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Landwards

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Contents

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Front cover: *New 1365 mower-conditioner plus grouper from John Deere (photo: John Deere Ltd).*

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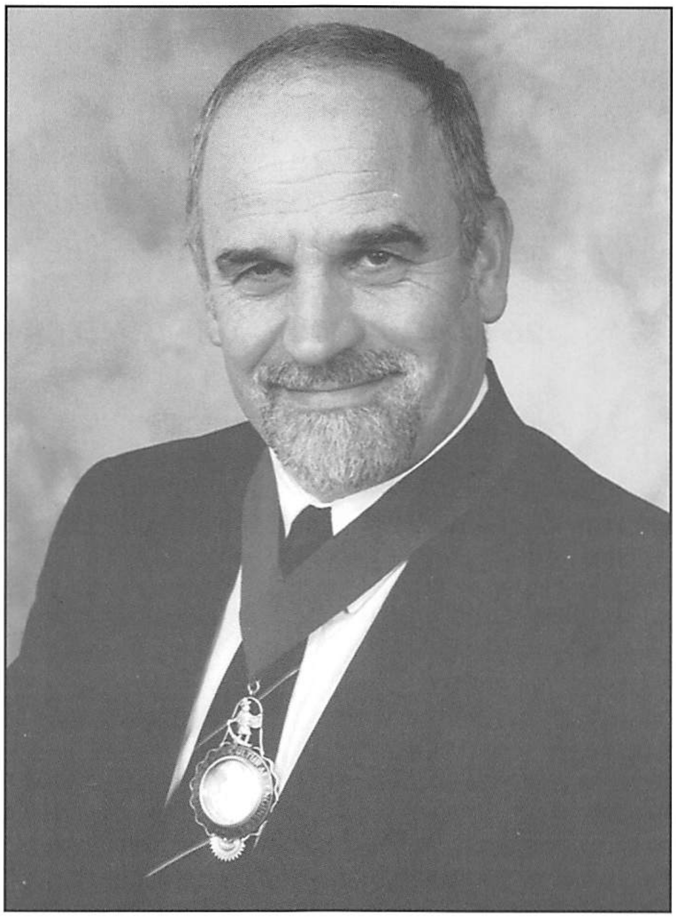
Presidential Address

Geoffrey J H Freedman



Professional Engineering Institutions are under pressure from their members. Numbers are falling and this is confirmed by the fall in Engineering Council registrations. Employers no longer give the support they used to because pressure on profit margins has forced them to cut everywhere, even good value zones. On top of all that, the Institution of Agricultural Engineers (IAgrE) membership comes from a shrinking industry, however the Institution has found efficiencies and through difficult times has maintained a full service to members; but nevertheless, they want more - they want value for money just like everyone else these days.

First let me explain what a professional Institution does for its members. It maintains the high professional standards demanded by today's industry. It accredits the academic courses and sets the review standards for the various membership grades. Without that service, employers would be searching in a wilderness for properly qualified personnel. The Institution sets the Continuing Professional Development (affectionately known as CPD) standards which maintain the assurance that this valuable asset retains its value. The Institution creates the forum for exchange of professional experience and knowledge. Our journal and conferences present the necessary fabric for research and practical development work, to be presented and recorded for the use of others in the industry. Our international links bring knowledge and new ideas from other parts of the world and avoids duplication of research effort. Our bulletin, newsletter and website keep the busy membership informed in an efficient, professional and friendly manner. Our extensive database offers members the opportunity to contact others who hold particular expertise in a specific field.

These services, like everything else, come at a cost and the only income the Institution generates is from membership fees plus a little from the proceeds of conferences. It has been a constant battle over the last 5 years to maintain the full service, with membership reducing from 2000 to 1700, but we have succeeded; however, resources are presently stretched to the limit. Unless we take action, I think the trend will be downwards so we have now set a plan into action to move forward, rather than just try to mark time at the brink. We discounted raising the fees more than inflation because the personnel in the industry are not generally well paid. We are avoiding amalgamation because of the fear of losing our particular focus which I feel is one of our greatest assets. However, numbers are the key to reduced costs.

We are therefore planning to recruit from outwith our closed agricultural engineering community. We feel that engineering is central to so many rural industries and IAgrE could form a hub for a number of groups which are quite small and do not have our status as a nominated body of Engineering Council. I am thinking of those in water, land management and technology, equestrian studies, *etc*. Even if these members are not Engineers, they can gain from links with engineers working in the rural industries. To achieve this, we have set up a research programme, to be completed by the end on this academic year, in order to identify these people and societies and report back to Council. We will then embark on a new well planned recruitment drive. Like all good ideas this is not a new one - it has been successfully carried out by our sister organisation, the American Society of Agricultural Engineers (ASAE) in the United States. We are however not putting all of our eggs in the one recruitment basket, we have a number of other initiatives running parallel - *e.g.* Commercial Membership, targeting students, and incentives for members to bring colleagues into the fold.

Everything in this recruitment plan will cost money and we have made a policy decision to pay from our savings, and not from fees which will be held in line with inflation. Council has agreed to spend what will amount to about 10% of our funds for about three years to try to turn things around.

This Institution has been responsible for the coordination and development of so much innovation in the UK over the last 70 years. Tractors were in their infancy and implements were crude. As a result of invention and research, the unit cost of food has plummeted and in a way we are victims of our success. This downward pressure on prices seems set to continue and will therefore require further efficiencies many of which can only be provided by Agricultural Engineers. This will not be easy because efficiencies are already so high - we are now in the era of 'set aside' and in certain technical areas further development is no longer necessary. However Agricultural Engineers, with their inborn ingenuity, will come up with exciting new challenges to increase efficiencies as they always have done. The Institution's network will then spread until the right groups are found to solve these new problems.

Over the last 10 years the Institution has embraced Forestry and many exciting developments have been reported at IAgrE meetings during that time. Indeed it has been the specialist groups, *e.g.* Forestry Engineering, Horticultural Engineering, Soil and Water Management and Pioneering Technology which have been much of the driving force behind Institution activities over recent years. The local geographic branches maintain links regionally, but the common professional links have been maintained through conferences held by specialist groups.

The Institution may be stretched as it has never been before but the excellent personnel at our Headquarters, supported by the many hard working volunteers, are holding the ship steady and working hard to achieve these new goals which will bring renewed health to IAgrE.

I am going to finish now with an important message of policy. During my Presidency this Institution will not lose its identity and will not amalgamate. It will maintain its own distinct focus on rural engineering. It will continue to provide the traditional service to members as it has done since its beginnings nearly 70 years ago.

The Institution is Mother, Father and Mentor to all of its members. Throughout any successful career, there are liable to be a number of changes in employment - so where does the stability come from? The Institution. It advises you at school and accredits your university course. It sets the standard for your full professional status when you become a master at your craft. It ensures that you keep up to date throughout your career. It rewards you for special achievements with Awards from you peers. Finally when you retire, your Institution provides a place for you to have some influence and help maintain the high standards you have always cherished. In fact, to an active member, the Institution is one of the very few stable influences which one can rely on and benefit from throughout. My message is, therefore, Industry needs Professional Institutions to maintain their development and standards and the members need them to maintain control throughout their life career. Your Institution is not a club you join after University and show face a few times until you get your Charter. Your Institution is for life.

Hanson funds compost drive across the UK

People across the UK are being given a chance to go to 'compost school', and help to reduce the 27 million tonnes of household waste produced in this country each year, thanks to a £42,000 grant by the Hanson Environment Fund.

The Community Composting Network is currently establishing a national network of 15 Composting Demonstration Sites for community composting. The centres will provide demonstration facilities to encourage community groups or individuals to set up their own composting sites.

The award will equip 15 current community composting sites to make them Composting Demonstration Sites - providing information boards, newsletters, 'mucktrails' around the sites, facilities for people to obtain their own composting equipment and home visits to show householders how to use home composting bins. Once established, the sites will be used to host visits, run training events and answer composting queries over the 'phone.

In encouraging home and community composting, the scheme will directly tackle new legislation aimed at reducing the amount of green waste going to landfill.

The £42,000 grant includes a contribution from Heeley City Farm. Under Government regulations only 90% of a grant can be provided from landfill tax, the remaining 10% must come from another source.

This is one of a growing number of projects to benefit from the £4 million a year Hanson Environment Fund - one of the largest schemes set up as part of the landfill tax credit system. The fund, established in October 1997, uses landfill tax credits generated by Hanson's waste management division.

Nigel Sandy, board member of the fund, said: 'With drives towards cutting down, and eventually banning, green waste from landfill it's important that viable solutions are found for the disposal of this waste. Home and community composting are such methods, and the Community Composting Network's work in encouraging this is a good step in the right direction.'

David Middlemas, co-ordinator for the Community Composting Network, said: 'Thanks to the Hanson Environment Fund, the Centres of Excellence project will enable reasonable access to a composting demonstration site, providing training and advice in community composting to everyone in the UK.'

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Precision farming - a multidisciplinary approach for cereal production

Richard J Godwin

Abstract

This paper reviews the results after 3½ years of a 5½ year study to develop practical guidelines for precision farming for cereal producers in Britain. The early years of the study established the background variation within the four selected fields. Soil texture together with its associated water holding capacity and variations in nitrogen were considered to be the most significant. Strip experiments were conducted which ran through the historically good, average and poor parts of the fields to test various nitrogen management strategies. Whilst different yield versus nitrogen response curves were obtained for different parts of the fields, the most promising longer term management approach would be to base the variable nitrogen application rate on the number of tillers/shoots immediately prior to fertilizer application. Aerial digital photography provides an effective method of rapidly assessing shoot density within a field. Experiments examining seed rate variation showed there are significant economic benefits from reducing seed rates below currently recommended levels. This resulted from improvements of yield and savings in seed costs. The effects of water logging can be very significant.

Practical conclusions are given that can assist farmers in identifying and correcting causes of variation together with suggestions for further work in the development of precision farming.

This keynote paper was presented at the International Conference SEAg 2000, held in Adelaide, Australia, 2-5 April 2000, and is published by permission of the author, with full acknowledgement of the Conference Organisers. Professor Richard Godwin is Head, Institute of AgriTechnology, Cranfield University at Silsoe, Silsoe, Bedford MK45 4DT, UK; e-mail: r.godwin@cranfield.ac.uk

1. Introduction

This paper provides an overview of the approach taken by Cranfield University and its partners, namely: Arable Research Centres, AGCO Ltd (Massey Ferguson), Hydro Agri and Shuttleworth Farms, to develop practical guidelines for implementing precision farming technology for the UK cereal industry by:

(i) developing a methodology for identifying the causes of within-field variation,

(ii) exploring the use of remote sensing methods to enable management decisions to be made in 'real-time' during the growth of the crop,

(iii) determining the potential economic benefits of precision farming,

(iv) collaborating with farmers to ensure that the research findings are appropriate for adoption.

Reference will be made to parallel work undertaken by the team as appropriate. The emphasis of this work is placed on practical application that shows a benefit to the farmer by providing tools that can help him manage an ever-increasing size of enterprise when the economic margins are under great pressure. The concept of managing parcels of land with different soil and agro-climatic factors in a spatially variable manner to optimise the economic returns is not new, as our forefathers used the same approach when allocating field boundaries. It is the technology that assists in recognizing the spatial boundaries together with equipment for yield recording and the variable application of agronomic inputs that has created much excitement in recent years. The advent of affordable differential global positioning systems started the development, with a number of yield mapping systems appearing on the market from 1990. A conceptual model of the principles of precision farming is shown in *Fig. 1*.

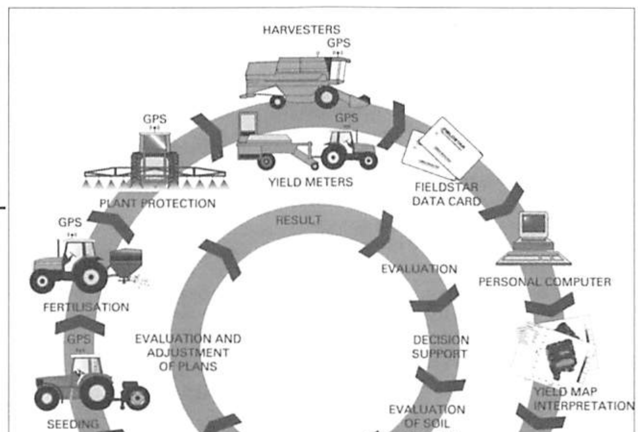

Fig. 1 Overview of Precision Farming system (courtesy of AGCO Fieldstar)

Agricultural engineers have been the core to these developments, where engineers with expertise in instrumentation and control, information technology, soil management, soil and water engineering, remote sensing, geographical information

Table 1 Factors influencing yield variation

Little control	*Possible control*	
Soil texture	Soil structure	pH levels
Climate	Available water	Trace element levels
Topography	Water-logging	Weed competition
Hidden features	Nutrient levels	Pests and diseases

systems, and field mechanization have joined forces with soil surveyors, agronomists and crop nutritionists. Whilst there have been, and still are, challenges to the hardware and software aspects of the precision farming system, the single greatest challenge is in combining the information from yield maps, crop performance records (both historic and 'real time') and soil analysis into a practical strategy for the variable application of crop treatments for a particular field.

2. Approach

The factors in Table 1, after Earl *et al.* (1996), show those which could influence the yield of crops in a given location. Those on the left of the table have to be considered as they can have major effects upon yield yet there is little that can be done to control them. The factors on the right, however, can be manipulated in a spatially variable manner and could lead to economic benefits from either (i) yield improvements due to increases in input or (ii) savings in input costs without an adverse effect upon crop yield.

The main HGCA funded study was planned for five cropping seasons with harvests in 1996-2000, where each of four fields (typical of approximately 55% of the land used for cereal production in England and Wales) were selected as they had been in continuous cereals for several years prior to the experimental work. AGCO Ltd. harvested and produced yield maps for the fields during the 1995 harvest.

At the outset of the project, it was agreed that the reasons for the underlying field variation needed to be established prior to managing the crop in a spatially variable manner. Hence, uniform 'blanket' treatments were applied in the 1995-6 and 1996-7 seasons. The yield maps for these two seasons, together with that of the 1995 harvest, provided an indication of crop yield variation both in space and time. Since the 1997-8 cropping season, variable inputs of both nitrogen and seed have been studied, together with other significant corrective factors.

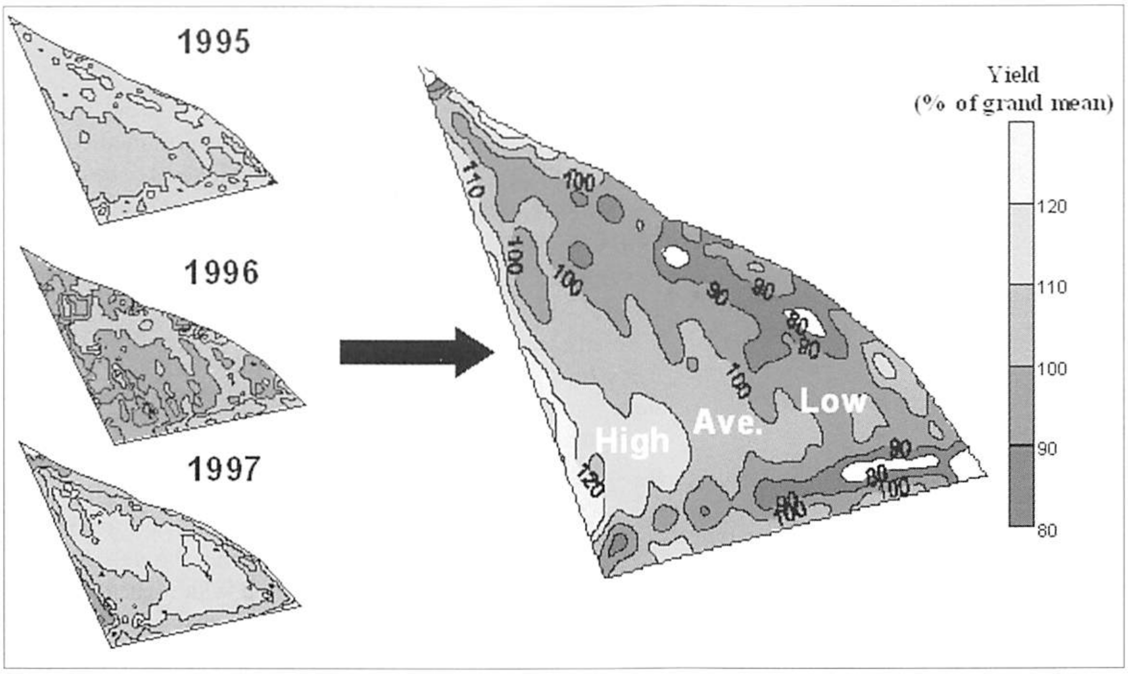

Fig. 2 Spatial trend map for yield at Trent Field, Andover 1995 - 1997

3. Background variations

3.1. Crop yield

Typical variations in crop yield can be seen in *Fig. 2*, which shows that there is some similarity over the three-year period. The spatial trend map (Larschied *et al.*, 1997) for the period shows that, on average, the yield range is in excess of 20% of the mean, with the higher yielding zones to the west and the lower yielding zones to the east of the 100% (or mean) contour. These maps have been corrected using the algorithms developed by Blackmore and Moore (1998) to compensate for field operational problems of combine harvester grain filling at the headlands and crop harvesting widths of less than the full width of the combine harvester cutter bar.

3.2. Soil types

The fields were initially surveyed at a commercial detail level of approximately 1 auger hole/ha to give an overview of soil textural and profile variation. These were followed by 'targeted' profile pit observations. The positions of the profile pits, 3 m long by 1 m wide by 1.5 m deep, were selected to encompass the range of yields observed in the spatial trend map and from the results of auger sampling. These pits were to provide detailed information for soil classification and information on crop rooting depth and soil drainage status. The farmers were present in the field during this activity and in each case it was the first time they had seen the soil below a depth of 0.3 m in a number of locations in the same field. They were intrigued by the results. Photographs taken of these geo-referenced soil profiles can be passed to successive generations and have greater impact than traditional written profile descriptions.

Further studies with both soil coring apparatus (to a depth of 1 m) and electromagnetic induction (EMI) equipment (Waine, 1999) gave improved

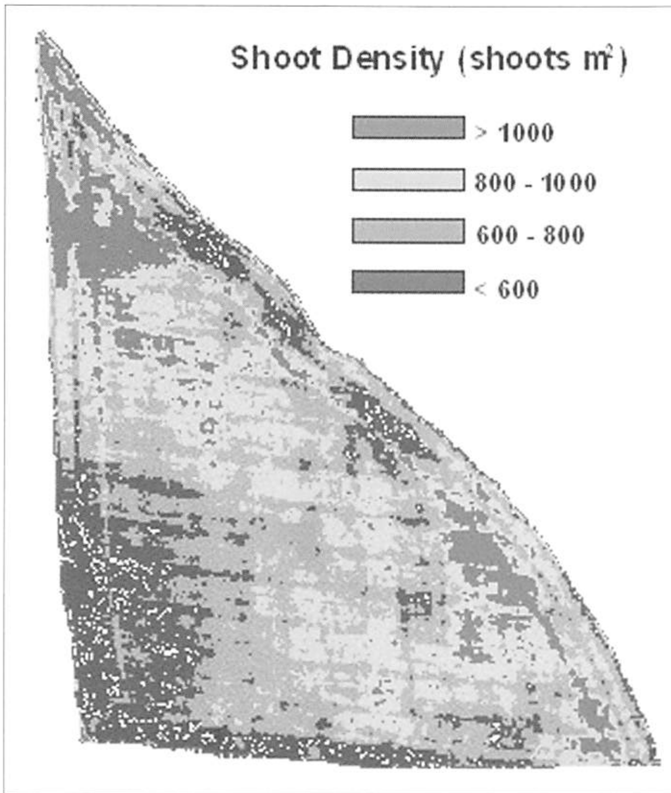

Fig. 3 Normalised Digital Vegetation Index (NDVI) image of Trent Field, Andover

resolution to soil textural boundaries. The latter technique is particularly applicable in areas without saline conditions, which are at field capacity for a period of the year. This enables the soil texture to be estimated and can also provide an indication of the available water between field capacity and permanent wilting point.

3.3. Soil fertility and crop nutrition

Detailed analysis of macro- and micro-nutrients in both soil water extract and plant tissue was conducted at 100 m grid spacings. These indicated that whilst there was variation in each of the fields, none were below the critical threshold for crop growth.

