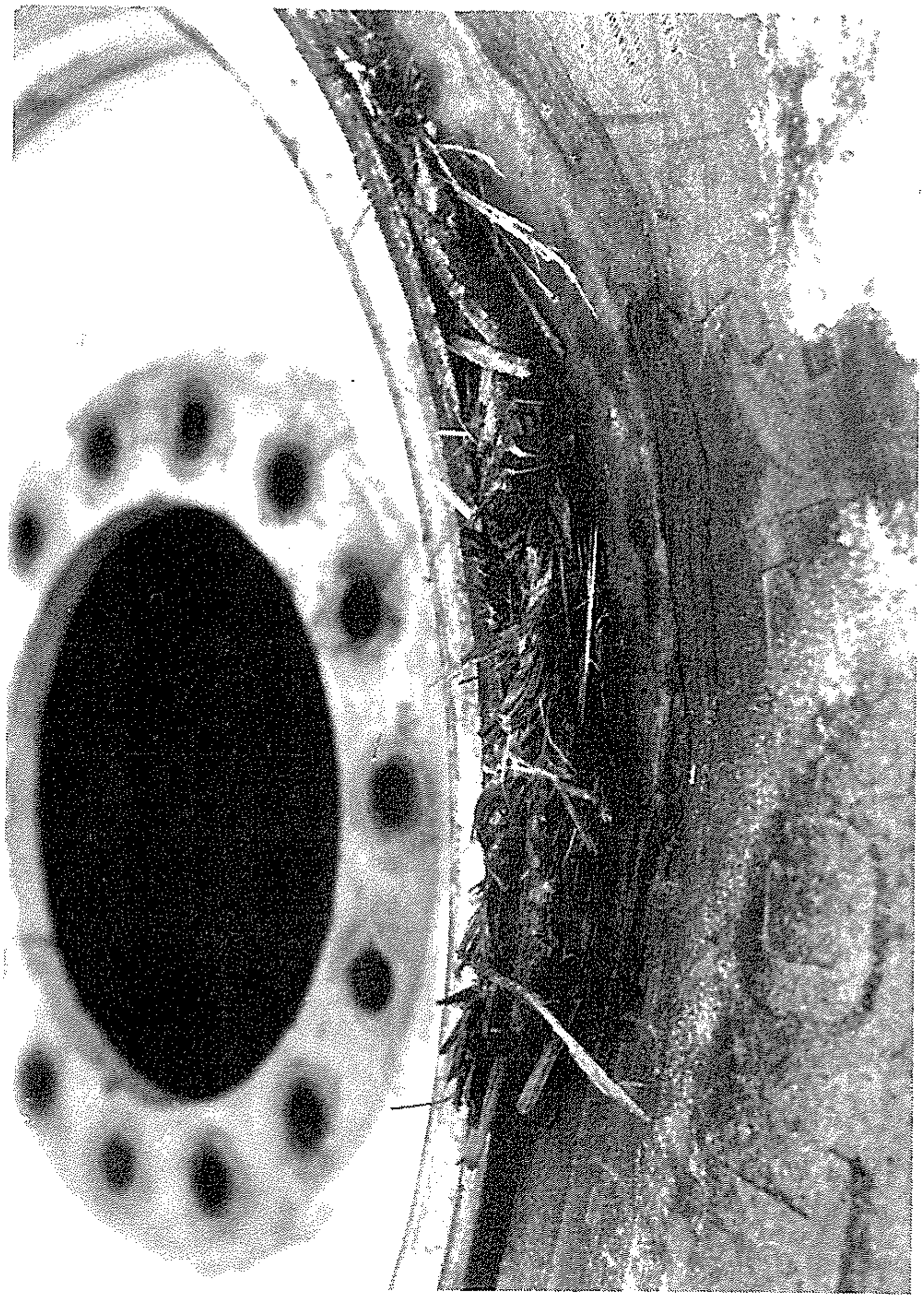

Figure 45 : In the Douglas fir in Kaingaroa, slivers of wood and bark were forced between the tyre and rim when the wheel ran up against a stump. Tyre pressures at that stage were 110 kPa. This separation of the tyre from the rim caused a loss of pressure and the tyre had to be deflated to remove the debris.

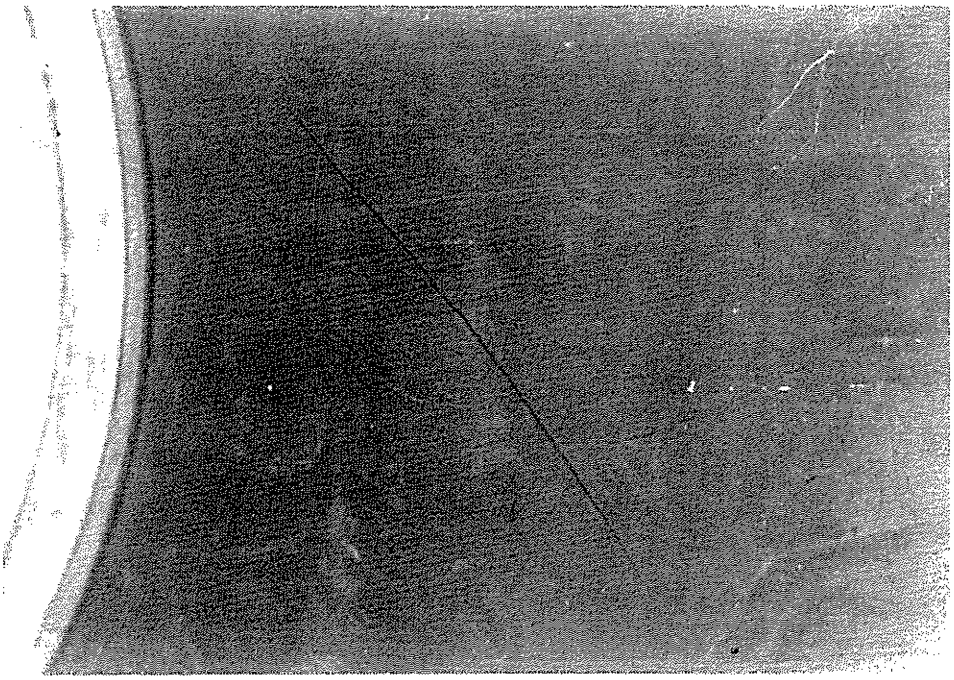

Figure 46 : After the thinnings trials in Kinleith, a fairly deep cut was noticed in two of the tyres sidewalls. Again the cuts did not cause any problems with pressure loss.

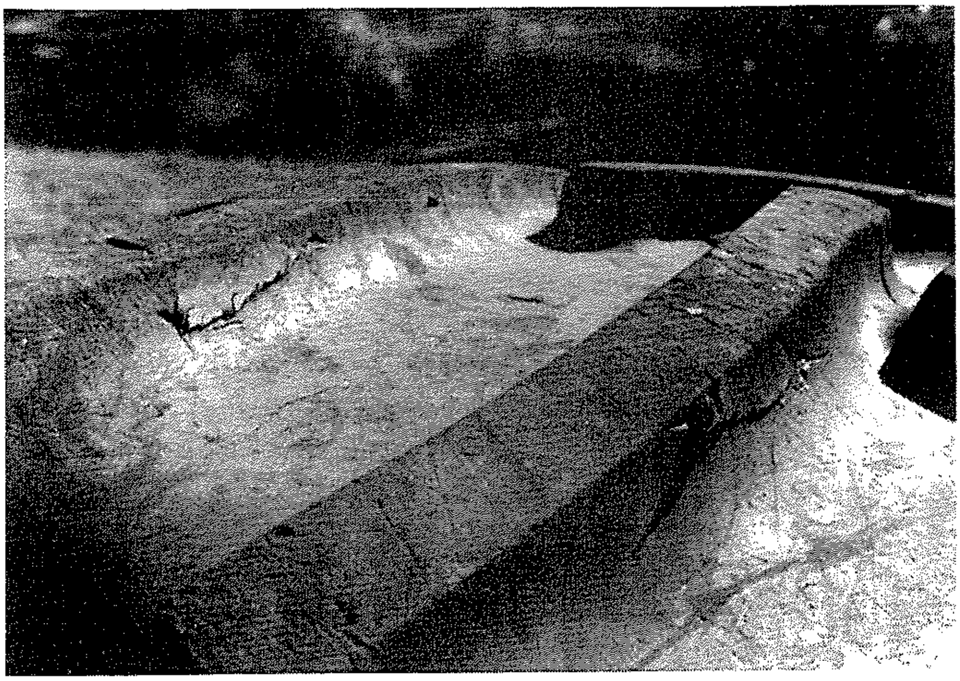

Figure 47 : On one forest, the tyres were shifted with a forklift and three of the lugs on one tyre were damaged. Eventually the strips of torn rubber were ripped off.

