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Landwards

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IAgrE Soil & Water Management Specialist Group

National Conference

17 November 1999 at 9.20 a.m.
Cranfield University, Silsoe Campus

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Prof. Gordon Spoor

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Tyres and tracks - a practical guide to selection.
Dr Frans Tÿink

Crop and environmental protection - minimising the risks.
Dr Vic Jordan

The Bottom Line - setting targets and choosing systems.
Mr John Bailey

Weeds - a practical guide to their control

Some systems available and the thinking behind their design.
Company representative from: Simba, Dowdeswell, Väderstad, Wallis Great Plains, Kverneland Accord, John Deere, and Lemken Tri-Ag

Some systems in use and how to get the best out of them: The plough; Minimum tillage - approach 1; Minimum tillage - approach 2; Direct drilling

Landwards

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Editor
Eur Ing Prof Brian D Witney
PhD CEng FIMechE HonFIAgrE MemASAE
Land Technology Ltd,
33 South Barnton Ave,
Edinburgh, EH4 6AN
Tel/Fax: 0131 336 3129
Email:landtec@ednet.co.uk

Advertising Manager
Philip Northcott,
PRN Media Ltd,
Office C, First Floor,
17 Market Hill,
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Web site at
http: //www.silsoe.cranfield.ac.uk/iagre/default.htm

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Forestry Engineering Conference papers

News and comment

Front cover: *Timberjack 762B harvester head with non contact measuring frame*
(photo: B Löfgren, The Forestry Research Institute of Sweden)

ISSN 1363 8300

Timberjack 762B harvester head with non contact measuring frame.

Make money without touching a log

Björn Löfgren

This paper was presented at the 1st International Conference on Forestry Engineering entitled: " Forestry Engineering for Tomorrow", organised by the Forestry Engineering Group of the IAgrE and held at the University of Edinburgh, Scotland UK on 28-30 June 1999.

Björn Löfgren is a Senior Researcher, primarily working on the development of forestry machines, measuring and control, at SkogForsk, The Forestry Research Institute of Sweden, Uppsala Science Park, S-751 83 Uppsala, Sweden.

Introduction

To satisfy the need for increased end-use and customer satisfaction, combined with increases in efficiency, the dimension measurement equipment on harvesters need to be improved. Demands on the performance and accuracy of measurement equipment will increase in the future. In the long run, it should be possible to use the measurement for the determination of wood value directly on the harvester. This type of system is already being applied in Finland.

Measurement data consist of length and diameter values and may eventually even include other types of information on the stem. The quality of the measured values obtained from the sensors must be high in order to ensure that the dimensions of the wood are in line with specifications. Measurement accuracy is also of great importance for the results of bucking according to value or demand. A suboptimal bucking reduces the value of the bucked log. Furthermore, correct information with regard to dimensions and bucking data direct from the forest makes it possible to increase efficiency all along the handling chain, *i.e.* from the forest to the retail store.

From the sawmill's point of view, there is great value in being able to measure diameter with high precision. If the harvester measures the diameter incorrectly and the log is assigned consequently to the wrong diameter class, the diameter or the relation between diameter and log length can end up outside of the sawmill's specifications.

A tree's bumpiness and taper can be used as variables for predicting a tree's lumber properties. This requires accurate, continual and reliable diameter measurement. According to a preliminary calculation made by Sondell

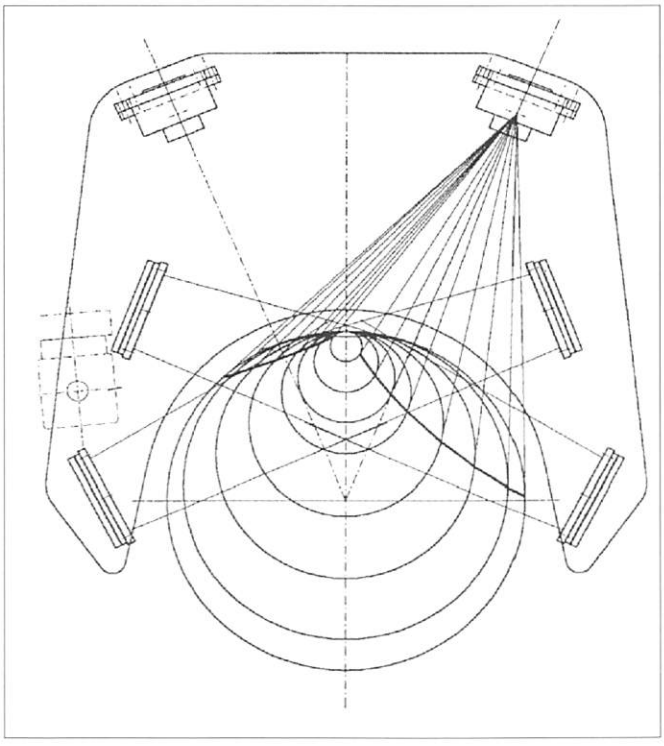

Fig. 1 Measuring frame with vision technique.

(SkogForsk, 1991) profits could be increased by about 1% of the timber value by improving the length sensor and by 1-2% by improving the diameter measurement process. If the value of the handled timber is *ca* SEK 10 million, this would translate into a yearly profit of SEK 250,000 per machine.

Vision technique

The diameter measured with the limbing knifes, which have 3-4 points of attachment, are mutually displaced 0.3-0.5 m along the stem and cannot be read separately. Distinct diameter measurements per cm are not obtained.

In normal cases, the limbing knives run above the stem bark, and a diameter value over bark is obtained. However, in limbing work, the knives can 'hop', resulting in an overestimate of the diameter. Between May and September, the knives alternately run over and under the bark which creates great uncertainty concerning the diameter value of individual logs.

With the new method, designed to avoid the above-mentioned problem, the diameter is measured without any contact with the log. This is accomplished by using cameras (vision technique) that view and illuminated the log. The Forest Research Institute of Sweden has been carrying out a project in which vision technique has been applied to measure log diameter on a single-grip harvester head. A measuring frame was constructed which contains two cameras and a large number of light emitting diodes (LEDs), see *Figure 1*.

The cameras 'view' the log with a 5 mm wide line perpendicular to the log. The angle between the cameras is 45°. The LEDs, which illuminate the log at the spot viewed by the cameras, flicker (turned on and off 1000 times per second) so that the cameras can get a better image of the log. Both cameras are connected to a computer that processes the information. The computer contains various types of filters which filter out disturbances in the form of sunlight, vibrations, remaining or loose twigs, wood shavings, snow, dirt, *etc.*, on the subject and illumination, as well as rapid changes in diameter. One diameter measurement (accuracy of ± 1 mm) is obtained every ½-1 cm along the log depending on its velocity.

The measuring frame was mounted on a Timberjack 762 B single-grip harvester head, which was then mounted on a FMG 250 SuperEva single-grip harvester, see *Figure 2*.

Results

Field tests were carried out in two rounds. To obtain a sample size large enough for statistical analysis *ca* 20 trees (75-100 logs) were cut in every field test. The non-contact diameter sensor stored diameter values for one tree at a time, whereupon the measured values were uploaded to a personal computer (PC) before measuring the next tree. Raw data from the diameter sensor were stored for further analysis. Since the raw data from each tree were stored in the cameras, it was possible later on to test various types of filtering processes aimed at improving the level of agreement with the measurements by calipers. Each of the cameras carries out a basic filtering at the time of measurement in order to remove brief disturbances. In the subsequent analysis, we conduct a filtering procedure at a higher level, utilising information from both cameras and knowledge as to how the a reasonable stem profile should

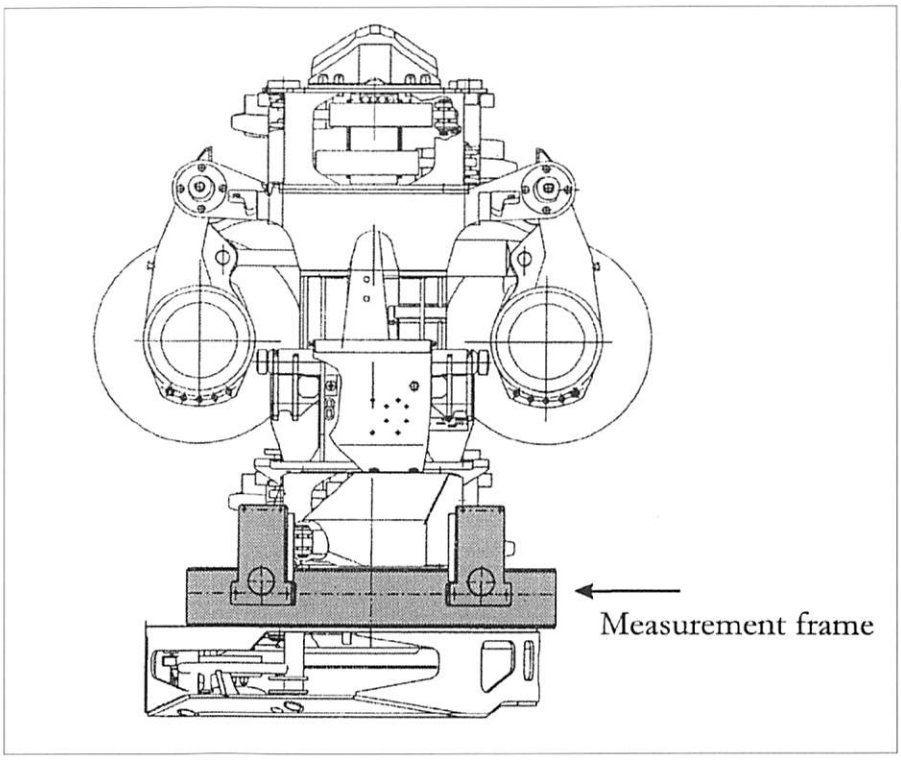

Fig. 2 Measurement frame mounted on a Timberjack 762B single-grip harvester head.

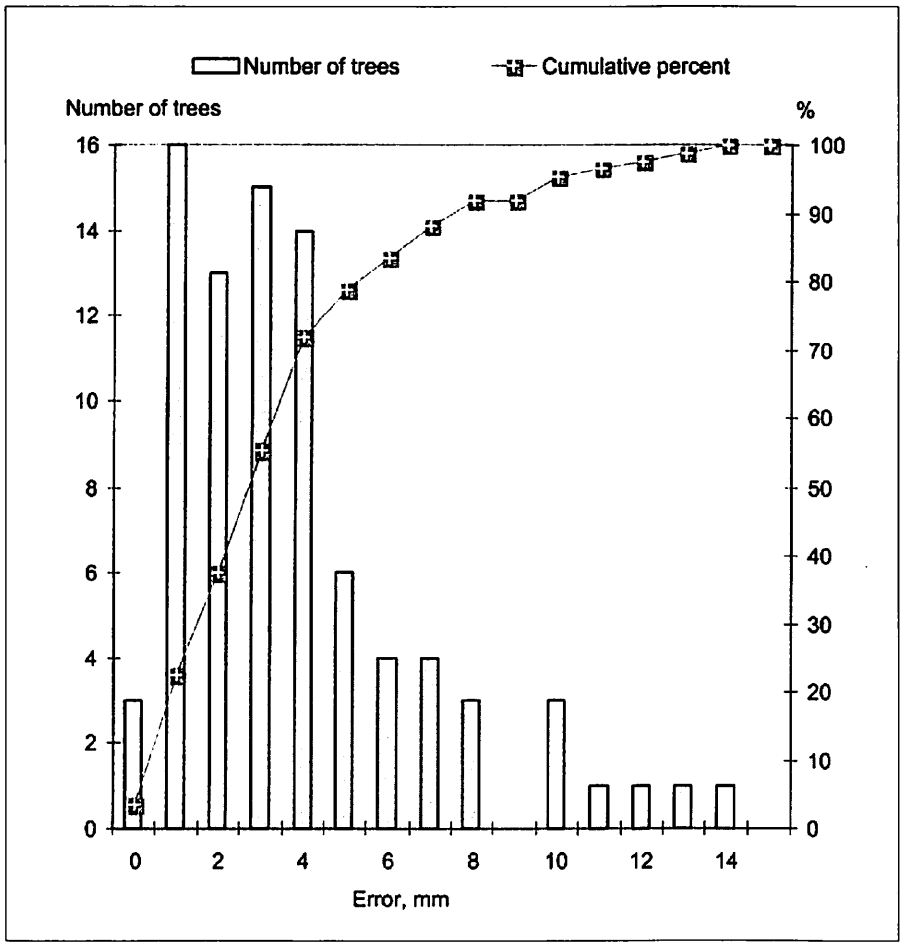

Fig. 3 Error in minimum diameter; distribution of values from all logs.

look.

The comparison with the caliper minimum diameter *(Figure 3)* shows that the deviation between the lowest camera value at the last 3 dm of the log and the mean of the calipered minimum and maximum values at the measuring point where the smallest diameter was measured.

Scots pine *(Figure 4)* gives 'dirtier' images than Norway spruce *(Figure 5)*, and thus results with pine are not as good. Additional mechanical improvements are probably the most effective way to solve this problem.

In cases where the deviation in minimum diameter is large, the explanation can be ovality, disturbances, or both.

Economic analysis

To be able to develop and introduce remote diameter measurement on a single-grip harvester head, a rough estimate of the costs involved is needed. It is also necessary to estimate revenues in various situations if the diameter can be measured more accurately than is possible using the system available today.

Revenues in connection with improved diameter measurement

The value of an improvement in the accuracy with which diameter can be measured in the harvester depends totally on how the system from forest to finish product is designed. The more specific the demands placed on raw materials for various end uses, the more profitable it will be to increase measurement accuracy in the forest. In a trial aimed at assessing the value of an improvement in diameter measurement in the harvester based on a profit contribution calculation for sawmills, the revenue increase was calculated to be SEK 0.5-2.20 per mm decrease in standard deviation and felled m^3 solid volume. These values are valid for an improvement in the range of 7-3 mm standard deviations between the measured and 'actual' values. Calculated on a per harvester basis, this corresponds to approximately SEK 20,000-90,000 per year and mm. Furthermore, a reliable determination of whether the diameter was measured on or under the bark, and

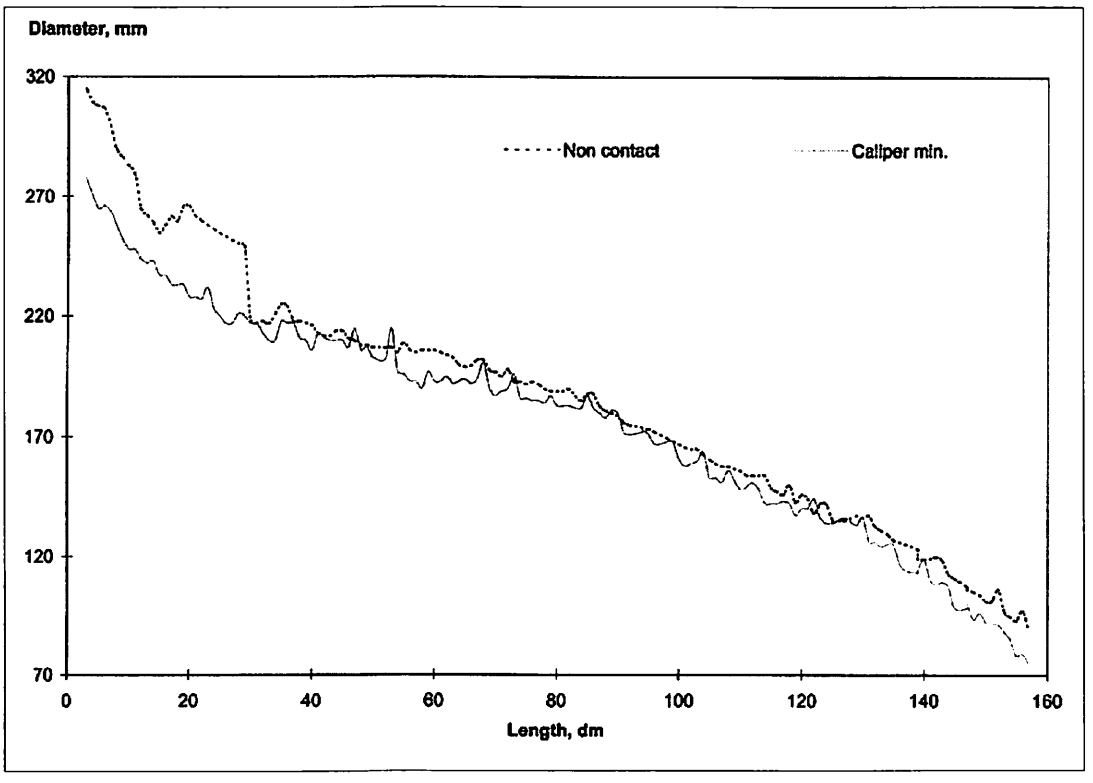

Fig. 4 Example of measurement results from Scots pine.

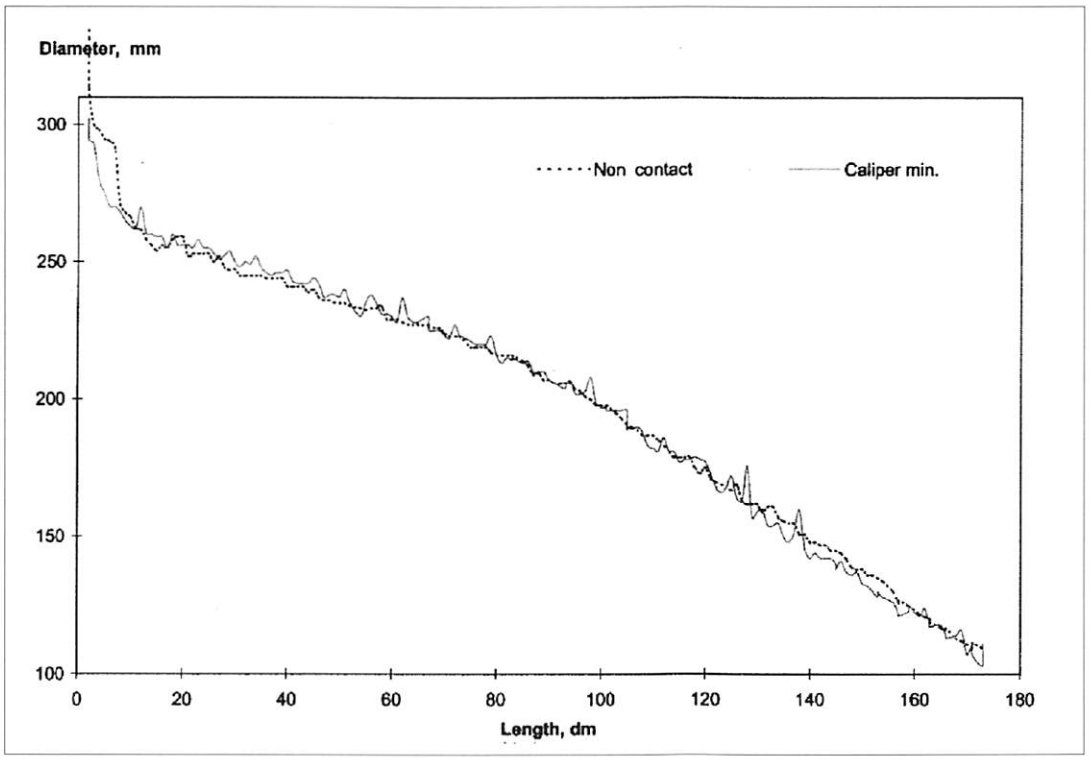

Fig. 5 Example of measurement results from Norway spruce.

the system's possibilities to contribute to a calculation of the inner properties of logs result in increased revenues and calculated cost savings for calibrations that did not have to be carried out of SEK 20,000-50,000 per harvester and year. Increased demands for a fast and reliable flow from the forest and the desire of sawmills and pulp mills to keep there stockpiles small further increase the value of improvements in dimension measurement in the forest. By contrast, a development towards increased template and decreased timber values would result in revenues lower those indicated by the calculations.

Cost of product

The time for a product introduction is estimated to be about 5 years. At a series size of 10 units in year 3, 50 units in year 4 and 100 units in year 5 the cost for a non-contact diameter measurement system would be *ca* SEK 150,000 per system.

Discussion

Results from the field studies showed that the non-contact diameter measurement system can measure *ca* 75% of the top diameters with a margin of error of ±4 mm, compared with calipered values. Although performance still needs to be improved somewhat to meet the current requirements (90%), the accuracy of the system is, on average, higher than that achievable by measuring diameter with the help of limbing knives (67%).

One might ask whether the requirement of 90% with an error margin of ±4 mm is reasonable. The logs are oval, and in a comparison between calipered and non-contact diameter values large deviations can be obtained. The magnitude of the deviations can vary depending on where on the log the measurements have been made and the occurrence of bark injuries. The reliability of diameter measurements of oval logs is influenced by the angle between the cameras. The angle is currently 45° but needs to be increased to at least 70°, preferably 90°, in order to reduce the influence of ovality. A faster processor in the camera and a doubling of the number of pixels in the CCD-chip should provide a larger number of measurements per unit time and higher resolution. This should, in turn, increase the number of correct measurement values.