3.4. Crop canopy

Variations in crop canopy occur both in space and time in the same field. To obtain consistent and reliable data to monitor crop development for 'real time' management and to explain field differences, a light aircraft was equipped with two digital cameras fitted with red (R) and infrared (IR) filters. Field images obtained from aerial digital photography (ADP) of the fields from a height of 1000 m (Wood *et al.*, 1998) give a pixel resolution of 0.5 m by 0.5 m. Normalised Difference Vegetation Index (NDVI) values were estimated using Eqn 1.

$$\mathrm{NDVI} = \frac{\mathrm{IR} - \mathrm{R}}{\mathrm{IR} + \mathrm{R}}$$

The resulting images, such as *Fig. 3* (normally in colour), show the effect of variations in crop development immediately prior to the first application of nitrogen. These images are (i) immediately valuable in recognising patterns of field variability, and (ii) provide detailed spatial data on crop tillers/shoot density. These data, when calibrated against detailed agronomic measurements at targeted locations, can be used in near 'real time' to estimate crop condition and potential nutritional requirements.

3.5. Interim conclusions from the field variability studies

(1) Major causes of yield variation in the study fields were
- soil and its associated water holding capacity
- spatial variation of nitrogenous fertilizer

(2) Potassium, phosphorus and the micro-nutrients were not limiting.

(3) Yield map sequences can identify stable yield patterns.

(4) Aerial digital photography (ADP)
- allowed variations in crop yield components to be mapped in near 'real time'; and
- can be used with confidence to monitor the effects of variable and uniform applications.

4. Variable application of nitrogen

4.1. Experimental design

One of the aims of this project was to develop an experimental methodology that could be employed by farmers to determine an optimal application strategy for a given input in any particular field, in this case nitrogen. To achieve this, it was important to use standard farm machinery for the experiments. This resulted in a move away from the traditional small plot randomised block experimental design.

In line with the suggestions made by Thompson and Robert (1995), the proposed design comprised a series of long strips, which ran through the main areas of variation within each field, an example of which is given in *Fig. 4*. The width of each strip was dependent upon the existing tramline system and/or the working width of the machinery available. The treatment strips were, therefore, half the width of a tramline. The fertiliser was applied using a

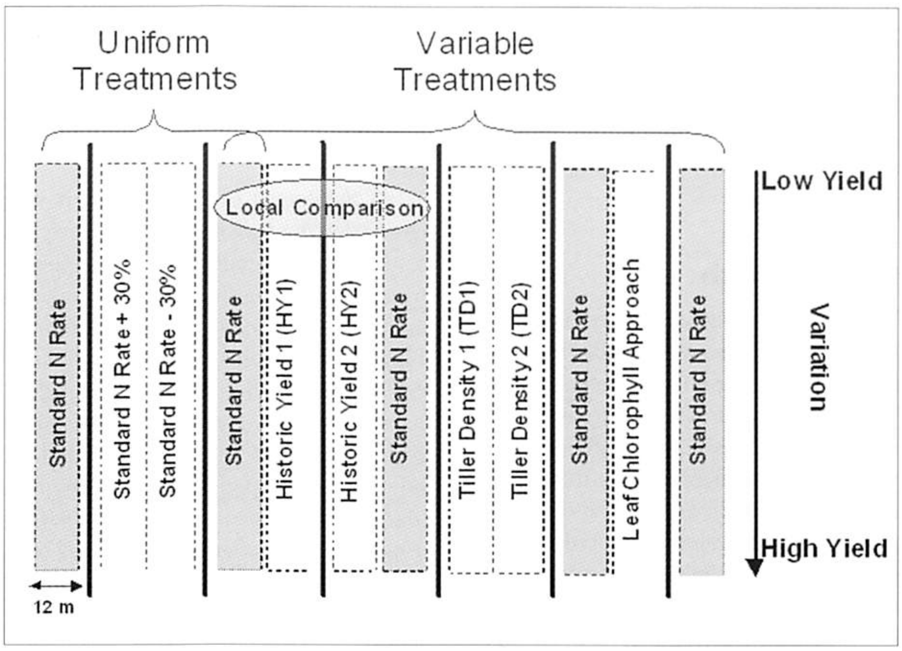

Fig. 4 Plan of field experiments

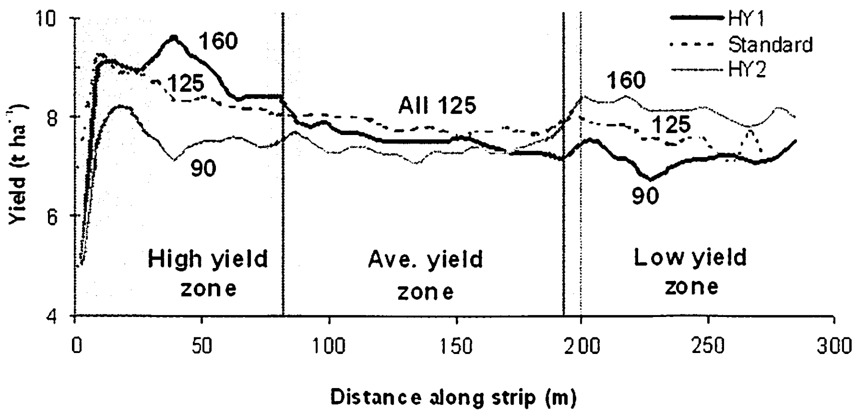

Fig. 5 Combine yield of 'Historic Yield' treatments (HY1 & HY2) compared with a standard application along the treatment strips; numbers in bold refer to the nitrogen application rate in that section of the field; shaded areas represent transition zones i.e. initial fill time of combine and fertilizer overlap areas between sections, which were omitted from the analysis

pneumatic fertiliser spreader that was capable of operating the left and right booms independently. The strip widths used allowed the experiments to be harvested by the combine harvester without the inclusion of the tramline wheel marks.

4.2. Treatments

Two types of treatment were conducted on each of the sites, uniform and variable.

(a) Uniform treatments

These treatment strips had different rates of nitrogen applied uniformly along their complete length. The purpose of this was to provide an indication of the crop response to different levels of nitrogen in the various management zones.

(b) Variable treatments

These treatment strips were established to test the following strategies (Welsh, *et al.*, 1999):

(i) increasing the fertilizer application to the better, or potentially better, yielding parts of the field whilst reducing the application to the poorer yielding parts;

(ii) reducing the fertilizer application to the better, or potentially better, yielding parts of the field whilst increasing the application to the poorer yielding parts.

However, before these strategies could be implemented, the high, average and low yielding zones had to be identified. Two methods were used:

(i)historic yield data, as shown in *Fig. 2*

(ii) tiller density data, estimated from NDVI data, as shown in *Fig. 3*.

Using this approach, experimental strips, as shown in *Fig. 4*, were established to give the following treatments:

• *Historic Yield 1 (HY1)* - high yield zone received 30% more nitrogen; average yield zone received the standard nitrogen rate; and the low yield zone received 30% less nitrogen;

• *Tiller Density 1 (TD1)* - high tiller density zone received 30% more nitrogen; average tiller density zone received the standard nitrogen rate; and the low tiller density zone received 30% less nitrogen;

• *Historic Yield 2 (HY2)* - high yield zone received 30% less nitrogen; average yield zone received the standard nitrogen rate; and the low yield zone received 30% more nitrogen;

• *Tiller Density 2 (TD2)* - high tiller density zone received 30% less nitrogen; average tiller density zone received the standard nitrogen rate; and the low tiller density zone received 30% more nitrogen.

Standard N rate strips were located adjacent to each of the variable treatment strips to allow treatment comparisons to be made, since classical experimental design and statistical analyses with replicated plots is not possible.

4.3. Results

An example of the yield distribution along the historic yield strips is given in *Fig. 5*. This shows the benefits of adding additional fertilizer to the high yielding zone and the consequences of reducing the fertiliser application to the low yielding zone. Nitrogen response data from 2 fields are shown in *Fig. 6*. This indicates that the Andover series soil area of Trent field not only performs better than the Panholes series, but that it benefited from additional nitrogen. In contrast to this, the results from Twelve Acres show different maximum yields in the three soil series zones, although the optimum nitrogen application rate remains constant.

The results of two harvests would indicate the greater reliability of the tiller density/canopy management approach to managing the nitrogen application.

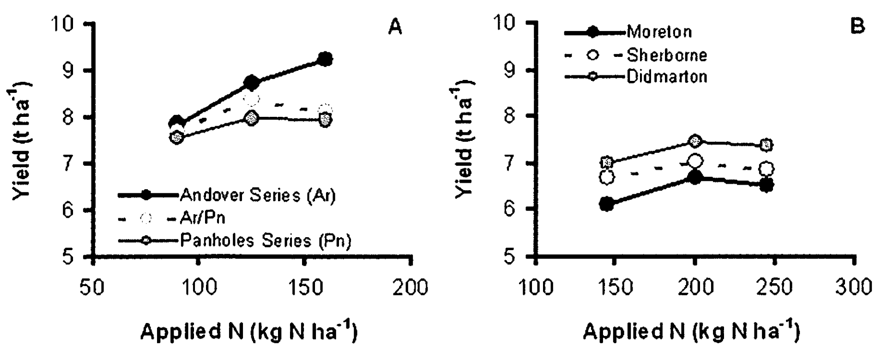

Fig. 6 Localised yield responses to applied nitrogen at (A) Trent Field, Andover and (B) Twelve Acres, Cirencester

5. Variable seed rate and canopy management studies

Similar strip experiments were established to study the above by varying seed rates to provide a range of crop canopy conditions (Wood *et al.*, 2000). The results are still under investigation, however, the immediate results support the capability of ADP as an indicator of canopy condition and show that whilst there are initial differences in crop establishment with seed rate there is significant tiller compensation. The most immediately valuable result is that farmers can reduce seed rates from the current level whilst maintaining or improving yields, thus providing economic benefits through savings in seed costs and, in some instances, improved output (*Fig. 7*). The results shown in *Fig. 8* illustrate the very dramatic effect that localised water logging can have on the yield of a given strip as it passes from high ground on the left through the low-lying ground in the centre. The effect of crossing a single tile-drain line can be seen at (**A**). Localised yield penalties of up to 4 t/ha resulted.

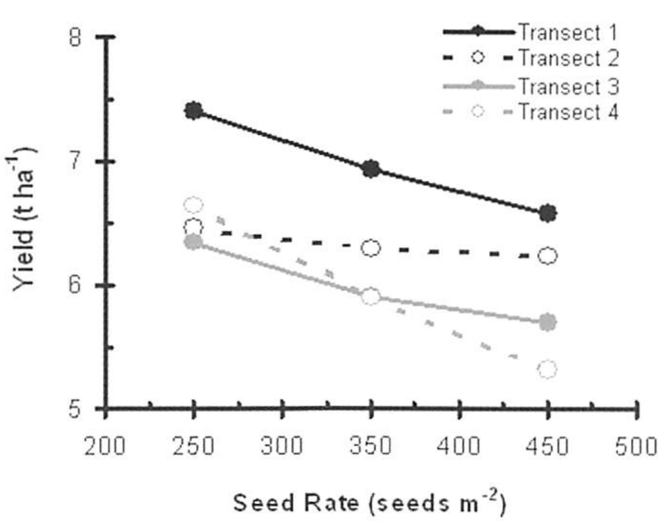

Fig. 7 Yield response to varying seedrates at Onion Field, Bedfordshire in 1998

6. Economic Implications

The results in *Fig. 6* have shown significant variation in the crop yield *versus* nitrogen response curves where in certain conditions the peak yield occurs at significantly different nitrogen application rates. Hindsight analysis can then most definitely show significant economic benefits as discussed by Godwin *et al.*, (1999). Some fields, however, show different parts having different levels of response but the 'peak' yield occurs at the same nitrogen rate. Whilst the 'most economic rate of nitrogen' (MERN) (Kachanoski *et al.*, 1996) would be different for each level of response the effect of this in practice would mean only very slight modifications in N application rate of 5 - 10 kg/ha. Wood *et al.* (2000) demonstrated that savings in seed rate and additional yield produce average benefits of £31/ha ($70/ha) while the impact of water logging reduced the return by £70/ha ($160/ha) for the field, which would be easily offset by reinstalling the network of mole drains (£15/ha/year) over the existing field drains.

7. Conclusions

(1) There is variation in yield in cereal fields in excess of 20% about the mean.

(2) Yield response to nitrogen varies within individual fields.

(3) Yield maps are of great assistance in understanding the causes of variability by directing targeted sampling. Routine grid sampling is too expensive.

(4) Electromagnetic induction can provide positive indication of soil textural variability in areas without salinity problems.

(5) Aerial digital photography is proving to be a powerful tool in spatially managing nitrogen applications in near 'real time'.

(6) Managing both nitrogen and seed rate can individually give economic returns of approximately £20/ha ($45/ha) depending upon soil conditions.

(7) Calculate the 'take off' of P&K from yield maps and apply using a replacement strategy.

(8) Strip experiments with yield mapping combines can be implemented on farms for local evaluation of site specific problems.

(9) Get the fundamentals of crop production right - take the trouble to correct the factors that should have always been corrected!

(10) Know your soils - photograph profile pits as a long term 'one-off' investment.

8. Future requirements

• Techniques to estimate the potential benefit of precision farming for a given farm enterprise prior to investment of capital and time.

• Further development of aerial digital photography for crop nitrogen management in real time.

• Product quality mapping and crop quality management.

• The development of 'traceability' records to satisfy consumer concerns (Miller, 1999).

• Tilth sensing and seed placement.

• Application to other crop sectors (Godwin *et al.*, 1997 and 1999).

• New and multiple link sensors (Miller, 2000) for determining crop nutrient and disease status.

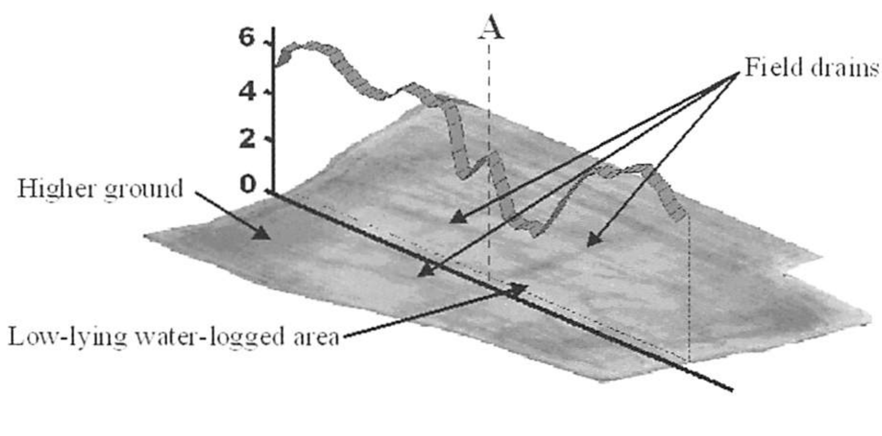

Fig. 8 Yield depression resulting from severe water-logging at Onion Field, Bedfordshire in 1999

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Intellikraft ignition system transforms the future of 2-stroke engines

A new ignition system is breathing new life into the future of 2-stroke engines, the use of which is being increasingly restricted by legislation because they are so polluting and so numerous. Two-stroke engines are fitted across a wide range of machines, from scooters and pleasure boats to lawn mowers.

As an example of the level of pollution, it is estimated that an average outboard 2-stroke motor is 250 times more polluting than an average car. The US Environment Protection Agency estimates that every year pleasure boats spill as much oil as 15 Exxon Valdez disasters - and there are 9 million powerboats in the US alone.

In the case of scooters their use is increasing - largely due to the growing problem of inner city traffic congestion - in 1999 UK scooter sales increased by 77 %.

Legislation is about to be implemented in the US that will prohibit the use of 2-stroke engines in lawn mowers within a few Years.

This new ignition system, that uses IntelliKraft technology, at once increases the performance of the engine and decreases the level of pollution. Tests conducted earlier this Year by an Italian scooter manufacturer show the ignition system:

- increases the power and torque of 2-stroke engines by up to 20% at over 9,000 rpm;
- reduces CO emissions by 23%.This new IntelliKraft ignition system achieves these impressive results because it does not rely on coils, but on smart transformers made of a breakthrough piezoceramic material manufactured using nanotechnology. This material gives the ignition system superior perfomance for the following reasons.

- The input to the combustion chamber is controlled digitally.
- It utilises a modified spark plug that produces a plasma glow that fills the entire chamber and burns the fuel with extreme efficiency.
- The system is 'smart' because the properties of the IntelliKraft material automatically adjust the discharging voltage and current every 12.5 microseconds to meet the fuel burning requirements in the combustion chamber.

'Concerns, about controlling emissions are more acute than ever before', says Andrea Mica, Sales Director of Intelligent Power Systems, the company promoting the technology. 'The beauty of the IntelliKraft system is, it gives very impressive results and the technology can be applied to every type of spark ignited engine.'

Contact: **Andrea Mica, Intelligent Power Systems. Tel: 01491 411022. Web site: www.intellikraft.com**

Developing a fuzzy logic controlled agricultural vehicle

Hani Hagras, Victor Callaghan, Martin Colley and Malcolm Carr-West

Malcolm Carr-West

Abstract

This paper describes the design of a fuzzy controlled autonomous robot for use in an outdoor agricultural environment for crop following. The robot has to navigate under different ground and weather conditions. This results in complex problems of identification, monitoring and control. In this paper, a fuzzy controller is identified which when used in conjunction with a novel outdoor sensor design deals with both crop tracking and cutting. The controller was tested on an indoor mobile robot using two ultrasound sensors. The controller showed a good response in spite of the irregularity of the medium as well as the imprecision in the ultrasound sensors. The same controller was then transferred to both an electrical and diesel powered robots which operate in an out-door farm environment. These outdoor robots have used our novel sensor (mechanical wands) as well as outdoor ultra sound sensors. The robot had been tested in outdoor environments on fences and real crop edges. The robot displayed a good response following irregular crop edges full of gaps under different weather and ground conditions within a tolerance of roughly 50 mm.

Hani Hagras, Victor Callaghan and Martin Colley are at The Computer Science Department, Essex University, Wivenhoe Park, Colchester, England, UK; and Malcolm Carr-West is at The Agricultural Engineering Department, Writtle College, England, UK.

1. Introduction

The problem of a decreasing agricultural workforce is universal. Therefore, there is a need for automated farm machinery, ultimately including unmanned agricultural vehicles. Many machinery operations in agriculture are essentially repetitive and work with crops planted in rows or other geometric patterns. These operations involve making a vehicle drive in straight lines, turn at row ends and activate machinery at the start and finish of each run. Examples of this are seen in spraying, ploughing and foraging.

In agriculture, the inconsistency of the terrain, the irregularity of the product and the open nature of the working environment result in complex problems of identification, control and dealing with sensing errors. These problems include dealing with the consequences of the robotic tractor being deeply embedded into a dynamic and partly non-deterministic physical world (*e.g.* wheelslip, imprecise sensing and other effects of varying weather and ground conditions on sensors and actuators). Fuzzy logic excels in dealing with such imprecise sensors and varying conditions which characterises these applications.

Artificial intelligence (AI) techniques including expert systems and machine vision have been successfully applied in agriculture. Recently, artificial neural network and fuzzy theory have been utilised for intelligent automation of farm machinery and facilities along with improvement of various sensors. Ziteraya and Yamahaso (1987) showed the pattern recognition of farm products by linguistic description with fuzzy theory was possible. Zhang *et al.* (1990) developed a fuzzy control system that could control maize drying. Ollis and Stentz (1996) has used machine vision to follow and cut an edge of a hay crop but he did not address the problem of turning around at the end of bouts or the detection of the end of a crop row. Cho and Ki (1996) has used a simulation of a fuzzy unmanned combine harvester operation but he used only on-off touch sensors for his fuzzy systems and hence lost the advantage of fuzzy systems in dealing with continuous data which had led him not to have smooth response and gave him problems when turning around corners. It must also be noted that all of his work was in simulation which is different from the real world farm environment. Yamasita (1990) tested the practical use of fuzzy control in an unmanned vehicle for use in greenhouses. Mandow *et al.* (1996) had developed the greenhouse robot Aurora, but the application and environment variation in greenhouses are more restricted and controlled than those in the field. Little work has been done in implementing a real robot vehicle using fuzzy logic which can operate in the open field.