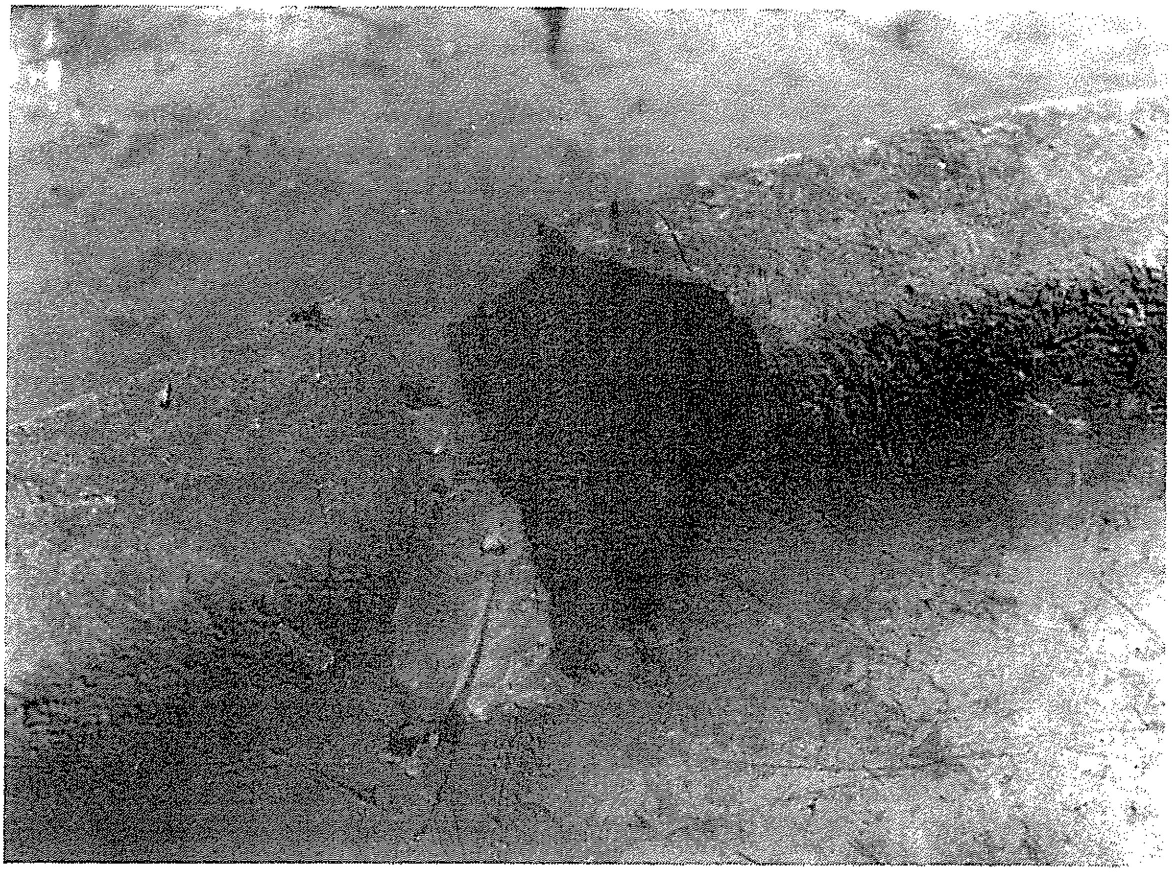

Figure 48 : In the Woodhill trial, a large chunk 3 - 5 cm wide and 2 - 4 cm deep was torn out of a lug on one of the front tyres. No explanation could be found for the damage and it did not deteriorate any further during the rest of the trials.

After the Kaingaroa trial, all the wide tyres were deflated by specialists from Firestone Tyre Company, and the debris between tyre and rim removed.

With progressive reductions in tyre operating pressures, the amount of wood and bark that got between the tyres and their rims increased. Apart from the occasion described in Fig 39, no instances of pressure loss were recorded.

Removing this debris was often difficult and sometimes impossible. Normally, the slivers of wood would work their way out over a period of time as the tyres were being used. On other occasions the slivers would simply be sheared off with part of them remaining between the tyre and rim.

CONCLUSIONS

The damage occurring to the tyres during the trials did not appear to deteriorate beyond the original injury. Deep cuts and penetrating sticks did not cause any loss of tyre pressure.

The only loss of pressure was caused by slivers of wood and bark being forced between the tyre and its rim. Generally the build-up of debris between tyres and rims increased as tyre pressures decreased.

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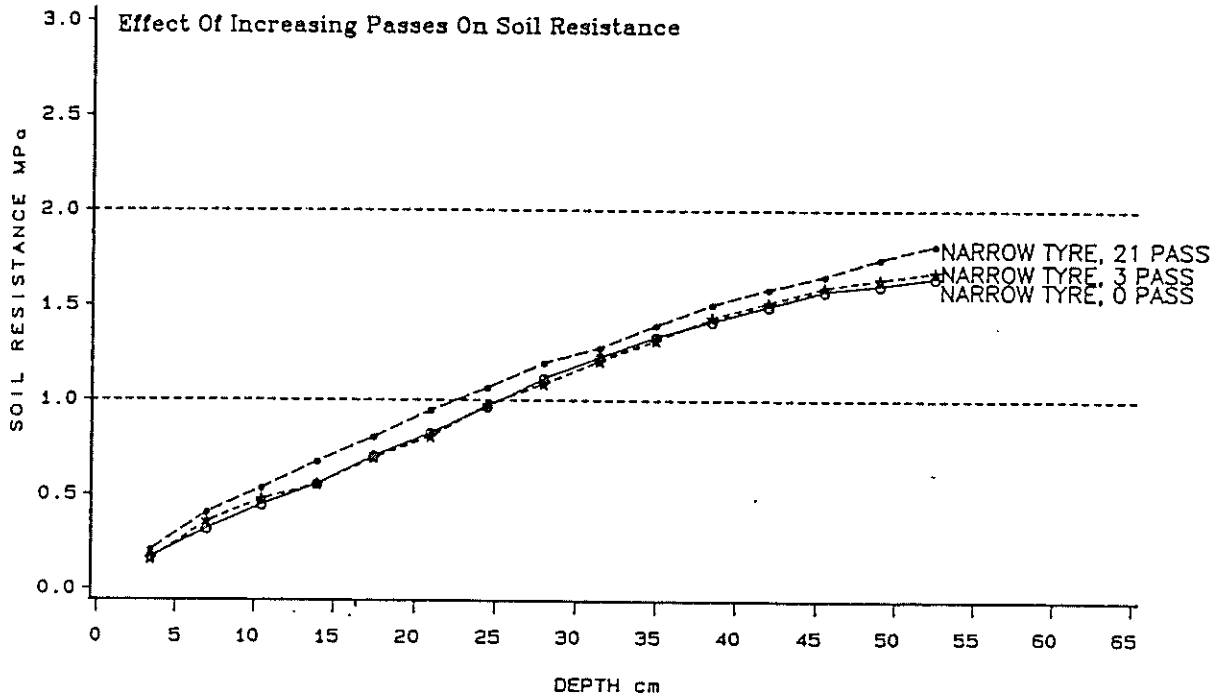
APPENDIX 1