A decisive factor affecting the measurement results is the amount of dirt, wood shavings, bark, *etc.*, that gets in the way of the cameras. With the measuring frame in its current position, the cameras become littered with wood residues from the pair of limbing knives, feed wheel, length- measuring wheel, and crosscut saw. Although these residues can never be eliminated completely, the amount of litter can be reduced by, for example,

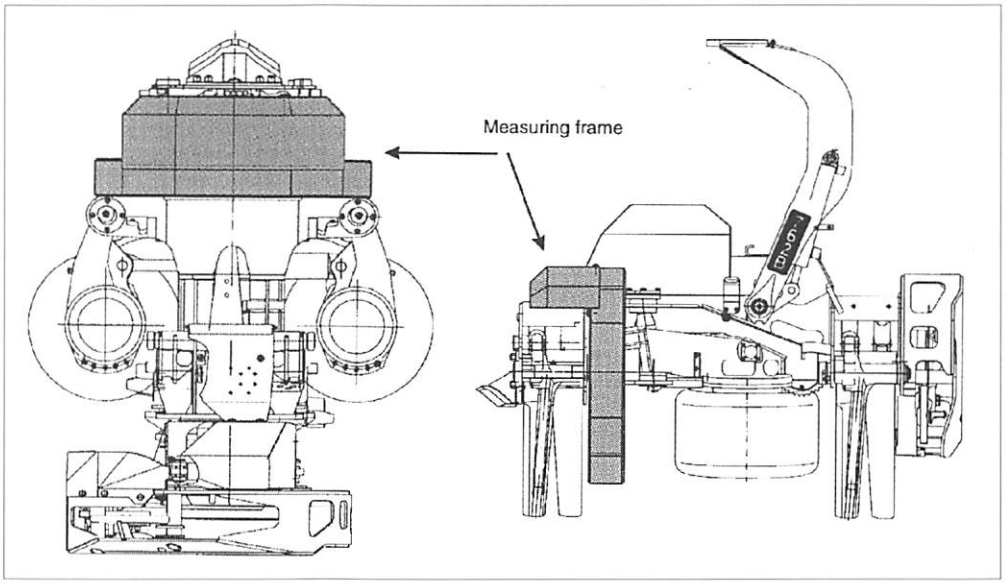

Fig. 6 Unit with the measuring frame in a new position.

placing the measuring frame close to the first limbing knives *(Figure 6)*.

There are relatively limited possibilities to increase the level of filtering of raw data in the programme application, since additional filtering would negatively affect measurement accuracy. On the other hand, algorithms that can predict log taper or measure the diameter of the log when it is stationary during the course of crosscutting should be able to improve the precision of the measurement system.

To eliminate various types of disturbances a filter was installed in the non-contact system. It would probably be possible to utilise these filtering principles more effectively in order to increase the accuracy of today's contact systems.

A non-contact diameter system might also offer possibilities for adding various quality measures, such as bumpiness remaining branches and more correct taper in the measurement programme. This would allow log properties to be described better and used when marking for crosscutting on the harvesters.

The costs of a non-contact diameter system are judged to be *ca* SEK 150,000. The analysis of revenues presented in this work should merely be considered as one example from which there can be large deviations between regions, companies, business relationships, *etc.*

If the efficiency of compensation estimates could be increased as a consequence of improved measurement techniques on the harvester, it could be worth up to about SEK 5 per m³ solid volume of timber and *ca* SEK 1 per m³ solid volume of pulpwood. On a per harvester basis, this would be equivalent to up to SEK 160,000 per year for a harvester which have measurement system for determining of wood value of all felled timber.

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Ricardo opens 'Advanced Engine Development Centre'

- First phase completed of one of the world's most advanced engine development facilities
- Highly transient and climatic-controlled test environment facilitates advanced engine research and development
- Driver and vehicle characteristics modelled using state-of-the-art software
- New facility provides the means to develop engines with greater fuel economy, reduced emissions, improved calibration and shorter time-to-market

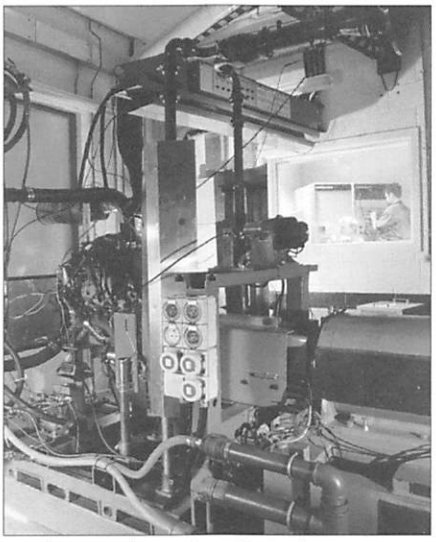
Ricardo - Europe's largest independent powertrain and vehicle engineering technology provider - officially opened its new Advanced Engine Development Centre on Wednesday 21 July 1999.

The company has built the new complex at its Sussex technical centre at Shoreham on England's south coast, one of five technical centres operated by Ricardo in the UK and North America. The company has invested £6m in the development of the first phase of this new facility, which on completion of subsequent phases will represent a total commitment of £12m.

On opening the facility, Ricardo chairman Sir Noel Davies said: "The Advanced Engine Development Centre is a major part of Ricardo's investment strategy, which is aimed at maintaining the company's position as a leading provider of powertrain and vehicle engineering solutions to the world automotive industry".

Within the motor industry, some of the most significant drivers for new engine technology include exhaust emissions legislation, pressures for greater fuel efficiency and reduced CO_2 emissions, the cost of product development and production, and the time to bring new products to market.

"The Advanced Engine Development Centre (AEDC) will enable Ricardo to address these issues head on, enabling us to develop the higher fuel efficiency, lower emissions engines that customers are demanding for the future," commented Ricardo chief executive Rodney Westhead. "The AEDC will also enable Ricardo to carry out advanced research and to provide practical engineering solutions to its worldwide client base."



Advanced Engine Development Cells

With the first phase of the complex commissioned, the new facility offers a wide range of test capabilities that will help to reduce vehicle development time, thereby enabling vehicle manufacturers to bring their latest models to market faster and at lower cost. The new facility will also accelerate the process of meeting increasing legislative and market demands.

"Meeting the demands for improved fuel efficiency and the latest international emissions regulations is of paramount importance to manufacturers globally," said Rodney Westhead. "As manufacturers outsource more of their test and development work, so a matching commitment is required by Ricardo to invest in new development and research facilities."

"We have taken the logical step of increasing the level of control we have over vehicle testing," said Ricardo's director of operations, John Needham. "This facility enables us to carry out more sophisticated development work than would previously have been possible, including highly transient and climatically controlled tests. Additionally, the advanced control systems and software incorporated in the facility enable us to simulate operating conditions that replicate the engine performance in a vehicle and emulate variable driver characteristics for a variety of driving conditions."

One initial application of the new centre is the calibration of vehicle engine management systems on the test bed without the need for an early prototype vehicle. As well as simulating the vehicle parameters, drive cycle and driver characteristics, the climatic capability of the new facility enables several extreme climate tests - such as cold starts - to be carried out in a single day. These test bed based processes will enable manufacturers to cut the full calibration process by at least six months and reduce the risk and cost associated with the testing of prototype vehicles in extreme climate locations.

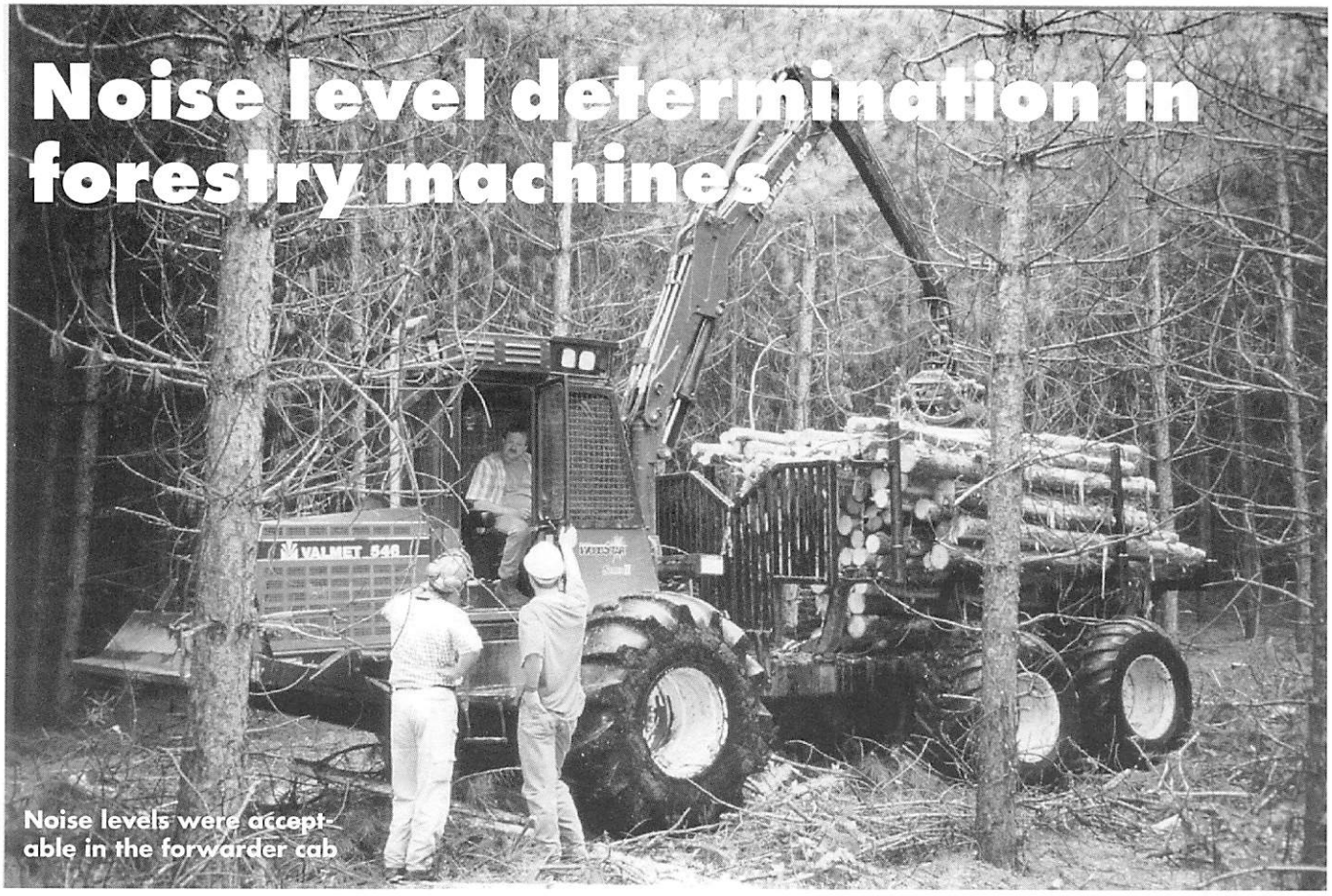
The new centre will also facilitate advanced research projects. Among the first of these is a collaborative programme with DaimlerChrysler and Kistler, which is partly funded by the European Commission. Code named ANEAS, this project aims to investigate novel engine management systems design using intelligent control algorithms and advanced sensor technology. The objective of this work is to provide better control of the combustion process and hence enable further emissions reductions and improved calibration robustness.

Ricardo's Advanced Engine Development Centre has been developed with the future needs of the automotive industry firmly in mind, With the first phase of its development completed, Ricardo has designed and commissioned a highly evolved engine test environment.

John Needham added: "The AEDC building has considerable capacity for further expansion. The specification of the subsequent phases of development will be enhanced as technology permits and according to market demands. In this way, Ricardo strategy aims to maintain our leading position in technology development in this critical area for the automotive industry."

Contact: **Anthony Smith. Tel: +44 (0) 1273 794460 email: AVSmith@rce.ricardo.com**

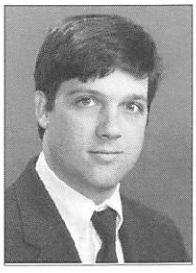
Noise level determination in forestry machines



Noise levels were acceptable in the forwarder cab

Fernando Seixas, Rafael Alex Barbosa and Robert Rummer





This paper was presented at the 1st International Conference on Forestry Engineering entitled: "Forestry Engineering for Tomorrow", organised by the Forestry Engineering Group of the IAgrE and held at the University of Edinburgh, Scotland, UK on 28-30 June 1999.

Dr Fernando Seixas is Professor of Harvesting, Forest Science Department, Escola Superior de Agricultura "Luiz de Queiroz" University of Sao Paulo (ESALQ/USP), C.P. 9, Piracicaba, SP, Brazil; Rafael Alex Barbosa is a Forest Engineering undergraduate student at ESALQ/USP; and Dr Robert Rummer is Project Leader, Engineering Research Unit, USDA Forest Service, Auburn, AL, USA.

Abstract

Until recently, the high noise level of many forestry machines presented an occupational risk of hearing loss for operators exposed over a long period of time. This is a serious health and occupational safety problem, with different regulations in various countries concerning noise levels and exposure time allowed.

This study evaluated the noise level of sixteen relatively new forestry machines (forwarders, loaders, harvesters, processors, skidders and a slingshot), during normal operational activities. The percentage time of all activities of each machine was determined with respective noise levels obtained by a Metrosonics db-3080 noise monitor. The results showed that all machines had noise levels below the Brazilian legal limit of 85 dB(A) for an 8-hour shift. The skidders were the only machines with a concern since their average noise level of 82 dB(A) was close to the limit. The next step will be to follow these machines during their operational life, to see if operational noise levels will change over time due to normal machine wear.

Keywords: noise, wood harvesting, forestry machines.

1. Introduction

Occupational noise exposure can reduce or damage the hearing ability of operators who are exposed to high noise levels over a period of time. Many forestry machines have open cabs which may expose operators to noise levels above accepted limits. However, since noise exposure is a cumulative environmental factor which results in a gradual physical change to the person, it is often overlooked or neglected by

workers and supervisors. The process of hearing loss may take 5 to 10 years at noise exposure levels typical of tractors before there is definitive evidence of auditory damage, usually around frequencies of 4000 Hz (Gregg, 1972).

In Brazil, legislation specifies the exposure time allowed for several noise levels, with a maximum value of 85 dB(A) for an eight hour shift without personal protective equipment (PPE) (Saad, 1981). A recent survey conducted by an insurance company in the USA found that only 10% of forestry workers utilized auditory protection (Table 1). The low level of use of PPE could be due to the difficulty of perceiving hearing loss, a lack of management concern about hearing loss, lack of training and education, or the perceived discomfort of personal protective equipment.

Table 1 Utilization of personal protective equipment among forestry workers in the USA. (Robert Rummer, personal communication, 1995)

Personal protective equipment	*Percent in use*
Hardhats	36
Safety footwear	29
Chainsaw chaps	24
Eye protection	17
Hearing protection	10
First aid kits at job site	50

To determine if there is a legal requirement for hearing protection, the employer must calculate a representative noise exposure for each worker. Simply knowing the noise level of specific equipment is not enough. Noise exposure is a cumulative environmental stressor and must be assessed during a work shift. Two machines working side by side, for example, create a higher noise level than either machine by itself. This can be a factor in yards or at handling areas where several machines may be working close together at same time.

Some studies have documented the high noise levels associated with typical wood harvesting operations. Reif and Howell (1973) evaluated the noise level of 57 forestry machines in Canada and concluded that 49% did not meet accepted exposure limits to continuous or intermittent noise. Skidders had the worst noise level with 70% of the machines above the action limits. Another Canadian study found that skidders operated with an average noise level of 104 dB(A), varying between 90 and 112 dB(A) (Myles *et al.*, 1971).

Research conducted in the 70s by the Pulp and Paper Research Institute of Canada found some machines, such as feller-bunchers, harvesters and processors, above the accepted noise limits (Powell, 1970; Heidersdorf, 1973; Powell, 1974a and 1974b). The Forest Engineering Research Institute of Canada (FERIC) continued noise measurements and found two feller-bunchers, one feller-forwarder and one delimber with noise levels under 90 dB(A) (Folkema, 1977 and 1982; Levesque, 1983 and 1985; Hope, 1986). Other studies detected unacceptable noise level in some skidders (McDonald *et al.*, 1978; Ryans, 1982; Heidersdorf, 1983).

In Brazil, Fernandes (1991) analyzed 198 domestically manufactured agricultural tractors in real field operations and concluded that all of them were above the legal limit of 85 dB(A) for an eight hour shift. Audiometric testing of a sample group of 111 operators indicated that 60% of them had hearing problems. Fiedler *et al.* (1995), working with forestry machines in eucalyptus plantations, also found noise levels above the limit of 85 dB(A) on a shear feller-buncher (106 dB(A)) and a wheeled skidder (101 dB(A)).

Several researchers have studied the relationship between machine design aspects and noise exposure. Fischer (1978) collected noise data from harvesting machines and concluded that some of the variation found in an "unloaded" condition could be due to climate (moisture, wind, precipitation), period (of year, day), machine life or obstacles (trees, leaves, *etc.*). During the "loaded" condition, other factors must be considered: the load weight, internal wear, operator control and travel speed. Several machines, including a loader, skidders, yarders, trucks and one chain saw, exceeded the USA limit of 90 dB(A), established by the Occupational Safety and Health Administration (OSHA). Hope (1986) reported that reducing the engine speed of a delimber from 2800 rpm to 2500 rpm, also reduced the noise level from 85-87 dB(A) to 83-85 dB(A). McDonald *et al.* (1978) determined the

Table 2 Standard work cycle for forestry machines.

Machine and work cycle element	*Percent of work cycle*	*Work condition*
Rubber-tyred cable skidder		
Hooking	41	3-5 logs, 80% of capacity
Travel loaded (182 m)	14	15 min cycle time
Unhook	21	
Decking	7	
Travel empty	10	
Position	7	
Rubber-tyred grapple skidder		
Grapple	24	3-5 logs
Travel loaded	23	9 min cycle time
Decking	24	
Travel empty	17	
Position	12	
Tracked feller-buncher		
Travel and swing	20	Wooded or open area
Position and cut	45	Trees may or may not be cut
Swing and bunch	35	Cycling the cutting mechanism
Rubber-tyred feller-buncher		
Travel to trees	35	Acceptable
Cut and accumulate	40	
Travel to pile, bunch	25	

operational noise level of a skidder was 98-100 dB(A) travelling unloaded and 99-101 dB(A) in a loaded condition. Liley (1985) evaluated a cable skidder and found a noise level of 78 dB(A) at the operator's station with the engine idling and transmission in neutral. At maximum travel speed, the same skidder produced 95 dB(A).

Forestry machine manufacturers can give some indication of noise level exposure for forestry conditions using a standard procedure outlined in Standard J1166 "Sound Measurement–Off-road Self-propelled Work Machines–Operator–Work Cycle" (SAE 1990). This U.S. document presents instrumentation and procedure specifications for the evaluation of time-weighted operational noise levels of various construction and industrial machines. The standard identifies work cycle times and representative conditions for each type of machine. Table 2 summarizes the standard conditions for forestry machines that are included. Some manufacturers provide noise levels for their products based on this test. Another standard noise test for forestry machines is outlined in International Standard 5131 "Acoustics–Tractors and machinery for agriculture and forestry–Measurement of noise at the operator's position" (ISO 1996). The ISO standard specifies measurement of noise under unloaded conditions at a constant speed of 4 km/h.

Many new machines are equipped with features such as climate control, which can reduce the noise level. Recent designs of cut-to-length technology, such as forwarders, harvesters and processors, operate with lower noise levels compared to conventional harvesting systems with chainsaws, skidders, and feller-bunchers. With these improvements, one question that arises is whether manufacturers have fully addressed the noise problem. Are the new models operating within legal limits or is hearing protection required? Do the new designs, such as closed cabins, give adequate noise attenuation? Does the operational condition, such as yard design and machines working close together, affect the operator noise level exposure?

The objective of this study was to determine the operational noise level of new models of forestry machines in real working conditions. New machines were observed, getting data that will be compared in the future with additional noise data from different periods of the same machines' life, and looking for the effect of machine age on the noise level inside the cabins.

Table 3 Noise level and operational activity of a forestry loader (CF) with a CAT 312 crawler base machine.

Activity	*Noise level, dB(A)*		*Percent of work cycle*
	CF 1 (use: 689 h)	*CF 2 (use: 10 h)*	
Loading	70.9	73.3	41.4
Unloading	70.6	73.1	50.1
Moving	73.9	73.1	2.7
Technical pause	68.7	73.3	5.7
Average	**70.7**	**73.2**	

2. Method

This study was conducted in eucalyptus plantations located on Duratex S.A. lands in São Paulo State, Brazil. A Metrosonics db-3080 noise monitor obtained the noise level inside the cabin. This instrument records noise level over specified intervals and had been programmed to measure sound with A-scale weighting, slow response and a 5 s interval. The microphone was located 200 mm to the right from the central axis of the operator's head, in line with the ear and pointing towards the engine.

Machine operational activities were observed in a time study, simultaneously with the noise level recording, by an external observer. Each operational activity was correlated with its respective noise level at every 5 s.

The life of the machine (engine hour) was recorded to establish for future reference the relationship between machine age and the noise level inside the cabin. The following machines were observed in this study: three Valmet 636 forwarders; two CAT 312 track loaders; one adapted loader on a Massey 290 wheeled tractor; one tracked feller-buncher on a CAT 312 base machine; two Valmet 601 harvesters ; one harvester on a CAT 312 base machine; three processors on CAT 312 base machines; two CAT 525 skidders; and one "slingshot" harvester on a CAT 320L base machine. (The use of trade names is for the convenience of the reader and in no way implies an endorsement of the these products to the exclusion of others.)

Each machine was observed for approximately 50 minutes, registering the necessary data each 5 s, with a total of 600 noise level data points and the respective activity.

2.1. Data analysis

The noise level data were aggregated to obtain an average sound level (Lav) for each operational activity and also a global average for the entire machine operation. The study time data were summarized to determine the average percent of total time utilized for each activity. The incremental noise levels of air conditioning and FM radio, when available, were also determined inside the closed cabin, with the engine working in neutral position. Finally, the noise level exposure was calculated for an eight hour shift for every considered machine.

3. Results and discussion

Almost all machines had an operational noise level under the 85 dB(A) legal limit. The only exception was the Massey 290 wheeled tractor adapted as a loader, which also had a damaged cabin. This tractor had noise values of 90.8 dB(A) for "loading", 91.3 dB(A) for "unloading", 77.9 dB(A) for technical pause (engine in neutral position) and an average of 89.6 dB(A) for the whole operation.

Table 4 Noise level and operational activity of a disk feller-buncher with a CAT 312 crawler base machine.

Activity	*Noise level, dB(A) Feller (use: 2913 h)*	*Percent of work cycle*
Cut	78.4	13.3
Travel loaded	78.7	32.7
Bunching trees	80.3	13.5
Travel unloaded	80.4	40.0
Average	**79.6**	

3.1. Forestry loader

Two tracked log loaders were observed

during the study (Table 3). The higher values for the very new loader may be due to the natural running-in of the engine parts, but even these levels were not harmful to the operator. The noise level with the transmission in neutral reached 56.6 dB(A) and the increase with the air conditioning working was 10.2 dB(A), much higher than other air conditioning equipment observed during the study.

was turned off during the operational data collection. One forwarder (Forw 2) had higher noise levels during the travel stage that may indicate that this machine was running faster than others.