The aim of this paper is to develop a fuzzy vehicle controller for real farm crop following. An emulation of 'crop-

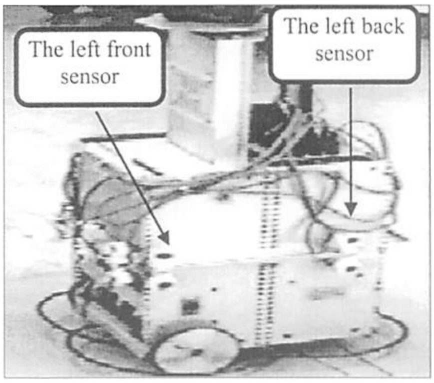

Fig. 1 The indoor robot and its sensor configuration

following' (which is also an example of fence following) is presented and its response and control surfaces are analysed. Then the same control architecture was moved to our outdoor robots. These robots are equipped with special outdoor sensors (a mechanical wand and an outdoor ultra sound sensor) which are designed to deal with the crop characteristics. The fuzzy controller has succeeded in following various outdoor crop and fence edges ranging from metal structures, lines of trees, to crops of hay (including irregular edges which include small gaps) within a tolerance of 50 mm. It has shown it ability to turn different kinds of corners smoothly and worked in a variety of weather and ground conditions.

2. Problem definition

In this section, we introduce the architecture of the robot and describe our novel sensor design which is suitable for sensing crop boundaries. The robot is designed to mow a crop by following its edge while maintaining a safe distance from the uncut edge, in this case 450 mm. While the development work has been based on mowing, the team have taken into account the requirements of other fieldwork operations.

Initially, we have tested our design with an indoor mobile robot, introducing to it all the hard conditions that it might encounter in a real field. Although there are clearly big differences between the indoor environment and that in the field, we have done what we could to make the experiments more realistic, such as using noisy and imprecise sensors, irregular geometrical shapes and fences constructed from baled hay. However, it is-self evident that ultimate test of a farm robot is in the field and we thus included as a subsequent stage an assessment based on the use of our outdoor electric and diesel_-vehicles. We feel that this approach is better than a computer simulation which suffers from well known modelling difficulties (especially when trying to model the physical environment comprising varying ground and weather conditions and objects such as trees telegraph poles).

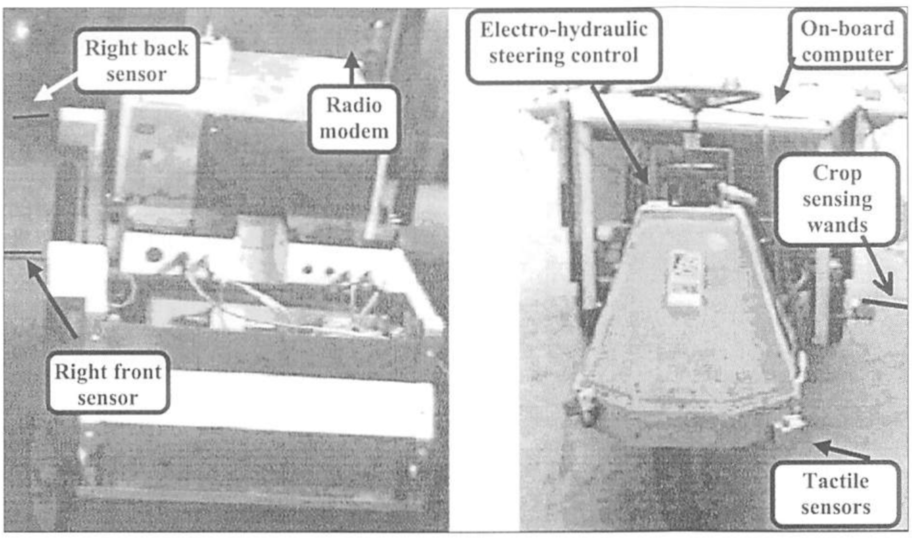

Fig. 2 (a) The outdoor electrical robot; and (b) the outdoor diesel robot

2.1. The robot description

The diesel field robot is constructed on the chassis of a three wheel farm truck. The engine is a New Holland three cylinder diesel engine coupled to a hydrostatic transmission to the differential. Hydrostatic transmission was chosen as providing a simple clutchless transmission. Steering power is provided by an auxiliary pump to a non balanced double acting ram. This was chosen as providing a more complex control problem than a balanced ram would have done. The electric outdoor robot is about the size of a wheelchair and indeed utilises many wheelchair parts. Both robots have mechanical wands (potentiometer arms connected to analogue to digital converter to sense the edge of a crop), ultra-sound sensor, global positioning system (GPS), and a camera. The camera forms part of a system developed by our group (Schallter, 1996) to locate hay bales. The electric robot have two separate motors for traction and steering.

The indoor robot shown in *Fig. 1* has a ring of seven ultrasonic proximity detectors, an 8-axis vectored bump switch and an infrared (IR) scanner sensor to aid navigation. It also has two independent stepper motors for driving the front wheels, with steering by driving at different

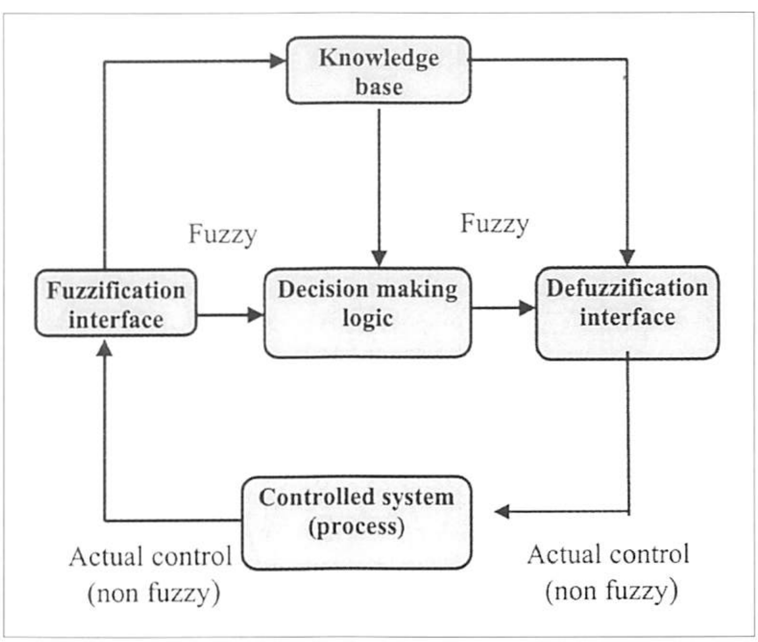

Fig. 3 The basic configuration of a fuzzy logic controller

motors speeds. We try to give all our robots a similar architecture (to simplify development work) so its hardware is also based on embedded Motorola processors (68040) running VxWorks RTOS.

Other papers reported problems using certain types of sensor in outdoor environments. One reported solution uses simple touch sensors (Cho &Ki, 1996) which have ON-OFF states only which is not efficient for fuzzy control. However, we have designed a mechanical wing which is simply an 80 cm. elastic rod connected to a variable potentiometer providing a varying voltage which can then be converted to digital value through an analogue to digital converter. In this way, we can have a cheap sensor which gives a continuous signal monitoring distance from the crop edge (and other obstacles). The sensor configuration for crop harvesting implemented on the electrical vehicle is shown in *Fig. 2a* and the diesel robot is shown in *Fig. 2b*, the outdoor robots are also equipped with ultrasound sensors which are characterised by high noise immunity level.

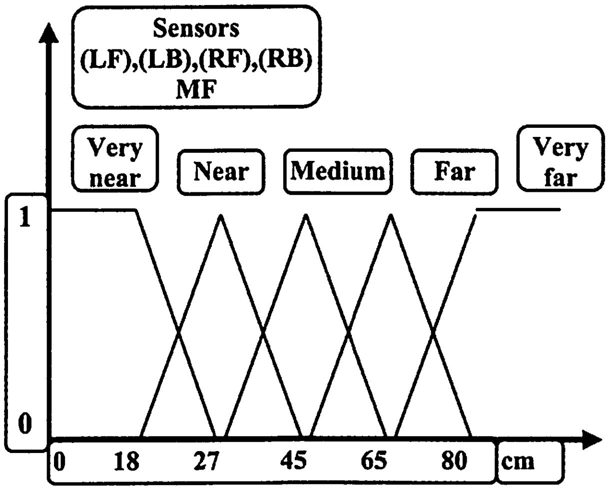

Fig. 4 The membership functions (MF) of the input sensors; LF, left front; LB, left back; RF, right front; RB, right back

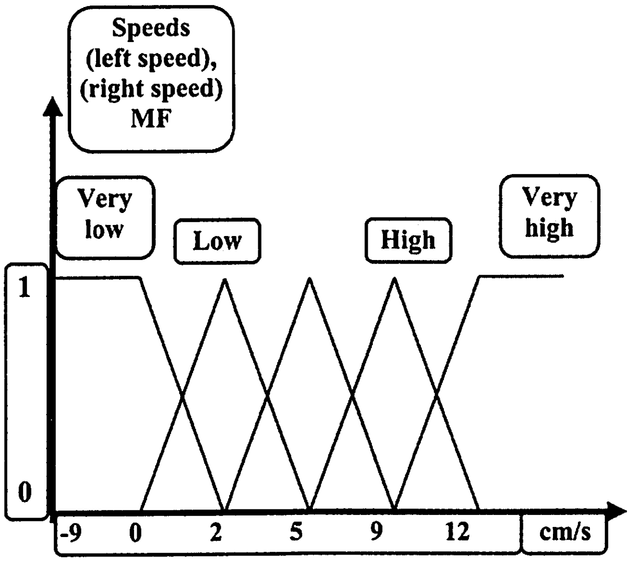

Fig. 5 The membership functions (MF) of the indoor robot output speeds

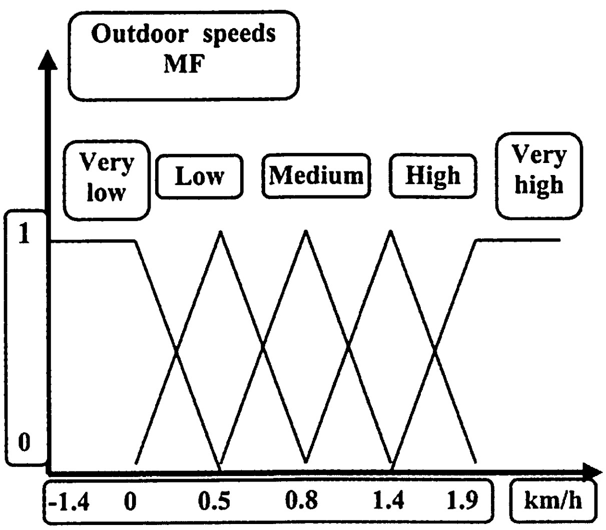

Fig. 6 The output membership functions (MF) of the outdoor robot speed

3. The fuzzy logic controller design

Lotfi A. Zadeh introduced the subject of fuzzy sets in 1965 (Zadeh, 1965). In that work, Zadeh suggested that one of the reasons humans are better at control than conventional controllers is that they are able to make effective decisions on the basis of imprecise linguistic information. He proposed fuzzy logic as a way of improving the performance of electromechanical controllers by using it to model the way in which humans reason with this type of control information. *Figure 3* shows the basic configuration of a fuzzy logic controller (FLC), which consists of four principal components which are the fuzzification interface, knowledge base (comprising knowledge of the application domain and the attendant control goals), decision making logic (which is the kernel of an FLC), and defuzzification interface.

In the following analysis, we use a singleton fuzzifier, triangular membership functions, product inference, max-product composition, height defuzzification. These techniques are selected due to their computational simplicity. The equation that maps the system input to output is given by:

$$\frac{\sum_{p=1}^{M} y_p \prod_{i=1}^{G} \alpha_{Aip}}{\sum_{p=1}^{M} \prod_{i=1}^{G} \alpha_{Aip}}$$

where: M is the total number of rules; y is the crisp output for each rule;$\alpha\alpha_{Aip}$ is the product of the membership functions of each rule inputs; and G is the total number of inputs. More information about fuzzy logic can be found in Lee (1990).

The membership functions (MF) of the inputs denoted by left front (LF) sensor and the left back (LB) sensor [right front (RF) sensor and right back (RB) sensor in the case of the outdoor robots] are shown in *Fig. 4*. The output membership functions shown in *Fig. 5* are the left and right speeds for the indoor mobile robot, the robot steering being performed by moving at different wheel speeds. The outdoor memberships are the same for the inputs sensors (in spite of using different sensors from the indoor robots). As the outdoor robots have a steering motor, the output membership functions consist of speed in *Fig. 6* and the steering parameters in *Fig. 7*.

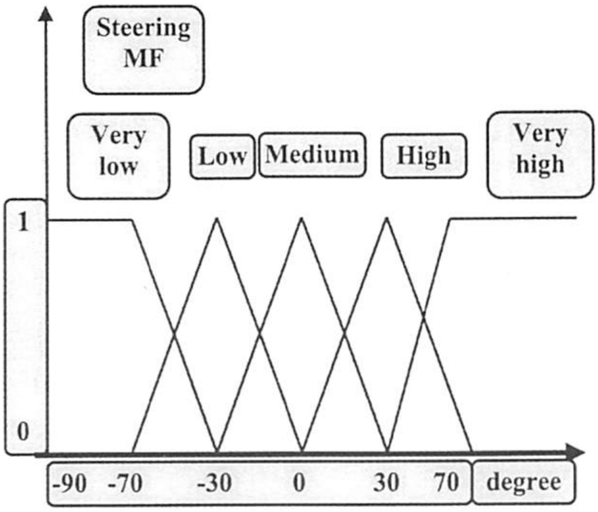

Fig. 7 The output membership functions (MF) of the outdoor robot steering

The rule base of the indoor controller is the same for the outdoor robots except for speed and steering aspects. Also the indoor robot was left edge following while in the outdoor robots it will be right edge following (a peculiarity of the fact the vehicles were built by different people). These rule bases and the membership functions were designed using human experience but we are developing methods to learn them automatically using genetic algorithms.

Figures 8 and 9 represent the control surfaces of the indoor and the outdoor robots. *Figure 8* represents the indoor robot control surface in which the LF and the LB were plotted against their outputs which are the left speed (left figure) and the right speed (right figure). *Figure 9* represents the control surface of the outdoor robots in which RF and RB were plotted against their outputs which are the robot speed (left figure) and the robot steering (right figure).

4. Experimental results

The performance of the architecture has been assessed in two main ways. Firstly, we physically emulated (rather than simulated) the crop following process. In this emulation, we have conducted practical experiments with the indoor robots to track the robots paths and reactions to the irregular geometrical shapes forming fences that fake the crop edge. These fences included one formed with real bales of hay which are real challenge to the robot because of their irregularity and low sensitivity of sonar sensors toward them. In the next phase, we have tried the same architecture in the outdoor environments to track fences and real crop edges in real farms. Each experiment was repeated five times and each time the path was recorded to test the system repeatability and stability against different weather and ground conditions (such as rain, wind, holes in the ground, going up and down hill, *etc.*). *Figure 10a* shows the robot emulating the crop cutting operation. Here it continues going inwards to complete the harvesting operations. The cutting action was simulated by reducing the size of the fence. Note that the response is smooth especially when the robot turns. This is due to the smooth transition between rules and the smooth interpolation between different actions which are characteristics of fuzzy logic. The same experiment was repeated but with real bales of hay and gave a very smooth and a repeatable

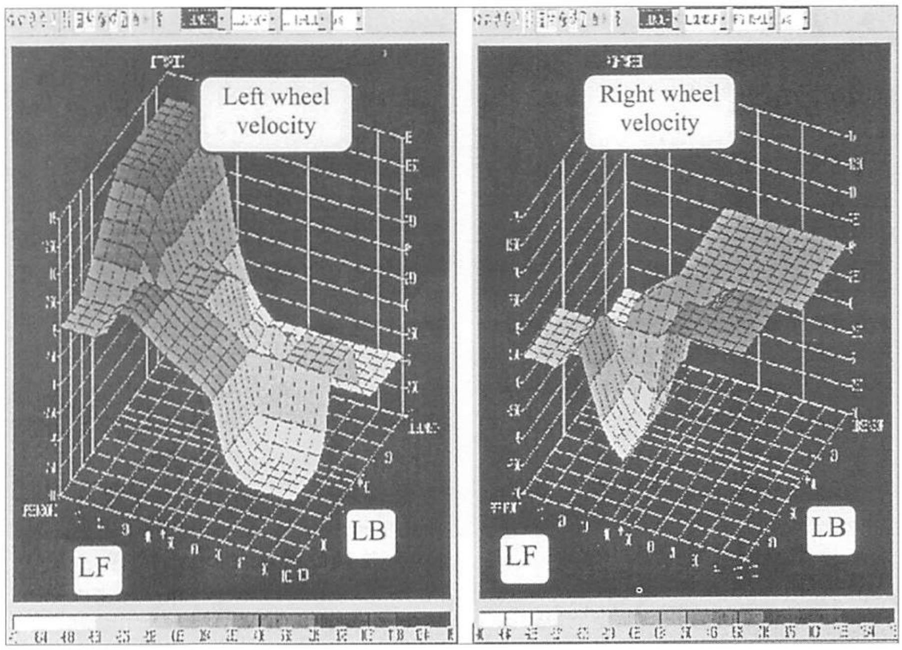

Fig. 8 The control surface of the indoor robots; LF, left front sensor; LB, left back sensor

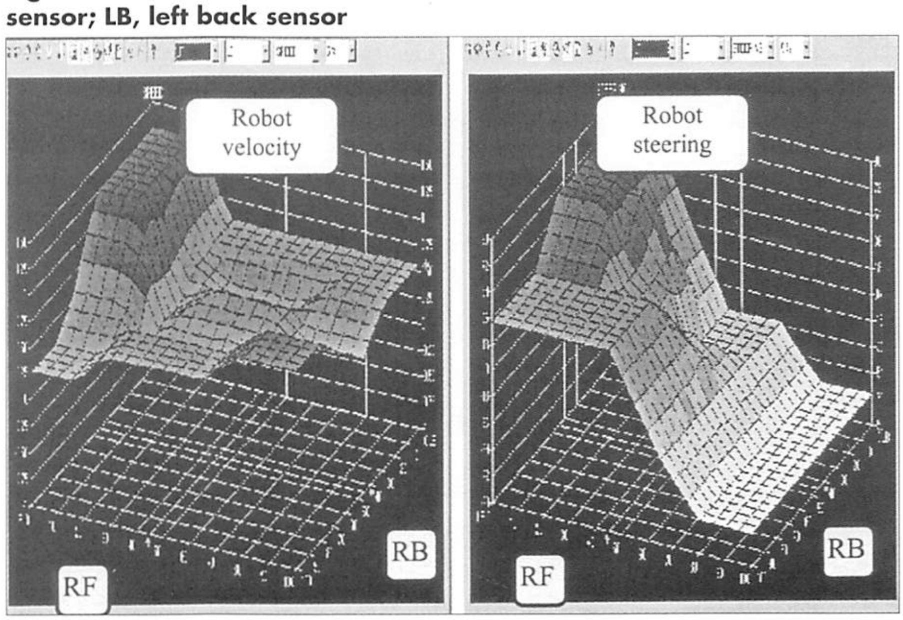

Fig. 9 The control surface of the outdoor robots; RF, right front sensor; RB, right back sensor

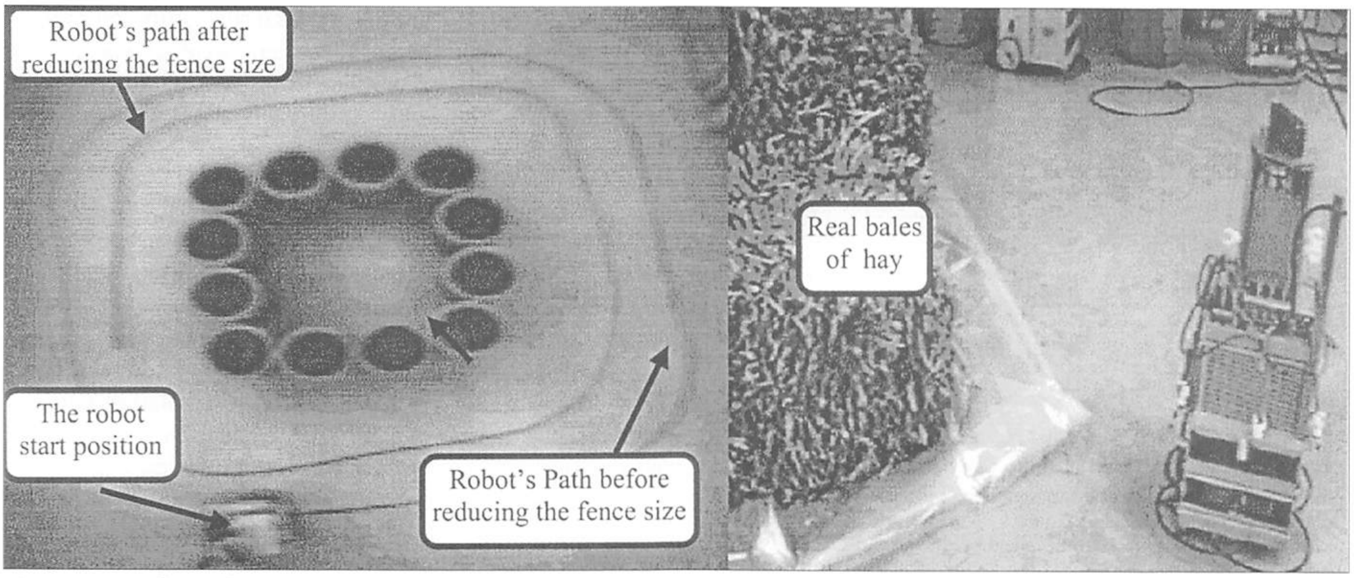

Fig. 10 (a) The robot emulating the harvesting operation; and (b) the robot following fences formed by bales of hay

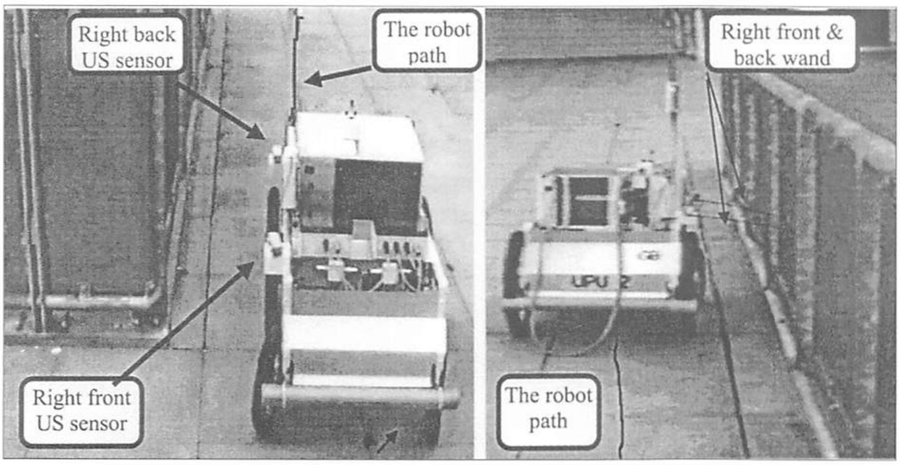

Fig. 11 (a) The outdoor electrical robot following an irregular fence using ultra sound sensors; and (b) the outdoor robot following an irregular fence using the mechanical wand sensors

response as in *Fig. 10b.*

We then tried the electric robot in a range of out-door environments. These involved following many types of cut edge, such as rough pasture, hay crops and hedges. The system was also tried under different weather conditions and under different ground conditions, such as mown turf, hay stubble and ground that was rutted. It was also tested on flat land as well as on slopes, both up and down and across the slope.