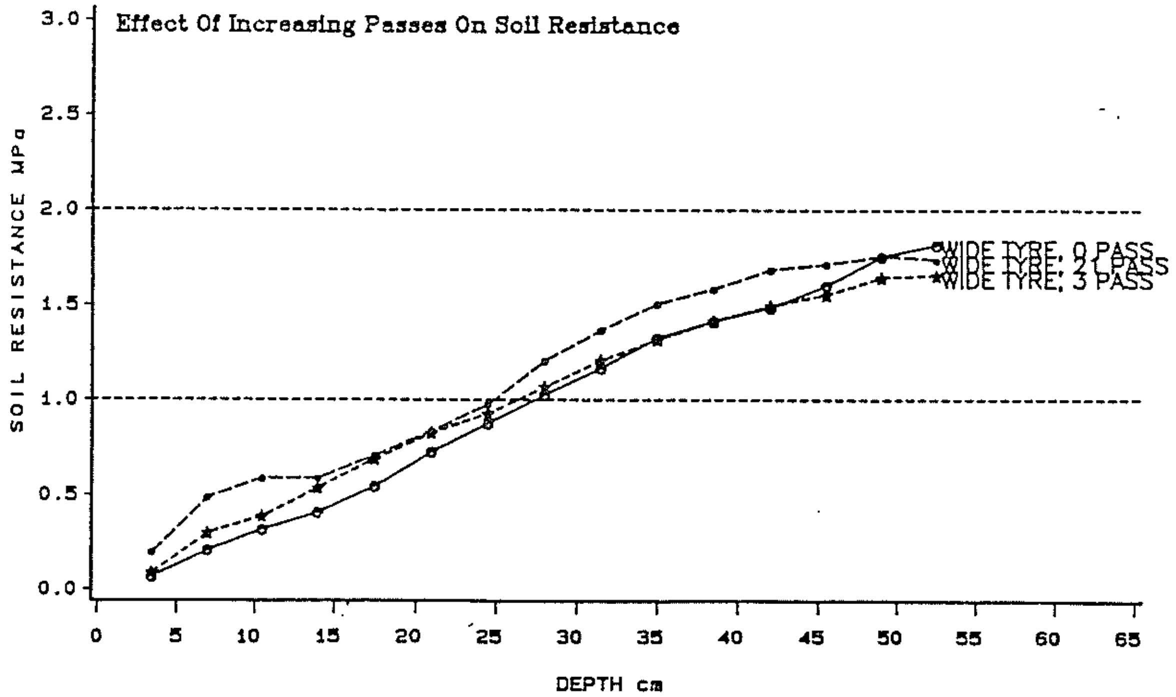
MARAMARUA WIDE TYRE SKIDDER STUDY

SOIL RESISTANCE versus DEPTH

(i) NARROW TYRES



(ii) WIDE TYRES



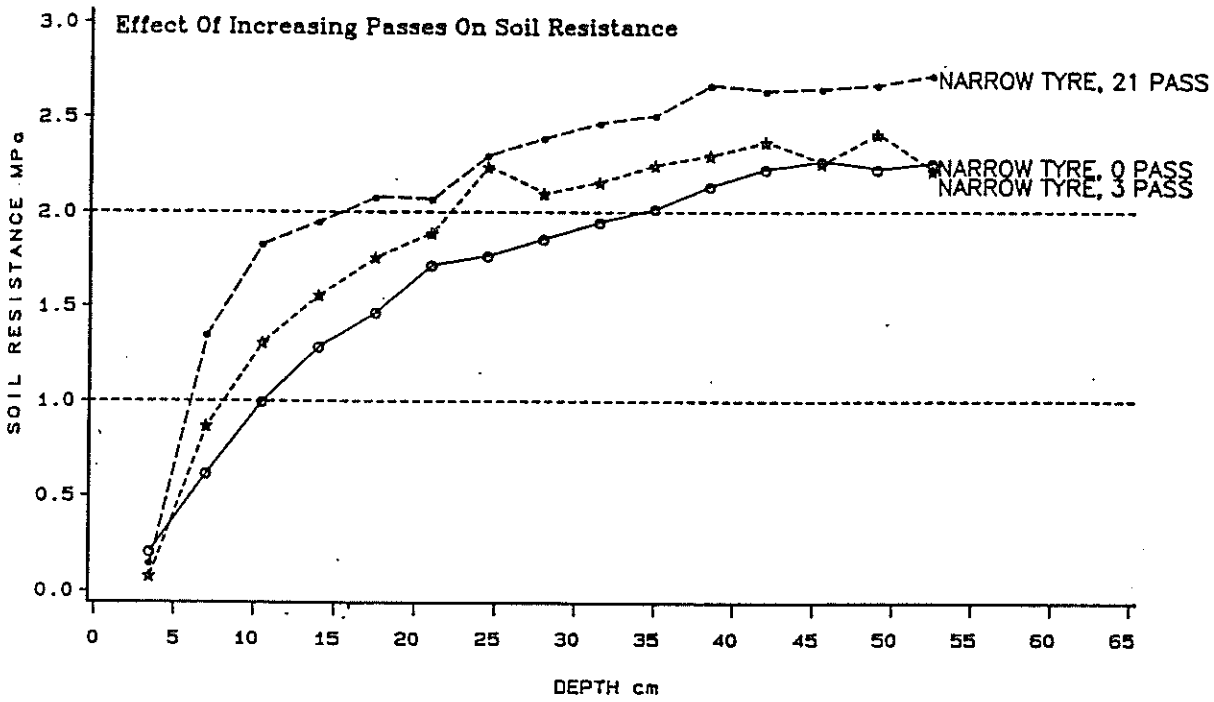
APPENDIX 1 Cont.

(iii) COMPARISON OF WIDE AND NARROW TYRES

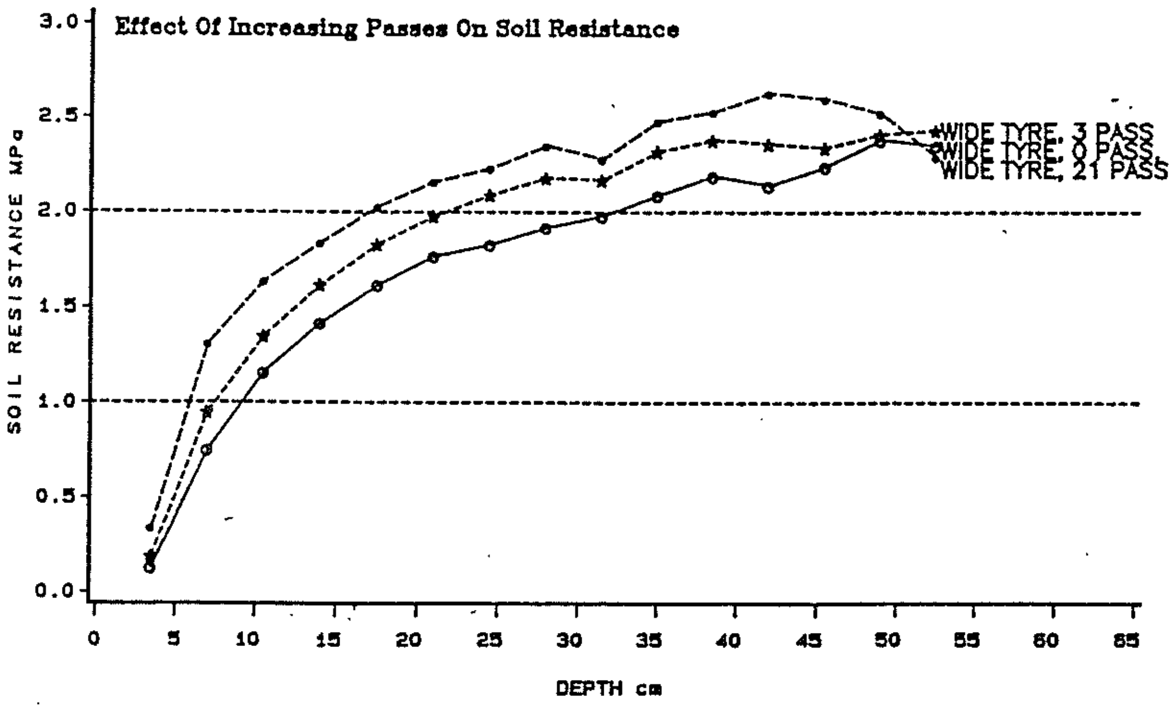
MANGATU WIDE TYRE SKIDDER STUDY

SOIL RESISTANCE versus DEPTH

(i) NARROW TYRES

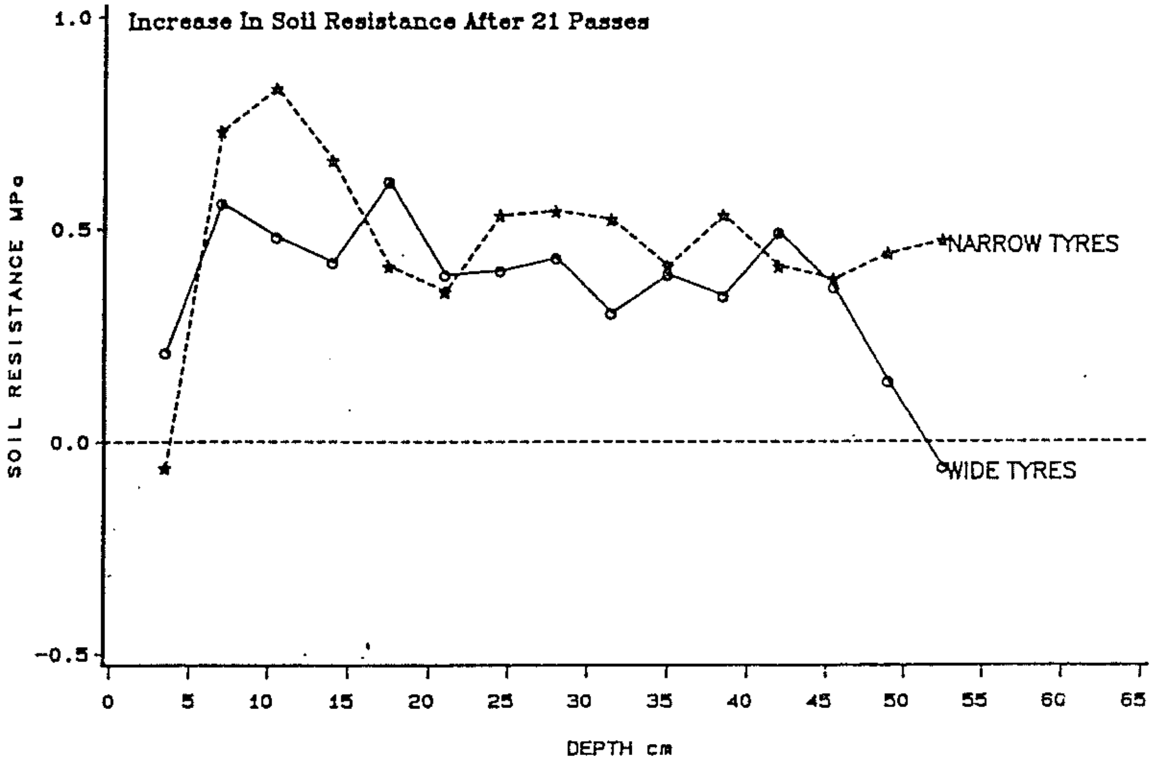


(ii) WIDE TYRES



APPENDIX 2 Cont.

(iii) COMPARISON OF WIDE AND NARROW TYRES



APPENDIX 3

SOIL MOISTURE AT SITES AND PHYSICAL PROPERTIES OF SELECTED SOILS

TABLE 1 - Soil moisture at sites

Site		MC %	Proctor optimum MC
Maramarua	A	37	20
	B	28	25
Tarawera		Dry	-
Mangatu			
Class 5		25	24
Class 6		45	10

TABLE 2 - Physical properties of selected soils

Site	Textural class	% sand	% silt	% clay	Loss on ignition %
Maramarua A	Sandy Clay Loam	28.0	34.0	38.0	8.2 (1)
B		11.0	29.0	60.0	7.1
Tarawera	Coarse Sand				
Mangatu					
Class 5 A	Sandy Loam	60.4	26.6	13.0	13.7
B	Clay Loam	47.7	24.3	28.0	2.9
Class 6	Clay Loam	39.7	24.5	35.8	9.1

(1) Robertson (1983)

APPENDIX 4

AVERAGE RUT DEPTHS AND ANOVA ANALYSIS FOR RUTTING TESTS

TABLE 1 - Average rut (cm) depths on Maramarua clay

	Wides	Narrows
Flat ground		
Pass 1	-0.1	3.0
Pass 3	1.1	1.9
Pass 7	2.0	1.4
Pass 13	0.4	2.4
Pass 21	1.4	0.9
Uphill		
Pass 1	2.1	6.3
Pass 3	3.0	5.2
Pass 7	4.2	8.4
Pass 13	7.5	6.6
Pass 21	6.3	10.4
Downhill		
Pass 1	4.9	3.2
Pass 3	5.9	6.8
Pass 7	9.6	10.0
Pass 13	12.0	14.1
Pass 21	13.2	19.0

TABLE 2 - Results of ANOVA of rutting depth main effects at Maramarua

Effect	Tyre	Direction	Tyre x Direction
Pass 1	0.0310	0.0021	0.0004
Pass 3	0.0744 N.S.	0.0001	1.0000 N.S.
Pass 7	0.0854 N.S.	0.0001	0.1546 N.S.
Pass 13	0.0073	0.0001	1.0000 N.S.
Pass 21	0.0001	0.0001	1.0000 N.S.