3.4. Harvester

The two Valmet 601 harvesters (Harv 1 and Harv 2) did not have air conditioning or FM radios and Harv 1 worked with the cab open because of the heat. The noise level on this machine, with the transmission in neutral position and an open cabin, was 68.1 dB(A). Harvester 2, however, had the cab closed and the idling noise level was 63.6 dB(A). Harvester 3 (tracked CAT 320 base machine) had a noise level of 65.4 dB(A) idling, 3.7 dB(A) more with the air conditioning working and an additional 6.6 dB(A) because of the FM radio. The data collection for operational activities was done with the radio off. Harvester 1, even with the open cabin under working conditions, did not exceed the legal limit of 85 dB(A) (Table 6).

It is interesting to note the difference in work elements between the wheeled and tracked harvesters. The work element with the highest noise level for both types of harvesters was bucking. However, the tracked harvester spent about one-half the time in this element compared to the wheeled harvesters. There was also a greater variation in noise between the two Valmet 601 machines than between the tracked machine and Harv 2. The analysis of these percentage time differences was not a matter of this research, but could be studied in another opportunity.

Table 5 Noise level and operational activity of a forwarder Valmet 636 (Forw).

Activity	*Noise level, dB(A)*			*Percent of work cycle*
	Forw 1 (use: 2071 h)	*Forw 2 (use: 1938 h)*	*Forw 3 (use: 1675 h)*	
Loading	76.4	76.0	76.1	49.8
Travel loaded	76.5	81.7	76.0	18.5
Unloading	76.3	74.1	75.9	22.8
Travel unloaded	76.7	82.0	78.4	8.4
Technical pause	72.5	-	72.2	0.5
Average	**76.4**	**77.7**	**76.1**	

Table 6 Noise level and operational activity of harvesters (Harv).

Activity	*Noise level, dB(A)*		*Percent of work cycle*	*Noise, dB(A)*	*Percent of work cycle*
	Harv 1 (use: 4600 h)	*Harv 2 (use: 4232 h)*		*Harv 3 (use: 2790 h)*	
Cut	83.4	74.4	21.5	75.3	18.4
Delimbing	84.0	75.0	34.0	75.0	22.2
Bucking	83.6	77.0	17.1	75.3	9.9
Moving	83.4	75.3	24.4	74.5	46.0
Technical pause	76.5	70.6	3.0	73.7	3.6
Average	**83.4**	**75.1**		**74.8**	

3.5. Processor

The three processors based on CAT 320 tracked machines (Proc 1, 2 and 3) were quite similar to the harvester 3. In fact, one of them had been working as a harvester during the study period. The engine noise, in neutral position, reached an average of 61.1 dB(A) (Table 7). The noise increase with air conditioning was 4.2 dB(A) and the FM radio raised the noise level another 10.4 dB(A). Again, the radio was turned off during the operational data collection.

3.6. Skidder

Skidders had the highest reported noise levels in the literature and a similar result was observed in this study (Table 8). The

3.2. Feller-buncher

Only one disc feller-buncher on a crawler base machine (CAT 320) was observed, with no air conditioning during the test period. The noise level with the transmission in neutral was 63.1 dB(A) and working noise levels are listed in Table 4. The comparison with the literature results is not possible because the different models, but is possible to verify the development of this kind of machine getting a better noise isolation to the operator.

3.3. Forwarder

Two of the three forwarders (Valmet 636) had radios. The noise level with the transmission in neutral averaged 69.9 dB(A), with and additional 5.1 dB(A) with the air conditioning and 0.8 dB(A) due the FM radio (Table 5). The radio

Table 7 Noise level and operational activity of processors with a CAT 312 crawler base machine (Proc).

Activity	*Noise level, dB(A)*			*Percent of cycle time**
	Proc 1 (use: 2636 h)	*Proc 2 (use: 2528 h)*	*Proc 3 (use: 2736 h)*	
Cut	-	76.8	-	-
Delimbing	75.7	77.1	77.2	35.3
Bucking	75.4	77.0	77.2	21.0
Moving	75.1	77.0	75.8	40.2
Technical pause	74.0	74.2	63.0	3.4
Average	**75.3**	**76.9**	**76.3**	

* Excludes data for processor 2.

Table 8 Noise level and operational activity of skidders CAT 525 (Ski).

Activity	*Noise level, dB(A)*		*Percent of cycle time*
	Ski 1 (use: 3067 h)	*Ski 2 (use: 3007 h)*	
Loading	81.1	83.6	14.1
Travel loaded	79.7	84.2	40.3
Unloading	78.4	82.7	5.5
Travel unloaded	80.4	82.4	40.0
Average	**80.1**	**83.4**	

CAT 525 wheeled skidder had the highest noise levels of the various types of machines observed. Even so, the average operational noise levels over the duration of the eight hour shift did not exceed the legal limit of 85 dB(A). It appears that current designs of wheeled skidders are significantly improved over previous models. Nevertheless, this is a noise level very close to the limit where it is recommended to use personal protective equipment by the operator. The idling noise level, with the transmission in neutral, reached an average 73.0 dB(A) and simultaneous use of air conditioning added 2.9 dB(A).

3.7. Slingshot

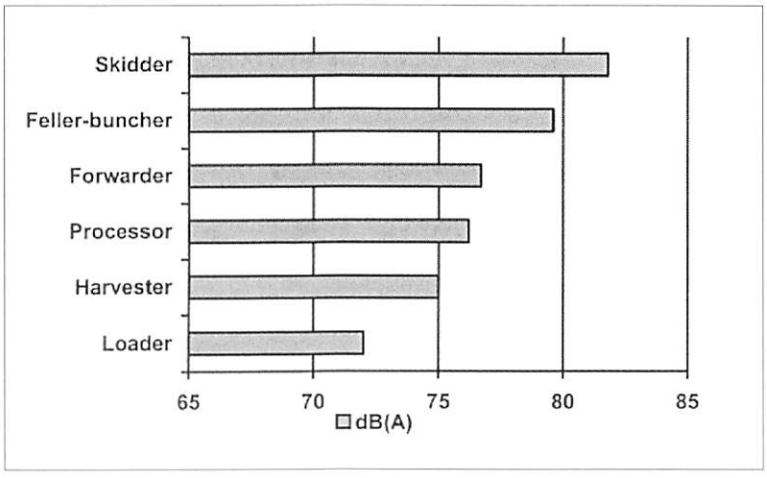
The recently acquired Slingshot, a uniquely-designed harvester based on a CAT 320L tracked machine, was analysed as a case study due to limited data. The basic results were: (a) felling - 77.1 dB(A); (b) delimbing - 77.0 dB(A); (c) bucking - 77.0 dB(A); and (d) moving - 77.1 dB(A). The global average was 77.1 dB(A).

All machines in this study would allow an eight hour shift without the mandatory use of hearing protection for the operators. Nevertheless, the use of hearing protection is recommended in the skidder operation, considering the noise level is close to the Brazilian legal limit. The air conditioning function did not increase noise levels above action limits, but regular maintenance should be performed to reduce its noise level and minimize the possibility that the machine would have to function with an open cabin due to malfunction.

4. Conclusion

In this initial evaluation of noise levels on forest machines in Brazil, with new machines in good shape, all observed noise levels were below the legal limit of 85 dB(A). The different work activities did not greatly influence the observed noise levels, except during forwarder travel, maybe because of a higher speed in that specific situation.

The same evaluation will be repeated after these machines been used for a period of time to determine the effectiveness of the noise level control as the machines wear. The most positive conclusion of this study is that the new forestry machine models are not harmful to the operator's hearing capacity and provide a healthier work environment in the forest than forest machines of the past.



Average operational noise levels of the forest machines in this study.

Acknowledgement

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Assessing exposure to electromagnetic fields - guidance from ERA Technology

ERA Technology Ltd has published a report emanating from work commissioned by the Health and Safety Executive. The report gives simple, practical guidance in assessing non-ionising electromagnetic fields (EMF) and radiation. It provides an easy to understand interpretation of the National Radiation Protection Board's (NRPB) 'Statement on Restrictions on Human Exposure to Static and Time Varying EMF and Radiation' (1993) and a review of 'Occupational Exposure to EMF: Practical Application of NRPB Guidelines' (1998). The publication demonstrates how the guidelines should be applied and will be extremely valuable to inspectors, site surveyors and anyone involved in the assessment and the use of EMF and radiation.

The contributing factors that govern the coupling and absorption of electromagnetic (EM) energy into the human body are identified. Information and data including the relevant equations are provided, so that measured EMF parameters can be compared with investigation levels or converted into basic restrictions. Various antennae, monitors and special meters and sensors for assessing EMF strengths and power flux density (PFD) are discussed. PFD probes in particular are studied as they are used both for full assessment of EM exposure and for measuring EMF close to the surveyor. Various techniques for calibrating PFD monitors are examined.

A typical site survey measurement procedure is given together with the analysis of the measured data. The spatially averaged field strength is compared with the investigation level for single and multiple source irradiation. The procedure for full assessment is provided for use when the investigation level has been exceeded - the application of time averaging is demonstrated. Finally the preventive options most commonly available through engineering and administrative control and the use of personal protective equipment are dealt with, for circumstances when the product of the investigation level PFD and the averaging time has been exceeded.

The report 'A Practical Guide in Non-ionising Electromagnetic Fields and Radiation Assessments' (99-0001), is available priced at £125 per copy (£110 for ERA Technical Services Scheme members) from: **Publication Sales at ERA Technology, Cleeve Road, Leatherhead, Surrey KT22 7SA. Tel:+44 (0) 1372 367014 e-mail: pub.sales@era.co.uk**

Revised evaluation dates for European Research Funding

The European Commission (EC) has issued new evaluation dates for some research projects due in October 1999. The schemes affected include Collaborative Research, which is aimed at Companies of any size that have adequate research facilities to develop new products or processes. Demonstration Projects are post-research projects that lead to commercial exploitation, for example building prototypes, clinical trials, and field trials.

There are also special schemes aimed at Small and Medium sized companies who do not have the necessary research facilities but wish to have research carried out into a new product or process on their behalf. There is also a grant (of approximately £15,500) available for small companies to enable them to prepare a proposal.

The European Commission are keen to see projects that include traceability and processing of raw food materials, safer food, new or improved agriculture, fisheries or aquaculture production and projects that lead to more sustainable utilisation of forest resources.

Contact: **Ruth Comforth at Beta Technology. Tel: 01302 322633 e-mail: ruth@betatechnology.co.uk or, web site : www.betatechnology.co.uk**

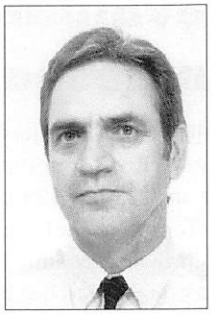
Lone working on a well-maintained, key extraction route, with the forwarder in the distance traversing a typical brash covered, pole decked bridge.

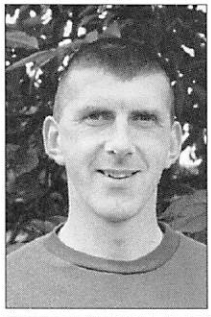
The health and safety implications of increased mechanisation in forestry

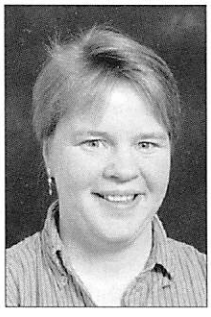
William M Jones, Colin J Saunders and Emily B Ramsay

This paper was presented at the 1st International Conference on Forestry Engineering entitled: "Forestry Engineering for Tomorrow", organised by the Forestry Engineering Group of the IAgrE and held at the University of Edinburgh, Scotland, UK on 28-30 June 1999.

William Jones is Head of Technical Development Branch, Forest Research – an Agency of the Forestry Commission. Colin Saunders is Technical Development Officer and Emily Ramsay is Safety Officer, Forest Enterprise







Introduction

Forestry was considered to be one of the most dangerous industries with regard to accidents although significant improvements have been made over the past years. The increase in mechanisation has to a significant extent taken the man out of the most dangerous of the environments he had to deal with *i.e.* exposed situations in harvesting sites. In such operations, the man is now in a protective cab and the danger of falling trees has largely been eliminated. In addition, with the reduction in the use of chain saws, the problem of Hand Arm Vibration Syndrome (HAVS) has also been reduced and many other aspects with regard to operational hazards have been improved.

However, the increase in mechanisation in harvesting and other operations, such as ground preparation, brings with it new problems for the manager and machine designer to address.

With regard to safety, the problems of lone working, safety zones of equipment and public/ supervisory access to operating machines are issues which require careful evaluation, procedures identified and standards set. With regard to health, Whole Body Vibration (WBV) problems such as Work Related Upper Limb Disorder (WRULD) and in particular Repetitive Strain Injury (RSI) which relate to long spells of operating harvesters, forwarders and excavators require further research to identify the extent of, to analyse and to solve the problems.

Bad machine parking, difficult access, footplate above recommended 0.4 m height, track grousers worn with little grip for the feet, and operator had to swing on the door and handle to assist in entering the cab

Safety issues

Lone working

Machine operators are very often working on their own for whole shifts and at other times could be finishing their shift on their own. It is necessary to have a system in place by which the operator can call out assistance if necessary and also to enable regular checks to be made to ensure a serious accident has not occurred which has prevented the operator from calling for assistance. In the upland areas of Great Britain, telephone coverage cannot be relied upon in all situations and therefore, if a system of personal, on site support is not available (such as adjacent operators or other members of the workforce) then a radio system is necessary and someone must be on standby to react to the call-out if it occurs. The call-out system could be an actual call to the operator from a supervisor or co-worker at another location or an automatic check signal sent by computer which, if not acknowledged by the operator, will instigate full check procedures by a supervisor. The latter is more flexible. Failure to acknowledge the automatic check (which uses the more effective radio system in the forestry environment) can raise the alarm by telephone (which is likely to be more appropriate if the supervisor is on call at home).

Safety risks to the operator

The most serious areas of risk to the operator are mainly when he is out of the cab:

- climbing on the machine to carry out maintenance or repairs, when poor design of hand or foot holds or inattention to climbing techniques could cause a fall leading to injury;
- working on the harvesting head, when careless working could cause the knives/rollers to close and crush the operator;
- lifting or carrying loads, such as fuel or oil drums which can be awkward, particularly when walking on the very uneven harvesting sites; and
- walking in or out of the wood across the operational site, especially at the end of the shift when the operator is tired and most likely to have an accident, the light can be poor and obstacles or the uneven terrain difficult to walk across.

Reducing the risk to the operator

Machine design factors which can reduce the risk.

- Consider how daily maintenance requirements can be reduced for the operator.
- Design central greasing points at a locations which avoids the need for the operator to climb.
- Evaluate and provide slip free hand and foot holds.
- Ensure step heights are with safe limits and all movements around the machine for access, maintenance or repair do not require excessive stretching or reaching.
- Provide lift pumps to avoid the need for awkward lifting.

Operational factors

NOTE:- This paper does not attempt to repeat all the safe working practices which are covered in the Forestry and Aboriculture Safety and Training leaflets for the appropriate equipment but highlights certain actions which can reduce risk.

- Ensure high levels of maintenance are maintained to reduce the need for repairs in the forest (particularly checks on hoses).
- Consider moving the machine away from the woodland site to carry out awkward repairs.
- When working at heights, tie on if necessary and always use 'three point holding'.
- Minimise manual handling - use lift pumps. Oil spillage in particular can increase risk by increasing the possibility of slipping when climbing on the machine.

The risk to others

Be aware that chain shot can occur in both directions.

Minimise the chance of chain breakage.

Good foot grips on track sides, well proportioned hand rails and grips, and footplates covered in anti-slip material

Use the best quality of chain for repair and construction.
If buying reels rather than individual chains, is the quality of the construction high?
Are home repairs satisfactory?
If roadside processing, preformed loops are recommended and avoid using repaired chains.

Safety zones
The problems of safety zones for the public, co-workers and supervisors can be complex and procedures should be robust and applied with discipline. Some sites such as recreation areas can be particularly difficult to control and standard measures may not be adequate. Education of other forest users may need to be considered with the use of educational signs, visits to user groups, notices in local newspapers, *etc.* Further consideration with regard to identifying the need for and defining Safety Standards could be appropriate in this area.

Operator health issues

Several health surveys have been carried out on machine operators. These indicated that there was a high proportion of operators who had some form of health problem which could be related to machine operation.

Muscloskeletal disorders are still common among forest machine operators and farm tractor drivers working in forestry. These workers are particularly prone to neck and shoulder injuries. A number of surveys carried out in Scandinavia since the late 1980s and early 1990s found that 50% or more of the machine operators had subjective complaints (Ericson, 1995). Moreover, despite the substantial ergonomic improvements made to forest machinery in the 1980s, the incidence of Repetitive Strain Injury has not declined among machine operators. The one sided, repetitive work involved in crane operation is certainly one cause.

In a New Zealand survey, Byers (1997) found that 10 out of 23 operators surveyed were always in pain and that longer hours and lack of initial training may have contributed to the development of these injuries. The operators experienced this pain primarily in their wrists and hands.

The survey of harvesting machine operators in Great Britain was undertaken by the Forest Enterprise of the Forestry Commission in 1995. The survey was not a scientific survey but a snapshot of health problems reported by forest machine operators. Over one third of operators expressed health concerns, regarding the use of harvester machines. Furthermore, the health concerns/complaints centre around the upper limbs - shoulders, arms, elbow, wrist, hand and fingers. A further survey is being carried out by the Health and Safety Executive.

Whole Body Vibration, Work Related Upper Limb Disorder and Repetitive Strain Injury
Two main forms of injury can be caused in the operation of forest machines. Whole Body Vibration (WBV) can cause pain in the back, shoulders and arms which is called Work Related Upper Limb Disorder (WRULD). The repetitive nature of using the machine controls can cause Repetitive Strain Injury (RSI) and this problem can be exacerbated by the WBV. Repetitive Strain Injury is a particular form of WRULD.

Symptoms/effects of Work Related Upper Limb Disorder and Repetitive Strain Injury
Pain occurs in the upper limbs when either carrying out the activity or, when it becomes more severe, the pain carries on after the activity and in extreme cases the pain can be constant and aggravated further by the activity. The progression of the symptoms is discomfort, followed by fatigue, followed by pain.

Recurrent episodes of chronic back pain can occur as can distinct premature changes of the spine, intervertebral disc disorders and increased stiffness of the spine. If there is a history of spinal injury, chronic gastritis or peptic ulcers, further exposure to WBV should be avoided.

The cause of Whole Body Vibration

The vibration and shock are caused by travel over the rough terrain, by the boom movements and tree felling. This vibration and shock, experienced by the machine operator can on its own cause WRULD but the effects of this machine movement are thought to be made worse by the fixed working position of the operator. The operator is less able to mitigate the effects of the movement which is normally achieved by keeping the body relaxed. A forestry machine operator has to maintain his/her arms, hands and fingers in position to control the machine functions. This is thought to cause tension in the body and limbs and thus increase the effects of the WBV. The uneven terrain, slopes which cause the operator to lean forward to see out the top of the windscreen at the tops of trees, side slopes which cause him/her to twist and put uneven loads on the back and shoulders, and the difficult visibility causing him/her to twist in the seat all increase the severity of the problem.

Poor posture and increased body tension continually coping with rotation of a cab tilted on a cross slope

Additional factors which can increase the risk are:
poor posture resulting from poor control or seat design;

controls needing forceful exertion;
cold; and
poor work organisation.

Controlling factors to reduce the health risks

Regular breaks are required.
Exercise of back, shoulders, arms, hands and fingers is needed before commencing and during work periods.
Work periods should not be excessive.
Planning of maintenance and rest to split up the work periods is beneficial.

Excavator based harvesters

Excavator base machines are commonly used instead of purpose built machines as harvesters and the design features of excavators could increase problems of WBV. Excavators designed for civil engineering purposes have a completely rigid undercarriage system with no suspension or pivoting members which would allow it to alleviate the unevenness of a harvesting site. This increases the shock and vibration levels experienced by the operator. The rigid undercarriage results in increasing the machine 'rock' when harvesting although this can be reduced by specifying a longer undercarriage.

On slopes, the cab tilts; and as the cab rotates, the operator has to constantly cope with varying side slope components. This will result in poor posture and also probably in increased tension in the body which will decrease the ability to mitigate the vibration and shock.

The tracks of the excavator provide no cushioning effect as is obtained from the pneumatic tyres of a purpose built harvester.

The articulation of purpose built harvester bogies reduces the effect of obstacles, helping to level the cab. An excavator does not have this. The amplitude of movement experienced in the excavator is therefore increased.

The potential severity of Whole Body Vibration

In 1996, an investigation into '*Shoulder-arm muscle load and performance during control operation in forestry machines — The effects of changing to a new arm rest, lever and boom control system*' was carried out in Sweden (Attebrant *et al.*, 1997). The investigation found that it was not possible to draw any definitive conclusions regarding effects of the boom control system due to technical problems. According to literature, however, the duration of lever operation has increased considerably in forestry during recent years as part of the rationalisation process. Partly due to this, it is suggested that the investigated work station improvements may not be sufficient to eliminate the risk for shoulder-neck disorders.

Table 1 Whole Body Vibration action levels

A_{eq} level, m/s^2	Action required
< 0.25	No hazard
≥ 0.5	Control action + surveillance
≥ 0.7	PPE required
> 1.25	Declared to enforcing authority

Vibration levels in harvesters and forwarders

In 1994, the Forest Enterprise of the Forestry Commission commissioned an investigation into the actual WBV levels of two harvesters and two forwarders used by the them.