The same control architecture was used in all robots only varying the output (MF) of the robots and slightly varying the rule base to cater for the differing steering and speed characteristics of the robots. We experimented with mechanical wands and ultra sound sensors. In spite of the varying weather conditions, the systems displayed a very good response showing the fuzzy controller can deal with imprecision and noise.

Figures 11a and11b show the robot path of the electrical outdoor robot following an outdoors fence. In *Fig. 11a*, the robot succeeded in following an irregular rectangular metallic fence under different weather conditions (*i.e.* wind

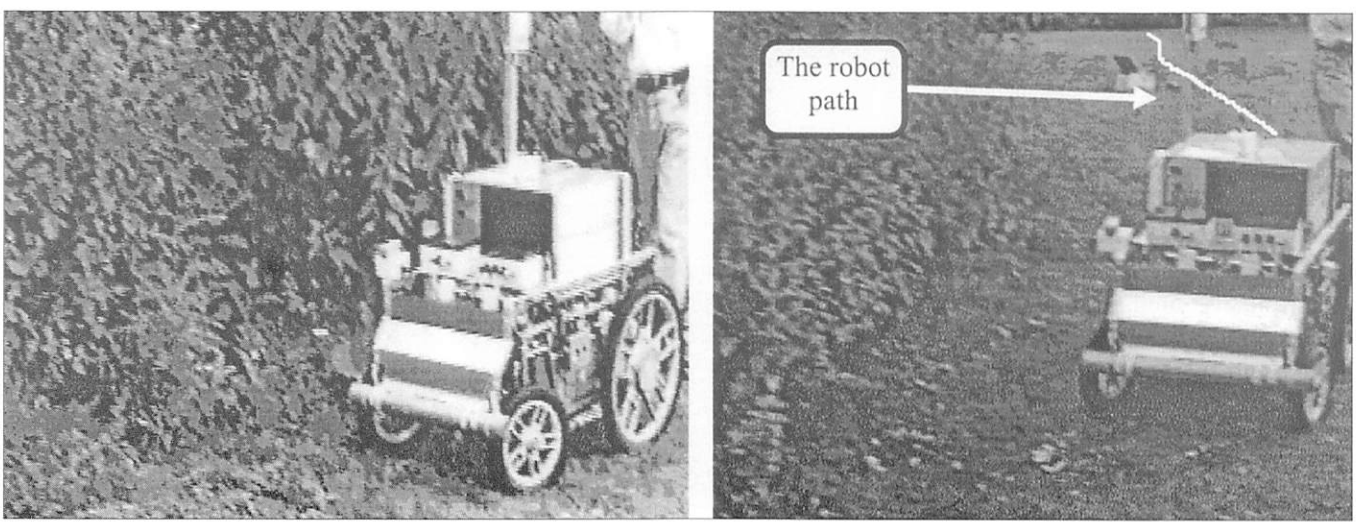

Fig. 12 (a) The electrical robot following out door irregular tree hedges; and (b) the robot path

Membership Matters

Quarterly The Newsletter of the Institution of Agricultural Engineers Summer 2000

Award of Merit 1999 Paul C H Miller

Paul Miller is one of the world's foremost Agricultural Engineers in the area of pesticide application. His research spans strategic and applied problems in engineering science and is recognised by academic, government and industrial organisations as providing the essential understanding of the application process to permit the improvements in application methods and the control of pesticide usage that are essential for the future.

He qualified as an Agricultural Engineer from the National College of Agricultural Engineering - now Cranfield University - Silsoe, in 1971 and then began a career at the National Institute of Agricultural Engineering, now Silsoe Research Institute, the same year. After periods on root crop harvesting (during which he gained his PhD) and grain drying, he took over responsibility for chemical application research in 1984.

Paul's research programme has provided major insights into the application process. A primary focus has been methods that can lead to improved targeting and thus reduced pesticide contamination of the environment inlcuding patch spraying and mathematical models to predict drift of sprays. Formulation has been shown to be a significant cause of variation in the physical properties of the spray generated from agricultural nozzles, and this has led to new lines of research to evaluate, predict and, hence, improve the control of the application process.

Other major contributions to machinery for the application of agricultural chemicals have been the design and computer stimulation of spray-boom suspension systems and the evaluation of the performance characteristics of granular fertiliser applicators and the impact of granule formulation.

His research contribution has been recognised through numerous invitations to give keynote papers at international conferences and through awards such as the Archimedes Medal for the work on patch spraying in 1992 and the British Crop Protection Council Medal in 1997 for his contribution to UK crop protection.

He is also a major contributor to national and international institutions and committees including FAO, British Standards, BCPC and AEA committees and the Institution of Agricultural Engineers.

Honorary Fellowship Award 1999 *Roger M Hay*

Roger Hay CBE qualified as a Civil Engineer at the Heriot Watt College, Edinburgh. After training with an Edinburgh consultant he spent time on the construction of the Hunterston Nuclear Power Station before taking up a post in the, then, British Guiana as an Irrigation and Drainage Engineer. He joined the Forestry Commission in 1967 and in 1981 became the Director of Engineering, where he supervised both the introduction of mechanised harvesting systems and the reorganisation of the Civil and Radio Engineer branches.

He has published a number of papers on roading for forestry and has been a consultant on harvesting to FAO and various private concerns in this

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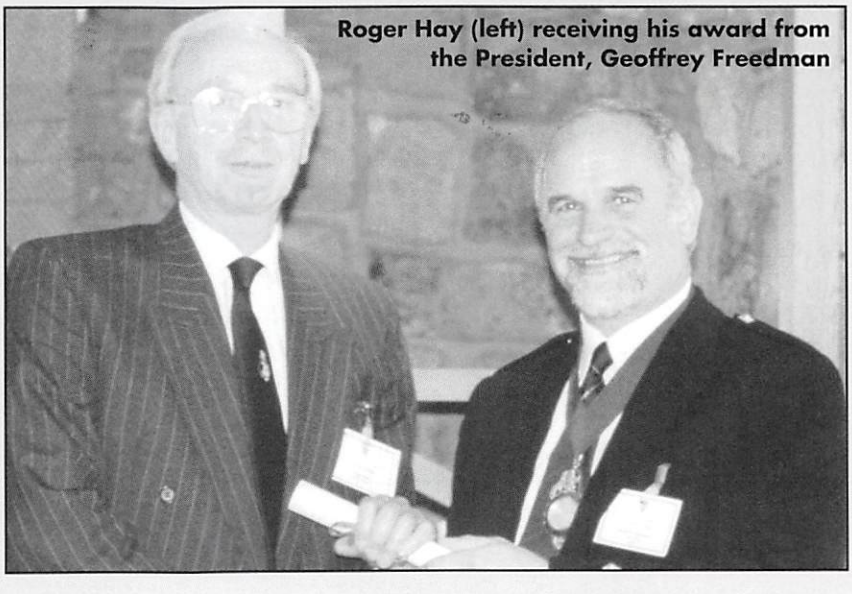


Roger Hay (left) receiving his award from the President, Geoffrey Freedman

Branch Meritorious Award 1999

Geoffrey F D Wakeham

Geoffrey Wakeham (left) receives congratulations from the President

Geoffrey Wakeham joined the Institution in 1960 and his contribution to Institution activities goes back many years.

In the early eighties he moved to Harper Adams and has seen it grow to one of the country's leading establishments involved with graduate level education in all aspects of agricultural engineering and there is little doubt that Geoff's contribution to this has been significant.

As a member of the Wrekin Branch, Geoff has given immense commitment. As a chairman, committee member and ordinary member he has always been reliable and prepared to go 'that extra mile' to ensure that local activities are organised for the benefit of all. I cannot remember a meeting when Geoff is missing unless he is out of the country or dealing with some more important work commitment.

As an ambassador for the Wrekin Branch, Geoff's contribution has been beyond the normal call of duty. He regularly attends the annual conferences, serves on various committees and represents the Wrekin Branch as and when required.

His greatest contribution is in the development of young engineers - the Institution's next generation of members. 'Challenging young people to think' as one member put it. Geoff can always be relied upon to challenge conventional thinking. It must be a great source of satisfaction for Geoff that many young agricultural engineers have done so well in their careers with the help and support given them from such a valuable mentor. Attendance at Wrekin Branch meetings is above average largely due to Geoff and his colleagues' encouragement to students to attend meetings and also to join the Institution at an early stage.

He is a regular contributor to 'Landwards' and his articles are always thought provoking and valuable in pushing forward the industry.

As Geoff heads towards retirement years (not too soon we hope!) we can think of no better way of marking his contribution to the Wrekin Branch and the Institution in general by proposing him for this Meritorious Award.

from previous page

country and abroad. He has lectured on roads to colleges in Britain, Romania and Canada.

A member of the Institution of Agricultural Engineers for nearly 20 years, he was instrumental in setting up the Forest Engineering Specialist Group and has been involved, as Chairman of that Group, in the many successful seminars and conferences the Group has held over the last 10 years. A former member of Council he has been active in Institution affairs for many years. He is also a Fellow of The Institution of Civil Engineers and The Institution of Highways and Transportation.

He was awarded the CBE in 1994 for services to forest engineering.

Institution Membership changes

Admissions

Companion
R H Kendall (East Sussex)

Member
C D Salter (Cambodia)

Associate Member
S Bromley (Warwickshire)
E de Bonis (Surrey)
M Greaves (London)
I T James (Bedford)
G A Kareem (Ukraine)
S W Mwambu (London)
J A O'Kane (Co Antrim)
L A Stewart (Norfolk)
T J Wright (Nottinghamshire)

Associate
G E Randles (Merseyside)
M W Ward (Bedfordshire)
T D Williams (Co Tyrone)

Student
Abubacker Siddick (Kent)
J Bellali (Bedfordshire)
I S J Jensen (Wiltshire)
W G Mulholland (Co Armagh)
M Raghunath (Shropshire)

Readmission

A K M A Haque (Bedford)

Death

W E Klinner (Buckinghamshire)
R L Lodge (Tanzania)

Transfers

Fellow
C S Clark (Cheshire)

Member
J S Eastham (Lancashire)

Associate Member
N M Foley (Ireland)

Commercial Members

Bomford Turner Ltd
Salford Priors, Evesham
Worcestershire WR11 5SW

BSW Harvesting Ltd
Robertson House, Perth Business Park
Whitefriars Crescent,
Perth PH2 0NX

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

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

G C Professional Services
Highdown Cottage
Compton Down, Nr Winchester
Hampshire SO21 2AP

Law-Denis Engineering Ltd
Millstream Works, Station Road
Wickwar, Wotton-under-edge
Gloucestershire GL12 8NB

Spencer Environmental Care and Construction Ltd
Llwyn-yr-ynn, Llandeilo Rd
Girslas, Llanelli
Dyfed SA14 7LU

White Horse Contractors Ltd
Lodge Hill, Abingdon
Oxon OX14 2JD

Academic Members

Cranfield University
Silsoe
Bedford MK45 4DT

Harper Adams University College
Newport
Shropshire, TF10 8NB

Lackham College
Lacock, Chippenham
Wiltshire SN15 2NY

Pencoed College
Pencoed
Bridgend CF35 5LG

Sparsholt College
Sparsholt
Winchester
Hampshire SO21 2NF

Writtle College
Chelmsford,
Essex CM1 3RRR

Obituaries

Wilfred Erwin Klinner

1926-2000

Wilfred Klinner, CEng, Institution member for 40 years, inventor and research worker and former Honorary Consulting Engineer to the RASE, died on 10th March after a short illness. He was 73.

Wilfred joined the National Institute of Agricultural Engineering in 1952 after several years in practical farming and contracting. For four years he was engaged in translation and abstracting work in the Scientific Intelligence Unit, and he then joined the Testing Department to begin what became a career of international significance in testing and the development of new equipment for agriculture. He became head of the Forage Machinery Department which produced the mower-conditioners now in use throughout the world and which alone account for more than twenty patents bearing his name. Before he retired in 1986, when he was Head of the Field Machinery Division, he invented the combine stripper-header which is used in mechanised rice production worldwide. The success of his work is indicated in around 180 refereed papers, test reports and other publications, many public lectures, two Queen's Awards for the National Institute of Agricultural Engineering and, in 1985, the McRobert Award for engineering excellence which was shared with Rolls-Royce. He made substantial contributions to the work of BSI, National Safety, S E Midlands Branch of IAgrE, and East of England Agricultural Society committees.

He brought the sound practical experience of his contracting years, his enthusiasm for testing and machine performance, and his positive style of leadership to bear on all his activities. His personality and generosity of spirit will be sadly missed within the industry and this Institution, in his own community at Woburn Sands, and most of all by his widow Margaret, daughter Julia and four grandchildren.

Brian Finney

James P O'Neill

1977-2000 (aged 22)

James P O'Neill, Student Member of Council, was tragically killed in a motorcycle accident on 11 May 2000 at the age of 22. He was due to graduate from Harper Adams in July with a BEng (Hons) degree in Agricultural Engineering. Initially he was planning to spend the summer working on a relative's farm in Canada, after which he was considering a number of options including a job with JCB, a career in the army, or taking an MSc in Fluid Power at The University of Bath. Jim's sad and untimely death deprives the Institution of a young active and enthusiastic supporter with both enormous drive and boundless energy.

During his time at Harper Adams, Jim spent most weekends on exercise with the Territorial Army. As a corporal in the Royal Military Police, one of his proudest moments came when he provided security for the G8 summit retreat at Weston Park. There was hardly a free moment in Jim's life, for as well as his studies and TA activities; he found time to run the TA bar, was night manager of the college bar, restored Landrovers, built and repaired computers and developed expertise in a number of different computer operating systems. On more than one occasion, Harper Adams Computing Department used this expert knowledge to help resolve some technically complex problem in their computer network.

A unique character who never failed to impress those who met him, it was of no surprise when JCB decided to offer him sponsorship at the end of his first year of studies. He was a great talker who had the ability to entertain without being dull and will be sorely missed by his friends, colleagues and family. The Institution offers its deepest sympathy to his parents and family.

Richard Green

Michael Dwyer Memorial Prize 1999

Philip J Wright

Philip Wright has been awarded the Michael Dwyer Memorial Prize, which is awarded to young engineers who have made outstanding progress in the agricultural engineering industry.

Philip has worked for Simba International Ltd since leaving Silsoe College with an honours degree in 1979. Whilst at Silsoe he was awarded the Sir Stephen Watson Memorial Prize for best final year student in Agricultural Mechanisation and has continued in the same vein of winning prizes for his company. Employed initially as a design engineer, he soon took over responsibility for all product design and development, and was made Technical Director in 1986.

A predominantly tillage implement manufacturer, Simba is one of the few British companies to have expanded in a market being lost to overseas imports. In less than 10 years, Philip's expertise has brought many awards to the Company for their machine design. Most recently two new designs of equipment have been produced, namely the 'DD' ring on soil presses which is a simple but effective design to improve seedbed preparation and the "Solo" cultivator. Through its innovative combination of soil engaging components this cultivator provides, in one pass, a suitable drilling tilth for Simba's Freeflow drill.

Philip has also been at the forefront of developing 'Eco-tillage', a system of dealing effectively and more cheaply with resistant arable weeds, such as blackgrass and brome grasses.

Simba's future looks bright with Philip, persevering as he does, with new products and designs in what has always been a fickle and difficult market.

Branch Meritorious Award 1999

W Hugh Mackenzie

Hugh Mackenzie (left) with Geoff Freedman, both suitably attired for the presentation at the Scottish venue of the National Conference

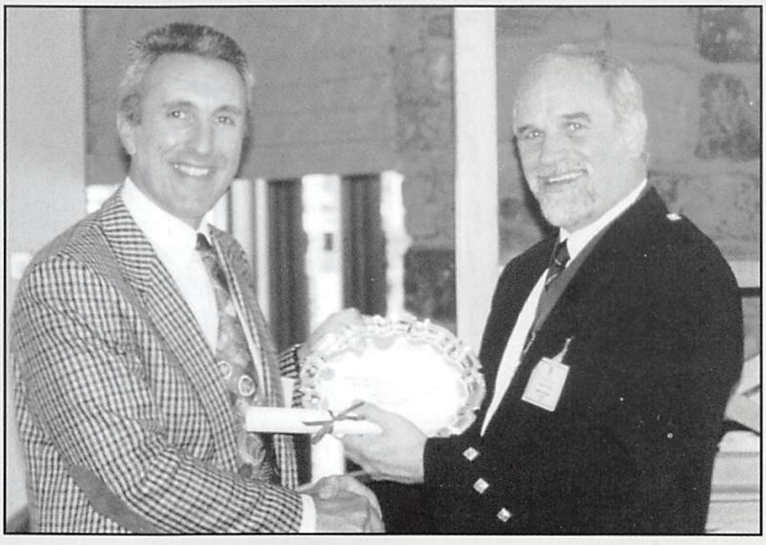
Hugh Mackenzie joined the Institution in 1958 as a graduate member. He became a member of the Scottish Branch Committee in 1973 and has served as a chairman, vice chairman and member. With the exception of the period 1988-1994 his service has run without interruption for 37 years.

Over the period of his activities with the Scottish Branch it has been one of the most successful in the UK and Hugh has made an important contribution to this success. His encyclopaedic knowledge of agricultural engineering matters has been a valuable resource in the Branch.

Perhaps Hugh's most notable achievement has been in raising the profile of the Branch, so that it has become very well known in the agricultural machinery service industry. He played a notable role in promoting the Weir Shield Award, given to the best agricultural engineering apprentice and the sponsoring firm. He has always been active in the encouragement of young people entering agricultural and agricultural engineering industries.

The Scottish Branch wishes to acknowledge Hugh's contribution by proposing him as a candidate for the Branch Meritorious Award.