N.S. = No significant difference

TABLE 3 - Duncan's multiple range test between tyres (all slopes combined) Maramarua

	Wides	Narrows
	(Rut depth cm)	
Pass 1	2.3 B	3.7 A
Pass 3	3.3 A	4.7 A
Pass 7	5.2 A	6.6 A
Pass 13	5.6 B	8.4 A
Pass 21	5.7 B	10.8 A

Means with the same letter are not different

APPENDIX 4 Cont.

TABLE 4 - Average rut depths on Tarawera scoria (cm)

	Wides	Narrows
Flat ground		
Pass 1	3.2	6.7
Pass 3	5.2	8.8
Pass 7	6.3	10.9
Pass 13	6.7	11.9
Pass 21	4.9	12.8
Uphill (12-27%)		
Pass 1	4.0	2.8
Pass 3	5.4	3.8
Pass 7	5.2	6.8
Pass 13	5.9	11.0
Pass 21	5.9	12.2
Uphill (27-40%)		
Both failed to climb these plots.		
Downhill (12-27%)		
Pass 1	3.6	11.2
Pass 3	4.8	11.5
Pass 7	5.9	14.0
Pass 13	7.0	14.4
Pass 21	4.1	14.6
Downhill (27-40%)		
Pass 1	5.0	10.5
Pass 3	9.5	12.4
Pass 7	13.7	15.6
Pass 13	12.9	13.9
Pass 21	10.9	15.2

TABLE 5 - Average rut depths on Mangatu clay (cm)

	Wides	Narrows
Class 5 flat		
Pass 1	2.0	2.0
Pass 3	1.2	0.8
Pass 7	1.1	1.5
Pass 13	1.3	2.4
Pass 21	1.5	2.8
Class 5 down		
Pass 1	1.9	2.0
Pass 3	2.2	1.8
Pass 7	2.8	2.5
Pass 13	2.3	2.9
Pass 21	3.2	3.4
Class 6		
Pass 1	2.0	2.0
Pass 3	2.8	5.5
Pass 7	4.2	7.5
Pass 13	3.8	10.1
Pass 21	4.6	13.3

N.S. = No significant difference between tyres

TABLE 6 - ANOVA of rutting depth main effects at Mangatu

Effect	Tyre	Class	Tyre x class
Pass 1	0.3242 N.S.	0.0002	0.0503
Pass 3	0.1082 N.S.	0.0001	0.0772 N.S.
Pass 7	0.0004	0.0001	0.0028
Pass 13	0.0002	0.0001	0.0009
Pass 21	0.0001	0.0001	0.0006

N.S. = No significant difference

TABLE 7 - Duncan's multiple range test between tyres
(all classes combined)

	Wides	Narrows
	(Rut depth cm)	
Pass 1	2.1 A	2.7 A
Pass 3	2.7 A	3.8 A
Pass 7	2.5 B	5.1 A
Pass 13	3.1 B	5.9 A
Pass 21	3.1 B	6.8 A

Means with the same letter are not different

APPENDIX 5

RESULTS OF TRACTIVE CAPACITY TESTING

TABLE 1 - Test Results with Wide Tyres set at 103 kPa.
Test Track Length - 52.5 m

Run No.	No. Revs.	Nominal Load	Actual Load	Slippage
0	10.56	0.00t	0.00t	N/A
1	10.79	2.00t	2.35t	2.1%
4	10.70	2.00t	1.66t	1.3%
7	10.75	2.00t	2.02t	1.8%
3	11.00	3.50t	3.11t	4.2%
6	11.04	3.50t	2.85t	4.5%
8	11.08	3.50t	3.19t	4.9%
2	11.75	5.00t	5.21t	11.3%
5	11.67	5.00t	4.83t	10.5%
9	11.75	5.00t	4.64t	11.3%
10	*	7.00t	6.70t	11.3%

* = Run failed

TABLE 2 - Test Results with Wide Tyres set at 69 kPa.
Test Track Length - 52.5 m

Run No.	No. Revs.	Nominal Load	Actual Load	Slippage
0	10.56	0.00t	0.00t	N/A
1	10.83	2.00t	1.94t	2.6%
4	10.83	2.00t	2.00t	2.6%
7	10.88	2.00t	2.13t	3.0%
2	11.16	3.50t	3.35t	5.7%
5	11.16	3.50t	3.06t	5.7%
8	11.29	3.50t	3.32t	6.9%
3	12.08	5.00t	5.09t	14.4%
6	11.98	5.00t	4.85t	12.9%
9	11.96	5.00t	4.71t	13.3%
10	13.04	6.00t	5.93t	23.5%

APPENDIX 5 Cont.

TABLE 3 - Test Results with Narrow Tyres set at 138 kPa.
Test Track Length - 50.5 m

Run No.	No. Revs.	Nominal Load	Actual Load	Slippage
0	10.54	0.00t	0.00t	N/A
4	11.00	2.00t	1.91t	4.4%
7	11.17	2.00t	1.98t	6.0%
3	11.67	3.50t	**	10.7%
6	11.75	3.50t	3.65t	11.5%
9	11.75	3.50t	3.50t	11.5%
10	11.75	3.50t	3.63t	11.5%
5	13.42	5.00t	5.34t	27.3%
8	13.17	5.00t	5.10t	25.0%
11	15.58	6.00t	6.03t	47.8%

** = Load Measurement illegible

TABLE 4 - Summary of Results

Tyre Config.	Pressure	Average Load	Slippage
66x43-25	103 kPa	2.01t	1.8%
		3.05t	4.5%
		4.89t	11.0%
		6.70t	*
66x43-25	69 kPa	2.02t	2.7%
		3.24t	6.1%
		4.88t	13.5%
		5.93t	23.5%
63x23.1-26	138 kPa	1.95t	5.2%
		3.59t	11.5%
		5.22t	26.1%
		6.03t	47.8%

* = Run Failed

APPENDIX 6

DESCRIPTION OF MACHINES TESTED FOR CLIMBING ABILITY

Kinleith

Machine	Power	Width	Wheelbase	Age	Tyres	Tread
John Deere 540D	75Kw	2.93m	2.69m	48h	N	100%
John Deere 540D	75Kw	3.74m	2.69m	27h	W	100%
Caterpillar D7	200Kw	NR	NA	NR	NA	NR
Timberjack 207	50Kw	NR	NR	NR	*	10%

* Tyre chains fitted to the front wheels
NR = Not Recorded
NA = Not Applicable

Kaingaroa

Machine	Power	Width	Wheelbase	Age	Tyres	Tread
John Deere 540D	75Kw	2.93m	2.69m	426h	N	100%
John Deere 540D	75Kw	3.74m	2.69m	425h	W	94%
Cat 518	90Kw	2.65m	2.89m	2448h	N	51%
Clark 666C	84Kw	2.71m	2.64m	4702h	N	62%

Matahina

Machine	Power	Width	Wheelbase	Age	Tyres	Tread
John Deere 540D	75Kw	2.93m	2.69m	465h	N	100%
John Deere 540D	75Kw	3.74m	2.69m	472h	W	94%
Treefarmer C7	91Kw	2.72m	3.21m	1817h	N	70%
FMC 220CA	149Kw	NA	NA	NR	NA	NA

NA = Not Applicable
NR = Not Recorded

APPENDIX 6 Cont.

Woodhill

Machine	Power	Width	Wheelbase	Age	Tyres	Tread
John Deere 540D	75Kw	2.93m	2.69m	593h	N	97%
John Deere 540D	75Kw	3.74m	2.69m	592h	W	93%
Clark 666C	84Kw	2.71m	2.64m	7309h	N	89%

Tarawera

Machine	Power	Width	Wheelbase	Age	Tyres	Tread
John Deere 540D	75Kw	2.93m	2.69m	752h	N	97%
John Deere 540D	75Kw	3.74m	2.69m	740h	W	92%
Cat 518	90Kw	2.65m	2.89m	3971h	N	57%

APPENDIX 7

FORMS USED FOR DAILY DATA COLLECTION

Study ID ______________________

306.1 Environment Description   Date __ __ __

.101 Weather Conditions

.101.1 Temperature (celsius)
.101.11 __ Maximum
.101.12 __ Minimum
.101.13 __ Average

.101.21 __ Wind velocity
a. no wind or still (<2 km/hr)
b. light wind (2→20 km/hr)
c. moderate wind (20→40 km/hr)
d. high wind (>40 km/hr)

.101.22 __ Wind Direction
.101.23 Wind Consistency
a. Constant
b. irregular
c. occasional

.101.3 __ Relative humidity %
.101.4 Precipitation

.101.41 Type	.101.42 Duration
a. none	________ hrs
b. drizzle (very light rain)	________ hrs
c. rain	________ hrs
d. hail	________ hrs
e. sleet	________ hrs
f. snow	________ hrs
g. other	________ hrs

.101.43 __ Accumulation (mm)
.101.5 Atmospheric conditions

	Continuous	Beginning shift	Mid shift	End shif
a. clear				
b. fog				
c. cloudy				
d. overcast				

.102 Average skid or forwarding distance ____________ meters.

APPENDIX 7 Cont.