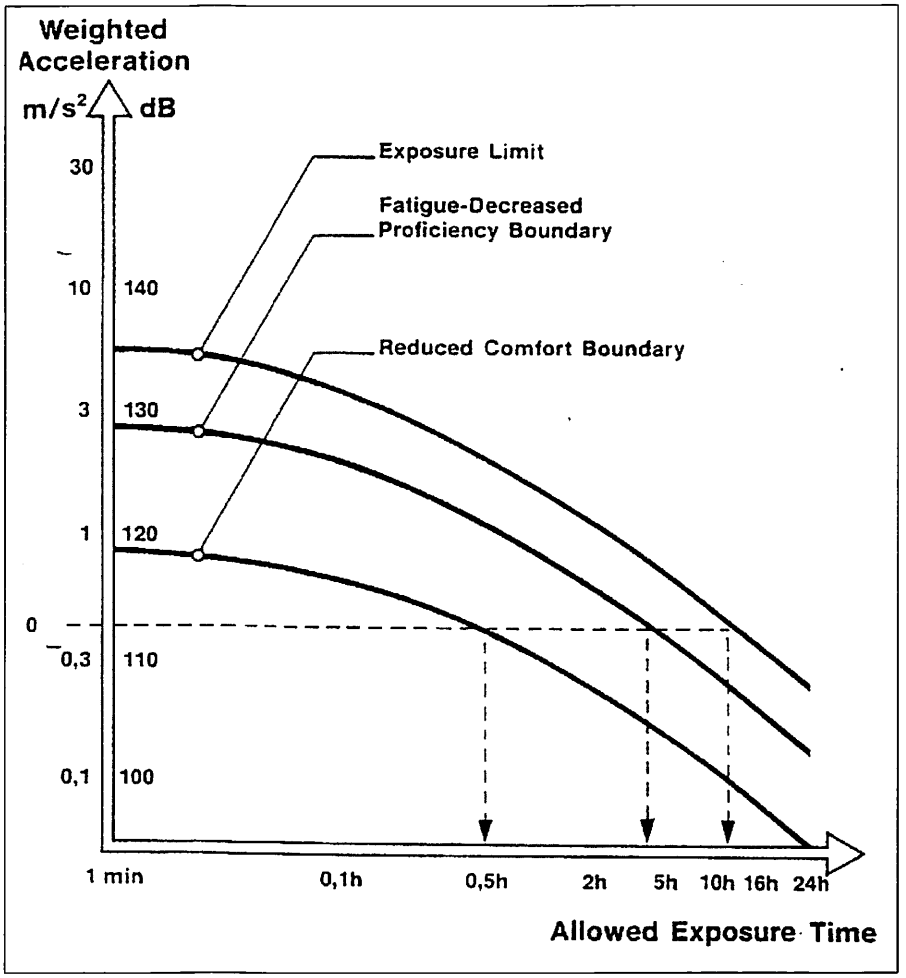
Whole Body Vibration is defined as the vibration energy, in the frequency range 0.5 to 100 Hz input to the body through the feet, buttocks or back.

Exposure limits (frequency weighted acceleration levels in m/s^2) of the three axes relative to the body are defined in ISO 2631 as a function of frequency and exposure time. The limit is half that considered to be the threshold for pain. The evaluation of vibration dose is more complex in BS 6841 which specifies the fourth root of the integral of the fourth power of the acceleration and takes into account the higher peaks of shock.

The Draft European Commission proposal - Physical Agents Directive - normalises the vibration exposure levels to eight hours and gives these as action levels (Table 1).

The Forest Enterprise investigation

Vibration levels were measured on two harvesters and two forwarders. All machines were nearly new and equipped with the latest suspension seats. The



The ISO Dose System for Whole Body Vibration

machines had been evaluated by the Forest Enterprise and an ergonomic assessment which had been included in accordance with a Swedish Skogsarbarten (Forestry) Standard awarded the machines a top grading mark. The original assessment did not include assessment of WBV.

Vibration on all machines reach a level which indicated that organisational methods should be identified to minimise exposure and health surveillance should be implemented. As yet, there are no standards for measuring the vibration levels of these particular machine types in order to identify the vibration levels actually being experienced by the operator. The vibration levels measured would not have taken into account the damping effects of the seat. Therefore, the measurements made could only be indicative.

Current action available

Machine operator selection: ensure operators do not have a medical history of back or upper limb problems.

Machine selection: ensure a full ergonomic check is carried out.

Site assessment: consider ergonomic factors of machines and that they are linked to the site *e.g.* avoid using excavator based harvesters on slopes or other sites with obstacles where their effects are likely to be more severe.

Monitor the health of operators

Ensure full training is given and the importance of exercise regimes, regular breaks etc. is known and followed.

Work organisation:

- limit shift length, particularly on excavator machines
- break up periods of work with maintenance and rest
- shorten continuous working by changing between harvesters and forwarders
- take hourly breaks and exercise
- exercise hand/fingers more often (about every 10 minutes possibly during machine movement).

Further investigative work required

Comparisons are required between the health problems experienced by machine operators and a control population. While the studies to date have identified high levels of health problems, it is not clear how this would compare with a normal population and therefore how much is due to machine operation.

Those factors of machine design and operation which most greatly increase WBV and have the most significant effect on the health of operators requires investigation. As discussed above, the high level of WBV is not the only factor which increases the possibility of WRULD. The ergonomics of the machine and in particular those which can improve the working posture and reduce body tension could have just as significant an effect as reducing WBV.

Machine design and work practice improvements need to be identified to reduce the effects of WBV.

In order to obtain data on the vibration levels of machines and the exposure experienced by operators, some standardisation of vibration measurement is required. Measuring the actual vibration levels experienced, allowing for the cushioning effects of the seat and armrests is a complex problem. In order to be able to compare data between studies, it is important to clearly identify where and how accelerometers are attached.

The vibration levels experienced by the arms are likely to be different to those experienced by the upper body. Should vibration levels of arm rest be measured as well as seats? The effects of breaks during the working day are also not fully understood and therefore should some measurements be taken to take into account how the daily exposure was experienced in terms of work periods?

Should some attempt be made to take into account posture *i.e.* the effects of working uphill, downhill or on side slopes? If this is found to be a significant factor, then perhaps more emphasis would need to be placed on using self levelling cabs. The need to stretch forward to look at the tops of trees when felling could be reduced by better window design.

The Health and Safety Executive of Great Britain is currently carrying out a survey of Forest Enterprise machine operators to more clearly define the health problems and identify links with machine design or working practice.

Conclusions

There is still a considerable lack of understanding with regard to the levels of Whole Body Vibration being experienced by operators and what aspects are causing the most effect on their health. The starting point must be to gather more data on the health of operators and how it might relate to their machines and working practice. The objective has to be to identify what changes and improvements can be made to reduce the health problems.

In the meantime, machine manufacturers can be taking those actions already known in relation to machine design to improve the ergonomics of machines, particularly those which will improve the working posture in all working conditions, and the managers should ensure that those actions and practices which will relieve the stresses of the operator are implemented. This relates to both safety issues and Whole Body Vibration.

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Membership Matters

Quarterly The Newsletter of the Institution of Agricultural Engineers Autumn 1999

Tribute: Peter Bailey, 1922 - 1999

Peter Bailey, who has died aged 76 leaving a widow (Betty) and son (Alan), made important and original contributions to the development of agricultural engineering over the three decades following the Second World War. In 1942, and as part of the war effort, twelve of the twenty-three staff of the Institute for Research in Agricultural Engineering at Oxford University were transferred to temporary quarters in the Yorkshire Institute of Agriculture at Askham Bryan to form the nucleus of the National Institute of Agricultural Engineering (NIAE). Between June 1947 and July 1948 the new Institute now numbering some one hundred and fifty staff transferred to a permanent site at Wrest Park, Silsoe, where it continues today as Silsoe Research Institute. In 1943, after completing a wartime degree at King's College, London, Peter became the first graduate in Mechanical Engineering to be recruited at the new site. As such it seems odd that his first, and tedious, task was to research the distribution of potatoes in ridges and in relation to clods and stones. However, his enthusiasm and natural bent for meticulous attention to detail, as well as principles, produced a study still acknowledged as a design guide for harvester lifting shares.

More in keeping for an engineer, and working in an ethos primarily dedicated to helping manufacturers, he developed a new electrical loading car for tractor testing. Another 'milestone' contribution to tractor wheel and tyre performance research was his resolution of earlier and controversial arguments on the design of the single wheel tester. Tyre deflection was studied with particular relevance to improving traction by 100% water ballasting. Subsequently he published the first U.K. comprehensive performance data on tyres and traction aides. Within days of his death he was still being consulted on this topic.

Alongside the wheel/tyre research he had also worked on the drying of grass, grain and hops and had become increasingly involved in testing grain dryers. Testing full-scale dryers on farms posed problems every bit as complex as those facing the researchers. Peter's great achievement was not only to develop logical procedures for carrying out what were in fact large scale drying experiments carried out under very difficult conditions on farm but also to recognise the importance and relevance of the underlying physics and biology. He always strove to build a bridge between what seemed to many at the time to be the rather esoteric research of Universities and Institutes and the practicalities of drying on farm. From 1956 to 1966, the Institute published reports on 13 dryers and 4 moisture meters from tests initiated by manufacturers. Peter's achievements and experience in those early years were embodied in the British Standard BS3986: 1966, Methods of Test for Agricultural Grain Driers. In addition to providing a detailed prescription for test procedure, the standard incorporated at least two innovative ideas. The first was a method of correcting dryer test results to standard conditions and the second was the concept of screening grain by a 'normality' test. The hypotheses underlying this test, which Peter developed in association with Melvyn Hughes, were later found to have exact parallels with fundamental work on the deterioration of stored seeds led by Professor Eric Roberts at the University of Reading. In due course, BS3986 became a work of reference for dryer engineers' world-wide. It has been revised (1991) and expanded (1998) but the substance of these revisions was grounded in Peter's pioneering work and his foresight in pointing the way to them.

From 1969 to 1971, Peter was on sabbatical leave at Newcastle University where he was awarded a MSc for work on the high temperature drying of cereal grain. Perhaps more importantly he played a crucial role in the team developing further the mathematical modelling of grain drying. This role was to provide unrivalled knowledge and insight into the performance of dryers in real life and subsequently to nurse the work through to publication.

He returned to NIAE as Head of Cultivations and Traction Department but his stay was brief. Mainly so that he and Betty could be near the special facilities required by Alan, he transferred, in 1972,to the NIAE (Scottish Station) as Head of the Crop Drying Section. Here he was able continue his work on grain quality in heated-air dryers and initiate studies in the operation of low temperature grain dryers and the drying of forage in barn and field conditions. Motivated by his concern for the relatively rapid consumption of irreplaceable fossil fuels, he also started a program to study the potential of solar assisted barn drying of grain and forage. From this research he was able to

demonstrate that, even at Edinburgh latitudes, a simple form of solar assisted drying can reduce the demand for fossil fuels. He retired from the Scottish Institute of Agricultural Engineering in 1982.

Peter's documented achievements do not fully illuminate his influence on post-war agricultural engineering in general and crop drying in particular. Peter was a true boffin who could always be relied upon to supply informed comment and enthusiasm on any topic. When in 1980 The Institution of Agricultural Engineers formed its first specialist group, the Crop Drying and Storage Group, Peter was the obvious choice for Chairman. The subsequent success of this Group stimulated the formation of further Groups.

Outside agricultural engineering Peter had many interests. He was especially interested in railway engineering and photography and, in later years, bridge. He had an encyclopaedic knowledge of the history of the Institute at Askham Bryan and at Wrest Park and of Wrest Park itself. Both before and after retirement he worked hard for the education of the deaf and for several years was a Governor of Donaldson's School for the Deaf in Edinburgh. Our thoughts are with Betty and Alan.

David Manby and Martin Nellist

Commercial Members

Autoguide Equipment
Stockley Road, Heddington, Calne,
Wiltshire SN11 0PS

Bomford Turner Limited
Salford Priors, Evesham,
Worcestershire WR11 5SW

BSW Harvesting Ltd
Robertson House,
Perth Business Park,
Whitefriars Crescent, Perth
PH2ONX

Canning Professional Services
Highdown Cottage, Compton Down,
Nr Winchester, Hampshire
S021 2AP

Douglas Bomford Trust
16 The Oaks, Silsoe,
Bedford MK45 4EL

Environmental Care and Construction
Liwyn-yr-ynn, Llandeilo Road,
Gorslas, Lianelli, Dyfed SA14 7LU

Farm Energy Centre
NAC, Stoneleigh, Kenilworth
Warwickshire CV8 2LS

Lackham College
Lacock, Chippenham
Wilts SN15 2NY

Long Service Certificates

50 years

Name	*Grade*	*Date of Anniversary*
Wattie Jesse **West**	FIAgrE	30 Nov 1998
John Herbert Wyndham **Wilder**	HonFIAgrE	3 Dec 1998

35 years

Fred **Cross**	IEng MIAgrE	26 Sep 1998
David William **Jewett**	FIAgrE	26 Sep 1998
Roderick McLeod **Munro**	EngTech AMIAgrE	26 Sep 1998
James Robertson **Christie**	IEng MIAgrE	2 Apr 1999
William Thomas Worthington **Cory**	CEng MIAgrE	5 Apr 1999
James Donald **Greig**	CEng MIAgrE	2 Apr 1999
Andrew **Lyford-Smith**	IEng MIAgrE	2 Apr 1999
Amery **Massey-Crosse**	AMIAgrE	2 Apr 1999
John **Maughan**	CEng FIAgrE	2 Apr 1999
John Trevor **Mills**	IEng MIAgrE	2 Apr 1999
Richard Crossley **Bilborough**	AIAgrE	27 Aug 1999
Thomas Clive **Khoor**	IEng	27 Aug 1999
Geoffrey John **Meikle**	MIAgrE	27 Aug 1999
David Edmund **Morrish**	IEng MIAgrE	27 Aug 1999
Colin Ralph **Willcocks**	MIAgrE	27 Aug 1999

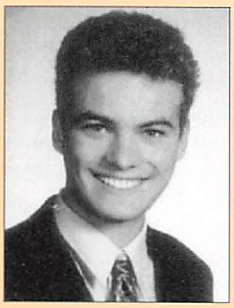
25 years

Malcolm St John **Carr-West**	MIAgrE	8 Nov 1998
Stephen James **Hackett**	IEng MIAgrE	4 Oct 1998
Peter Thomas **Jackson**	IEng MIAgrE	6 Nov 1998
John Peter **Neat**	CEng FIAgrE	4 Oct 1998
Robert Graham **Wilson**	IEng MIAgrE	8 Nov 1998
John Edward **Ashburner**	CEng FIAgrE	10 Jun 1999
David John **Butterworth**	MIAgrE	5 Jun 1999
Humphrey Sidney Guy **Cholmeley**	MIAgrE	5 Jun 1999
Eric Charles Terence **Cooper**	EngTech AMIAgrE	10 Jun 1999
David Nathaniel Heuston **Dagg**	IEng MIAgrE	28 Mar 1999
Stephen John **Kittle**	MIAgrE	28 Mar 1999
Nigel **Ford**	MIAgrE	5 Apr 1999
James Joseph Colin **O'Connor**	MIAgrE	8 Apr 1999
John Maurice **Bradfield**	CEng MIAgrE	6 Sep 1999
Michael John **Copeland**	FIAgrE	9 Sep 1999
Timothy John Ross **Havard**	EngTech AMIAgrE	2 Aug 1999
John Llewelyn **McIver**	MIAgrE	2 Aug 1999
John Joseph **Madigan**	IEng MIAgrE	1 Aug 1999
Peter Ian **Ross**	IEng MIAgrE	1 Aug 1999

News of Members

Marcus Hemsted has returned to England from Kenya and started a new job with Engineering Business Limited in Northumberland.

Ian Petts who is a Student Member recently graduated with First Class Honours in Agricultural Technology and Management from Cranfield University and was also awarded the Claude Culpin Prize for the best Farm Mechanisation Project. He has now secured a Department for International Development (DFID) Associate Professional Officers' Scheme (APOS) award which will allow him to study for a MSc at Reading University before taking up an overseas assignment with DFID.



David Topping is now the Construction Manager for a new deep sea container port at Tanjong Pelepas, working for a Malaysian company L & H Geotechnic. He says that it is not agriculture but they are surrounded by plantations!

Reen L A Ysselmuiden says that he is still working whenever he has a chance. Recently, he has been involved with assisting a non-government organisation in Botswana. This has been financed by a Dutch organisation and is intended to provide advice to the management of the NGO for a ten-year development plan. He is also involved with a project in SE Sulawesi, Indonesia, where he is a Management Adviser to the Managing Director of an Indonesian owned Oil Palm Plantation. He says that he is due to return to Indonesia for a further six weeks later this year. In the meantime, he is trying to get further financing for this plantation, but this is not easy as all the existing reports including a feasibility study are in Indonesian.

Membership Movements

Mem No	*Name*	*From*	*To*
6662	**J K Bailey**	**Bedfordshire**	**Derbyshire**
5335	**S J Doble**	**Yorkshire**	**Gloucestershire**
5957	**S W E Butler**	**London**	**Wiltshire**
6639	**M B Douthwaite**	**Berkshire**	**Ireland**
4428	**M P Dufton**	**Berkshire**	**Worcestershire**
6666	**M R Hemsted**	**Australia**	**Northumberland**
5962	**A W Moore**	**Australia**	**Northampton**
6557	**L D Pritchard**	**Essex**	**Worcester**
2796	**J M Swanson**	**Essex**	**Lincolnshire**
6191	**A Wilson**	**Mozambique**	**Zambia**

Gone Away - does anyone know the whereabouts?

Name	*Last known address*
Augustine Engoru-Ebinu	1466 Lakewood Road West, Edmonton, Alberta T6K 3M2, Canada
Brian Huw Griffiths	Bell Equipment (Pty) Ltd, Box 198, Richards Bay 3900, South Africa
Agus Margiwiyatno	27 High Street, Silsoe, Bedford MK45 4DU
Arnold Sauti Nyirenda Jnr	Flat 14, Stepstairs Court, 62 Watermoor Road, Cirencester GL7 1LD
Neil Anthony Robinson	38 Estcourt Street, Devizes, Wiltshire SN10 1LW
Bryan Webb	Farm Repair Services, The Forge, Clanfield, Oxfordshire

Minister opens new Machinery Hall

Students on Agricultural Engineering courses at *Harper Adams University College* will reap the benefits of a new £58,000 Machinery Hall when lectures restart in September. Mr Elliot Morely, MP, officially opened the new hall during a recent visit to the college, when he also unveiled a £250,000 pig unit and research facility.

To mark the opening of the Machinery Hall, Team Sprayers and Cyanamid, both businesses which have developed close links with Harper Adams over the years, donated a closed-transfer pesticide system to the engineering staff.

Mr Bob Hubbard, Managing Director of Team Sprayers, and Eric Gussin, UK and Ireland Marketing Manager for Cyanainid, attended the opening ceremony and presented the pesticide keg and transfer system to staff. Mr Morely was later asked to put the system to the test and pushed the button to begin the first pesticide transfer.

Former Senior Engineering Lecturer Bob Bradley, who saw the Machinery Hall completed and opened before his retirement, said: "This facility will be an excellent teaching tool, not only for full-time students but for short courses, such as Basis, as well."

The Machinery Hall, which measures 48 m by 30 m, will house a variety of agricultural machinery and will also provide a suitable environment in which to demonstrate the use of such equipment to students. Other facilities include a 12 metre water slot, allowing students to calibrate spraying machinery under cover, and provisions for materials handling courses and experimental work.

The location of the hall, adjacent to Near Meadow, makes it a convenient base for students practical work, including taking machinery out into the field for testing under normal farming conditions.

Precision farming support service launched

An initiative has been taken by a new company based in Nottinghamshire to establish a precision farming support service. The service, set up by Gotech Technology Ltd, and to be known as the Gotech Precision Farming Support Service will provide independent information and advice to farmers to support and assist them in adopting practical precision farming developments.

Gotech Technology Ltd was established earlier this year by John Sartain MIAgrE, Richard Turner CIAgrE and Michael Bowen CIAgrE to facilitate the advancement, adoption and effective use of new technology to support the efficient use of natural resources by providing a bridge between manufacturers, suppliers and users. The three directors of the company have all served the agricultural industry throughout their working lives. Their careers have developed in three separate but complementary key areas building on their basic agricultural and agricultural engineering knowledge.

John Sartain, managing director of Gotech Technology Ltd, is an acknowledged expert in training and education in agricultural engineering, agriculture and rural development. Richard Turner is a world leader in the application of remote sensing and of information technology linked with present techniques of crop production. Michael Bowen is renowned for his experience in marketing and training in agricultural engineering and agriculture both in the UK and overseas. The Gotech team is therefore uniquely able to work alongside all those in the agricultural and agricultural engineering industries to incorporate the new technologies within agricultural systems in an easily understandable and practical manner.

Precision farming as a technique has been the subject of developing interest among the farming community in recent times. It has developed mainly through the use of satellite technology both for remote sensing and for measuring and mapping systems as well as accurate measuring equipment such as the yield monitors now found on many combine harvesters. These, together with computer systems using custom-made software which achieve automatic control of the output of a range of agricultural equipment, are capable of providing the farmer with a crop management system far more precise and accurate than was considered possible only a few years ago.

John Sartain said, "The aim of this initiative is to make available to farmers an independent, 'one-stop shop' offering broad guidance on effective precision farming practices. To achieve this we will be providing a range of technical services. These will include consultancy, information and training together with computer and land management services. The Gotech team which is involved in this development is experienced in management, consultancy and training as well as in the disciplines of agricultural engineering, agriculture, computers, and software production".

The company, which will operate independently, will provide the essential links between the farmers, the machinery manufacturers and their distributors and the world of science and technology to increase understanding of the latest developments for precision farming and their application in practice.

Free introductory half-day training sessions are planned for later in the year in various venues around the country. Contact: **Gotech Technology Ltd, Trebeck Hall, Bishop's Drive, Southwell, NG25 0JP. Tel: 01636 816428.**

Broadcast Systems Director chairs the IIE Council

Nottinghamshire-based Systems Design Director, Arthur Moore, has been appointed Chairman of Council of the Institution of Incorporated Engineers (IIE).

Arthur, an IIE Fellow and member since 1972, began his engineering career in operational resources at the BBC. He then moved on to Thames Television as an Engineer and Pye TVT as Head of their Planning and Installation Department where he was responsible for major studio and transmitter projects in over 30 countries. Further career progression included Head of Operational Resources at Central Independent Television and Managing Director at Teleprojects prior to assuming his current role as Systems Design Director at Television Partnership International whose Head Office is in Newcastle-upon-Tyne.