Philip Wright (left) receiving the Michael Dwyer Memorial Prize from the President - representing Mrs Brenda Dwyer whose travel arrangements, along with those of several other conference delegates, were disrupted by a flight delay



Johnson New Holland Award

Paul Mitchell-Roberts

Paul Mitchell-Roberts has been awarded the Johnson New Holland Award. This award is presented to recognise and encourage innovation by younger students. It is awarded to the best final year project submitted by a student or group of students, as part of a First Degree, Higher National Diploma or Higher National Certificate course in Agricultural Engineering.

The aim of Paul's project was to design, build, test and evaluate a device capable of increasing the cleaning interval of engine water cooling radiator cores on rear engined telescopic handlers. This was achieved by investigating and defining the fundamental causes of this problem. It was found that straw and chaff are picked up by the wheels of the machine and the direction and speed of airflow into the radiator and drawn through the screen, into the core, causing plugging.

A detailed investigation of available systems on associated agricultural machinery and communications with experts in the field generated several concepts to reduce the rate of core plugging. It was found that many manufacturers use the principle of a dense screen with a vacuum cleaning means to remove trash from the air stream. An appraisal of these concepts suggested that this principle could be adapted for use on telescopic handlers.

A bi-directional, high-density plastic screen with a vacuum means to clear the accumulated straw was developed and tested on a JCB Loadall 526-55. Initial testing and appraisal of the principle behind the device suggests that the concept is sound and with further development, could successfully be taken to production stage.

Paul has enjoyed varied employment, whilst a student, including: work on arable and dairy farms; employment with a fertilizer blending company; a quality assurance role within the Claas Group; and most recently harvesting work on a 4,000 acre arable farm in Western Australia.

Having a keen interest in engineering, Paul undertakes his own car and motor cycle maintenance and has just joined the Institute of Agricultural Engineers as a graduate member.

Paul Mitchell-Roberts (left) holding the shield presented by Roger Goddard of New Holland, the sponsors of the award

Engineering Council registration analysis

At the end of each year the Engineering Council analyses the registration statistics for the year, and there was a total of 283,557 names on the Engineering Council's register as at 31 December 1999. This represents a reduction of 972 (0.34%) over the previous year. As can be seen from the attached chart, registrant numbers are still higher than they were in 1989, but have been declining slowly since the peak in 1992. The CEng and EngTech sections of the register decreased, but the IEng section showed a.small increase. However, it is possible that the losses of IEngs in the year have been understated as updating of data by the IIE has been affected by the recent merger with the IIExE.

The good news is that the number of female registrants continued to rise and now totals 5,728, representing 2.02% of the register as against 1.87% a year earlier. However, the number of registrants aged 65 years and over has also increased, with for Chartered Engineers the proportion increasing from 23.13% to 23.78%. This of course reduces the Council's income because retired registrants pay a reduced annual fee. Statistics have not been compiled on all those retired because not all Institutions provide that information.

The continuing slow but steady decline in registrations is a worrying trend, as has been highlighted frequently. However, it is hoped that the Marketing the Register campaign, 'Recognising Excellence', will not only halt the decline, but also reverse it.

Contact: **Malcolm Shirley, Director General, Engineering Council, 10 Maltravers Street, London WC2R 3ER. Tel: 020 7240 7891. e-mail: mcshirley@engc.org.uk**

Membership movements

Mem No	Name	From	To
5328	M J Battcock	Warwickshire	Glasgow
4810	R M C Bennett	Singapore	Italy
0195	T J Blake	Oxfordshire	Gloucester
6755	D Chan	Bedfordshire	Lancashire
6580	D G Crabb	Leicestershire	USA
6769	N M Foley	Bedfordshire	Ireland
6276	I Gardner	Suffolk	Norfolk
4468	H G Gilbertson	Hampshire	Bedfordshire
6333	J M Greatorex	Norway	Sweden
4730	T Massen	Swansea	Cornwall
6581	P J Moseley	Bedfordshire	Shropshire
6241	E C Mubaya	Zimbabwe	Swaziland
6745	A J Puddephatt	Northamptonshire	Germany
6118	J M Sparrey	Bedfordshire	Bangladesh
6736	T I Stacey	Powys	Shropshire
6270	P M Wightman	Lancashire	Buckinghamshire
6191	A Wilson	Zambia	Lancashire
6722	M E Worth	Bedfordshire	Mozambique

Gone Away

Name	Last known address
Lewis Oludare Adenuga	5 Lamberhurst Close, Orpington, Kent BR5 4QE
Pollard Martin Blakeley	c/o FAI Ltd, Booth House, 15-17 Church St, Twickenham TW1 3NJ
Edward Davidson	Holmdene Farm, Beeston, Kings Lynn, Norfolk PE32 2NJ
Robin Jackson	South Stoneham House, Wessex Lane, Swaythling, Southampton SO18 2NU
Murray Charles Thorne	45 Dunnington, Alcester, Warwickshire B49 5NX
Saul Nathan Townshend	34 Aled, Acrefair, Wrexham, Clwyd LL14 3HB
John Herbert Wyndham Wilder	John Wilder (Agricultural) Ltd, Hithercroft Industrial Estate, Wallingford, Oxfordshire OX10 9AP

Harper Adams all terrain website

Harper Adams has initiated a web site dedicated to Off Road Machines. The main purpose is to attract young people to the industry and to advertise our new courses in Off Road Vehicle Design. To make the site of interest to browsers and surfers we will need to keep it up to date with news, views and information. If anyone from the industry would like to promote themselves, encourage future employees and support the industry in general we would be pleased to hear from them.

If anyone wishes to look at where we have got to so far then log on to **http://www.offroadmachines.com** They are welcome to send us their comments and suggestions on how to develop this site.

Geoffrey Wakeham

Health and safety training up by a third

The number of people attending integrated training and assessment courses registered with Lantra has jumped by more than a third since Christmas.

Despite the pressures on agricultural and horticultural businesses, these increases are apparent across the whole country and throughout the range of health and safety courses run by training providers and colleges registered with Lantra.

The increase in demand is attributable to three things:

- the major health and safety awareness campaign which Lantra and the Health and Safety Executive have run during the past year with support from the European Social Fund;
- the requirement of many assurance schemes for producers to be able to demonstrate up-to-date skills in relation to health and safety matters; and
- simplified administration and lower costs for course registration, making it easier for training providers to organise events which integrate training and assessment into a single event.

This has the added benefit of less time away from work for those who are undertaking training.

Integrated training and assessment courses are available for:

- chainsaws
- manual handling
- lift trucks
- 4x4s
- all terrain vehicles
- tractor driving
- brushcutters
- abrasive wheels
- vermin control
- first aid at work

These are complemented by training only events which cover everything from safe use of pesticides to sheering, and environmental conservation skills to fence erection.

Contact: **Information on these courses and the national network of training providers is available by calling Lantra Connect on 0345 078007.**

Innovative bio-solid application into arable cropping

Cranfield University, Silsoe's Centre of Agricultural and Amenity Engineering, has developed an innovative liquid waste recycling system for bio-solids by injecting waste products into growing cereal, oilseed rape and grassland crops in an environmentally friendly way. This work has been carried out in collaboration with Anglian Water Services Innovation and with significant assistance from Greentrac Ltd.

The application of bio-solids into agricultural land is regarded as the best practical environmental option for the disposal of surplus waste from sewage treatment plants and farm silos. Historically this has been achieved by 'deep injection' into cereal stubble and grassland at depths greater than 0.15 m, generally achieving reduced emissions (odour and ammonia) with satisfactory application rates (100 to 250 m^3/ha), but causing a variable degree of surface damage to the crop.

In recent years, increased environmental concerns and legislation restricting other disposal methods has provided the impetus to refine the land application of bio-solids. This has resulted in a need for more land for injection and hence a shift towards in crop application techniques.

The Growing Crop Injector, developed at Cranfield University, Silsoe, allows efficient injection of liquid wastes into the soil at very shallow depths (typically 0.05 to 0.08 m), during the growing season and without significant crop damage. Studies have shown that the improved incorporation of bio-solids into the crop root zone reduces harmful emissions (NH_3) and odour concentrations, without increasing concentrations of nitrate in soil water, and without affecting crop yield.

The use of this injection technology increases the potential value of bio-solids by increasing the retention of available nitrogen by its incorporation into soil and the crop root zone. Studies found that up to 40% of available nutrients are lost into the atmosphere by surface application, this can be reduced by commercial deep or shallow injection methods to 15%, with a further reduction to just 4% achievable by effective injection using the Growing Crop Injector.

The ability to inject bio-solids into the land during the growing season also has implications for storage and other logistical considerations. A management study concluded that the increased 'window of opportunity' for land application presented by using the Growing Crop Injector could potentially significantly reduce storage needs, tankering costs and transport distances through more effective use of land close to liquid waste sources.

The Growing Crop Injector uses existing supply technology (umbilical) over a working width of 6 m, and is best used with a low ground pressure tractor/implement combination.

Further corporate interest and sponsorship is needed to develop the product further into a 12 m boom design for tramline work, reducing any wheeling effects and improving the field efficiency. Feasibility studies have shown that the extension of the system is possible.

Contacts: **Professor Richard Godwin, or Dr Richard Earl for further information on the Growing Crop Injector and design and manufacturing services available from Cranfield University, Silsoe (Tel: 01525 863000); production enquiries to George Reed, Greentrac Ltd (Tel:01849 464599).**

Long Service Certificates

50 years

Name	*Grade*	*Date of Anniversary*
James Thomson **Simpson**	IEng MIAgrE	1 Apr 2000
John Roland **Marshall**	MIAgrE	10 May 2000
Douglas McDonald **Walker**	IEng FIAgrE	10 May 2000

35 years

Francis John **Pirie**	IEng FIAgrE	24 Jun 2000

25 years

Alan **Plom**	MIAgrE	22 Apr 2000
Roger Simon **Horner**	AIAgrE	22 Apr 2000
Gordon James **Fowlie**	CIAgrE	22 Apr 2000
John Nicholas **Tofts**	IEng MIAgrE	28 Apr 2000
Christopher Frank Howard **Bishop**	MIAgrE	29 Apr 2000
Rodney Edward **Pragnell**	IEng MIAgrE	29 Apr 2000
Michael John **O'Dogherty**	CEng FIAgrE	29 Apr 2000
Morgan James **Milne**	IEng MIAgrE	29 Apr 2000
Charles John **Bevan**	MIAgrE	29 Apr 2000
Brian Christopher **Stenning**	FIAgrE	13 May 2000
Cecil James **Bracey**	CIAgrE	13 May 2000
Paul **Austin**	AIAgrE	21 May 2000
Stuart Robert Keir **Gray**	IEng MIAgrE	10 Jun 2000
Alan James Harold **McKenzie**	IAgrE	10 Jun 2000
Alfred David **Gracey**	CEng FIAgrE	10 Jun 2000

News *of Members*

David Crabb is now working for Caterpillar in North Carolina for a period of two years. His job is concerned with Product Support for Telescopic Handlers and the area covered is North and South America and Canada.

E C Mubaya has recently moved to Swaziland from Zimbabwe where he is employed as an agricultural engineer by the Swaziland Sugar Corporation.

Martin Worth is currently working in Mozambique as a Mechanical Adviser for Scott Wilson and is expected to be there for the next year or so.

Julian Sparrey is at present living in Bangladesh. He is there as an accompanying spouse and says that he tends to pick up little bits of work every so often, whilst waiting for the big break! He says that there does not seem to be a Bangladesh branch of IAgrE but a group of Civil engineers recently got together for the first time to discuss Continuing Professional Development. They will probably start meeting regularly and if they do he intends to join them.

John W Roberts has recently retired and after spending 17 years in Essex has moved to Doncaster. In recent years his mechanisation interests have been concerned primarily with livestock production equipment and environmental matters and the development of sensible EU and UK legislation affecting these aspects. He says that it is interesting to note how frequently the deeply held views of environmentalists, animal welfarists, animal health interests and local planners lead to conflicting and occasionally, diametrically opposed demands.

Seamus Maguire is now a student at Cranfield University at Silsoe where he is studying for an MSc by research. He started last October and hopes to finish by the end of September this year.

Chris Meek who has been working in South East Asia since 1993 is now based in Mindanao, the southern most island in the Philippines. He says that since living in Mindanao his focus has been on the inward transfer of appropriate agricultural technology which can be adapted to suit the local conditions. Chris has already been involved with Sugar Cane, Corn (Maize), Rice, Bananas, Pineapples and other high value field scale vegetables, such as Asparagus. He says that although the agricultural economy in the Philippines is dominated in numbers by small scale subsistence farmers, there is also a thriving export oriented plantation sector run with professional management.

Currently, Chris is working with an American company on a part time basis to promote the use of the CFValve, a simple pressure regulator to improve the accuracy of the local knapsack sprayers which have no form of pressure relief or regulation. He says that he is very keen to work with any British Agricultural Engineering manufacturing companies by helping them to understand the potential of the South East Asian export markets and how they can be best approached. Chris can be contacted by email: cmeek_associates@yahoo.com

Dr Peter Moseley is now working as the Technical Development Manager for ASE SoluTech Ltd. He is working on the TurfTrax project where he is concentrating his efforts in areas such as web development and some new and innovative technologies in the horse racing industry. Some of the 'going' reports for the Grand National televised over the three-day event by the BBC were part of the TurfTrax package.

Peter says that the job is providing him with a challenge to achieve success within the corporate sector rather than in academic research, which is so often the norm after completing doctorate studies. He says that the management studies contained within the EngD programme are proving to be very useful.

Richard D J Lacey was employed by Wessex Water in England where he was Divisional Manager for the Dorset Division, when it was purchased by Enron, a major US energy company in July 1998. Previously, Enron had seen an opportunity for the globalisation of water services and decided that to become a major player in that market they needed to expand overseas. Therefore, after some research they decided to purchase Wessex Water.

Richard then spent some time travelling the globe looking after specific development engineering projects in Brazil, Argentina, Mexico, North America and Canada. He then moved to the Houston Head Office of Azurix (as the new water company became known) as Vice President of Development Engineering and one of the projects they were successful in obtaining was to run the water and waste water operations in the Province of Buenos Aires.

Richard moved with his wife and family to Buenos Aires in July 1999 as the Chief Operating Officer and has recently been promoted to the position of joint Managing Director of the entire concession. He says that he has been pleased to accept the challenges of creating a new world-class water company, one of which included conversing in Castellano which is a Latin American dialect of Spanish.

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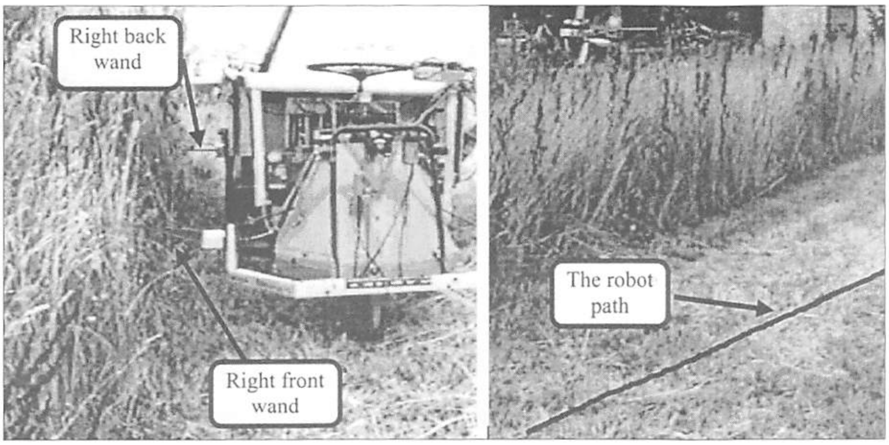

Fig. 13 (a) The diesel robot following real irregular hay crop edge using the mechanical wands; and (b) the robot path

and rain) using only two ultra sound (US) sensors. The robot gave repeatable and smooth path following on the whole fence, as well as turning around corners. *Figure 11b* shows that the robot succeeded in following the same fence using the mechanical wands, the robot again following the fence with high repeatability and stability and responding rapidly but smoothly to any changes in the fence line.

Figure 12a shows the electrical robot in the field following a crop edge which is characterised by high irregularity (gaps in the edge, plants falling from the edge). The robot was also required to navigate uphill and downhill in a ground full of ruts. It used two ultra sound sensors to sense the crop edge. Again the robot gave a smooth response and followed the crop keeping a safe distance from the crop edge and responding rapidly but smoothly to any changes in the edge *Fig. 12b*. Although we currently have no quantitative means for evaluating the precision of the crop following, we estimate that the crop edge was tracked successfully within a tolerance of 50 mm.

Figure 13a shows the diesel robot with the mechanical wand sensors in a hay field that has a very discontinuous edge and ill defined corners. The robot gave stable, repeatable and robust response as shown in *Fig. 13b*, and tracked the edge of the crop successfully within a tolerance of 50 mm. The robot also turned smoothly around the ill-defined hay crop corners, as shown in *Fig. 14a*. *Figure 14b* shows the robot after turning smoothly around this corner.

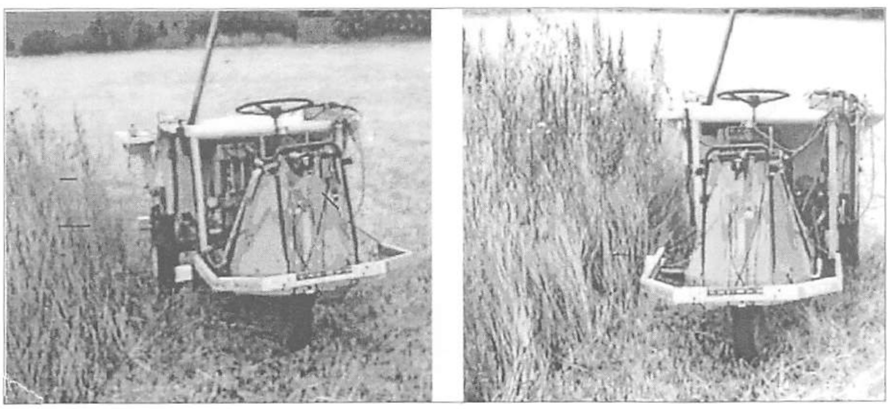

Fig. 14 (a) The robot starts turning around an irregular hay crop corner; and (b) the robot after turning smoothly around the corner

5. Conclusions

In this paper, we have developed a fuzzy controller for a robot aimed at automating the crop following processes. We have developed a novel sensor design (outdoor mechanical wands) to be used in real farms under different conditions. We tested the fuzzy control architecture on an indoor mobile robot with only two ultrasound sensors. It had succeeded in maintaining itself at a constant distance from the crop in spite of boundary irregularities and the imprecision in the ultrasound sensors. After testing the architecture successfully indoors, the control architecture was moved to the outdoor robots. In the field environment, the robots displayed a smooth and fast response and were able to track various edges under different weather and ground conditions.

The outdoor robots tracked irregular crop edges successfully within a tolerance of 50 mm. The robot also turned around real crop corners smoothly and gave a highly repeatable and stable response. To the authors' knowledge, the work described in this paper is the only system which has successfully guided a diesel tractor in the outdoor environment, following real crop edges (including irregular edges which include gaps) and turning around corners with a high degree of repeatability and following the crop edge with a tolerance of 50 mm. The system is totally autonomous with no pre-specified plans and reacts in real time to the changing field conditions.

We are currently investigating the performance of other farm tasks (such as the collection of bales of hay or fruit boxes). In these, we are going to use a fuzzy hierarchical controller to combine several behaviours for safe navigation toward our goals. In this work, we will integrate a vision system for bales of hay detection and will try to integrate it with the fuzzy system for reactive navigation. Also, we are currently investigating the use of GA based methods in respect to adding a learning capability to the controller so that it can adapt itself to the changing conditions of a field.

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Lantra report points to increasing requirement for higher skills levels

The latest research into labour market trends by Lantra (the National Training Organisation for land-based industries) shows that there is an increasing need for higher levels of skills in most land-based industries. Traditional unskilled and semi-skilled jobs are in decline and skills levels have to rise to meet the challenges of new working practices, rapid developments in technology and increasing competition.

The report, launched at the Farmers Club, London on 19 February states that 10 years ago many land-based employees needed skills equivalent to, or just above, level 2 in a National or Scottish Vocational Qualification (N/SVQ). This has increased to level 3 or higher. Other key findings from the report include:

- workforce turnover is increasing and averages 14%
- 43% of workers have industry-relevant qualifications at N/SVQ level 2 or above
- 26% of the workforce is qualified to level 3 or above
- an average of only 1.3 days per person was spent on training last year
- less than 25% of land-based businesses arrange formal training
- only 10% of land-based businesses have a formal training plan

The labour market information report presents the results of a two-year project through which Lantra has collected information from over 7,500 businesses operating in all aspects of the landbased sector across Great Britain. As well as providing the basis for the report, this data is also held in an economic forecasting database which can be used to help predict future demand for numbers of workers and their skill levels.