Study ID ____________________

Date ________________________

New update date ______________

306.20 Ground Conditions - General

306.201 Ground Strength

		CPPA Class
a.	Coarse sand, gravel	1
b.	medium coarse sand, sandy loams	2
c.	fine sands, sandy silt, clay loam	3-4
d.	silt, clay, and sandy clay	4-5
e.	organic > .6m	5

306.202 Ground Roughness

a.	very even	1
b.	slightly uneven	2
c.	uneven	3
d.	rough	4
e.	very rough	5

306.203 Slope

a.	level 0-10%	1
b.	gentle 11-20%	2
c.	moderate 21-33%	3
d.	steep 33-50%	4
e.	very steep 50%	5

306.204 Average depth of humus layer

a. < 10cm
b. 10-30 cm
c. 30-50 cm
d. 50-100 cm
e. > 1m

306.205 Slope Relation to access

a. level
b. uphill
c. downhill
d. on contour
e. rolling or broken

306.206 Soil Moisture

a. frozen
b. dry
c. fresh
d. wet
e. saturated
f. underwater

306.207 Snow

306.207.1 Snow depth average ____________ cm

.207.2 Surface

a. loose-powdery
b. loose-wet
c. light crust
d. moderate crust
e. heavy crust

APPENDIX 7 Cont.

306.34 Strip road/skid trail conditions

Study ID ________________

Date ____________________

New Revised

306.340 No trail
306.341 Slope class 1 2 3 4 5
306.342 Slope relation to access (direction of loaded travel)

a. level
b. uphill
c. downhill
d. rolling or broken

306.343 Roughness

1 very even
2 slightly uneven
3. uneven
4 rough
5 very rough

306.344 Origin

a. no preparation
b. clearing only
c. clearing and humus removed
d. bladed
e. bladed and ditched
f. bladed, ditched and some surface applied
g. Other

306.345 Surface Composition

a. organic
b. clay
c. silt
d. fine sand/loam
e. coarse sand
f. gravel
g. stone
h. rock
i. snow
j. ice
k. slash

306.346 Surface moisture

a. frozen
b. dry
c. fresh
d. wet
e. saturated

306.347 Surface Condition

a. smooth
b. rutted
c. holes and protrusions
d. corrugations
e. other

306.348 Alignment

a. straight
b. slightly curved
c. winding
d. crooked
e. very crooked

APPENDIX 7 Cont.

306.35 Landing or roadside conditions

Study ID____________________

Date ____________________

New Revised

306.350 ________No landings

306.351 Slope Class 1 2 3 4 5

306.352 Ground roughness
- 1 very even
- 2 slightly uneven
- 3 uneven
- 4 rough
- 5 very rough

306.353 Origin
- a. no preparation
- b. clearing only
- c. clearing and humus layer removed
- d. bladed
- e. bladed and ditched
- f. bladed, ditched and surfaced
- g. other

306.354 Surface composition
- a. organic
- b. clay
- c. silt
- d. fine sand/loam
- e. coarse sand
- f. gravel
- g. stone
- h. rock
- i. snow
- j. ice
- k. slash

306.355 Surface moisture
- a. frozen
- b. dry
- c. fresh
- d. wet
- e. saturated

306.356 Management
- a. excellent
- b. very good
- c. good
- d. poor
- e. very poor

APPENDIX 7 Cont.

Form 352.20 Shift Recorder Analysis

Study ID ____________

.201 Date ________ .202 Shift ____________

.203 Machine ____________________________

.204 Operator ___________________________

.210 Period — Shift

.211 Start time ______________ .213 Start time ______________

.212 Stop time ______________ .214 Stop time ______________

.220 Operating time

.221 Productive — Describe ______________________________

.222 Non Productive — Describe ______________________________

.223 Other ______________________ ______________________________

______________________ ______________________________

______________________ ______________________________

.230 Idle or down time

.231 Mechanical

231.1 Service: Active ______________ waiting ______________

231.2 Repair Active ______________ waiting ______________

231.4 Modification ______________ Describe ______________

231.5 Other ______________ ______________

.232 Non Mechanical

232.1 Personnel ______________________________

232.2 Oper host ______________________________

232.3 Inventory ______________________________

232.4 Weather ______________________________

232.5 No work ______________________________

232.6 Moving ______________________________

232.7 Other ______________________________ describe ______________

.234 Comments

APPENDIX 7 Cont.

rm 352.7 Repair Report   Study ID ______________

chine No. ______________________ Date ______________

.71 Nature of repair

352.711 Machine component or assembly involved ______________

352.712 Repair type ______________

352.713 Materials used ______________

352.714 Crew time involved ______________

352.714.1 operator ______________

352.714.2 mechanic ______________

352.714.3 other ______________

.72 Cause of repair

352.721 accident, abuse, wear, fatigue, other

352.722 other components affected as a result of the failure or accident

____

____

____

____

352.723 Could down time have been reduced

a. by replacement before failure

b. by maintaining larger on site parts and tool inventory

c. by better communications/scheduling of mechanic

.73 Corrective action taken

____

____

____

____

'4 Repair is considered permanent - temporary

APPENDIX 7 Cont.

Periodic Expense Report (individual machine)

Study ID ____________

352.11 Consumable supplies

Date ____________

352.111 Machine ID ____________

352.112 Period from date ________ shift to date ________ shift

352.113	352.114	352.115	352.116			352.117	352.119
	Service interval	Fuel (liters)	oil (liters)			lubricant KG	other Specify
shift			Engine	Drive train	Hydr		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							

Date ____________

312.121 Period: From To:

312.122 Employee	312.123 Reg. Hrs.	312.124 Prem. Hrs.	312.5 Production Type	Amount	312.127 Comments

APPENDIX 8

TIME STUDY ELEMENT DESCRIPTIONS

RUN EMPTY

Skidder moves unloaded to the landing edge after dropping logs on the landing.

START : When skidder moves off after freeing strops from logs.
END : When fairlead roller crosses a predetermined boundary line between landing and haul track.

TRAVEL EMPTY

Skidder travels unloaded from predetermined boundary of landing to breaking out site in the bush. This element can be interrupted for bladework.

START : When fairlead roller crosses the predetermined boundary line.
END : (1) When skidder stops at breakout site.
(2) When skidder moves off track to position for breakout.

BLADEWORK

All work where the skidder blade is used.

BLADE LOGS - Bladework associated with pushing or lifting of logs in the bush to assist breakout.
OTHER - All other work done using the blade, e.g. fleeting, pushing trees, clear landing, tracking.

START : When machine moves forward to commence blading.
END : When machine has completed blading and lifted blade.

POSITION

Skidder arrives at breakout site and manoeuvres into place ready to breakout. This element may be interrupted by breakout.

START : When skidder moves off track to turn.
END : Skidder stops and is ready to breakout.

BREAKOUT

Breakerout (can be skidder operator) takes main rope and strops to logs and attaches them.

START : (1) When breakerout takes hold of strops or mainrope.
(2) When skidder operator begins to get off machine.
END : When logs are completely broken free of any entanglement and are winched up under the fairlead.

APPENDIX 8 Cont.

TRAVEL LOADED

Skidder travels with load from breakout site to skid edge. This element can be interrupted with winching and bladework.

START : When skidder is free to move towards landing from breakout.
END : When fairlead crosses predetermined point at bush/ landing boundary.

RUN LOADED

Skidder travels loaded from bush edge across landing to drop zone.

START : When fairlead crosses predetermined point at bush/ landing boundary.
END : Skidder releases winch to drop logs from fairlead.

DROP

Involves the uncoupling of strops from logs at the drop zone.

START : When logs are released from skidder onto landing.
END : When all strops are pulled free from logs.

WINCH

Allows time for the skidder to winch the load when minor obstacles occur on haul tracks. This element interrupts the travel loaded element.

START : When skidder drops load.
END : When skidder moves forward with the load in position under the fairlead.

APPENDIX 9

HOURLY MACHINE COSTS FOR WIDE AND NARROW TYRES ON THE SAME SKIDDER

(i) JOHN DEERE 540 - NARROW TYRES

Cost of Machine	= $126,560	Resale Value	= $31,500
Life of Machine in Years	= 5		
Prod. Hrs/Yr	= 1530	Prod. Hrs/Day	= 6.5
Rate on Invest.	= 18%	Insurance	= 2%
Fuel Consump.	= 11.7	Fuel Cost	= $.58¢
Oil Consump.	= 2	Oil Cost	= $2.65
R & M Factor	= 50%		
Strop Cost	= $340	Strop Life	= 130
Mainrope Cost	= $220	Mainrope Life	= 195

JOHN DEERE 540 - NARROW TYRES

Own Cost/Hr		Operating Cost/Hr	
Depreciation	= 10.9621	Fuel	= 6.786
Return Inv.	= 10.416	Oil	= 5.3
Insurance	= 1.15733	Tyres	= 2.8
		Mainrope	= 1.12821
		Strops	= 2.61538
		R & M	= 5.48105
TOT OWN $/HR	= 22.5354	TOTAL OP $/HR	= 24.1106

TOTAL COST PER HOUR = $46.65

(ii) JOHN DEERE 540 - WIDE TYRES

Cost of Machine	= $150,160	Resale Value	= $37,400
Life of Machine in Years	= 5		
Prod. Hrs/Yr	= 1530	Prod. Hrs/Day	= 6.5
Rate on Invest.	= 18%	Insurance	= 2%
Fuel Consump.	= 10.7	Fuel Cost	= $.58¢
Oil Consump.	= 2	Oil Cost	= $2.65
R & M Factor	= 50%		
Strop Cost	= $340	Strop Life	= 130
Mainrope Cost	= $220	Mainrope Life	= 195

JOHN DEERE 540 - WIDE TYRES

Own Cost/Hr		Operating Cost/Hr	
Depreciation	= 10.1909	Fuel	= 6.206
Return Inv.	= 12.3595	Oil	= 5.3
Insurance	= 1.37328	Tyres	= 8.7
		Mainrope	= 1.12821
		Strops	= 2.61538
		R & M	= 5.09543
TOT OWN $/HR	= 23.9237	TOTAL OP $/HR	= 29.045

TOTAL COST PER HOUR = $52.97

APPENDIX 10

TYRE WEAR ASSESSMENT FORM

Date .... Location ....

NOTES

(1) Inspection of tyre wear is to be done two weekly.

(2) All measurements are to be taken at the lug closest to the valve stem. The inside lug measured should be the one immediately behind the outside lug next to the valve stem.