As well as being an accomplished engineer, Arthur has also remained a proactive member of IEE over the past 17 years in the shape of Technical Advisory Panel Chairman, Continuing Professional Development Committee Chairman, Midlands Regional Committee Member and Council and Executive Committee Member to name but a few!

Despite such a hectic lifestyle, Arthur manages to find time to pursue his favourite pastimes enjoying classical music, the performing arts, model and historic railways and scuba diving.

IIE is the largest professional institution for Incorporated Engineers and Engineering Technicians in electronic, electrical and mechanical engineering and boasts a membership of 40,000 with 12 UK and 3 overseas regional centres.

Correction

Johnson New Holland Trophy for Harper Adams University College

Andrew Miller who won the Johnson New Holland Award read for his degree at Harper Adams University College. The college submitting the prize-winning project receives the trophy to hold for one year. The Editor apologises to Andrew Miller and to Harper Adams University College for the error appearing in *Membership Matters* which was published with the Summer Issue of *Landwards*, 1999.

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INSTITUTION of AGRICULTURAL ENGINEERS, WEST END ROAD, SILSOE, BEDFORD, MK45 4DU, UNITED KINGDOM. Tel: 01525 861096 Fax: 01525 861660

Thrige Agro forms Howard Group

Danish based powered cultivation and drill specialists Thrige Agro has announced that it is to change its name to the Howard Group. The new name has been introduced to reflect the increased product range offered by the company. This now includes advanced non-powered cultivation equipment. The main Howard Group products continue to include the Howard power harrow and Rotavator ranges and the established Howard/Nordsten pneumatic and conventional seed drills.

In addition, the Howard Group is now manufacturing its own non-powered cultivation equipment. The new range includes disc harrows, stubble cultivators, tillage-trains and combination cultivators. Of equal importance, the established one pass drilling systems developed by the company have been enhanced to include new models based upon both powered and non-powered cultivators.

The new machines offered cover a broad range of farming requirements and confirm the Howard Group as leading cultivation and drill equipment specialists. All tillage equipment is finished in familiar Howard orange. The Howard range of Nordsten drills will continue to be finished in traditional dark blue.

The Howard Group has made considerable investment in both manufacturing and design over the past two years. Highly advanced CAD/CAM software has been developed for the company and employed in the development of new equipment. Modern laser cutting and robotics systems have also been installed in the company's factories to further improve quality and output.

Howard Group products, along with the existing loader range, divide into three main categories - non-powered cultivators, powered cultivators and drills.

The non-powered cultivator range includes the Terra X tandem disc harrow in widths from 3.00 to 12.00 m, the Titan 'cultivation train' in widths 3 m to 9 m, the Delta stubble cultivator in widths 2.5 m to 6 m, Combi-pack in widths 2.5 m to 6 m and Multi-pack 3 m to 9 m seedbed cultivators

Howard power harrows and rotavators now include the latest HR41 and HR43 rotavator models. Available in widths from 1.80 to 4.05 m, these new models are even stronger and are suitable for tractors of up to 110 kW. Power harrows are represented by the new HK32, heavy-duty unit in 3 m, 3.5 m and 4 m working widths.

The Howard Nordsten drill range now includes a number of new single-pass drilling combinations based on non-powered cultivators. These are an important development for the Howard Group. The CS3000H tractor-mounted Combi-Seeder comprises a non-powered harrow and conventional seed drill. It is offered in widths of 2.00, 3.00, 4.00, and 4.50 m. The similar CS4000H Combi-Seeder is based around a Nordsten pneumatic drill, this model being available in widths of 4.00, 4.50 and 6.00 m. Suitable for mulch drilling or working into ploughed ground, the MS4000 trailed Multi-Seeder is an advanced combination unit designed to meet the changing needs of farmers. The unit features a Nordsten NS4000 pneumatic drill and is offered in widths of 4.00, 4.50 and 6.00 m.

On the powered drill combination front, the Howard Group continues development. The latest CS4030 mounted Power-Seeder is based upon an HK32 power harrow and Nordsten NS4000 pneumatic drill. Two working widths, 3.00 and 4.00 m, can be supplied, the new combination having close drill to harrow coupling to bring the units centre of gravity close to the tractor.

Howard Group products will continue to be handled in the UK by Tri-Ag of Wymondham, Norfolk. Tri-ag Ltd, based in Wymondham, Norfolk, operates two sales divisions, LEMKEN and HOWARD, and has a turnover of £5 million.

The LEMKEN range of products includes a market leading range of ploughs, tined and powered cultivators, box and pneumatic drills.

The HOWARD range of equipment includes powered cultivators, Nordsten seed drills and loaders. C-DAX ATV accessories, which includes spraying and spreading attachments, is also handled by this division.

Contact: **Tri-ag Ltd, Eleven Mile Lane, Suton, Wymondham, Norfolk, NRI8 9LR. Tel: 01953 605151.**

The Syncrofalke medium sized, truck mounted, cable yarder.

Process simulation to evaluate steep terrain harvesting systems

Karl Stampfer and Jens Henoch

This paper was presented at the 1st International Conference on Forestry Engineering entitled: "Forestry Engineering for Tomorrow", organised by the Forestry Engineering Group of the IAgrE and held at the University of Edinburgh, Scotland, UK on 28-30 June 1999.

Karl Stampfer is University Assistant at the Institute of Forest Engineering, University of Agricultural Science, Vienna, Austria; e-mail: stampfer@mail.boku.ac.at

Jens Henoch is Research Assistant at the Institute for Operations Research, Swiss Federal Institute of Technology, Zurich, Switzerland; e-mail: henoch@ifor.math.ethz.ch

Abstract

To secure the competitiveness of forestry on steep slopes, harvesting systems must be further developed in a systematic, efficient and goal orientated manner. The common 'trial and error' method is associated with high development costs. This raises the question: how can forest harvesting systems be cost-effectively analysed and optimised in the future. A successful concept is the use of computer simulation.

A simulation model prototype for steep terrain forestry systems has been developed. With the simulation environment Harvesting System Simulator (HaSyS), various harvesting systems (chainsaw, walking harvester, and tracked harvester in combination with cable systems) can be analysed. For the first time, the interaction effect of thinning intensity and the productive system was modelled.

The simulation model allows productivity prediction to be made dependent on system, terrain and stand variables. Productivity comparisons between different working systems have shown that, through mechanisation of timber harvesting, not only the felling and cross-cutting, but that also the cable extraction can be rationalised.

1. Introduction

Timber production remains the core competency of the forestry industry and therefore defines the competitiveness and the survivability of forestry companies. There are three primary solutions available to increase the competitiveness: (1) product innovation, (2) social innovation and (3) process innovation. The product timber itself is difficult to improve and companies are rarely interested in comprehensive organisational changes. Therefore, emphasis is placed on automation and mechanisation on the process side.

A comprehensive mechanisation concept is available for terrain traversable by wheeled machinery that is widely promoted in Scandinavian countries. A similar concept for steep terrain is not yet available. To guarantee the competitiveness for the future, a push in

the area of process innovation is urgently required. This leads to the question of how timber harvesting systems for steep terrain can be further developed in an systematic, efficient and goal orientated manner. While, in industry, these processes are dealt with in a holistic 'Process Design and Planning' approach, such a systematic approach is almost completely lacking in the forest industry. Many harvesting systems have been developed along the 'trial and error' principle, which leads to high development costs due to the capital intensive systems. In the future, timber harvesting systems will be mainly developed or optimised with the help of computer simulation.

Computer simulation models were first used for the evaluation of new forest machinery concepts in the 1960's (feller-bunchers, debarking machines and processors). The aim was to optimise carrier platforms with respect to crane geometry for reliability and productivity (Newnham, 1967; Newnham, 1970; Newnham & Sjunnesson, 1969; Seppälä, 1971). Most of these simulation programs had a deterministic character. Subsequently, especially in North America, simulation was used as an aid for the analyses of single machinery as well as of whole work systems. Goulet *et al.* (1980) provide an overview of simulation models that were developed prior to 1980. Simulation programs improved with increasing computer performance. Graphic interactive simulation was used for the development of feller-bunchers for use in thinning operations (Fridley *et al.*, 1985; Fridley *et al.*, 1988; Green *et al.*, 1987b). Green *et al.* (1987a) stated that the possible result differences from an operator using an interactive simulation model can mimic the real differences caused by the machinery operators' performance depending on training and experience. With the trend towards forestry operations on smaller land areas, silvicultural factors have been increasingly integrated into timber harvesting models (Wang & Green, 1999; Eliasson, 1999). Bragg *et al.* (1994) developed a method for predicting stand damage depending on silvicultural strategies alongside an interactive simulation program.

The existing simulation models are limited in their ability to compare whole work systems with each other and are usually limited to terrain traversable with wheeled machinery. Differing thinning regimes have only been modelled using basic information. The aim of this work is to develop a modular simulation model for steep terrain timber harvesting systems that can analyse and optimise current as well as future harvesting systems. The effects of silvicultural regimes on the productivity of the systems is presented.

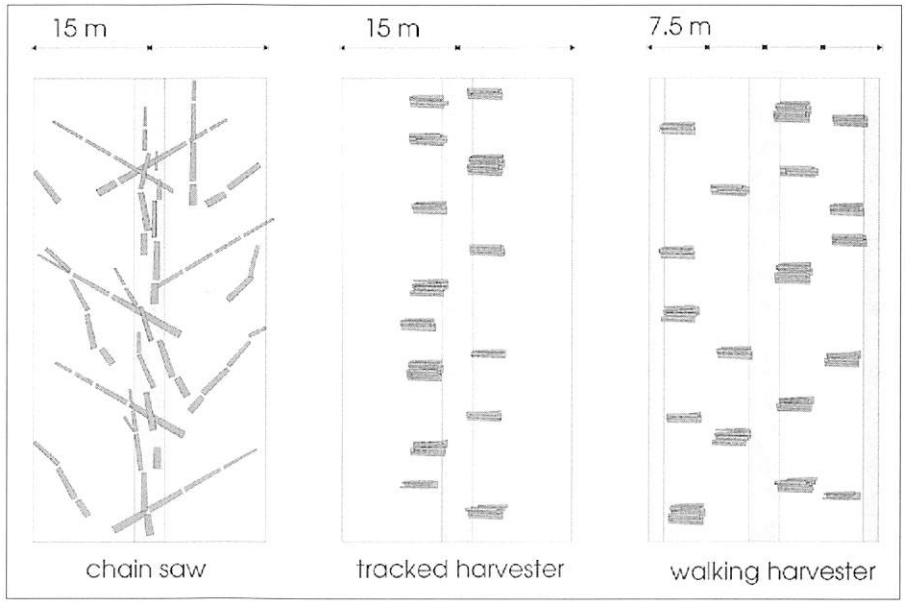


Fig. 1 Process layout.

2. Model development

The model consists of the following components: stand generation, future tree search, tree removal and process models. In a following implementation phase, these components are incorporated into the simulation environment.

2.1. Stand generation

The method of generating a stand can be freely chosen by the user. Real data from forest stands can be imported, or the stand can be generated from distribution information. The most common distributions for stand generation such as Weibull and normal distributions can be selected. To create a best possible and random distribution of the trees over the area, x and y co-ordinates are randomly generated. The tree at a given location is assigned a diameter breast height (DBH) using the selected distribution. From the DBH-tree height curve for the stand, an appropriate tree height is assigned to the tree. The tree volume calculation is carried out using the cylinder and taper functions by Pollanschütz (1974). The conversion from standing volume with

Fig. 2 The Königstiger tracked harvester operating on steep terrain.

bark to harvested volume without bark occurs through the reduction factor of 0.8.

2.2. Process layout

In the current development state of the simulation model, three different work systems are available for timber harvesting in steep terrain *(Figure 1)*: motor-manual felling and cross-cutting, tracked harvesters *(Figure 2)* and walking harvesters. The subsequent timber extraction is carried out exclusively by cable system *(Title photo)*. Other machinery or work systems can be modelled through minor changes in the simulation program. The tracked harvester, through a crane reach of 15 metres, can work with a distance between extraction corridors of 30 metres. The walking harvester has a boom length of just 7.5 metres and therefore requires additional harvesting corridors. For the extraction using a walking harvester, it is assumed that from a single cable system three harvester corridors can be extracted.

2.3. Future tree search

Based on conceptual considerations of Schädelin (1942) and Leibundgut (1966) in mid-Europe, the forestry regime is based around selecting a number of 'future trees' that are to be grown to maturity, and thinning operations are carried out at 25 year intervals whereby the competitor trees are removed. The operations presented here are based on such a thinning regime, which is currently by far the most common forest harvesting activity.

The trees located in the extraction corridor can be excluded as possible future trees. Future trees should have a height to diameter ratio of under 100. This criteria cannot be considered in the implementation of the model since the diameter and height of the trees are bound deterministically through the DBH-tree height curve so that similar diameter trees always have the same height ('ideal trees'). Therefore, a height criteria of 15 metres was used to indicate the desired future tree quality.

In practice, a number of triangles (equivalent to the number of future trees) are laid over the harvesting area (without extraction corridors). In every triangle, one future tree is chosen with the restriction that an already selected future tree is not within 7 metres distance. Since this method is empirical and currently difficult to convert into the program, two other selection methods have been developed for the search for future trees.

a) Volume heuristic

The trees are sorted according to decreasing height. Within this sorted list, future trees are selected one after the other, when:

1. the number of chosen future trees is smaller than the given number of trees in the simulation; and
2. all the trees already marked in a stand have a minimum distance of 7 metres from the tree under consideration.

b) Distance heuristic

If the number of future trees in the simulation is very large, it can happen that the volume heuristic method finds too few trees. The principle behind the distance heuristic is that future trees are first selected on the basis of having the fewest possible neighbouring trees (trees with a distance less than 7 metres). This ensures that a tree doesn't get selected that would preclude the selection of a large number of other possible trees. The procedure is as follows: the trees are first sorted according to increasing number of neighbouring trees. In the second step, the trees are sorted according to decreasing tree height. Finally, from this list, the same selection procedure as for the volume heuristic is carried out.

2.4. Tree removal

The 'A-value' according to Johann (1982) is a value for the objective analyses of the competitive tree nearest a future tree (Hasenauer *et al.*, 1996). The basic principle behind this value is that the competitiveness of a neighbouring tree can be measured primarily by the cross-section of the crown, which is linearly proportional to the diameter breast height (Hasenauer, 1994). If the DBH of a tree is weighted with its radius of freedom j and its possible competitive trees i, the distance to the competitive trees to be removed E_{ij} can be calculated as shown by Eqn (1):

$$E_{ij} \leq H_j \, d_i/(A \, D_j) \quad (1)$$

where: H_j and D_j are the height and the DBH of the free standing tree; d_i is the DBH of a possible competitive tree; and A is the value to be given according to the proportionality factor that determines the thinning intensity. As recommended by Johann (1982) for pure spruce stands of the same age, values between 4 and 6 should be used.

The trees are felled in the direction of the nearest extraction corridor and cross-cut to 4 metre lengths, whose y co-ordinates are the same as the original tree. The calculation of the x co-ordinate is dependent on the extraction system. However, a common x co-ordinate for all the logs from a tree is assumed. Important for the extraction is the location of the individual logs and whether the logs are bundled (as is done by walking or tracked harvesters) or not (with motor-manual felling). Quadrants are determined on the whole harvesting area depending on the optimal drag size. For each drag, all the logs in one quadrant are taken. If the value exceeds the maximum allowable drag volume then the load is divided.

2.5. Process models

For the part processes of felling and cross-cutting, as well as extraction,

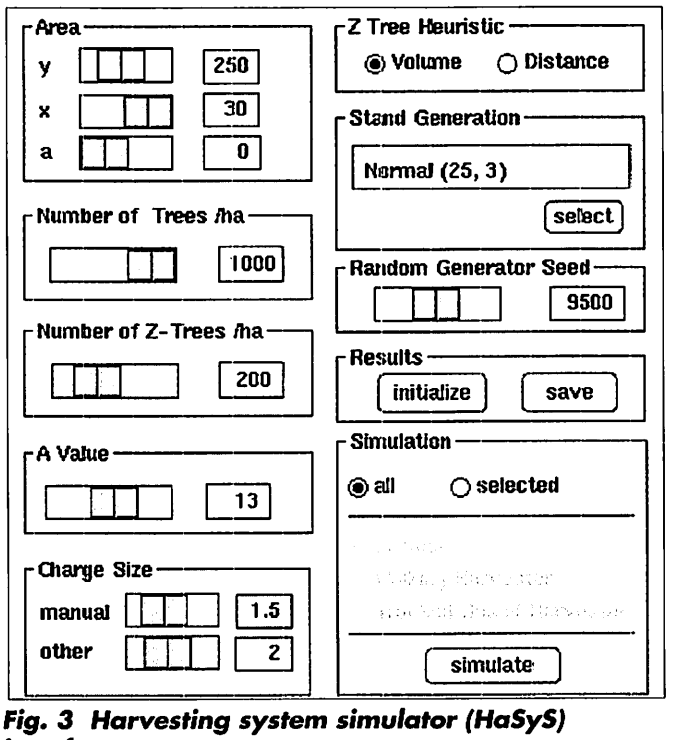
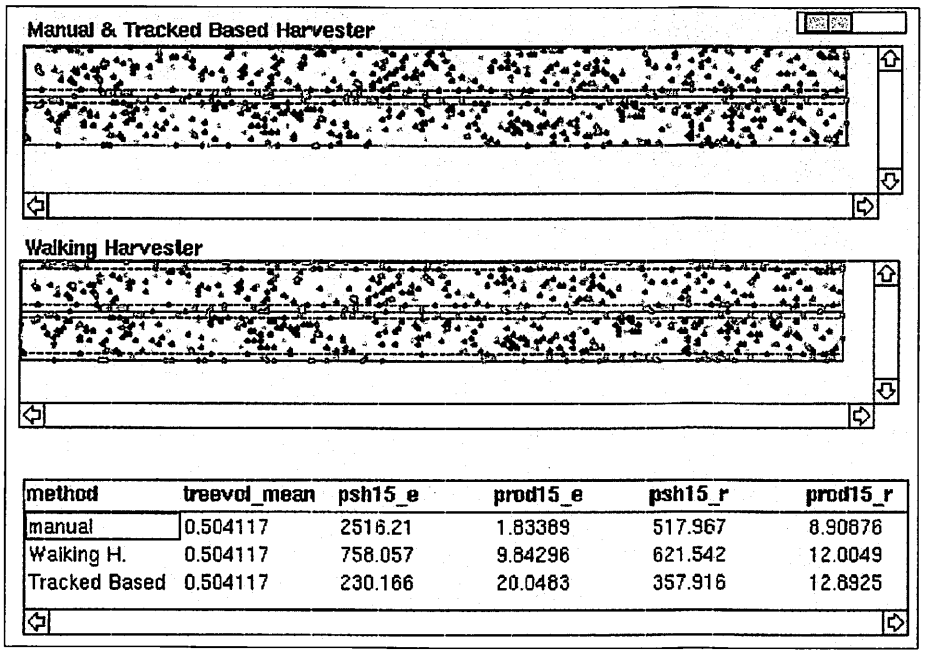


Fig. 3 Harvesting system simulator (HaSyS) interface.



method	treevol_mean	psh15_e	prod15_e	psh15_r	prod15_r
manual	0.504117	2516.21	1.83389	517.967	8.90876
Walking H.	0.504117	758.057	9.84296	621.542	12.0049
Tracked Based	0.504117	230.166	20.0483	357.916	12.8925

Fig. 4 Graphical display for the simulation output.

deterministic models are used with stochastic elements. Further division is made between tree manipulation and locomotion by the mechanised harvesting options. The models for parts of the timber harvesting processes (motor-manual felling, tree manipulation and locomotion with tracked harvesters and extraction using cable machinery) were obtained using empirical studies (Stampfer, 1999). The model from Fjeld (1994) was used for the tree manipulation component with walking harvester. Additionally, Heinimann (1995) had developed a locomotion model for the walking harvester using analytical methods.

3. Timber harvesting simulator

For the evaluation of the model, the Harvesting System Simulator (HaSyS) was written in the object oriented programming environment VisualWorks (Smalltalk). To ensure a user friendly interface, the display is divided into two windows. In the first the user can enter the simulation specific variables *(Figure 3)* and in the second, the results are displayed numerically and graphically *(Figure 4)*.

3.1. Simulation

Parameters that are of importance to steep slope timber harvesting can be changed in the simulation input data. These are the system, terrain and stand variables. The following parameters are considered *(Figure 3)*:

1. terrain slope;
2. number of trees per hectare;
3. number of future trees per hectare;
4. type and manner of stand generation, the two options being to use distributions or to read in actual stand data;
5. value for the determination of thinning intensity *A*;
6. two different heuristics to determine future trees;
7. choice of timber harvesting system (motor-manual, walking or tracked harvester);
8. the desired maximum drag size for the extraction with cable logging equipment;
9. seed for the random number generator that as an option can be set to examine retrospectively the occurrence of unexpected phenomena, the (pseudo) random numbers being produced by the linear congruence method.

Table 1: Description of the simulation stand.

Parameter	*Stand 1*	*Stand 2*
Corridor length, m	250	
Terrain slope, %	25	
Future trees, ha^{-1}	200	
Age, y	50	90
Stand density, ha^{-1}	1500	700
Diameter breast height, cm	20	32
Stand volume (without bark), m^3	312	492
Thinning intensity, %	21-47	27-57

3.2. Presentation of the simulation results

The user has the possibility to write all the simulation specific results to a data file in order to be able to evaluate these results using any statistical analysis program. Additionally, the presentation of the most important results occurs in a separate window (production data for the harvesting machine by felling and tree manipulation, as well as the extraction). For the various process layouts, the extraction corridors are graphically displayed. The various tree types (future trees, trees for removal and the remaining trees) are differentiated using colours *(Figure 4)*.

4. Example of a simulation

To indicate the functionality of the prototype timber harvesting simulator, two different stands are simulated. The stand characteristics are shown in Table 1. In addition to the harvesting system, the thinning intensity was also varied.