In the report's foreword, minister for lifelong learning Malcolm Wicks said: 'The data gathered in this report will serve as a solid foundation on which to develop the necessary foresight to future skills needs of the land-based industries. Naturally, this is a continuous process and this report only represents the first step in a much larger journey. Lantra must now gather support from employers, education and training providers, trade associations and others to develop a full Skills Foresight report and to put in place the measures necessary to address future skills needs.'

Lantra's chairman Andy Stewart said: 'The report highlights the difficult times now facing many parts of the land-based sector. These new challenges will have to be met by existing or future recruits and are likely to demand new skills and competences. If businesses are to compete effectively, employers must understand which skills are needed and take action to ensure that they exist in the workforce.

The report was used as the basis for a conference on 29 February for employers, trade association staff and education and training providers. 'This provided an opportunity for the sector to discuss the significance of Lantra's findings and shape a full skills-foresight report which we aim to publish in May' said Mr Stewart.

Contact: **Copies of the report are available from Lantra Connect on 0345 078007.**

Gentle new potato planter boosts planting accuracy

Kverneland has launched a brand new two row potato planter in time for this Spring's planting season. Designated the UN 3000T, the new planter boasts two major new benefits aimed at improving planting efficiency.

The first is an Hydraulically tipping 1.5 tonne capacity hopper, which has been found to be extremely gentle when handling chitted seed. The hopper feature is ideal for larger potato growers who require increased efficiency from a compact and manoeuvrable planter, especially when working long runs.

The second new feature is electronic vibrating agitation. The cupped belt vibrates from top to bottom, ensuring that only one potato per cup is delivered down. The degree of agitation is variable to suit different working conditions and tuber sizes, and the system has proven itself far more reliable and accurate than standard 'one bump' manual systems. The vibrating agitation system can also be fitted to the standard Kverneland UN 3000 planter.

The UN 3000T retains many of the well proven and popular features of the existing UN 3000 range, including a large planting unit with 74 mm cups as standard to handle large sized tubers, a top drive shaft for cup belts, and spacing that is adjustable from the side of the planter. A ridging hood is also available in lieu of the standard ploughs.

Retail price for the new UN 3000T planter is from £7,990 complete with the new agitation system.

Contact: **Les Davidson, Potato Product Manager, Kverneland (UK)**

Guide to woodland certification published

A woodland managers' guide to the UK Woodland Assurance Scheme (UKWAS), which certifies forests and woodlands whose management meets the highest environmental standards, has just gone on sale in booklet form.

The *UKWAS Guide to Certification* is a companion publication to the *UKWAS Standard,* which is also now available in booklet form. The Standard sets out the standards of environmental and community care that forest management must meet in order for forests and woodlands to be certified under the UKWAS.

The *Guide* outlines and explains the procedures that woodland managers must follow in order to gain UKWAS certification. It includes:

- an outline of the concept and process of certification, and points to consider when deciding whether to get a woodland certified;
- guidance for the managers of small woodlands who have never previously prepared a comprehensive woodland management plan, which is a requirement of certification;
- clarification of two of the more complex requirements of the UKWAS Standard, namely, monitoring and the restoration of ancient woodland sites;
- checklists and templates that can be photocopied and filled in to help woodland managers meet some of the UKWAS requirements quickly.

The UKWAS is a voluntary scheme that was launched in June 1999 by a wide range of stakeholders in UK forestry, including the Government, private forest and woodland owners, the wood-processing sector, people who work in forests, and environmental and community groups. It was established in response to the growing demand by consumers and retailers for independent assurance that the wood products they buy come from well managed forests. Owners whose woodland management is audited, or inspected, to the UKWAS Standard by auditors accredited by the Forest Stewardship Council (FSC) may use the FSC's internationally recognised trademarks on their products.

'The UK's forest and woodland management standards bear comparison with the highest standards in the world, and we anticipate that most actively managed woodlands in the UK could qualify for UKWAS certification without the need for major changes to current management practices,' said UKWAS Steering Group Chairman Paul Hill-Tout. 'The *UKWAS Guide to Certification* will provide valuable information to those considering having their woodlands certified, and it will help to make the process of gaining certification simpler. 'It is just one of the actions that the UKWAS Steering Group is taking to make certification more accessible to all, in particular the owners of small woodlands.'

The UKWAS Guide to Certification and the UKWAS Standard booklets are available, priced £5.00 each, from Forestry Commission Publications. Tel: 01329 331345. e-mail: orderline@telelink.co.uk

Contact: **Stuart Goodall in the UKWAS Support Unit at the Forestry Commission. Tel: 0131 314 6350. e-mail: ukwas@forestry.gov.uk**

HSE publishes revised guidance on working with chainsaws

The Health and Safety Executive (HSE) has published revised guidance to help the users of chainsaws work safely.

The guidance, INDG317 *Chainsaws at Work*, sets out the practical measures to be followed by employers, the self-employed and those in control of work equipment when the work involves the use of a chainsaw. It takes account of recent legislative changes on young people and work equipment.

Neil Craig, from HSE's Agriculture and Wood Sector, said, 'People's recognition of the dangers from chainsaws has increased in recent years. However, we still have a significant number of injuries being reported. Chainsaws themselves, and the work for which they are used, pose significant risks to people's health and safety unless they are used by properly trained and competent individuals.

'Injuries from contact with a running chainsaw can be horrific. It cuts a trench in a person's flesh, filling it with dirty oil and wood debris. In addition, chainsaw work with trees has resulted in serious and fatal injuries when operators and bystanders have been struck by falling timber. Chainsaws also expose operators to high levels of noise and vibration which can lead to hearing loss and conditions such as Vibration White Finger. All of these risks need to be properly controlled.'

The leaflet gives guidance on operator fitness and age, health risks, training, selecting and maintaining a chainsaw, personal protective equipment (PPE), lone working, first aid and safe working practices. It also gives some basic points to remind people what needs to be covered in the risk assessment for the worksite.

Mr Craig concluded, 'This guidance is intended for all users, not just those in forestry and arboriculture. Many businesses - including farmers, landscapers, builders, sawmillers, and grounds maintenance companies - use chainsaws in their work. All should read and act on the guidance in this leaflet.'

Contact: **Free copies of *Chainsaws at Work*, ref INDG317, are available from HSE Books, PO Box 1999, Sudbury, Suffolk, CO10 6FS. Tel: 01787 881165. Fax: 01787 313995.**

Measuring and modelling soil erosion processes in forests

W J Elliot, R B Foltz and P R Robichaud

Abstract

A prime forest resource is clean water for downstream beneficial uses. Sediment from forests may impair those beneficial uses. Sedimentation by water erosion is rare unless road activities, timber harvesting, or fire disturb the forest. We have been researching forest soil erosion processes and developing erosion prediction models for over 10 years. This paper presents an overview of some of our findings.

Rut formation dominates road erosion processes. Road maintenance practices that reduce rutting also reduce erosion rates. Road ditches can also be a major source of sediment if the ditches are recently disturbed from construction or maintenance. Generally, if roads are properly designed and located at a sufficient distance from nearby streams, then stream sedimentation is minimal.

Forest harvesting activities can lead to increased erosion due to the exposure of mineral soil or the alteration of soil properties due to compaction. Fires can lead to major erosion in forests, especially during the first few years after the fire. Spatial variability of the severity of disturbance is common after fire. Fire effects include a reduction in soil hydraulic conductivity and a loss of the protective organic layer on the soil surface. These two impacts can increase erosion rates by several magnitudes.

The Water Erosion Prediction Project (WEPP) model can model disturbed forest erosion processes. The WEPP can be a powerful tool to provide quantitative estimates of the amount of sediment entering forest streams for many management activities. Templates for the current WEPP model and user-friendly interfaces have been developed to assist field managers to apply this technology to various forest conditions.

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1. Introduction

Soil erosion results from complex interactions of climate, topography, soils and geology, vegetation, and management activities. Rainfall is inadequate to cause major erosion problems in many of the non-agricultural forested areas managed by federal agencies in the western U.S. The soil surface litter layer prevents surface runoff, so there is little concern from upland erosion processes. In these areas, much of the runoff is from near-surface flow, and shallow groundwater dominates stream flow. The net result of these processes is that natural erosion rates within most U.S. forests is low, in the range of 0.04 to 0.1 Mg ha^{-1} y^{-1} (Hickey, 1997; Megahan & Kidd, 1972; Patric, 1976). Forest disturbances, however, can increase erosion rates to 100 Mg ha^{-1} y^{-1} (Megahan & Molitor, 1975). These disturbances include roads, forest operations including harvesting, and fire. The objective of this paper is to describe research activities and findings about measuring and modeling soil erosion resulting from forest disturbances.

Roads are the greatest human-induced disturbance on a forested landscape. The soil disturbance and compaction caused during road construction considerably reduces the hydraulic conductivity of roads (from 40 mm h^{-1} or more to under 1 mm h^{-1}). The resulting increased runoff coupled with the absence of vegetation are responsible for the increased erosion rate observed on road surfaces. Harvesting activities and fire have similar effects in increasing runoff and decreasing surface cover but to a much lesser extent. The degree to which conductivity is decreased, and surface cover reduced, determines the level of erosion that will follow. Even though erosion rates may not be as high as on roads, the larger spatial extent of the disturbance may result in an overall greater delivery of sediment. The forest vegetation, however, can soon return following a forest disturbance, reducing erosion rates back to undisturbed levels. The process-based Water Erosion Prediction Project (WEPP) model has the ability to model most of these processes, but building the input files for such complex conditions has been too time-consuming for many forest specialists.

2. Road erosion processes

Rut formation dominates road erosion processes. Roads with ruts caused by traffic produced two to four times as

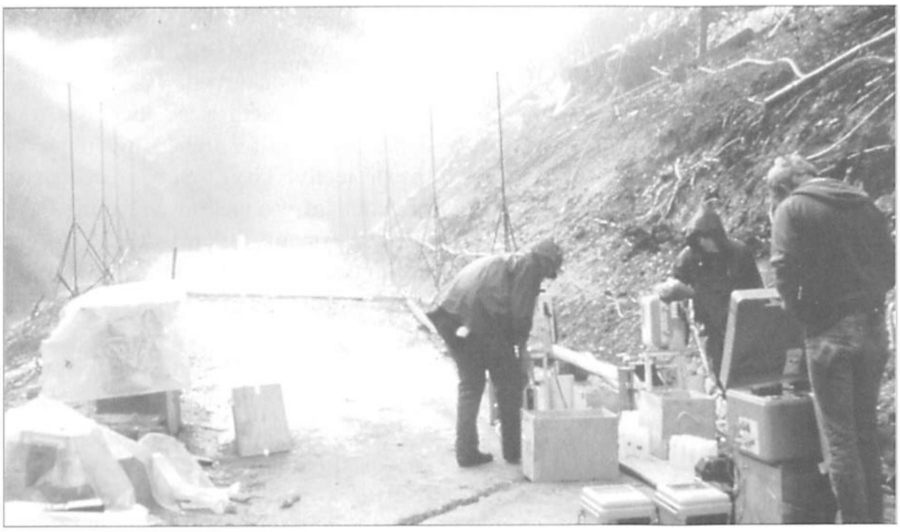

Fig. 1 Measuring road erosion rates in central Idaho with a rainfall simulator

Fig. 2 Measuring rutting on a road in the Willamette National Forest, OR.

much sediment as freshly graded roads in studies using rainfall simulation (*Fig. 1*) or natural rainfall (Foltz & Burroughs, 1991; Foltz, 1993). These studies reported on ruts that were deep (50 mm) and continuous (greater than 15 m long). In these studies with well defined continuous ruts, the dominant process responsible for the increased sediment was a change from short overland flow paths across the road to long concentrated flow paths down the road. *Figure 2* shows Forest Service professionals measuring the degree of rutting on a road in a recent study in Oregon.

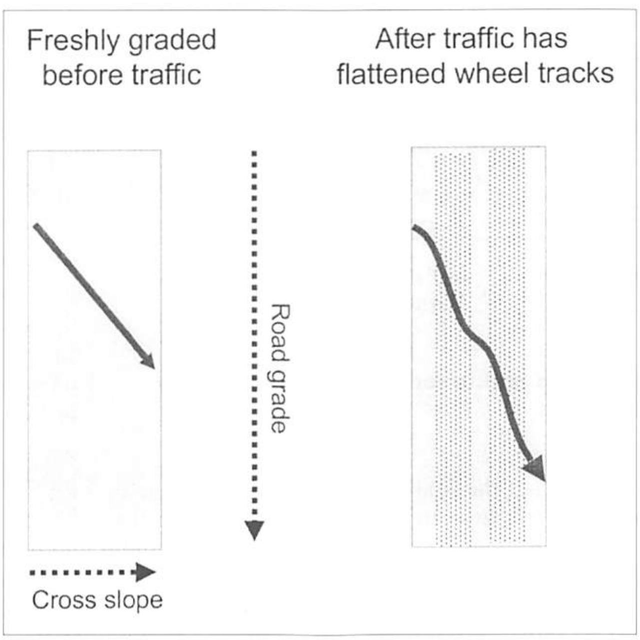

Fig. 3 Impact of traffic flattening an outsloping road on flow path length

Overland flow occurs along a path that is a combination of the road grade and the cross slope on a recently maintained road without ruts (*Fig. 3*). Even before deep ruts form on a road, traffic causes changes in the road surface topography that may increase erosion. On most forest roads, traffic tends to reduce the cross-slope, so that runoff follows the road surface for a greater distance (*Fig. 3*). The increase in surface erosion due to this increased flow path length may be doubled, or more, even before rutting occurs.

Road maintenance practices to remove ruts can result in major reductions in erosion rates. Elimination of ruts and reestablishment of cross-slope reduces overland flow path length, which reduces erosion rates. Road maintenance practices can leave erodible material on the surface ready to be washed off in the next storm. The shorter overland flow path leads to lower accumulated runoff, resulting in lower sediment detach and transport rates of this loose material and less surface erosion.

A decrease in sediment production over time is an important characteristic of road erosion. Two time scales can be distinguished: within a single runoff event, and over several years. In rainfall simulation studies, sediment concentrations start high and decline during a runoff event even though the runoff rate remains constant (*Fig. 4*). Foltz (1993) reported sediment concentration declines of 67 to 78% during high intensity, long duration simulated rainfall storms (50 mm h^{-1}, 90 minute duration). The reason for this decrease appeared to be a sediment supply deficiency. We postulate that the sediment supply recovers between storms by a combination of desiccation of the surface and additional traffic. Desiccation causes larger aggregates to break into more transportable sizes. Traffic crushes the surface into smaller, more transportable sizes. In a study of these recovery mechanisms, Foltz and Elliot (1999) estimated the time scale for desiccation to be approximately one week. The amount of traffic needed to regenerate a similar sediment supply was 50 to 100 passes of a pickup truck (3.6 Mg) or a single pass of a fully loaded logging truck (22.5 Mg).

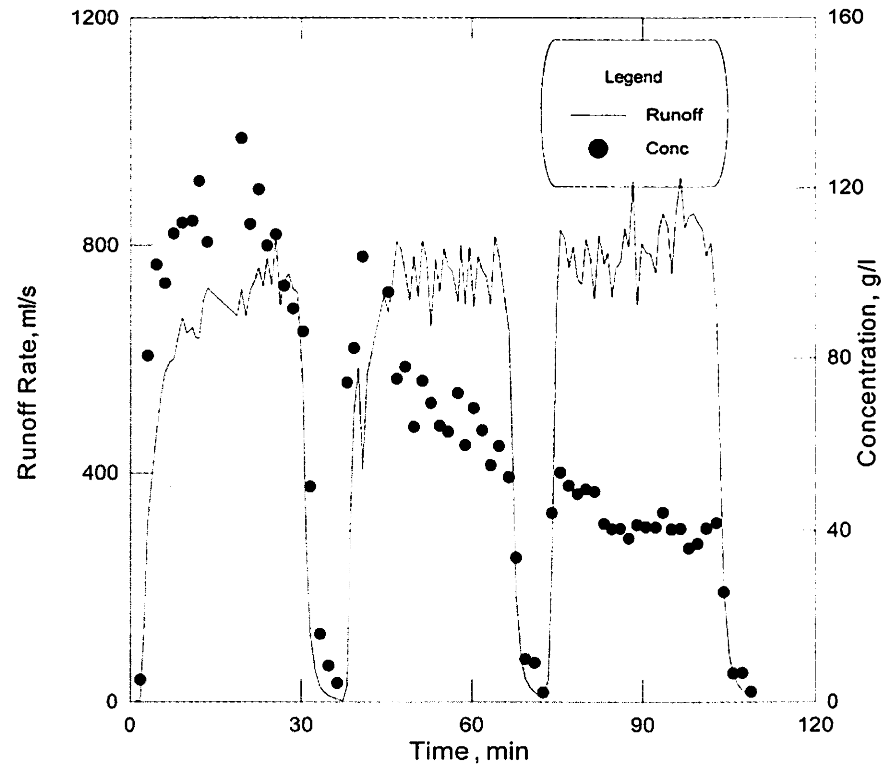

Fig. 4 Typical rainfall simulation data showing the relationship between road runoff and sediment concentration and time during a sequence of three constant-intensity rainfall events

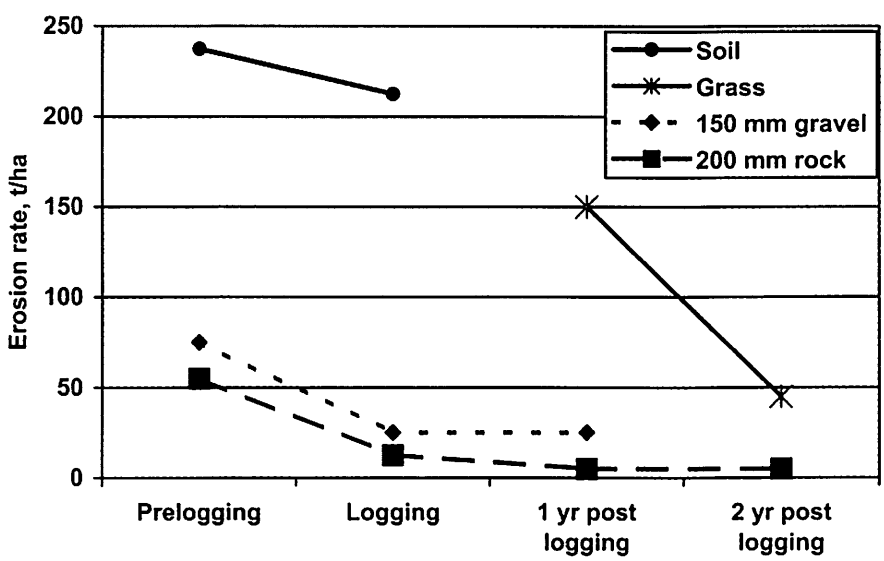

Fig. 5 Decline in road surface erosion rate over several years in the southeastern U.S. (Swift 1984)

The long time scale decrease in sediment production represents a period of several years (*Fig. 5*). Megahan (1974) measured erosion from a new logging road in central Idaho for a period of six years. Sediment production from the entire road prism decreased exponentially from 175 Mg ha^{-1} y^{-1} to 4.6 Mg ha^{-1} y^{-1} for the sixth year of the study where traffic on the road was minimal after the first year. Megahan discounted both variations in rainfall and re-vegetation as causative agents in the observed sediment decline. He postulated that armoring of the surfaces was responsible. Classical armouring occurs in mountainous rivers where the smaller size particles are washed away by the flow leaving the larger ones undisturbed. The larger sizes subsequently shield the smaller ones from detachment until a higher flow removes the protective layer. Similar decreases of sediment production with time have been incorporated into U.S. Forest Service regional erosion models and Washington [State] Forest Practices (1997).

If roads are free from ruts, then road ditches can be another major source of sediment where they have been disturbed by construction or maintenance. When routine forest road maintenance is performed, the ditch is often cleared of vegetation and accumulated sediment. This operation increases the water velocity by removing the retarding vegetation and makes detachable sediment more freely available. However, the faster water is more erosive. In a study of ditch linings in central Idaho, Foltz (1996) found water velocities two to three times higher in bare ditches than in grass-lined ditches. Luce and Black (1998) reported that road segments in Western Oregon with recently cleared ditches produced seven times as much sediment as well vegetated segments.