(3) The hardboard template must be used to assess wear on each lug. The height of the tread is the most important measurement.

(4) The outer edge of each lug should be measured 5 cm in from the centre of the lug end.

(5) The mid-point of each lug should be measured at 28.7 cm from either end of the lug.

(6) The inner lug edge should be measured at the widest point where the face of the lug chamfers towards the centre.

(7) All lug wear measurements are to be expressed in millimetres.

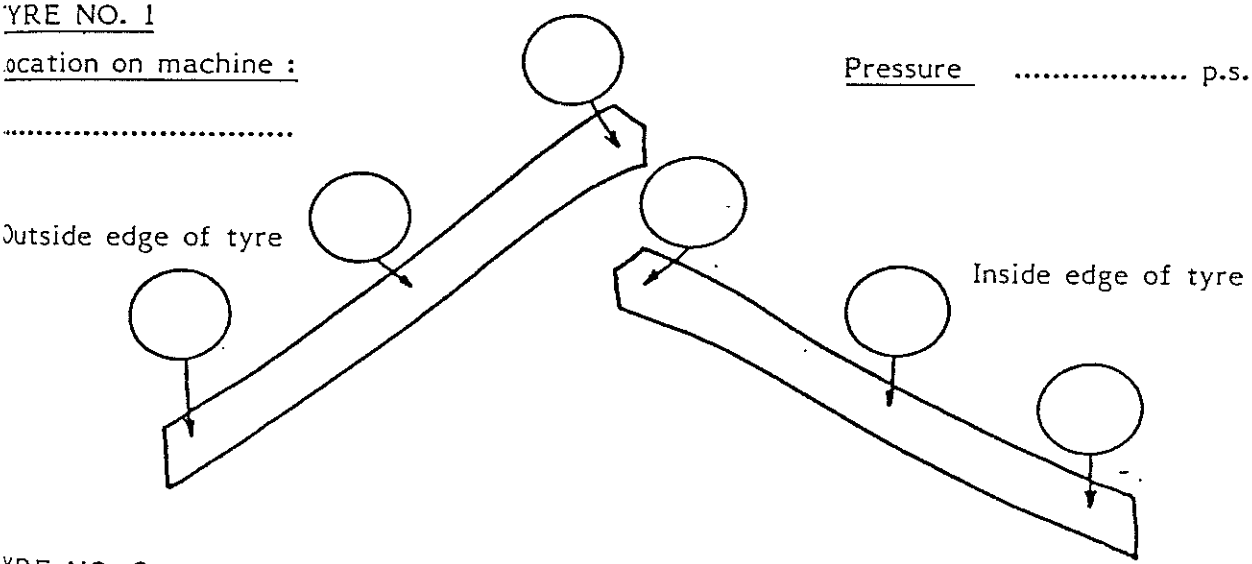
(8) Note any other wear patterns in the comments section.

'YRE NO. 1

.ocation on machine :

....

Pressure .... p.s.i.

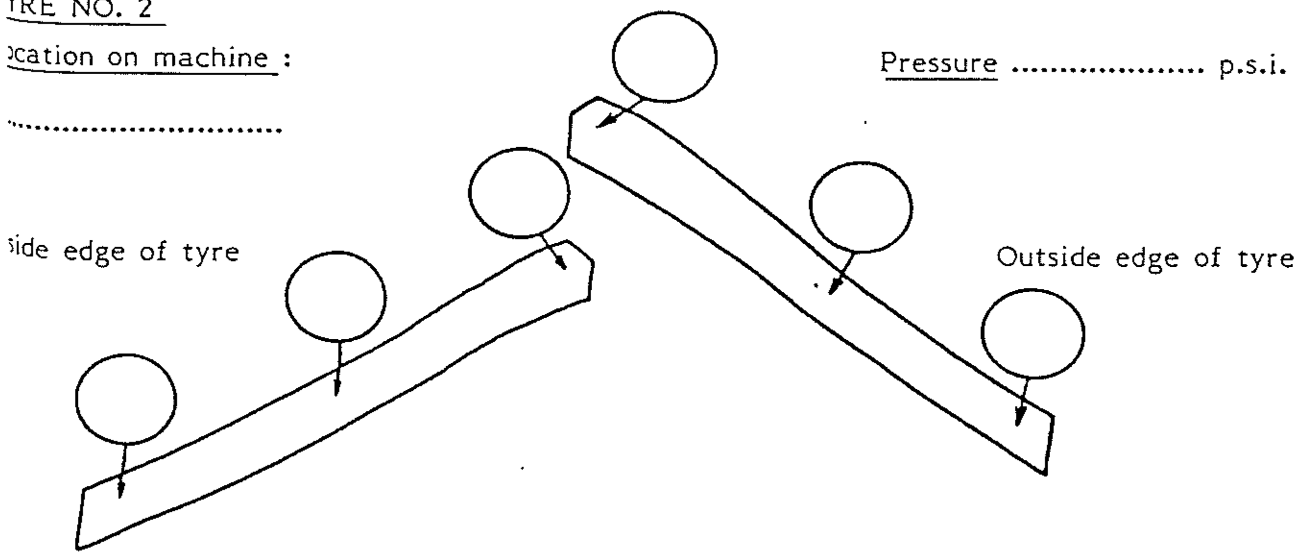


YRE NO. 2

:cation on machine :

....

Pressure .... p.s.i.



APPENDIX 10 Cont.

TYRE NO. 3

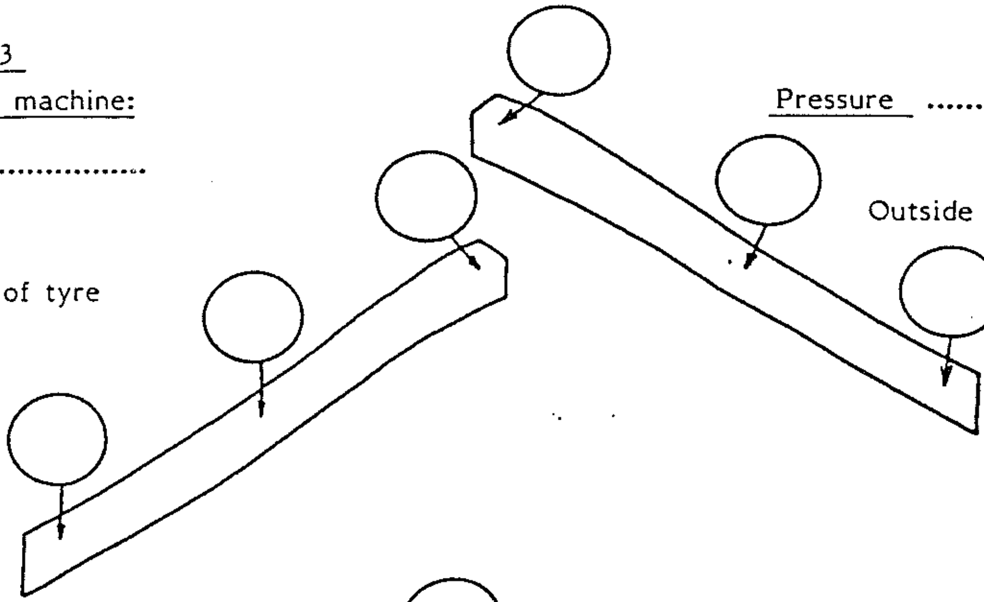
Location on machine:

....

Pressure .... p.s.i.

Inside edge of tyre

Outside edge of tyre



TYRE NO. 4

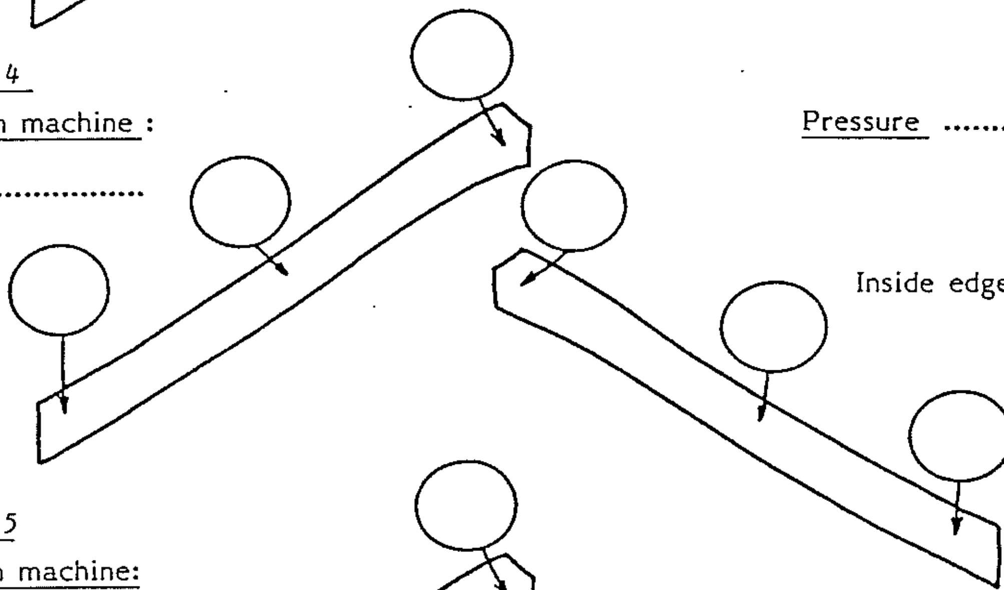
Location on machine :

....

Pressure .... p.s.i.