Based on the concept of productive system hour (PSH_{15}) which includes delays of less than 15 minutes, Table 2 shows that the productivity in m^3/PSH_{15} for each mechanised harvesting system is clearly superior to that for the motor-manual system option. By the felling and tree manipulation, the walking harvester takes a position between motor-manual and tracked harvester. The productivity achieved is comparable with that of wheeled harvesters. The trend relating thinning intensity to productivity is also evident.

The cable extraction productivity also increases after mechanised harvesting. The pre-bunching of the logs results in faster cycle times and larger average drag volumes. If the bundles must be pulled through the stand as is the case for the walking harvester, the productivity is only reduced by an insignificant amount.

5. Conclusions

The objective of this study was to develop a simulation model for steep terrain harvesting to analyse and optimise current and future work systems. One key component was the modelling of the

Table 2 Results of the simulations for three values of the proportionality factor *A* for thinning intensity; all results are given as output (without bark) per productive system hour including delays less than 15 minutes in m^3/PSH_{15}

System	Productivity, m^3/PSH_{15}					
	Stand 1			Stand 2		
	A=8	A=10	A=12	A=8	A=10	A=12
Felling and tree manipulation						
Chainsaw	1.46	1.45	1.41	2.54	2.52	2.50
Walking harvester	4.61	4.31	3.87	21.50	19.14	18.87
Tracked harvester	14.79	14.64	14.30	25.73	25.55	25.45
Cable extraction						
After chainsaw	7.42	7.29	6.63	14.99	13.92	13.30
After walking harvester	10.26	9.49	8.58	17.84	16.69	16.64
After tracked harvester	11.28	10.81	9.93	18.76	17.93	17.12

interaction between silvicultural regimes and production systems. The timber harvesting simulation model prototype, Harvesting System Simulator (HaSyS), allows for the first time the comparison between various mechanised, steep terrain, work systems. Motor-manual felling and cross-cutting, walking and tracked harvesters as well as the subsequent cable extraction can be simulated.

First results show that the mechanised harvesting systems are also superior to the motor-manual ones on steep terrain. This is not just through higher productivity by the felling and tree manipulation, but also through cable extraction productivity increases. The productive potential of the walking harvester lies between what can be achieved using the tracked harvester and motor-manual system. The difference between the cable extraction productivity following either walking and tracked harvester felling is very small. The cable system following the walking harvester used only one central location for every three harvester corridors. Visser and Stampfer (1998) also showed this to be the most effective solution based on empirical study results. The results presented are however preliminary and still need to be confirmed using a statistically balanced simulation study.

The developed heuristics for the distribution or determination of future trees with respect to carrying out thinning operations proved to be suitable. However, the options that allow the user to interactively select future trees should remain open. The thinning intensity is determined using the proportionality factor *A*, making it possible to select objectively and comprehensively which neighbouring tree to remove from a competitiveness point of view. Although the value of *A* can be very variable, three values between 8 and 12 have been shown to be most suitable.

A number of further developments are still desirable to improve the detail and usability of the model. In order to react to future machinery development in a more flexible way, an interface will be generated in which the model parameters can also be easily entered by a less experienced user. To complete a more comprehensive timber harvesting system analysis, a stand damage estimate model will be integrated. In general, this simulation model provides a flexible analysis tool for steep terrain timber harvesting systems which is also capable of incorporating future machine developments. It provides for significant cost savings potential through system optimisation.

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Branch Diary

Scottish Branch

All meetings start at 7.30 pm.

Wednesday, 6 October 1999

Venue: Moredun Institute, Bush Estate, Penicuik
GIS systems in forestry and agriculture
Speaker: Andrew Duff and A N Other

Wednesday, 3 November 1999

Venue: SAC Auchincruive – The Green Room
Off-road vehicles on the road and safe driving in the countryside
Speakers: Police Officers

Tuesday, 7 December 1999

Venue: Lomond Hills Hotel, Freuchie
Machinery rings and labour requirements
Speaker: Kenny Nichol

Hon Sec: Mr G M Owen Tel: 01968 675943

Wrekin Branch

For further details on times and venues, contact the Honorary Secretary

Monday, 11 October 1999

Tractor developments in the new millenium
Speaker: Representative from New Holland, Product Training

Monday, 8 November 1999

Young Engineers' challenge – an opportunity for young engineers to demonstratetheir technical capabilities
Features young engineers from within the Wrekin Branch area, solving a set engineering problem

Monday, 6 December 1999

Mechanisation in Developing Countries
Speaker: John Kilgour, Consultant and specialist in developing technologies

Hon Sec: Denis Cartmel Tel: 01785 712690

Engineering image campaign put on ice

The Engineering Marketing Group (EMG) has decided to postpone its proposed National Marketing Campaign, aimed at changing the national perception of engineering and promoting engineering careers to young people.

EMG, which comprises the Engineering Council, the Engineering Employers' Federation (EEF), the Engineering & Marine Training Authority (EMTA) and the Engineering Construction Industry Training Board (ECITB), has taken the decision because of the difficulty in securing the necessary financial support.

The DTI had pledged significant financial support, subject to industry also making a major commitment. The increasingly tough economic climate facing much of the engineering sector and the evolution being undergone by a number of leading engineering companies, however, have had a major impact in this regard.

A significant new factor in the equation is the plethora of Millennium related initiatives and events that are now diverting both the attention and funds of potential investors into other directions. This was not an issue when work on the campaign began, but has become one as the programme has progressed.

In order to mount the ground breaking five-year campaign, developed for EMG by advertising agency J. Walter Thompson (JWT), an estimated £3-5 million per year was required. The EMG had committed £1 million from within its own resources and hoped to make up the difference from engineering industry and Government - the principal beneficiaries of more, better quality engineering recruits.

EMG, over the last ten months, has met with more than thirty of the UK's leading engineering-led companies to present its proposals and invite investment in the initiative. The Group has also made presentations to the DTI, the DFEE, who also endorsed the campaign, and a number of engineering institutions.

While there has been an overwhelming response to the concept of an advertising-led marketing campaign and to the detailed proposals presented, translating that support into funding has proved difficult.

New piston pumps from Duplomatic Hydraulics

A new family of Variable Displacement Axial Piston Pumps have been introduced for use in open loop systems, with medium to high pressures, designated VPPM. They are available in three different frame sizes, with maximum displacements up to 29 cc/rev, 46 cc/rev and 73 cc/rev, giving maximum flow rates of 43 *l*/min, 69 *l*/min and 109 *l*/min at 1500 rpm. Main features of the pumps are:

- continuous duty at high pressure (up to 280 bar)
- high peak pressures (up to 350 bar)
- energy saving thanks to pressure compensation, pressure and flow regulator or power regulator controls.
- low costs
- low noise level
- long operating life, thanks to hydrostatic support and other design features
- high volumetric and total efficiencies
- compact dimensions in comparison-to flow rate
- good suction ability
- high resistance to dynamic axial and radial loads
- possibility to be coupled with other pumps to make up multiple pump units
- adjustment possible of both the maximum and the minimum displacements by use of the screws provided.

The pump flow rate is proportional to the rotation speed and to the angle of the swash plate, which can be varied infinitely. They can be controlled by any of five different types of regulator depending on the requirements of the system:

1. PC pressure regulator - keeps the pressure in the system at a constant level;
2. PCR remote controlled pressure regulator;
3. PCE proportional pressure regulator;
4. PQC pressure and flow regulator;
5. PQNC power regulator.

These pumps have tremendous versatility due to the complete range of regulators that are available, and thus have many fields of application. These include: sheet metal processing lines, moulding presses, punching/coining presses, plastic injection machines, machine tools, and many special purpose machines.

The VPPM pumps are generally supplied with ISO 3019/2 mounting flanges although others are available. Hydraulic connections are made with SAE flanges.

These pumps complement the extensive range of Duplomatic equipment available from stock at Hydraulic Equipment Supermarkets Ltd and their Duplomatic Distributors throughout the UK.

Contact: **Samantha Lake, Hydraulic Equipment Supermarkets Ltd, Innsworth Technology Park, Innsworth Lane, Gloucester GL3 1DL. Tel: 01452 730774**

Lamborghini's new Champion wins Golden Tractor Award at SIMA '99

The recently launched Lamborghini Champion, produced by Same Deutz-Fahr, stole the show at SIMA '99 in Paris, where it won the 'Golden Tractor of 1999' Award for outstanding design. Designed jointly by SDF and Italdesign, the Lamborghini Champion, which is available in 90 kW, 101 kW and 113 kW versions, met with an enthusiastic response from the panel of judges comprising leading journalists from the European agricultural press. They voted the Champion a clear winner, ahead of competition from all the other tractor manufacturers.

Apart from its aesthetic qualities, the new Lamborghini Champion also drew praise for the wide range of innovative technological developments, which are incorporated in all three models. Three-valves-per-cylinder Resonance Intake System Engine design, Incremental Power/Constant Torque outputs and electronic engine speed management controls combine with a host of other advanced engineering features to make the Champion a state-of-the-art competitor in the 90 kW to 113 kW sector.

The fact that this is the second successive time that Same Deutz-Fahr has won the Golden Tractor Award is proof of the Group's extraordinary design, innovation, technology and manufacturing skills. SDF is constantly striving to be first with new and better ideas to meet the needs of its customers. Always at the forefront of developments in tractor technology, the company was amongst the first to take up the challenge of applying electronics to tractor design. This relieves the operator of needless fatigue and stress, allowing tasks to be tackled with greater precision, and bringing about improvements in productivity and cost-effectiveness.

Today's Champion range continues

that development theme, incorporating advanced electronic systems which control key elements of the tractor's operation and provide the basis for precision farming operations in the future. The tractor's purposeful profile and smooth, flowing lines, provides a dynamic appearance which fully reflects its technical excellence and exceptional in-field performance.

Given such a level of innovation it is hardly surprising that, despite some general slackening of world-wide markets for agricultural machinery during the last two years, sales of Same Deutz-Fahr products continue to rise, against the general downward trend in the industry generally. SDF, which is based in Treviglio, Northern Italy, produces a total of 30,000 tractors per year and accounts for 14 per cent of the European tractor market.

Technical background to the Lamborghini champion range

Every Lamborghini Champion model is powered by a technically advanced six litre, six-cylinder Resonance Intake System Engine (RISE). Each of the six cylinders has a total of three valves - two inlet and one exhaust - ensuring maximum 'breathing' efficiency and performance. Increases in engine efficiency and output derive from the fact that each of the two inlet valves is equipped with its own inlet port, the length of which is individually matched to the requirements of each cylinder. The shorter of the two creates a resonance effect, which optimises the pressure waves created within the inlet ports over the medium to high engine speed band (1800 to 2350 rpm) corresponding to the maximum power range. The longer port causes a resonance effect over the low to medium engine speed range (1400 to 1800 rpm) where maximum torque is produced. Comparable to the 'variable geometry' air intakes found on the most advanced car engines, the two inlet ports ensure a generous flow of air into each cylinder. This results in optimum power and torque characteristics throughout the practical operating range from 1450 to 2350 rpm. All Champion engines are turbocharged to improve specific outputs and combustion efficiency, the 113 kW also being fitted with an intercooler to enhance specific power output.

An exciting design feature of the engines fitted to all Lamborghini Champion models is 'Incremental Power'. As engine speed decreases from the rated speed of 2350 rpm, power output increases by up to 5%, down to 1800 rpm. In the case of the Champion 120, power output rises from 90 kW to 96 kW, while the 101 kW Champion 135 generates 105 kW, and the Champion 113 produces 116 kW.

Commensurate with these increases in engine output are rises in pto power ratings, which actually increase to levels equivalent to the rated power of the engines. The reason for this apparent anomaly is that the mechanical power losses normally involved in delivering the power from the engine to the pto - about 5% - are effectively offset by increases in engine output resulting from Incremental Power.

A similar situation can be seen in the area of torque output. Maximum 'constant' torque is maintained between 1400 rpm and 1700 rpm. Within this band, the engines deliver exceptional levels of performance. Maximum torque figures are 540 Nm, 590 Nm and 665 Nm for the Champion 120, Champion 135 and Champion 150 tractors, with torque rises of 48%, 40% and 40%, respectively.

The practical advantages of the 'Incremental' power and 'constant' torque characteristics are maximum power delivery under all engine load conditions, sparkling engine performance, excellent flexibility, fewer gear changes and consequently enhanced driveability.

Designed to minimise operating costs, the new engines also incorporate a twin cooling system, which operates effectively across a range of operating conditions. The system uses powerful oil jets to cool each piston, with liquid cooling for the cylinders and cylinder heads. The special coolant used in the system eliminates corrosion and cavitation, ensuring optimum efficiency and reliability.

Advanced electronics govern engine speed

Designed for maximum combustion efficiency and optimum fuel utilisation, the injection system incorporates an Electronic Control System (ECS) which controls engine speed electronically. Self-monitoring and self-diagnostic, this well-proven system provides a number of advantages. Firstly, it eliminates the wear which can occur with conventional systems, ensuring greater precision, faster throttle response and reduced operator effort. Secondly, the system incorporates an electronic hand throttle, which provides all the functions of a conventional hand throttle, with the additional benefit of a 'memorise and recall' facility. This enables maximum and minimum engine operating speeds to be selected simply by pressing buttons on the multifunction joystick. Memorising these maximum and minimum engine speeds automatically engages the 'ISOCRONO' function, which maintains constant engine rpm even when the load changes. ISOCRONO also releases up to six per cent more engine power and produces more consistent performance from the implement being used.

The Electronic Control System is driven by an ECU. This contains all the engine control parameters, for all load and engine speed conditions; stores and manages optimum power, torque and fuel consumption data for each engine; and constantly checks that the system's components are operating correctly. Determining the optimum injection-volume results in optimum power and flexibility at all engine speeds, enabling the engine to handle sudden increases in load, providing greater operating sensitivity and minimising exhaust emissions.

The ECS system also optimises specific fuel consumption, a figure of around 209 g/kWh is quoted for all Lamborghini Champion models. With up to 380 litres of fuel stored in two tanks,the new tractors are able to operate for up to 15 hours without refuelling.

All Champion engines comply fully with all EURO standards governing nitric oxide and particulate emissions, and can also operate on Bio-diesel.

Fingertip control of new Powershift transmission

Standard equipment on all Champion models is an advanced Powershift System which incorporates 18 forward and 18 reverse speeds, nine in each of the two ranges. Gears 1 to 9 in Range 1 provide travel speeds (at rated engine rpm and on 580/70R38 tyres) from 2.50 to 10.79 km/h while Range 2, containing gears 10 to 18, produces speeds from 9.43 to 40 km/h. Reverse ratios are from 2.65 to 11.44 km/h in Range 1 and from 10 to 40 km/h in Range 2. A dashboard display clearly highlights the gear selected.

The gearbox also provides a range of

super-reduction gears, for jobs which require extra-slow speeds. A further nine forward powershift gears cover a speed range from 0.57 km/h to 2.48 km/h, with nine reverse gears from 0.61 km/h to 2.63 km/h.

A major feature of this advanced transmission, which replaces the conventional gear lever with a simple push-button on the multi-function joystick, is the Isokinetic Control Unit. This unit electronically controls the shift between the two gear ranges, from 9th to 10th gears. The operator simply has to press two control buttons, simultaneously, and the transmission does the rest, changing smoothly and progressively from one range to the next.

The system also incorporates an electronically controlled hydraulic reverser, which allows the operator to change direction in any one of the 27 forward or 27 reverse gears simply by pressing a button on the multi-function joystick. A further refinement is the 'programmed reverse gear selection' function, which enables the most appropriate reverse ratio to be pre-selected. For instance, although a particular task might dictate the use of sixth gear for forward travel, fourth gear might be most suitable for reversing, when turning on the headland for example. The advanced Powershift system makes this possible

The versatility of Lamborghini's Champion tractors can be further enhanced by the optional Automatic Powershift System (APS), which incorporates a fully automatic gear change facility. The operator has only to select the highest working gear to suit the operating conditions. From this point, the system takes over ensuring that the tractor moves off smoothly from a standing start then automatically selecting the most appropriate gear for any situation. As APS automatically takes account of engine rpm and ground speed it allows the operator to concentrate fully on the task in hand whether the tractor is working in the field on heavy draft operations, towing a trailer on the road, or simply operating around the farmyard.

To take account of the differing nature of these operations, APS can also be adjusted for sensitivity, in much the same way as the 'sport' and 'economy' settings can be selected in some cars fitted with automatic transmission. With APS set in 'performance' mode, gear changes are effected rapidly in response to changing engine loadings and speeds, ensuring maximum productivity at all times. In 'economy' mode, gear selection by the APS is more progressive, providing maximum operating economy. 'Manual mode' can be engaged at any time, allowing the operator to decide which gear should be used.

Maximum versatility from advanced four-wheel drive system

Lamborghini was one of the first companies to manufacture and market four-wheel drive tractors and has since become a market leader in this technology. The four-wheel drive system used on all Champion models builds on this experience, with advanced control technology to ensure maximum performance. At the heart of the four-wheel drive function is SBA, an easy-to-use electronic system which automatically controls the four wheel drive system and differential locks, ensuring maximum power delivery, optimum traction and maximum manoeuvrability.

The front-drive axle features an integrated braking system, compact centre differential, oversize epicyclic final reduction unit, together with large front wheels, all of which result in exceptional ground clearance. When combined with a 55° steering angle and 'articulating' front fenders, which can be adjusted for both height and angle, these features result in greater manoeuvrability, unrestricted steering angle and better protection from road spray and mud.

Powerful hydraulics and front linkage/pto option

An advanced electronic rear lift system, which ensures a fast, accurate response to changing loads and precise operation, is a feature of these new tractors. Standard lift capacity is 7000 kg on the Champion 120 (Cat. II) and Champion 135 (Cat. III) models, and up to 8600 kg where supplementary cylinders - standard on the Champion 150 (Cat. III) - are fitted. However, all Champion models sold in the UK will be equipped with supplementary lift cylinders, providing a lift capacity of 8600 kg.

The hydraulic system is powered by a high-capacity - 3 l/min - fixed-displacement, tandem gear pump and can be equipped with up to four double-acting control valves. This allows simultaneous operation of rear lift and auxiliary control valves, enables unlimited use of hydraulic implements and provides constant speed operation of hydraulic motors/dedicated auxiliary control valves for each specific function. In addition, modular control valves may be configured according to personal requirements, while the safety lock valves ensure maximum safety during transport.

The oil-immersed multi-disc 540/1000 rpm power take off is electro-hydraulically controlled using convenient pushbuttons mounted in the cab and on the rear fender. A modulating clutch ensures smooth, gradual engagement, while a pto brake prevents the shaft from rotating once drive has been disengaged.

To enable Champion owners to make full use of their tractor's performance, Lamborghini offer a powerful front linkage and pto system as an option. Capable of lifting up to 4000 kg, it incorporates quick-attach couplings, a purpose-designed ballast weight and a 1000 rpm electronically-engaged pto. Compact and with no external mountings, the front linkage system is integrated into the structure of the tractor and can easily be retrofitted. An implement lowering speed control valve ensures controlled, safe lowering of all implements, while the 'anti shock' valve and twin nitrogen-filled accumulators protect the circuit against pressure surges, which could otherwise cause accidental damage. A further feature of the front linkage system is the lift arms. In addition to the normal positions, they can also be used in the 'high' setting for implements which work at depth, in the 'float' position with implements which carry their weight on the ground and finally, 'retracted' to enable the overall length of the tractor to be minimised when the front link arms are not in use.

Lamborghini Champion models are also available with an electronic front lift system. Offering position, float, draft and mix control, allowing full use to be made of all the front-mounted implements, this optional system is operated using controls, which are integrated into the multifunction console.

Operator comfort a priority

The technical excellence of the Lamborghini Champion is enhanced by a superb cab which, at just 72 dB(A), is

one of the quietest available and provides 3200 of visibility through 7 m^2 of curved 'athermal' glass. The car-like cab interior uses durable 'soft touch' materials finished in colours which are restful on the eye and provide an unbeatable 3 m^3 of interior space. Opening rear/side windows and a glass roof hatch contribute to the feeling of spaciousness.

Standard equipment includes: a pneumatic, fully adjustable suspension seat; rake and reach adjustable steering wheel; together with generously sized foot pedals. For optimum year-round comfort, the four-speed ventilation system incorporates a powerful 8 kW heater-unit and a high-output air conditioning system to provide a cool, comfortable working environment even on hot summer days.

Further refinements within the cab include a retractable sun blind, refreshments compartment - which can either be used to keep drinks cool or food warm - ample storage areas, plus a cigarette lighter, ashtray, coat hook and clock. The cab is also fitted with a radio/cassette unit, has a power socket and comes complete with a 'data port' to allow information transfer between tractor and implement,

The working environment is centred around a multifunction console, which includes a full performance monitoring system. Attached to the driver's seat and adjustable to suit any driver, the console is arranged in two quadrants, one incorporating the main controls, the other enabling the settings of various functions to be adjusted. Operating in much the same way as a TV remote control, the setting quadrant is protected against inadvertent use by a special cover, which also provides a convenient armrest for the driver.

Electronics are ready for 'precision farming'

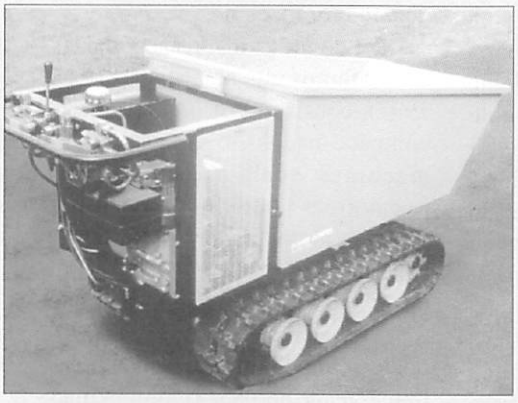
In designing the new Champion models, Lamborghini engineers have incorporated an advanced 'CAN BUS' electronic system which allows dialogue between the various electronic modules and results in optimum management of the tractor and tractor/implement combination. The various electronic operating systems - engine control unit, transmission control unit, lift control, electrical system, dashboard and multifunction console - have been integrated and rationalised to make the tractor electronics simpler, more reliable and more versatile. This guarantees high operating performance, easy system enhancement and simple diagnosis of electrical/electronic system faults.

The design of the electronic system also allows it to be connected to 'intelligent' implements which use the CAN BUS system (DIN9684) and makes possible data transfer to a PC.