A bare or vegetated fill slope, and a forested buffer area are generally located between roads and streams (*Fig. 6*). If roads are located at a sufficient distance from nearby streams, then sediment delivery to the stream is minimal. The erodibility, transportability, and conductivity of soils vary with parent materials. Burroughs and King (1989) studied travel distances below ditch culvert outlets in gneiss and schist parent materials on 30 to 40% hillside gradients. They reported that if the objective was to prevent 80% of the culverts from contributing sediment to streams, a distance of 50 m would have to be provided between the culvert outlet and the stream. In another study in central Idaho, Wasniewski (1994) found that 95% of the sediment travel distances below culverts did not exceed 45 m for gneiss and schist, and 60 m for granitic parent material, which had a higher hydraulic conductivity. Rhee *et al.* (1999) reported on a WEPP model study of a 4.4 km road in granitic parent materials that had been designed to minimize sediment delivery. No sediment delivery to the stream occurred from segments totalling 2.21 km. The maximum delivery of only

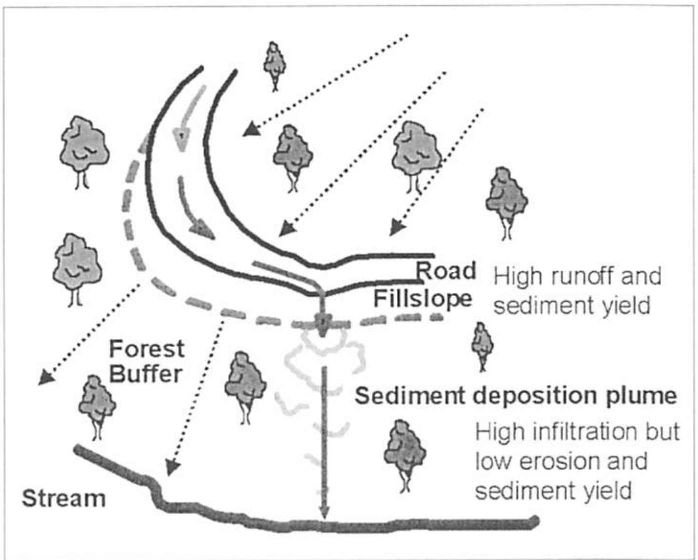

Fig. 6 Dominant erosion processes on roads with forest buffers

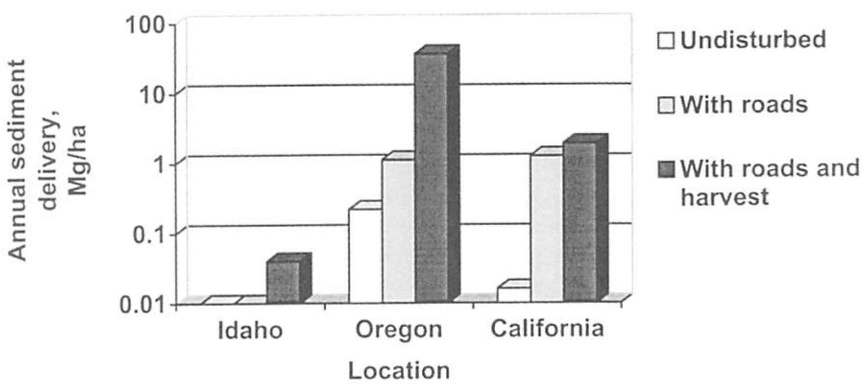

Fig. 7 Effect of roads and timber harvesting on annual watershed sediment yields (after Megahan & Kidd, 1972; Fredriksen, 1970; Rice et al., 1979)

1.2% of the sediment that was detached on the road occurred over a forest floor with a length of 180 m and a gradient of 40%.

State and federal regulatory agencies recognize the role of forest buffers in trapping sediment. In a recent document, an interagency group of managers recommended buffers of 92 m around fish bearing streams and 46 m around permanent non-fish-bearing streams (USDA FS & USDI BLM, 1995). Washington [State] Forest Practices (1997) Watershed Analysis assigns roads draining directly into streams a delivery of 100%. For forest buffers up to 60 m, a delivery of 10% is estimated; for buffers greater than 60 m, the sediment delivery is assumed zero. Any sediment delivery across a buffer will vary with climate and topography. Consideration to local factors therefore is necessary, and caution is recommended before transferring any remotely developed prediction technology to local conditions (Morfin *et al.*, 1996)

3. Erosion from forest operations

Roads are not the only source of erosion in forests. Forest lands are generally stable and do not erode unless disturbed by forest operations, prescribed fire, or wildfire. Forest operations such as thinning, harvesting, and site preparation activities may influence onsite erosion. Erosion from timber harvest areas generally is less per unit area than erosion from roads, but since these areas are much larger, the total erosion from timber harvested areas and roads may exceed that from roads alone (*Fig. 7*). Spatial variability is a complicating factor in determining the effects of forest operations. The variability of inherent site characteristics, (Robichaud, 1996), spatial extent of the disturbance (Robichaud & Monroe, 1997), and proximity to sensitive areas such as stream corridors and riparian zones (O'Laughlin & Belt, 1995) all impact upland erosion and sediment delivery.

Four common harvesting systems are skidder, ground cable, skyline and helicopter. Skidder logging systems cause the most disturbance (*Fig. 8*). The logs are dragged, disrupting the forest floor. The skidder tyres disrupt the forest floor, and repeated passes are common. Skidders displace the forest floor and compact the mineral soil. In addition to compaction, on slopes greater than 20%, the slippage of the skidder tyres may remove the litter cover and loosen the mineral soil beneath. Compaction increases runoff and soil erosion and adversely impacts productivity by reducing the water holding capacity of the soil. Litter removal increases the erosion rate of the mineral soil. The most erodible soils within a harvest area are skid trails because these soils have reduced infiltration, disturbed litter cover, and compacted soil (Robichaud *et al.*, 1993a). Cable systems and helicopter logging cause far less disturbance with erosion

Fig. 8 Skidder at work in a Georgia forest

rates approaching undisturbed rates, depending on how much care is taken during the operations.

The location of skid trails on a hillslope can also influence the rate of erosion and sediment yield. Skid trails near the top of a hill, and those following natural contours, are unlikely to cause any significant erosion or offsite sediment delivery. Skid trails nearer the bottom of the hill, with minimal undisturbed buffer zones, are more likely to erode. They are exposed to additional overland flow from uphill and are more likely to deliver sediment to streams. In Elliot *et al.* (1996), a skid trail near the bottom of the hill concentrated surface and subsurface runoff, leading to erosion in a channel that was stable prior to the disturbance.

4. Fire

Forest management activities impact the natural processes of fire and erosion, particularly fire suppression and timber harvesting. Fire suppression on steep terrain has increased for many decades in the western U.S. Fire suppression leads to fuel loads that exceed natural levels and may cause plant species composition changes (Agee, 1993). These changes in the plant community and fuel result in conditions that are more susceptible to high severity fires. High severity wildfires, especially on steep slopes, can have a major impact on erosion, mass wasting, and hydrologic processes. The result is often loss of soil mantle (from generally poorly developed soils), sediment movement and flooding, loss of nutrients held in organic matter and mineral soil, damage to fish habitat, and damage to structures such as roads, bridges, and water storage systems.

Fig. 9 Installing a weir and sediment collector on a site following a wildfire in the Wenatchee National Forest, Washington

Studies with both rainfall simulation on small plots and natural runoff studies on small watersheds (under 10 ha) are used to measure erosion rates from these disturbed areas (*Fig. 9*).

The most common method of site preparation for tree regeneration in the United States is prescribed burning. Prescribed fires are conducted alone, and in combination with other treatments, to dispose of slash, reduce the risk of insect and fire hazards, prepare seedbeds, and suppress plant competition from natural and artificial regeneration. The use of prescribed fire is likely to increase during the next decade as forest managers reintroduce fire into fire-dependent ecosystems.

Table 1 Typical Water Erosion Prediction Project (WEPP) model soil erodibility values for forest conditions for a sandy loam soil

Condition	*Interrill erodibility, Mg s m^{-4}*	*Rill erodibility, s m^{-1}*	*Conductivity, mm h^{-1}*
Forest	500	0.0005	42
Low severity fire	1,100	0.0006	25
High severity fire	2,800	0.0007	16
Skid trail	1,000	0.0005	10
Ungravelled road	3,000	0.0003	0.3
Gravel road	3,000	0.0003	3.0

Erosion following fires, either prescribed or wildfire, can vary from extensive to minimal, depending on the fire severity and areal extent. Erosion from high severity fire can cover large areas and fires may create water repellent soil conditions. Erosion from low severity fires may be 0.1 Mg ha^{-1} or less (Robichaud *et al.*, 1993b), whereas erosion from high severity fires can range from 6 to 38 Mg ha^{-1} (Robichaud & Brown, 1999; Robichaud & Waldrop, 1994). Variation in erosion is due to the variability of fire effects, ground cover differences, inherent variability in soil properties (Robichaud, 1996), and the weather patterns the year following the fire.

5. The Water Erosion Prediction Project (WEPP) model

The WEPP model was developed by an interagency team of scientists including the U.S. Department of Agriculture's (USDA) Agricultural Research Service (ARS), Natural Resource Conservation Service (NRCS, formerly the SCS), and the Forest Service. Participants from the U.S. Bureau of Land Management and numerous universities also have contributed to the development of the WEPP model (Laflen *et al.*, 1996). The WEPP model is a process-based soil erosion model that uses a daily time step for water balances and vegetation growth. When a day has a precipitation or snowmelt event, WEPP model predicts the runoff, distribution of sediment detachment on a given hillslope, and sediment yield from the bottom of the hill. The WEPP model can be run for a hillslope, with up to 10 different soils and/or vegetation conditions along the flowpath, or for a small watershed of up to about 100 ha. The WEPP model simulates rill and interrill erosion in the hillslope version and adds channel erosion or deposition in the watershed version.

The WEPP model is available with a MS-DOS text-based interface. A Windows 95 interface is under development by the USDA-ARS. Both of these interfaces allow the user to alter every input variable describing soil layer properties and vegetation conditions in great detail. It is not uncommon to have 400 variables for a given scenario, plus 10 daily climate descriptors. This considerable amount of input data allows users to describe a large number of conditions including agriculture, range land, disturbed forests, mining sites, and construction sites. Typical values for soil erodibility properties are presented in Table 1 for forest conditions. Values to describe forest vegetation conditions can be found in Elliot and Hall (1997), which is available from our internet web site (http://forest.moscowfsl.wsu.edu/4702/forwepp.html). Templates for a number of forest conditions are available from our internet web site for downloading and installing within the WEPP MS-DOS file structure.

Table 2 Results from a Water Erosion Prediction Project (WEPP) modelling exercise to analysis for a timber thinning operation in the Sierra Nevada Mountains in California; the slope was assumed to be 260 m long and 30% steep, with a 60 m buffer at the bottom

Exceedance probability,%	*Precipitation, mm*	*Runoff, mm*	*Upland erosion, Mg ha⁻¹*	*Sediment delivery, Mg ha⁻¹*
Undisturbed forest				
2	2475	130	7.1	5.2
4	2462	114	5.3	4.6
10	2239	46	2.1	1.9
20	2006	13	0.8	0.6
Average*	1695	13	0.6	0.5
P(x>0)†		0.90	0.86	0.90
After thinning				
2	2475	105	18.0	13.7
4	2462	53	8.1	5.3
10	2239	30	3.9	0.6
20	2006	6	0.9	0.2
Average*	1695	7.5	0.9	0.5
P(x>0)†		0.98	0.74	0.92

* Average erosion predicted from 50 years of WEPP simulation for site.
† Probability that the value is greater than zero.

The complexities of the input data have discouraged widespread application of the model. The authors, therefore, have begun development of simple interfaces for specific applications such as forest roads, harvested and burned forest areas, and range land. These interfaces can be accessed at our web site (http://forest.moscowfsl.wsu.edu/fswepp/) (or through the Forest Service Intranet for Forest Service users; Elliot *et al.*, 1999).

6. Typical field observations and modelling results

6.1. Forest roads

The importance of an undisturbed buffer to minimise sediment production was described earlier. *Figure 10* presents the predicted amount of sediment delivered to a stream from a forest road in Idaho as a function of buffer width. The WEPP model predicted an average annual road erosion rate on the 100 m road of 20 Mg ha⁻¹. Ketcheson and Megahan (1996) measured an average annual erosion rate of 24 Mg ha⁻¹ in a four-year study on 24 km of roads in northern Idaho, in close agreement with the predicted value. The predicted length of sediment deposition downhill from the 100 m road was about 45 m. Ketcheson and Megahan (1996) found the mean length of observed sediment travel from 26 sites to be 49.6 m in Idaho. These predictions and similar comparisons have led us to believe that WEPP model predicts reasonable values for road erosion and sediment plume length. We, therefore, believe that WEPP model also predicts reasonable values for sediment entering a stream, although we do not have direct measurements for comparison.

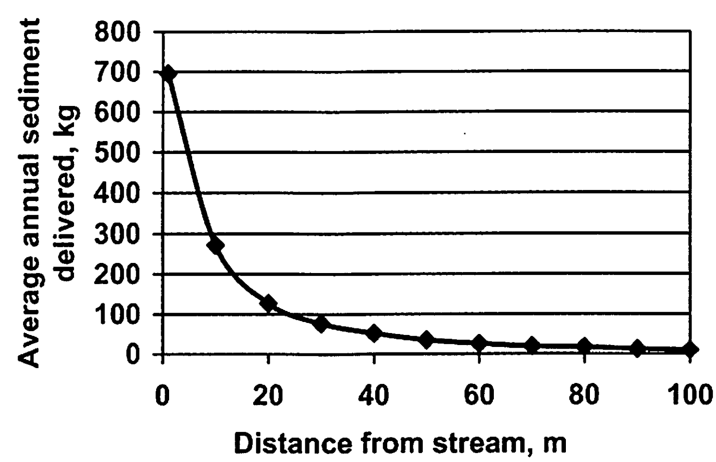

Fig. 10 Effect of distance from a road to the stream on predicted annual sediment yield to the stream (for a 100 m long road in northern Idaho); see Fig. 6 for a diagram of the relationship between the road and the stream

Some managers have assumed that if a sediment plume is evident, then there has been no transport of sediment to the stream. We have observed, however, that the WEPP model often predicts sediment delivery to a stream from a buffer area, even when there is significant predicted deposition. The WEPP model has shown that sediment commonly carried beyond the observed depositional area from the occasional large storm, which transports most detached sediment all the way to the stream.

6.2. Disturbed Forests

One of the features of predicting erosion from a disturbed forest is that the disturbance only lasts for one to three years before revegetation occurs. If high rainfall or snow melt rates occur before revegatation, then erosion rates may be very high. If the weather is less severe, there may be no erosion. For these revegetating forest conditions, predicting a mean erosion rate is inappropriate even though it is common in all agricultural erosion prediction methods. The dynamic nature of vegetation regeneration means that the forest vegetation cover is likely to be different each year. A design storm approach to predicting erosion rates has limitations in that the impact of the storm depends on the hydrologic and vegetative recovery condition when the event occurs. In many remote, high elevation forests, runoff and erosion are driven by snow melt rather than rainfall, and little information exists to aid in deriving design storms for snow melt. We are evaluating alternative strategies to address this situation. Our current approach is to predict the probability of erosion occurring after a disturbance by running the WEPP model for 50 or 100 years of stochastic climate. The WEPP model generates a detailed annual output file giving the precipitation, runoff, erosion, and sediment yield for each year of simulation. Our interface accesses this file to estimate annual probabilities for given magnitudes of precipitation, runoff, and erosion. The predicted probable erosion rates and sediment yields can then be evaluated by managers relative to other watershed characteristics, such as value of fisheries, property risks, and soil quality to determine the level of mitigation to recommend following a disturbance. A web browser accesses our web site for the entire analysis (Elliot *et al.*, 1999). Results of an example of such a study that was recently carried out for a forest in the Sierra Madre Mountains in California is presented in Table 2 with the exceedance probabilities, the mean values, and the probabilities of zero values for both undisturbed and thinned forests, as predicted by the WEPP model.

Table 2 Results from a Water Erosion Prediction Project (WEPP) modelling exerise to analysis for a timber thinning operation in the Sierra Nevada Mountains in California; the slope was assumed to be 260 m long and 30% steep, with a 60 m buffer at the bottom

The WEPP model can differentiate between upland erosion rates, which impact productivity, and sediment delivery from the toe of the slope, which impacts off-site water quality (Table 2). Timber harvesting by thinning increases erosion and sediment yields in the years with the greatest precipitation. However, Table 2 shows that there is a 96% probability that the runoff and erosion associated with thinning operations will not be greater than the undisturbed condition. Reasons for this minimal difference may be due to greater transpiration and earlier, slower snow melt rates after thinning. Table 2 also presents the probability that the runoff, erosion, and sediment delivery will be greater than zero (P(x>0)). In many forest conditions, surface runoff and erosion rates are zero in most years, and the WEPP model provides a tool to estimate the probability of non-zero years.

The values in Table 2 predict average erosion rates in Northern California of 500 to 600 kg ha^{-1} for undisturbed forest, and 500 to 900 kg ha^{-1} for disturbed forests (not including roads). These values are similar to those observed by Rice *et al.* (1979) in Northern California after harvesting of 630 kg/ha, and Betscha (1978) for a similar wet climate in the Oregon Coast range of 600 to 1100 kg/ha (both include roads). The similarity of these values gives us confidence that the WEPP model predictions are reasonable for disturbed for conditions.

7. Summary and conclusions

We have provided an overview of some of the recent findings in our research programme to determine the erosion processes, and measure the factors associated with those processes, in forests. An understanding of the sites of erosion and deposition, and the flow paths followed by runoff, is essential in estimating erosion amounts. In addition to topography, soils, climate, and vegetation cover, spatial and temporal variability are important factors in erosion processes in disturbed forests. We believe that the average values may be suitable for road erosion since roads tend to be permanent features on the landscape. With the epochal nature of erosion events, however, we suggest that probabilities of erosion are more appropriate for forest disturbances such as harvesting or fires, because the site quickly returns to pre-disturbance hydrologic conditions.

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Lantra accepts Prime Minister's challenge

Lantra has welcomed the Prime Minister's announcement yesterday that it will receive £1.2 million to promote the benefits of training to farmers and growers, and analyse the information technology training needs of 20,000 businesses. The funding is part of a £200 million package of aid outlined in the Action Plan for Farming.

Responding to the announcement, Lantra's chairman and Nottinghamshire farmer Andy Stewart said: 'Lantra is glad to be able to play its part in helping the agricultural and horticultural industries at such a difficult time. I am convinced that the information, learning, communication and marketing opportunities which will be made available to producers via information technology will be a tremendous aid to their business competitiveness.'

This initiative will be delivered through Lantra's established network of registered training providers including colleges and employer groups - who already provide access to a wide range of training and support services.

The Action Plan for Farming will help bring together a number of projects. Lantra is already receiving support under the Ministry of Agriculture, Food and Fisheries' Agriculture Development Scheme to work with the Department for Trade and Industry in developing a business analysis framework for farms that assists business planning. This links in with the planned £6.5 million announced yesterday to provide support and advice to farmers and growers through the new Small Business Service.

Plans are also well advanced for a partnership between Lantra and agricultural colleges to provide services through the University for Industry, which is developing a range of 'on-line' training materials aimed at farm businesses.

Contact: **Lantra Communications Department, NAC, Kenilworth, Warwickshire, CV8 2LG. Tel: 01203 696996. Fax: 01203 696732. e-mail: nto@lantra.co.uk**

Things to come

The spray bar, mounted underneath the autonomous vehicle, comprises a series of nozzles which are controlled by the computer and strictly related to the target plant. This ensures exact application and minimum use of spray material.

Geoffrey Lawson

Research is exciting, but more especially if the end object of the work can be seen and when the actual application, in the glasshouse or field in this case, has every prospect of being a reality in the forseeable future. Such was the case with the six subjects covered at the event entitled 'Into the 21st Century', and presented by their respective researchers at Silsoe Research Institute on the 15th of March.

Staged at the request of the Horticultural Engineering Group, it was attended not only by their members and guests, but also a number of Students from the Writtle and Hadlow Colleges. We hope this trend will continue and expand. The event neatly divided into two halves, in the morning three papers were given on glasshouse related subjects, whilst the afternoon was devoted to field crops.

Geoffrey Lawson is Information Officer for the IAgrE Horticultural Engineering Specialist Group

Glasshouse crop environment

Dr Paul Hamer

Dr Paul Hamer started the day by describing his work on the need to be able predict the effects on large scale glasshouse crops based on small scale experiments. Using tomatoes as the crop and working in collaboration with Horticultural Research International, the results were derived from small units at Silsoe and HRI Wellesbourne, and two large commercial units in Wales and the Isle of Wight.