Outside edge of tyre

Inside edge of tyre



TYRE NO. 5

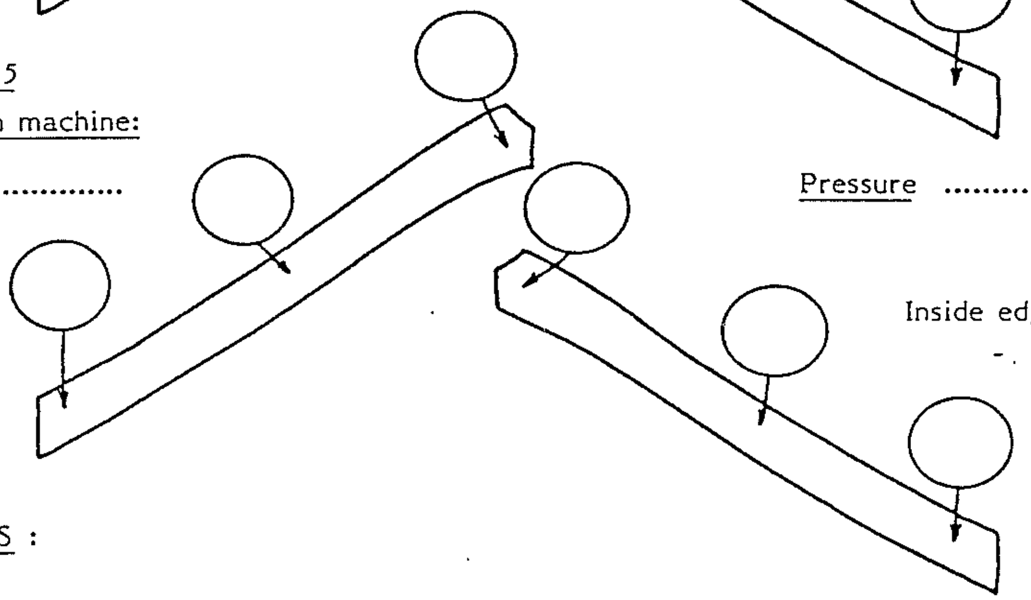
Location on machine:

....

Pressure .... p.s.i.

Outside edge of tyre

Inside edge of tyre



COMMENTS :

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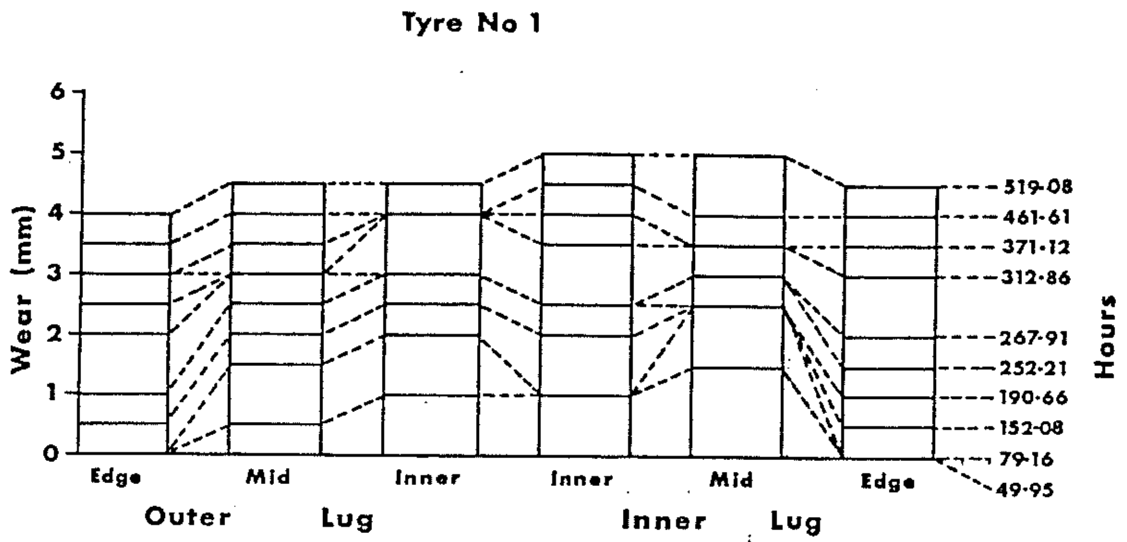
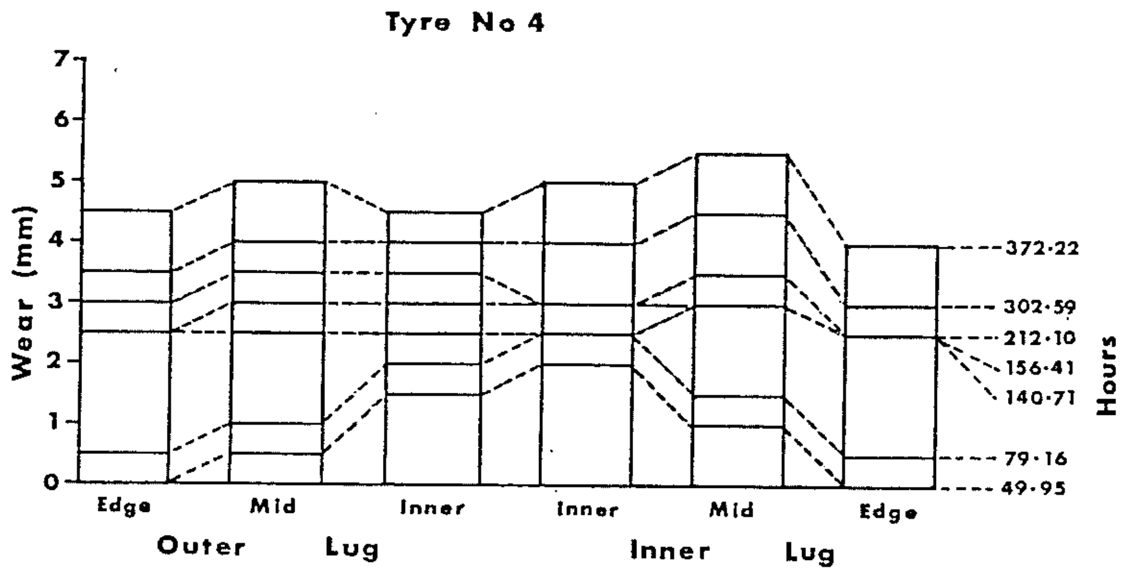
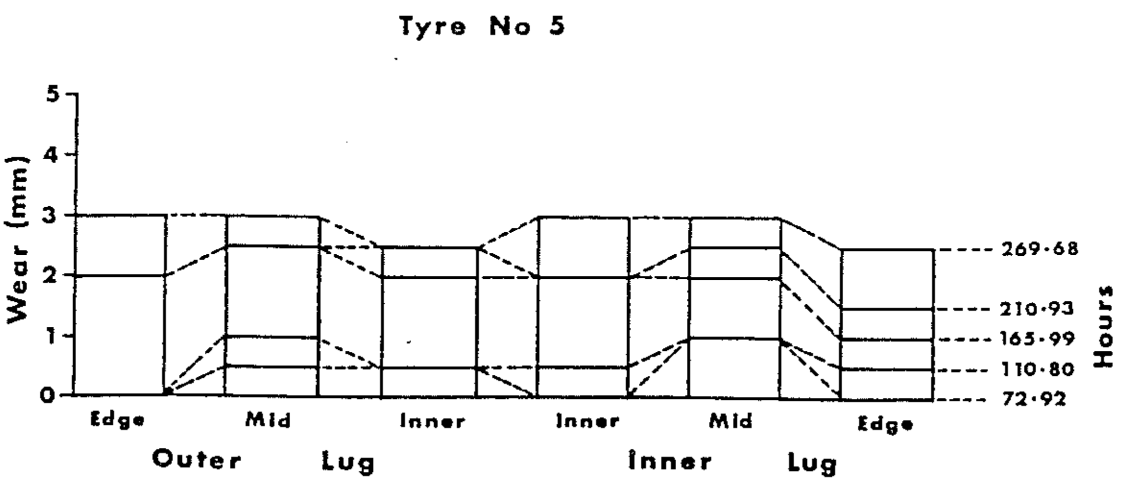
APPENDIX 11