At the very cutting edge of tractor design, the Lamborghini Champion range incorporates the very latest technology to make farming more efficient and productive, now and in the future.

Contact: **John Gilbert, Marketing Manager, Same Deutz Fahr UK Ltd, Barby Lane, Barby, Rugby, Warwickshire, CV23 8TD. Tel: 01788 891892**

Versatile new power dumper with extra load capacity



A new versatile tracked power dumper designed and manufactured by Trammic Ltd has a full 750 g load capacity, giving it the ability to keep up with a mini digger on most excavation or trenching work. Despite this impressive workload, the unit is highly compact, with an overall width of only 720 m which guarantees that it will pass comfortably through a standard doorway access.

Called the Octad TPD 750, this pedestrian controlled power dumper takes advantage of the latest developments in hydraulic controls. It is particularly suited to the horticulture industry, farmers, landscape gardeners, cable laying contractors, local authorities and even use on building and construction sites with limited access or where working in confined spaces would make conventional wheeled dumpers non viable. It is also ideal for construction or maintenance work on golf courses, parks and outdoor playing fields where the broad caterpillar tracks can cope with soft ground and do not damage grassed areas even when the unit is fully loaded. Optional fitments include a dozer blade, together with either steel or wooden flat deck loaders suitable for the safe transportation and tipping of stone slabs used for ornamental masonry and gravestones, *etc.*

The dumper features independently driven deep tread rubber tracks, which are wide-set for maximum stability. These are controlled by variable speed hydraulic motors, with the tipping operation also being hydraulic. The control mechanisms have been designed for ease of operation and the dumper can even tip loads in a line while reversing with a raised bucket. The tip/forward/reverse and turn controls are all conveniently placed at the rear of the unit, with a pram style steering handle provided which prevents operator hand injury when negotiating narrow doorways or manoeuvring within walled areas. The engine controls compartment is covered to prevent inadvertent damage while still providing easy access for maintenance.

The Octad TDP 750 dumper complements other units in the range with load capacities of 400 and 500 kg, respectively. All products are manufactured to ISO 9002.

Contact: **Trammic Ltd (c/o Enterprise Marketing Services Ltd), The Coach House, I Dunstall Road, Barton under Needwood, Burton on Trent, Staffordshire DE13 8AX. Tel: 01283 713185.**

Machinery production in Italy

The final data for production and sales of agricultural, gardening and earth moving machinery in 1998 confirm the growth forecasts of recent months: total production of 1.4 Mt, and turnover of 16.3 trillion lire (8.5 billion euros).

As illustrated by the president of the Unione Nazionale Costruttori Macchine Agricole (UNACOMA), Aproniano Tassinari, at the association's annual assembly at San Lazzaro di Savena, Bologna, these are best results ever for this specific sector and confirm Italy as one of the world's leading producers.

Sector by sector analysis shows a growth of agricultural machines, a fall in tractors, partially assembled tractors and spare parts, and a substantial increase for earthmoving machines. The fall of tractors and their spare parts was unexpected and caused primarily by the continuing crisis in Asia and South America. The increase in earthmoving machines should be ascribed to the 'recovery in construction and major civil engineering works.

The agricultural machinery sector

Overall production of agricultural machines in 1998, including tractors, agricultural operating machines, gardening machinery and incomplete tractors and parts reached 0.88 Mt, 1% down on 1997.

The corresponding value in terms of retail prices was 11.6 trillion lire (6 billion euros), slightly up on 1997. Complete tractors - 81,473 weighing. 0.23 Mt and worth 3.7 trillion lire - showed a fall of 4.1% on 1997 (-6% in weight and -3% in value); partially assembled tractors and tractor parts fell by 11%, for a weight of 0.11 Mt and a value of over 1.92 trillion lire. There was a growth of 'other agricultural machines' - trailed and self-propelled machines, machines and equipment for animal husbandry and agrarian industries, transport and handling, forestry, public parks and gardening - to a total of 0.54 Mt, up 4% on 1997 for a value of 6.04 trillion lire, up 7% on 1997.

Of agricultural machine output, 38% was sold domestically and 62% was exported. In quantitative terms, domestic sales accounted for 0.34 Mt, up 1% on 1997, while exports rose to 0.54 Mt worth 6.05 quadrillion lire (3.12 billion euros), down 2% on 1997's 0.55 Mt, when exports rose sharply by 4%. The main export areas were Europe's EU and non-EU countries with 72% of the total export value, followed by the Americas with 15%, Africa with 5%, Asia with 5% and Oceania with 2%. Compared to exports of 0.54 Mt, Italy imported 0.1 Mt of agricultural machinery, for 1.27 quadrillion lire, up 16% in weight and 23% in value. Although rising, the share of imports was much lower than exports, and the trade surplus for the sector was 4.78 trillion lire (-6% on 1997).

Looking specifically at the tractor market, 1998 saw a substantial increase in imports (+34%) equivalent to 9,172 machines, and a fall in exports (-7%) to 57,577 machines. The increase in imports should also be linked to the policies of some major domestic groups which have bought facilities in other countries and have shifted production abroad, bringing some difficulties to calculating imports and exports. In this connection, in a logic of globalization, and in particular within the single domestic European market, it is worth noting that terms such as 'imports' and 'exports' are destined to lose their importance with the increasing internationalization of the manufacturers.

Countries with an increase in exports to Italy are Poland, Britain and Germany, while there is a fall from the United States. Italian exports show an increase towards Spain, Germany, Portugal and France, and a fall towards Turkey, South Korea, the US and Britain.

In agricultural trailed machines, the increase in production to 0.54 Mt, up by 4% on 1997, should be linked to an increase of 2% in domestic demand and one of 5% in exports. The export figure is the best ever for this class of machine; 52% of the total produced go to exports. In particular, exports rose for sowing, transplanting, fertilizing, harvesting and first processing machines, and machines for animal husbandry and gardening, while there was a fall in machines for working the soil, crop protection, irrigation, agrarian industries, and the handling and transport of produce. Exports rose to Germany, France, Spain, Turkey and the US, but fell to South Korea, the Czech Republic, Brazil and Austria. Total domestic purchases (domestically produced machines + imports) totalled 0.44 Mt, up 4% on 1997. Foreign tractors covered 28% of the Italian market, 23% up on 1997.

The earthmoving sector

In 1998, the production of earthmoving machinery rose to 0.52 Mt between complete and partially assembled machines, parts and tracks, an increase of 9% on 1997. The value was 4.7 trillion lire (2.4 billion euros), up 10% on 1997. A special contribution came from complete self-propelled machines (+9%) and parts and spare parts (+14%).

A positive influence on the market for these machines came from the recovery in building and public works in 1998, in Italy and internationally. Cresme, the Centre for Economic, Sociological and Market Research in the Construction Industry, believes the recovery may continue this year. It should be noted that some types of machine are used in ground clearing and cleaning for agricultural uses and in construction and road maintenance, which for some years have produced a constant demand for machinery.

The domestic market absorbed 0.18 Mt of earthmoving machinery (+18% on 1997), consisting of both traditional and compact machines. Sales of traditional machines such as dozers, loaders, excavators, backhoe loaders, motor scrapers, motor graders and dumpers came to 7,700 units of which 3,500 were Italian made and 4,200 foreign made. The total for compact mini-excavators and skidsteer loaders was 9,500 units of which 3,500 Italian made and 6,000 foreign made.

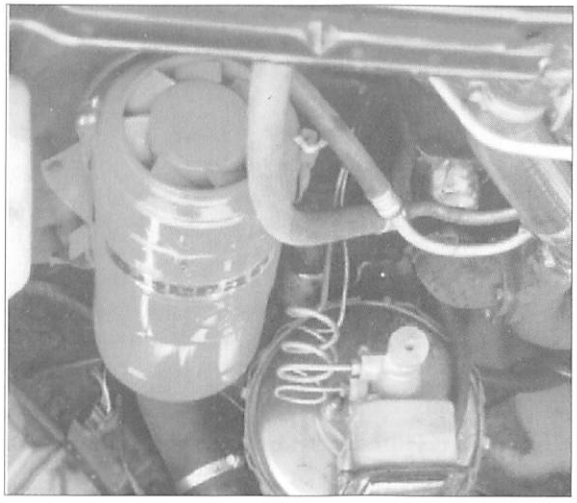
Exports of machines, equipment, components and spare parts rose from 0.42 Mt in 1997 to 0.46 Mt, an increase of 9% for a total value of 2.83 trillion lire, up 12% on 1997. The growth was due to demand for self-propelled machines and equipment, above all tracks (0.27 Mt exported).

The largest share of earth moving machines went to the United States (21%), but also to Europe with 28%, especially France, Spain, Britain and Germany.

Cyclonic pre-cleaner and air filter now combined

They said it could not be done - now the new 'Combi-Filter' from Agriemach is here. Fitted and hidden inside the engine compartment, a cyclonic pre-cleaner and air filter combined into a single unit is now a reality thanks to pioneering work by Agriemach.

Using a special turbine pre-cleaner and a conventional air filter element, 'Combi-Filter' takes the functions previously performed by two separate units and neatly blends them into a single, easily fitted, compact assembly.



In operation, air drawn into the engine intake first passes through 'Combi-Filter'. This causes the turbine to rotate at high speed, generating centrifugal force that spins out and ejects airborne contaminants before these can enter the filter chamber. With clean air having contaminant reduction efficiency rated at 90%, the result is up to a ten times increase in the life of the filter element.

The all-steel cylindrical bodied self-powered unit uses proven turbine efficiency which is maintenance free, while dramatically increasing air filter life, This means an important reduction in filter element replacement costs, with consequent savings in maintenance down-time.

Manufacturers and users of today's engine powered machinery and equipment seek sleek, uncluttered designs and avoid using external 'add-ons' wherever possible. This has made it difficult for pre-filter suppliers with their external units to meet many machinery designers criteria for 'clean lines'. Happily, Agriemach's new 'Combi-Filter' solves this problem by providing a highly efficient unit that does everything a pre-cleaner should do and it hides it inside the engine compartment to automatically work away - out of sight.

Also 'hidden' are the further benefits assured by purified air entering the engine in the form of lower fuel consumption, avoidance of impurities entering the lubrication system, reduction in exhaust pollutants, longer engine life, and higher residual value on resale,

Sizes and air volume capacities are neatly organised into five engine power bands starting at up to 52 kW; up to 60, 82 and 112 kW; and the largest suitable for engines up to 150 kW. Lengths and diameters are from (mm) 475 x 187 to 650 x 287 and air volumes (m^3/min) from 4.5 to 15. By doubling up on units for engines above 150 kW, these options cover virtually all possible under hood applications.

Contact: **Agriemach Limited, Wayfarers, Domewood, Copthome, Crawley, West Sussex, RH10 3HD. Tel: 01342 713743.**

Bericap launches new 28 mm agro-chem closure

To meet changing requirements in the agricultural chemicals market, Bericap UK Ltd is launching a new 28 mm closure. This has been specially designed for the packaging of concentrated chemical solutions, such as hazardous liquid and granular products including pesticides, herbicides, fertilisers and other chemical substances.

To date, agricultural chemical products have been packaged in relatively large packs with 45 mm, 50 mm or 63 mm closures, for use in applications where the contents are tipped into large spray tanks, for example. With the introduction of more concentrated chemicals in recent times, however, smaller containers and closures for chemical substances are now required. These small containers are also ideal for 'back pack' sprayer applications.

Developed for use with either PET or polythene containers, the new 28 mm closure is designed to provide exceptionally high levels of tamper evidence and product security on a wide range of agricultural chemicals. The closures are available in a range of colours and can be embossed or printed with safety messages, if appropriate.

In particular, the new closure features external tamper evidence in the form of a drop down tamper band. It is available with an IHS (induction heat seal) liner which, in addition to creating a hermetic barrier, provides excellent secondary tamper evidence. The closure also incorporates a 'cutter' for easy and safe piercing of the induction foil.

The combination of the new 28 mm closure with the induction seal also eliminates the problem of chemical leakage from unopened containers, improving safety for users in handling the products and reduces possible instances of environmental contamination.

Contact: **Bericap UK Ltd, Oslo Road, Sutton Fields Industrial Estate, Hull. HU7 OYN. Tel: 01482 826666.**

Vredestein focuses on quality and innovation

Agricultural highlights include the multi-functional Traxion + tractor tyre that helps farmers and contractors achieve bigger and better crop yield. The tyre's excellent performance, which is reflected in its strong sales, is endorsed by current Traxion + users. The enthusiastic response to a survey conducted throughout Europe confirmed users' confidence in Traxion +'s key characteristics of excellent traction, efficient work performance, high comfort levels and long life.

Also available are the award-winning Flotation + and a new tyre for hay making machines and a 'grass-friendly' tyre that is particularly suitable for horticultural machinery.

Traxion +

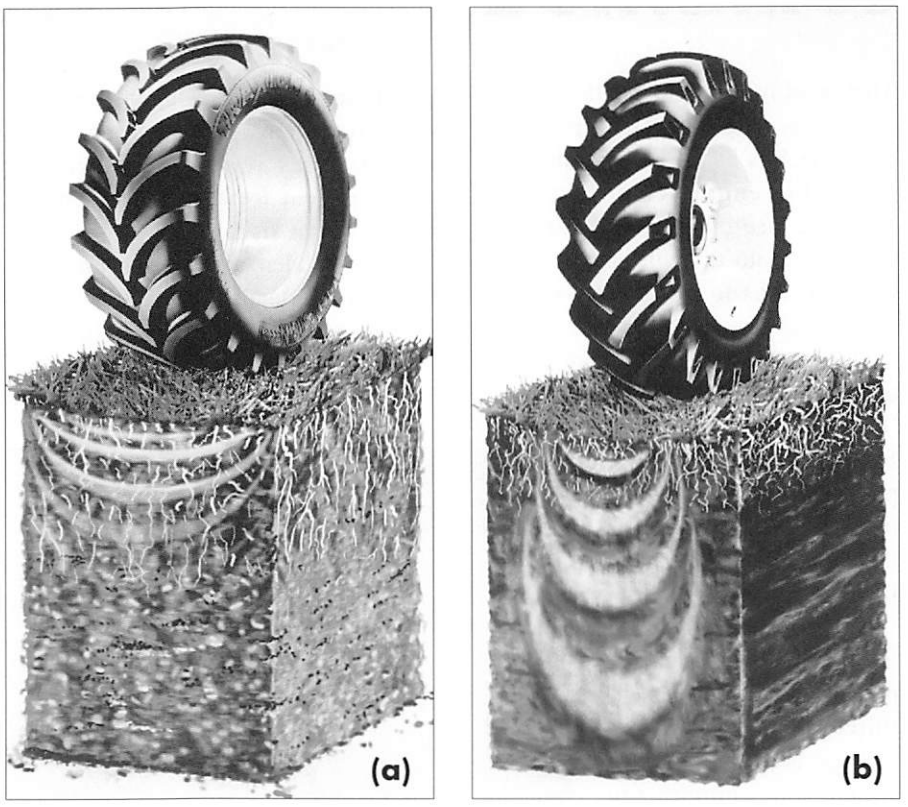
The launch of Traxion + has proved that advanced tyre technology really can make a difference, with outstanding results both in improved yield and increased comfort levels.

"Increases in scale, efficiency and improved yield are what all modern entrepreneurs in the agricultural sector are looking for. They are investing in high-tech tractors that work with the ground not against it - and they need a tyre to keep pace. Our solution is Traxion +,"explains Ian Wilson, Vredstein's UK Director and General Manager.

Traxion + is a high-tech tubeless tyre which gives an outstanding performance in both field and transport work, offering farmers a range of real benefits including the following.

- *Wider tread*

In a test conducted in co-operation with DLG-Prufstelle in Gross Umstadt in Germany, Traxion + proved consistently wider than its competitors. This extra width gives a number of advantages especially for work in the field. The Traxion + achieves the highest level of traction at 10 per cent slip on stubble and an average in practice of 5 - 15 per cent slippage on cultivated soil.



The Vredestein radial Traxion + agricultural tyre (a) has been developed in wider 70 and 65 sizes to ensure soil compaction is kept to a minimum compared to other narrower *agricultural tyres (b).*

- *Excellent traction*

The Traxion + tread has a large distance between the tread bars at the shoulders, in the traction zone. This ensures excellent self-cleaning properties on all types of soil and under every kind of difficult soil condition. The result is better grip and less slippage.

- *Extra large contact surface*

The extra large contact surface (20 to 30 per cent compared with the standard 80 series tyre) gives optimum grip to the soil and the bar shape is slimline right to the base. This guarantees excellent traction for the entire life of the tyre.

- *Efficient work performance*

With a Traxion + 65 series tyre, it is possible to work a greater land area in a shorter space of time and its excellent pulling power reduces slippage which means less fuel consumption for the same amount of work.

- *The comfort zone*

The short wheelbase of many modern tractors can equal more vibration, so Vredestein paid great attention to the comfort factor when developing the Traxion +. Its curved bar shape means there is a large area of bar surface in the centre of the running surface, the comfort zone creating an almost continuous contact with the ground, thereby reducing cab vibration.

- *Reduced rolling resistance*

The tread design means that during transport the bars roll easily and offer 10 per cent less rolling resistance than most common treads. A special carcass construction and a flexible side-wall, together with the relatively low tyre pressure, give the tyre excellent suspension properties.

- *Longer life*

The Traxion + is a tubeless tyre made of a high quality rubber compound, a combination which guarantees long life.

Traxion + is available in 65 and 70 series sizes to fit most tractors. Both versions can be fitted to four wheel drive tractors which have 80 series tyres fitted.

Flotation +

Flotation+ is a prime example of Vredestein's commitment to high-tech technology in agricultural tyre development and its superiority was endorsed by the award from the Royal Agricultural Society of England of the 1996 Silver Medal for excellence in agricultural machinery.

Technological innovation in the tyre's make-up has been shown to help deliver significant improvements in crop yield compared to conventional agricultural tyres. Independent research shows the Flotation + reduces compaction by up to 10% compared to standard tractor and implement tyres, by spreading the load across a greater contact area and running at lower air pressure.

The Flotation + is designed for a wide range of uses including slurry tankers, tipping trailers and modern harvesting machinery.

Hay Harvesting

The hay industry is using increasingly larger vehicles and Vredestein has recently launched an innovative tyre that has the advantage of offering a high level of thorn resistance. Based on the successful V61 tread, the tyre comes in a new 18 x 8.50 - 8 size designed to give improved stability, greater load capacity and provide extra protection against thorn penetration.

Grass-friendly

In the grounds maintenance business, the look of the grass is an important consideration, particularly on golf courses and in public parks. Vredestein has recently launched the V88 tyre, which is characterised by its friendly approach to lawns and therefore helps maintain the appearance of grass. The V88 comes in a 1 8 x 8.50 - 8 size which is especially suitable for golf carts, horticultural machines and vehicles for park maintenance.

Vredestein (UK) Limited is the UK arm of the Netherlands' only indigenous tyre manufacturer and supplies high quality, tyres for cars, vans, agricultural tractors, trailers and machinery for industrial use.

Partek Forest CRH 16 crane for Valmet 921

Latest crane option improves harvesting performance. The recently introduced Valmet 921 harvester from Partek Forest is now offered with a new crane option, the Cranab CRH 16. Offering a reach of up to 10 m, the parallel knuckle boom CRH 16 is purpose made for the high output 921 and has been specially developed to work with the harvesters' high-capacity harvesting head.

The new Cranab CRH 16 offers operators a number of key advantages. These include ease and speed of operation, improved stability, a more efficient slewing radius and the ability to work at close range. The crane also has a 1200 kg lift capacity at full reach, the highest in its class.

The crane is a parallel action design. This enables the harvesting head to be kept parallel to the ground during crane movements. This makes operation in thinnings and difficult terrain considerably easier.

Of equal importance, the system also allows the operator to fell and process the tree in the same spot, without having to slew or extend the crane to find enough room to limb and cross cut the tree. This promotes increased production, reduces fuel consumption, increases the service life of the crane, speeds cycle times and reduces wear on' the crane itself.

The CRH 16 also features a more efficient slewing radius enabling the crane to work closer to the harvester but without the loss of feedback to the operator. This can be a problem with some existing designs.

The telescopic and parallel functions are both cushion-stop damped. This helps to make the crane smoother in operation, reducing shock loads transmitted back to the operator. This is designed to relieve operator fatigue and to help protect the crane and hydraulics.

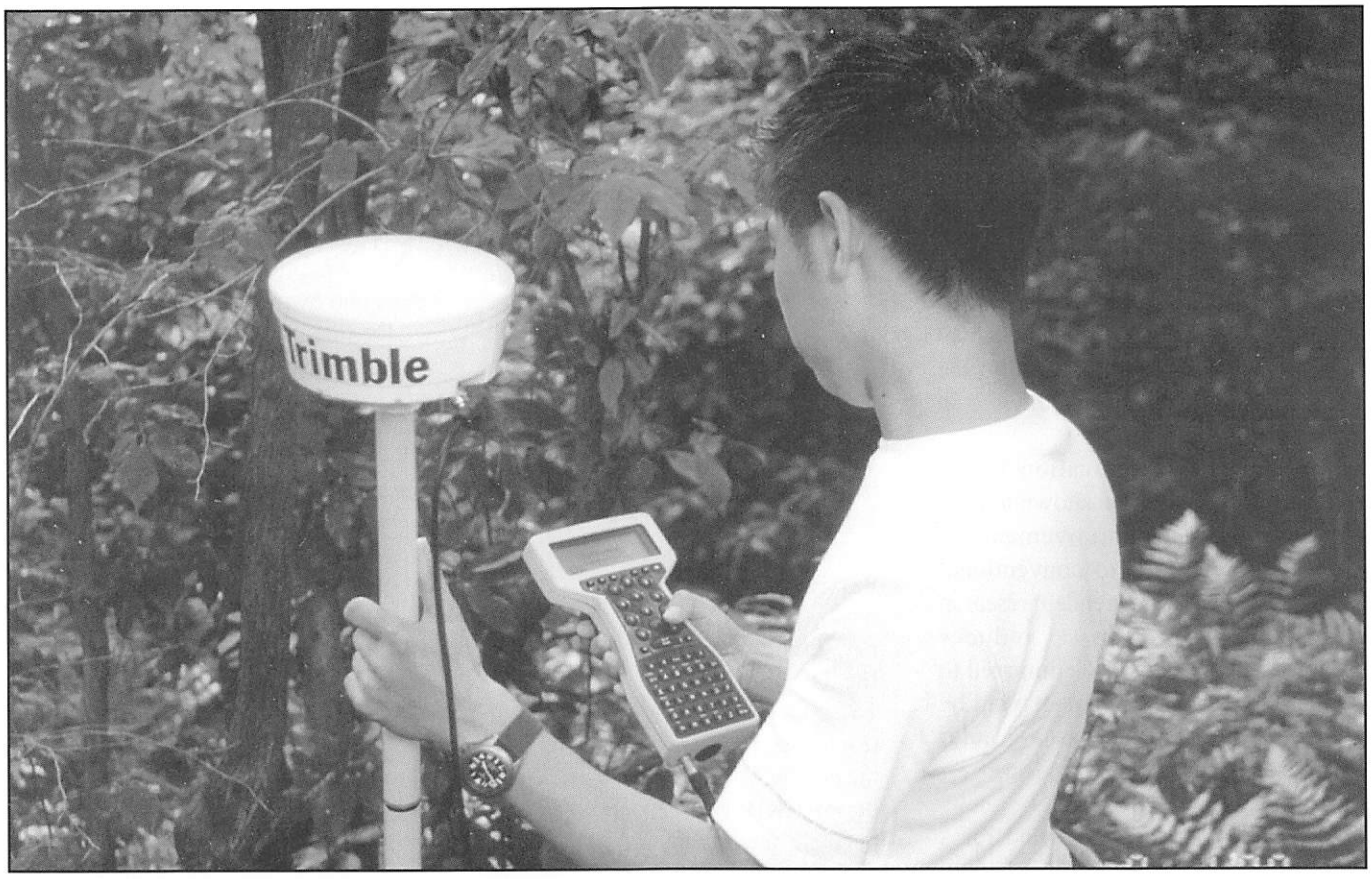
Despite its advantages, the crane has a relatively simple design, the number of articulation and link points having been minimised. This is to improve long term reliability and to reduce service and lubrication points. The tip of the crane and its bearings are also heavily dimensioned to accommodate the extremely high performance of the Valmet 921 harvesting head.

"The new CRH 16 crane is an important development," says Stewart Paul of Partek Forest. "It offers tremendous performance, particularly in its rapid-out and powerful-in telescopic movement and lift capacity. But it is the cranes' ability to operate at close quarters that is also of importance. UK operators will find this makes the CRH and Valmet 921 harvester combination extremely flexible and now well suited to thinnings as well as clearfell.

The Cranab 1600 two-stage telescopic crane will continue to be offered with the Valmet 921.

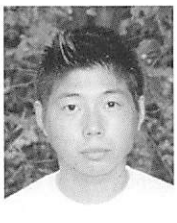
Reach	10.0 m
Gross lifting moment	171.8 kNm
Gross torque	38.0 kNm

Contact: **Partek Forest Ltd, Longtown Industrial Estate, Longtown, Cumbria, CA6 5TJ. Tel: 01228 79**



New techniques in GPS surveying in mountainous areas

Tetsuhiko Yoshimura, Masanobu Takagi and Hisashi Hasegawa


This paper was presented at the 1st International Conference on Forestry Engineering entitled: "Forestry Engineering for Tomorrow", organised by the Forestry Engineering group of the IAgrE and held at the University of Edinburgh, Scotland, UK on 28-30 June 1999.

Dr Yoshimura is Assistant Professor and Mr Masanobu Takagi is a graduate student at the Graduate School of Informatics, Kyoto University, Japan; and Mr Hisashi Hasegawa is Assistant Professor at Kyoto University Forest.

Abstract

It is difficult to capture Global Positioning System (GPS) satellite signals in mountainous areas because slopes or tree canopies block signals coming from GPS satellites. The objective of this study is to mitigate data quality degradation when field conditions adversely impact data capture. Thus, we developed computer software to utilize GPS effectively in forests, which estimates the number of available GPS satellites using Digital Elevation Maps (DEM). As a result of field testing, it was possible to estimate the number of available GPS satellites on the forest road with the discrimination rate of nearly 90%. It was also found that the discrimination rate under tree canopies was 89.1% with a Signal to Noise Ratio (SNR) mask of 0 and 68.3% with a SNR mask of 8. Furthermore, we showed the map of estimating the number of available GPS satellites according to time and location, which would be helpful when surveying at the bottom of valleys where it is difficult to capture GPS satellite signals.

Key words: GPS, mountainous area, number of available GPS satellites, software

1. Introduction

Global Positioning System (GPS) technology is being widely used to determine spatial positions and applied to many areas such as land survey, construction, agriculture, marine or car navigation. In Japan, 68% of land is covered with forests, and terrain is generally very steep. Therefore, it is difficult to capture GPS satellite signals in mountainous areas because slopes or tree canopies block signals coming from GPS satellites. Actually, GPS is not so often used in such adverse conditions compared with in more favourable

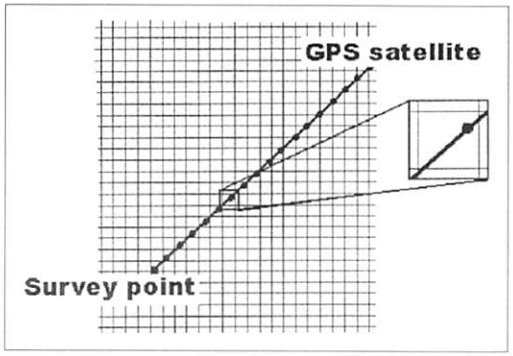


Fig. 1 Points at which the angles of elevation are calculated.

conditions, such as in cities, in farmland or at sea. However, it would be beneficial for foresters, climbers and many citizens who enjoy their holidays in mountains to know their precise spatial positions. Furthermore, GPS is also essential to manage forests effectively and to make forest production sustainable, for example, mapping conservation areas, knowing the location of forest

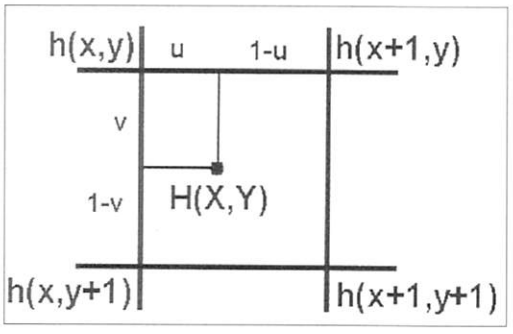


Fig. 2 Bi-linear interpolation.

fire or laying out low-impact forest roads. Our challenge is to undertake necessary steps to mitigate data quality degradation when field conditions will adversely impact data capture. Thus, we developed computer software to utilize GPS effectively in forests, which estimates the number of available GPS satellites using Digital Elevation Maps (DEM) according to time and location.

2. Method

2.1. Algorithm

We developed computer software to estimate the number of available GPS satellites, which had the following algorithm. The grid shown in *Figure 1* is the DEM with an interval of 50 m, published by the Geographical Survey Institute, a national surveying and mapping organization of the Ministry of Construction, Japan. First, a line was drawn from the survey point in the direction of the GPS satellite as shown in *Figure 1*. On this line, we put some points at an interval of 10 m and the angle of elevation was calculated at each point. The heights of these points were determined by using those of the surrounding four points based on bi-linear interpolation. This method is explained as follows:

$$H(X,Y) = uvh(x+1, y+1)+u(1-v)h(x+1, y) + (1-u)vh(x, y+1)+(1-u)(1-v)h(x, y) \quad (1)$$

The variables in this equation are shown in *Figure 2*. If the angle of elevation of the GPS satellite is larger than the maximum angle of elevation of these points *(Figure 3)*, GPS satellite signals can be captured at the survey point. If not, they cannot be captured at the point. We also defined the open sky rate which means the rate of sky to the hemisphere *(Figure 4)*. In *Figure 4*, the white area denotes open sky and the grey area denotes slopes. If the open sky rate is high, the survey point should be located on the ridge. If not, it should be located in the valley.

2.2. Field test

Field testing on the forest road was conducted in Kyoto University Forest in Wakayama *(Figure 5)* on August 14 - 17 and on October 6 and 7, 1998. The average slope of this area is nearly 40 degrees. The GPS receivers used were Lassen-SK8 (Trimble), GPS Pathfinder Pro XR (Trimble), GPS 3000XL (Magellan) and GPS38J (Garmin). Lassen-SK8 and Pro XR were set up with an elevation mask of 0 degree, a position dilution of precision (PDOP) mask of 10 and SNR mask of 3. Both GPS 3000XL and GPS38J are for leisure use and their elevation, PDOP and SNR masks can not be set up or changed. The SNR is a measure of the relative power levels of a communication signal and noise on a data line and is expressed in decibels (dB). In the investigation, we recorded time, PRN codes and the number of GPS satellites captured at 22 points on the forest roads.

On the other hand, field testing in the forest was conducted in Kyoto University Forest in Wakayama on January 7 and April 13, 1999. The GPS receiver used was GPS Pathfinder Pro XR (Trimble). It was set up with a PDOP mask of 10 and an elevation mask of 0 degree. It was also set up with a SNR mask of 0 and 8 at each point. In the same way, we recorded time, PRN codes and the number of GPS satellites captured at 22 points in the forest.

3. Results and discussion

3.1. Field test on the forest road

The summary of the field test on the forest road is shown in Table 1. According to this table, the discrimination rate, that is prediction accuracy, ranged from 84.0 to 89.8% and the accuracy seemed not to depend on kinds of the GPS receivers. Thus, we used the data of Lassen-SK8 and GPS Pathfinder Pro XR in the further

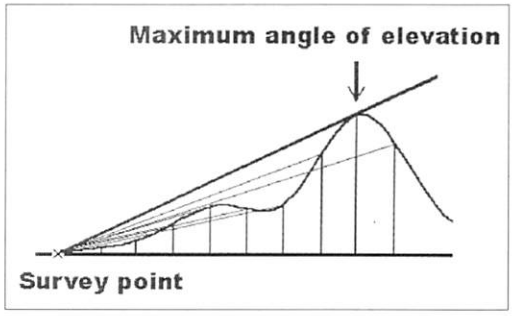


Fig.3 Maximum angle of elevation.

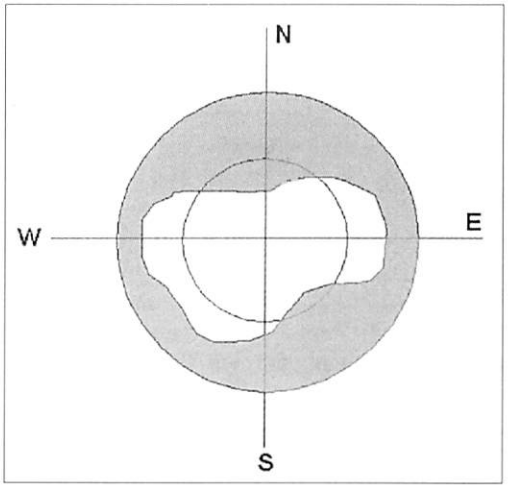


Fig. 4 The open sky rate.

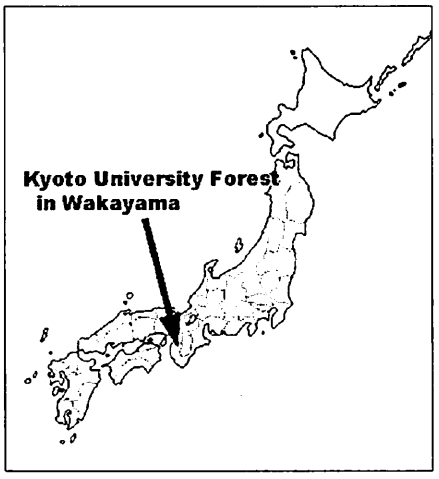


Fig. 5 Study area.

with a SNR mask of 0 and 68.3% with a SNR mask of 8. When the SNR mask is set at 8, degraded signals whose SNR is less than 8 are ignored. This result shows that GPS satellite signals are degraded when passing through tree canopies.

We also analyzed the relationships between the open sky rate and discrimination rate, and the result is shown in *Figure 7*. According to this figure, the discrimination rates with a SNR mask of 0 and 8 range from 78.6 to 96.3% and from 64.3 to 89.3%, respectively. As a result of the field test in the forest, significant relationships between the open sky rates and discrimination rates were not found, too. In conclusion, the discrimination rate was not affected by terrain conditions such as ridges or valleys and the discrimination rate was generally higher than 70% with a SNR mask of 0 and 80% with a SNR mask of 8.

Table 1. Summary of the field test on the forest road.

Receiver	*Total number of survey*	*S/S*	*S/U*	*U/S*	*U/U*	*Discrimination rate, %*
Lassen-SK8	616	360	60	3	193	89.8
Pro XR	817	391	83	5	338	89.2
GPS 3000XL	733	394	87	20	339	87.3
GPS38J	715	354	131	5	361	84.0

Notes: In A/B, A means the predicted number of GPS satellites and B means the actual number of GPS satellites; S means successful capture; U means unsuccessful capture.

Table 2. Summary of field test in the forest.

Receiver	*Total number of survey*	*S/S*	*S/U*	*U/S*	*U/U*	*Discriminating rate, %*
Pro XR with a SNR mask of 0	1214	764	114	18	318	89.1
Pro XR with a SNR mask of 8	1214	500	378	7	329	68.3

Notes: In A/B, A means the predicted number of GPS satellites and B means the actual number of GPS satellites; S means successful capture; U means unsuccessful capture.

analysis. It was also found that the discrimination rate was 53.0% without the use of this software while it was 89.6% with the use of it.

We also analyzed the relationships between the open sky rate and discrimination rate, and the result is shown in *Figure 6*. According to this figure, the discrimination rate ranges from 78.8 to 96.9%. Significant relationships between the open sky rate and discrimination rate were not found. In conclusion, the discrimination rate was not affected by terrain conditions such as ridges or valleys and the discrimination rate is generally higher than 80%.

3.2. Field test in the forest

The summary of the field test in the forest is shown in Table 2. According to this table, the discrimination rate was 89.1%

3.3. Map of estimated number of available GPS satellites

Figure 8 shows an example map of estimated number of available GPS satellites in the studied area. It is obvious that less GPS satellites are available at the bottom of the valley where GPS surveying is often difficult. In GPS surveying, at least four GPS satellites must be captured. Although four or more than four GPS satellites seem to be available at the bottom of the valley, it should be noted that GPS satellite signals are often blocked by tree canopies. Actually, the field test in the forest showed that discrimination rate was only 68.3% with a SNR mask of 8. Therefore, it would be better if GPS surveying at the bottom of valleys was conducted when more than six or more GPS satellites were available. We believe that the map of estimated number of available GPS satellites (*Figure 8*) would be useful for this purpose.

4. Conclusions

As a result of the field test on the forest road, the discrimination rate was 53.0% without the newly-developed software while it was enhanced to 89.6% with this software. In addition, we did not find

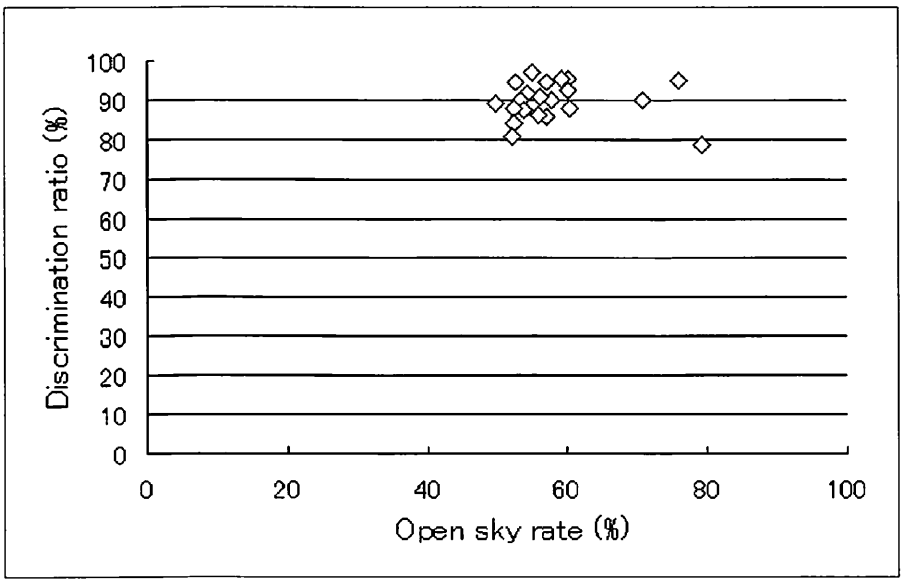


Fig. 6 Relationships between the open sky rate and discrimination rate on the forest road.

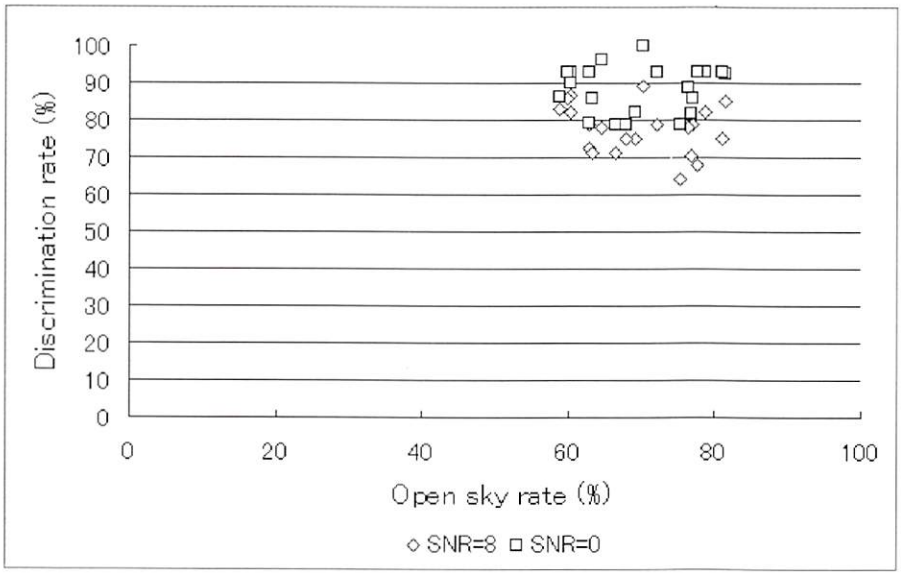


Fig. 7 Relationships between the open sky rate and discrimination rate.

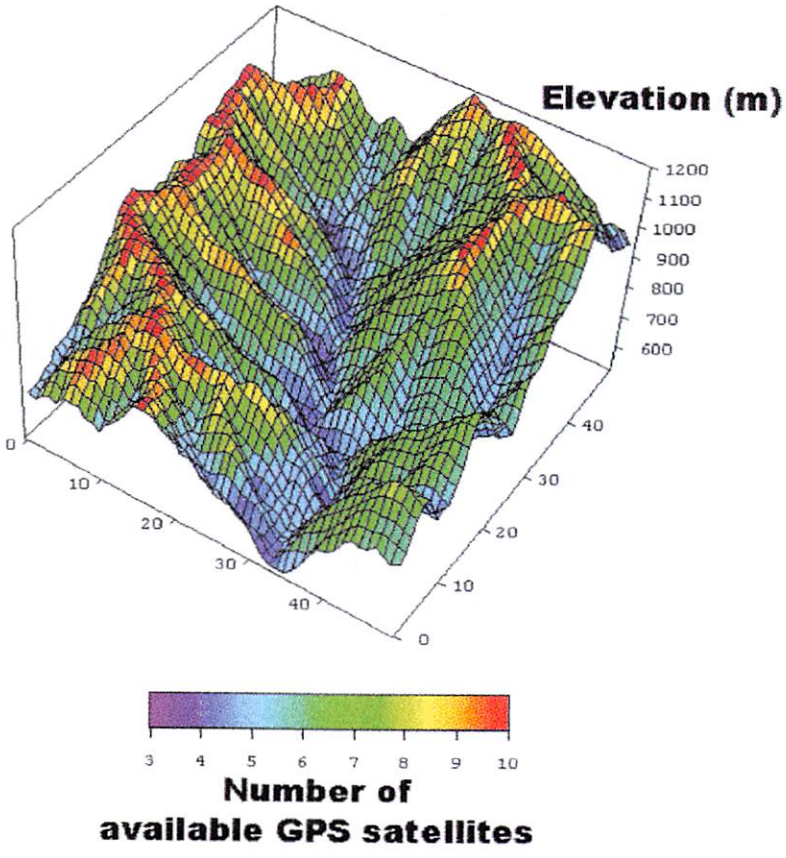


Fig. 8 Map of estimated number of available GPS satellites.

significant relationships between the open sky rate and the discrimination rate and, consequently, the discrimination rate was not affected by terrain conditions such as ridges or valleys. It was also found that the discrimination rate was generally higher than 80% regardless of terrain conditions.

As a result of the field test in the forest, the discriminating rate was 68.3% with a Signal to Noise Ratio (SNR) mask of 8 while it was enhanced to 89.1% with a SNR mask of 0. Significant relationships between the open sky rate and the discrimination rate were not found and the discrimination rate was generally higher than 80% with a SNR mask of 0 regardless of terrain conditions.

In the previous study (Hasegawa *et al.*, 1998), we investigated the accuracy of positions in differential GPS surveying in the same forest as this study. The result showed that the horizontal position error was a CEP_{50} of 2.6 m and a CEP_{95} of 7.4 m, where the circular error probable (CEP_x) is defined as the radius of a circle that includes x% of the error distribution. It was accurate enough for forest management using Geographical Information System (GIS). However, we sometimes could not capture GPS satellite signals when the positions of GPS satellites were unfavorable and such situations often happened especially at the bottom of the valley. The present study is expected to predict when and where we should conduct survey work using GPS and to enhance the efficiency and accuracy of GPS surveying in mountainous areas.

Acknowledgement

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Reference

Hasegawa H; Yoshimura T; Yamate N; Sakai S; Fukuda M (1998). A study on the accuracy and the method of surveying with differential GPS in mountainous areas. Journal of Japan Forest Engineering Society, **13**(2), 89-98 (in Japanese with English summary)

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