INDIVIDUAL TYRE WEAR MEASUREMENTS

Left Hand Tyres



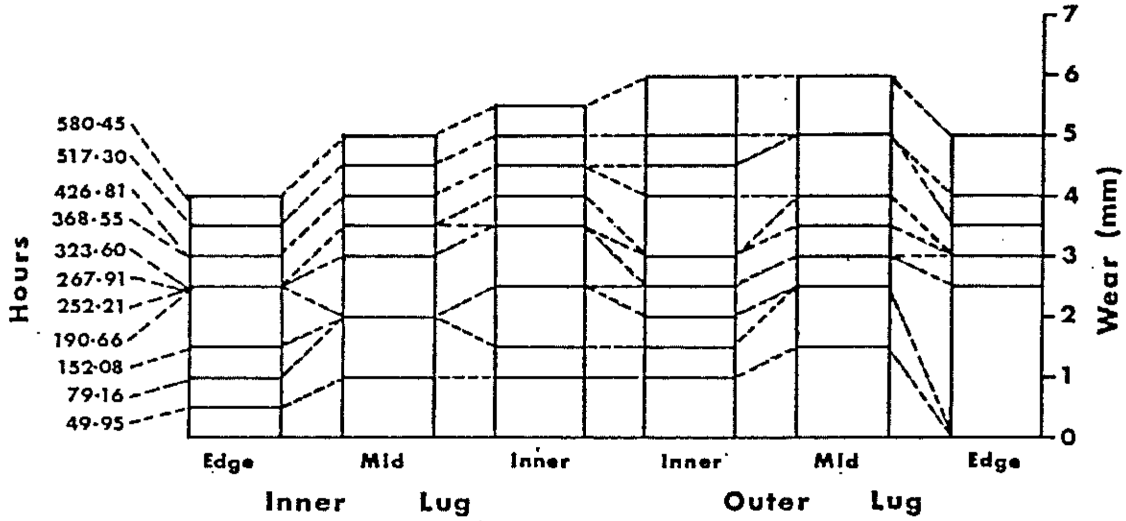




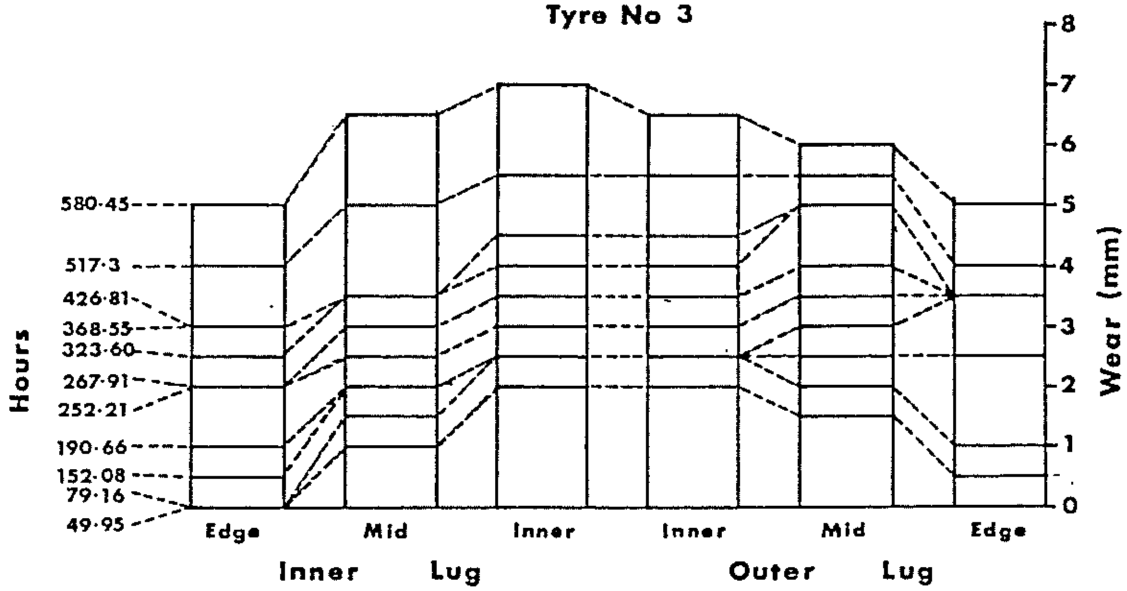
APPENDIX 11 Cont.

Right Hand Tyres

Tyre No2



Tyre No 3



TYRE DAMAGE ASSESSMENT FORM

Date .... Machine ....

Location .... Operator ....

Operating pressure .... psi

(1) Operation being carried out - (i) Clearfell (ii) Thinning (iii) Other

(2) Extraction direction - (i) Uphill (ii) Level (iii) Downhill

(3) Part of Cycle - (i) Travelling empty (ii) Positioning (iii) Breaking out
(iv) Travelling loaded (v) Winching (vi) On the landing
(vii) Other (specify) ....

(4) Type of damage

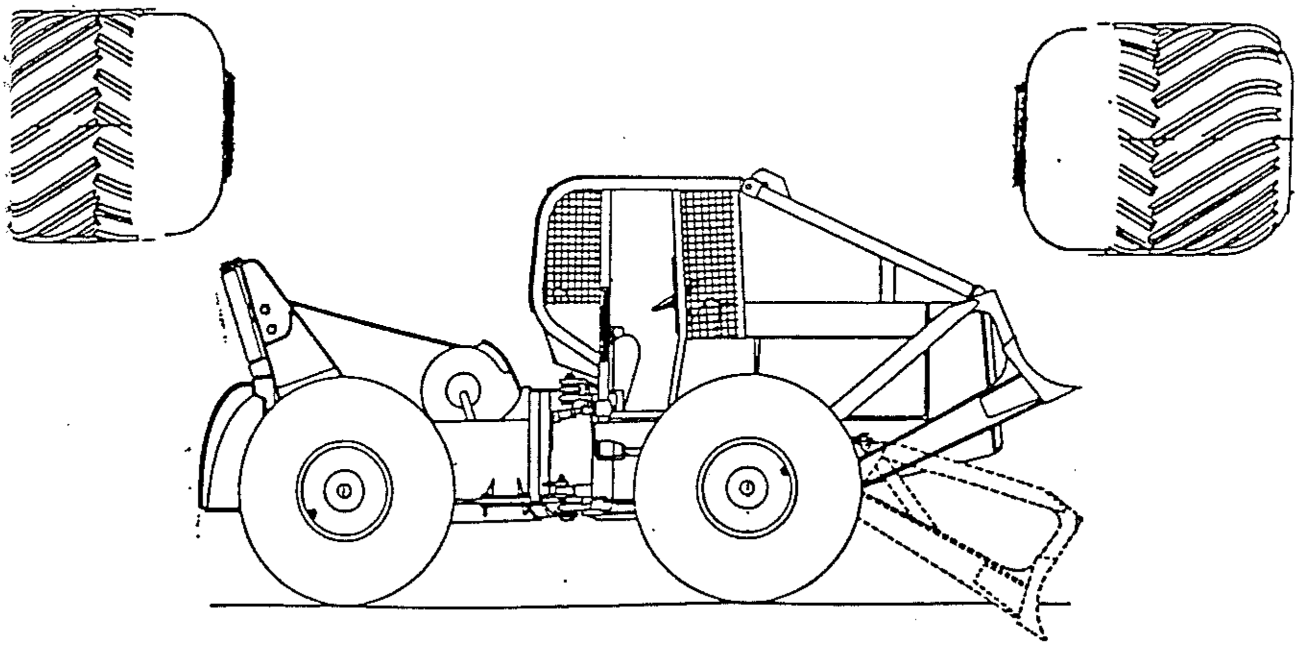
(i) Cut or slash made by sharp object
(ii) Puncture - by some agent penetrating the tyre
(iii) Rip or tear in the outer casing
(iv) Rupture - failure of the outer casing
(v) Lug(s) or part of Lug(s) torn off
(vi) Bead damage caused by wood or rim slippage
(vii) Bulge - unusual protrusion in tyre casing
(viii) Valve stem damage
(ix) Unknown - flat tyre but no apparent damage

(5) Cause of damage (if known) ....

(6) Amount of rim slippage .... mm

(7) Location of damage (mark on diagram)

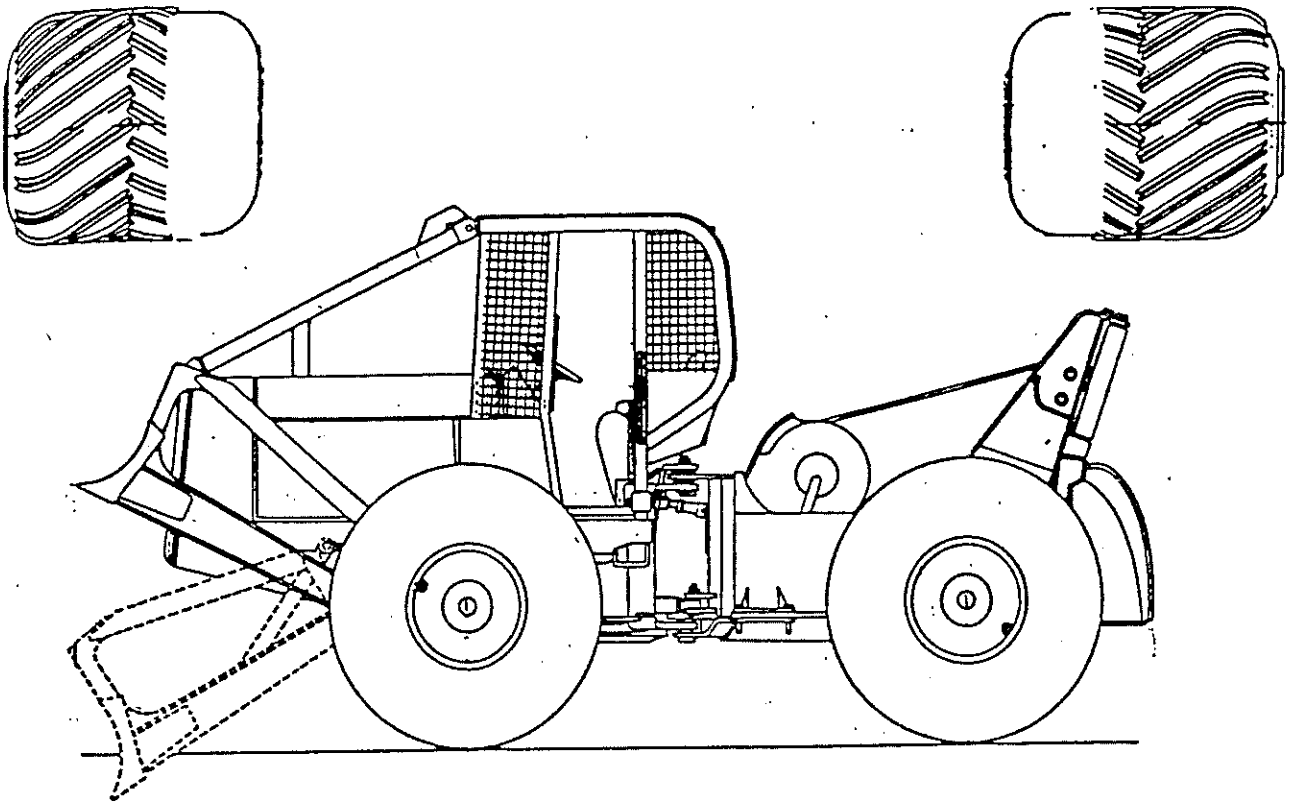
RHS



APPENDIX 12 Cont.

- 2 -

LHS



(8) Time the tyre damage was noticed ....am/pm

(9) Distance machine was from skid .... metres

(10) Action taken - what was done when damage was noticed

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(11) What in your opinion, could be done to prevent future failures of this nature?

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