It follows that there was a need to modify the results from the small units to relate directly to the large commercial houses, and this involved a lot of patient work. Whilst it involved the usual parameters of light levels, humidity and temperature, *etc*., the work also took into account both house and row orientation. There were also differences in the commercial units and especially as the light and CO_2 levels were higher in the houses on the I-of-Wight. It was here that the biggest individual yield was found to be from the Southern row of twin rows arranged in N/S orientation.

In short, Dr Hamer said that the results obtained, and they also included study of control systems and the effect of thermal screens, have provided a sufficient basis to allow the predictions that they sought to be made.

Glasshouse ventilation

Glasshouse ventilation turned out to be somewhat more complicated than one might first suppose. Dr Bernard Bailey, pointing out that glasshouses are being used in tropical and subtropical situations, said the need to know more about ventilation was important. More needed to be known about the behaviour of air as it passed through vents. Truly surprising, at least for most of his audience, was that in some circumstances air would actually pulsate in and out of a vent! This obviously presents problems for a researcher as it is difficult to quantify. His study of ventilation has shown that long vents are best and the combination of sidewall and roof vents are good. Even so apparent anomalies arise, or at least for the lay persons, in that air will enter vents of the leeward side and exit on the windward; though this effect is recognised by growers who are aware of the effects on temperature. That is they realise that the windward side of a house can be warmer than the leeward.

Full scale trials to study air flow in a house, using injected gas as a tracer combined with multipoint sampling, are difficult and especially as some gas is taken up in the photosynthetic process. Trials are therefore based on a combination of modelling and actual tests. Current work is conducted in an atmospheric flow laboratory, using 56 individually controlled fans, where it is hoped this will mimic airflow over 1/3 scale model houses.

The simple video camera, which 'looks' at a row of plants, is seen here mounted on the frame of the hoe which it keeps in line irrespective of the tractor's position.

Pest control

The need to reduce the use of pesticides, *etc.*, is important, and whilst the glasshouse industry have taken to biological control in a big way, there still remain some pests such as red spider on tomatoes which need a chemical treatment to maintain proper control. The work undertaken by Dr Steve Parkin looked at this need from two aspects; first of all to find the minimum amount of chemical required for control, and secondly the best means of application to ensure proper leaf cover. The experiments involved nozzle type and orientation, method of delivery, air assistance, and other novel application techniques. Sensitive paper strips, placed at different levels in the crop, were used to estimate the effective leaf cover of the trial sprays. Sprayed with water containing a tracer, the paper strips fluoresced when exposed to ultraviolet light, and from this both cover and optimum quantity could be assessed.

Dr Tony Hague (right) pausing while the note takers in the Group catch up

The results produced a surprise (certainly for the author and I suspect a number of the audience as well) since the time honoured flat fan nozzle produced the best results. This notwithstanding, it was tested against hollow cone, and air assisted nozzles as used on a vineyard sprayer, and its acknowledged wide range of droplet sizes.

The nett result is that a vertical spray bar fitted with 80° flat fan nozzles angled upwards at 45°, proved to be the best option. In practical terms, this can result in a trolley, running on the heating pipes between the rows, arranged with two spray bars so that it sprays the crop each side of the alley.

The patient work undertaken on application rates came out rather convincingly at 2,200 *l*/ha, and this at a pressure of 3-4 bar; altogether a very interesting study which can result in a direct practical application.

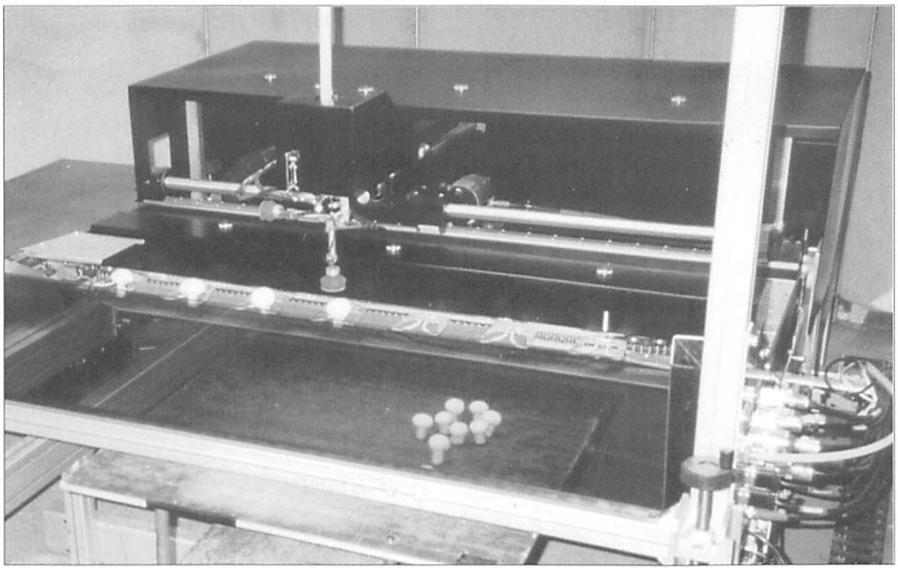
Autonomous vehicle

Bearing in mind the trends to organic growing, it should have come as no surprise that steerage hoeing and an autonomous toolcarrier is receiving attention at Silsoe. This work is undertaken jointly by Dr Nick Tillett and Dr Tony Hague.

Introducing the work, Nick Tillett explained that the increasing trend to organic crops has revived the use of steerage hoes but also with the target of one-man operation.

The result is the use video imaging of rowcrops as a means of accurate guidance for the tractor mounted hoe. A camera mounted on the toolbar and angled down at 45° scans the row 12 times per second and the alignment of the row is derived from this. Since the camera is mounted on the toolbar, it will recognise when the toolbar, and the hoe, is off line and cause the necessary correction to be made. This is done by activating a small, and hence responsive, double acting hydraulic cylinder to move the toolbar in the right direction. The design of the onboard computer program is such that the discrepancies can be allowed for. Or simply, if a plant is missing in the row then the computer will recognise this and not deviate in direction; and similarly, if a plant is seriously out of line, it will be ignored. The guided hoe has been shown to work successfully up to speeds of 6.5 km/h, and could go faster but may well be limited by other factors such as soil 'smother' from the hoes.

Another surprise is that, as well as



The experimental mushroom harvester with the robot arm (centre of photo) which has just placed a mushroom in one of the open fingered sideways conveyor, and will then return to collect another from the group seen below and in front of the conveyor

obvious vegetable and arable row crops, the machine is also contemplated for use in cereals. This will mean a return to the old traditional 18 cm rows, since the current narrower rows would be difficult to hoe without smother.

The fully automatic tractor or toolcarrier, working away in a crop without any supervision, has an obvious appeal. Much earlier work, and other studies, relied on buried sensor cables, whereas the current example at Silsoe uses video imaging to maintain the direction of the machine but is capable of other uses as well.

Professor Bill Day

Tony Hague said that the reasons for the machine, based on a venerable Evenproducts toolcarrier, was to reduce inputs, increase efficiency, and to positively identify where plants were situated in a rowcrop. The machine was arranged as a 'spot' sprayer with the object of just spraying the plant itself or, not spraying at all in the plant was not there.

The on-board computer control system again used a video camera, but in this case it scanned the whole width of the bed. This gave information for direction control which was conveyed to the individually driven wheels for maintaining a correct line, but at the same time recognised the position of the plants in the rows. The result of this, and again since it could differentiate between plants, weeds, soil, and misses, means that only the existing plants themselves would be treated. This was effected by a mid-mounted spray bar with nozzles mounted at 50 mm pitch and tumed off and on by signals from the computer.

Inevitably, any description here must be limited and the machine has to be seen to be appreciated, and especially as it will turn at the end of a bed and enter the adjacent one and continue working. It would seem that this unit really will work on its own and hopefully with only minimum periodic checking, and even this could be by remote TV monitoring.

Automatic harvesting

Video imaging also formed the basis of a potentially fully automatic harvesting system for mushrooms. Describing the work, John Reed said that the basis of the system would rely on a standard sized growing container which could be transported to the harvesting unit. Here the ready to pick mushrooms, based on size, would be removed. The container with the smaller mushrooms remaining would then be transported back to the houses to grow on, and it follows that it will be returned on a cyclical basis to gather subsequent flushes.

From the video image of the mushrooms in the container, the computer chooses which is the best mushroom to gather, and this is not only based on size, but also the other mushrooms in the vicinity of the chosen target. Once determined, a robot arm extends to place a suction pad over the target, it descends to gently attach to the mushroom, tilts the mushroom away from its neighbours if there is room to do so, twist the mushroom free, then lifts and retreats to place the mushroom into a conveyor which in turn takes and places it into a punnet. The computer then selects the next target, based on the same parameters, and detaches this in the same way, and so on. Noting that the total cycle time was 7 seconds, it was suggested to John Reed that this was not fast enough to be commercially viable. However, his response was that they envisaged multiple picking heads working over the same container simultaneously, and sourced frorn the same single imaging process which could increase the picking rate to commercial levels.

Acknowledgements

I am sure all who attended were well pleased with their privileged glimpse into the 21st Century, and the committee and members of the Horticultural Engineering Group would like to express their gratitude to the researchers and support staff of the SRI and our Institution, for organising such a successful event. We would especially like to thank Professor Brian Legg, whose original enthusiasm created the idea, and the now present Director of SRI Professor Bill Day, for continuing in the same vein.

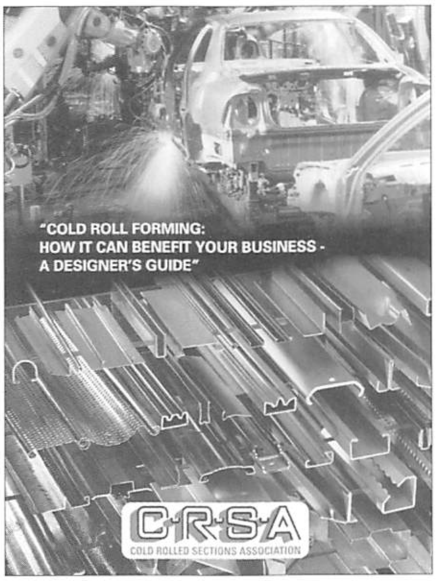
Industry missing out on custom roll forming benefits

German and North American manufacturers are stealing a march on their British counterparts through having a far greater understanding of the cost and design benefits of Custom Roll Forming techniques.

The Cold Rolled Sections Association first warned two years ago that almost every sector of British manufacturing was missing out on proven and constantly improving techniques that usually offered the best and sometimes the only way to deliver consistent products, systems and complex shapes to tight tolerances, at reduced cost and improved profitability.

As part of a programme to improve awareness of Custom Roll Forming, the CRSA has now published a Designer's Guide to address the questions most commonly asked by product designers, design engineers and other specifiers. The guide explains the Custom Roll Forming process and the range of ancillary operations which can be incorporated into the process to produce ready-for-assembly components.

Apart from the automotive and construction sectors - usually cited as the two industries capitalising on the benefits of cold rolled, high strength, low weight materials - the guide also features applications in office furniture, storage and racking, tractor cabs and earth moving equipment, electronics, white



goods and security installations.

The guide, in printed and CD ROM formats, will be widely distributed to design and engineering courses as part of the CRSA programme to raise levels of understanding to those existing among North American and European graduates. It will also be featured on the CRSA web site *www.crsauk.com* Manufacturers, engineering practices and other trade bodies are also being targeted by the Association.

Cold rolled sections are created by running a variety of base materials through successive pairs of rolls to produce complex shapes in high volumes to tight tolerances. Cold rolled sections can save 30% of the weight for the same strength in applications produced through traditional presswork and fabricating processes.

The CRSA was formed in 1944 as an association of manufacturers who produce both custom rolled formed shapes and products or systems manufactured by the cold roll forming process. Members possess a specialist knowledge of specific industries such as building and construction, aviation and transport and are able to identify best manufacturing practices and minimum cost designs to help improve customers' quality and profitability.

The objectives of the CRSA include:

- promoting the cold roll forming process
- promoting custom roll forming as an alternative to in-house operations
- providing a forum for the exchange of ideas and information
- setting and maintaining quality standards
- acting as a voice for the industry

The Association undertakes a range of activities from the preparation and presentation of learned papers to establishing links with similar organisations across Europe and North America. It has sponsored research projects and post-graduate research students at the universities of London, Cambridge, Sussex, Bristol and Strathclyde.

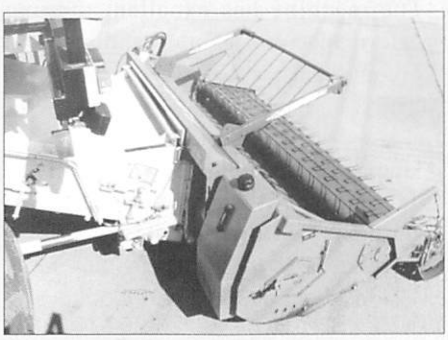
Contact: **Robson Rhodes, CRSA, Centre City Tower, 7 Fell Street, Birmingham B5 4UU. Tel: 0121 697 6000.**

Rape harvesting made easy!

The days of blocked combine drums and augers caused by uneven rape swathes are behind us thanks to a unique patented attachment marketed by Easy-Flo Products of Reepham, Lincolnshire. The Easy-Flo rape header kit simply bolts on to any Shelbourne Reynolds draper header and effectively guides the rape swathe into the auger preventing blockages and the old problem of the rape crop flowing over the top of the draper pick up auger.

The kit is simple to fit, bolting straight on to newer draper headers and only requiring two holes to be drilled to fit to older models; full fitting and operational instructions are supplied as standard.

The Easy-Flo was launched in 1999 and



has proved to be a tremendous success for all rape growers, says Easy-Flo, the proof being the reaction from users throughout the country. 'The Easy-Flo attachment increased the output of our combine, beyond expectation, stopping uneven swathes blocking the front elevator whilst combining 240 hectares of rape,' said Mr G Atkinson, Lincolnshire.

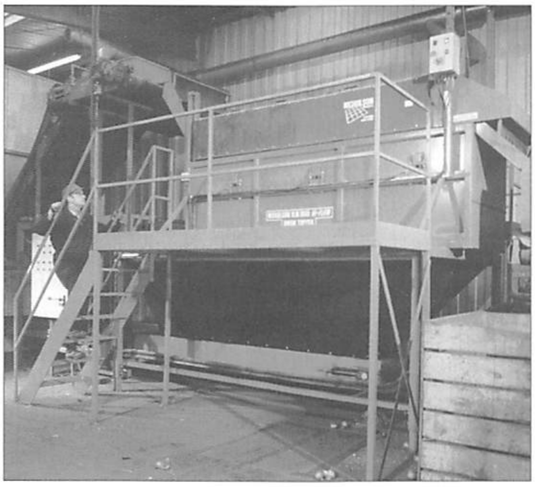
The Easy-Flo is priced at £399 plus VAT.

Contact: **Easy-Flo Products, Manor Farm, Reepham, Lincs LN3 4D2. Tel/ Fax: 01522 751159. Web Site: www.easy-flo.co.uk**

Nicholson Machinery introduce hi-flow onion topper

Root crop handling specialists Nicholson Machinery have introduced a new high capacity onion topper, the Hi-Flow. With a throughput of between 12 to 14 t/h, the new machine is designed to work with crops direct from store, and will produce onions to exacting retail standards quickly, economically and with the minimum of maintenance.

Key features of the new machine include gentle crop handling, low operating noise, reduced levels of dust generation and quick and easy maintenance. This has been achieved by careful attention to the design of the processing bed and screens.



Nicholson Machinery's new high capacity onion topper is designed to work straight from store and produce onions to exacting retail standards, quickly

The bed itself comprises three separate sections. These are completely level, but divided to allow each screen section to be quickly and easily removed for fast and easy machine cleaning. No tools are required. The onions are passed over the processing bed by 13 rows of soft paddles. The paddles are an integral part of the Hi-Flow and provide positive, but gentle movement of the onions. Of equal importance, the operating speed of paddles can be infinitely adjusted. This enables the operator to exactly match crop flow to different bulb sizes and conditions. As the onions are gently rolled over the bed screens, three heavy-duty spinning blades remove the tops. The topping height is adjusted externally, and once set is fixed via lock nuts.

As the processing bed requires no oscillation, the Hi-Flow is quiet in operation and crop dust and power consumption are also reduced. These combined features help to cut overall operating costs without any compromise in processing quality or throughput. The paddles and paddle drive motors are raised out of work by an electric motor for servicing. This gives operators quick access to the processing bed for cleaning. For safety, a timer lock is fitted to ensure all moving parts have stopped before the Hi-Flow can be cleaned. For added security, the paddle motor mechanism is locked out of work by pins during cleaning and servicing. To further reduce downtime, all internal surfaces have a smooth finish to help eliminate dirt traps. Overall routine maintenance needs are reduced as a result.

The Hi-Flow follows the modular build concept associated with Nicholson handling and processing equipment. This enables customers to specify more easily the machine to exactly meet their own individual requirements. Measuring 3.5m in length and 1.0 m in width, the Hi-Flow is readily integrated into existing onion handling lines with the minimum of disruption. This is to help reduce installation costs.

'The Hi-Flow onion topper is a high capacity machine but has reduced whole life operating costs,' says Tom Woollard, Nicholson Machinery marketing director. 'The machine has excellent topping performance and gentle handling, and combines this with low noise and less dust.'

Contact: **Tom Woollard, Nicholson Machinery, 1 Westgate Street, Southery, Nr Downham Market, Norfolk, PE38 0PA. Tel: 01366 377458. Fax: 01366 377331.**

Lechler reveals new ID nozzles at sprays and sprayers

Lechler Ltd, pioneer of innovative spray nozzle systems for agriculture, has increased its range of LERAP-approved spray nozzles, which were on show for the first time at 'Sprays and Sprayers'.

The ID 120° range now includes eight sizes from the 01 to 06 and a new range of ID 90° nozzles has been introduced - in 015 and 02 sizes. Lechler is the first company to launch such a narrow angle range, offering greater precision of chemical onto crop canopy, while eliminating water pollution and reducing wastage of expensive agrochemicals.

Sales manager Bill Sheldon said: 'We have been working with farmers to develop nozzles which enable them not only to comply with the new legislation, but also to benefit from it. These nozzles ensure that the amount of chemical wastage is kept to a minimum, by using air-filled droplets which deposit spray directly onto the crop. This high level of precision allows farmers to 'reclaim' land close to water courses that could not be sprayed with conventional nozzles.'

Lechler's ID nozzles, which were introduced in 1999 following the release of LERAP's strict new low-drift regulations, are manufactured from wear-resistant POM, or ceramic, to ensure longevity.

In addition to the standard range, Lechler exclusively offers boom-end nozzles, which produce an off-centre spray and enable farmers to spray to a very tight boundary, up to within one metre of a river.

Lechler's entire ID and IS ranges can be fitted onto quadrinozzles which allow rapid nozzle change for low drift or precision spraying.

Bill Sheldon said, 'Our objective is to help farmers to achieve the maximum and most cost-effective use of their land. Instead of taking the risk of using unapproved nozzles, farmers who use these ID nozzles can be confident they are complying with the regulations and benefiting both themselves and the environment.'

Contact: **Bill Sheldon, Lechler Ltd, 1 Fell Street, Newhall, Sheffield S9 2TP. Tel: 01142 492020.**

New mower conditioners and pickup for round balers

John Deere's new 1355 and 1365 pull type mower conditioners are stronger, more flexible and easier to use and service. They replace the existing 1350 and 1360 models - the 1340 mounted unit was replaced earlier this year by the new 324 and 328 mounted mower conditioners launched at Kemira Grassland '99.

Cutting widths on the 1355 and 1365 remain 2.5 m and 3 m respectively, and the 1.7 m and 2.2 m wide impeller conditioners incorporate free swinging V-shaped steel tines. Compared to plastic, steel tines are more hard wearing, reliable and shock resistant.

These steel tines are additionally featured on the new 228A front mounted mower conditioner, which has also been improved for 2000. This model has a cutting width of 2.8 m, and variable swath width from 1.1 m to 1.6 m.

John Deere's new front-mounted 228A mower-conditioner

The conditioning hood on the 1355 and 1365 can be raised or lowered as required for lighter or heavier conditioning, and there is a choice of two rotor speeds for different crops and conditions. The cutterbar has five or six discs with reversible, free swinging knives and an adjustable cutting height of between 30 mm and 150 mm.

Replacement of the heavy duty cutting knives can now be carried out through a hole in the skid shoe, directly from the front of the cutterbar, to make servicing easier. The cutterbar and the conditioner are fully suspended by heavy duty springs to provide excellent ground contour following and a high quality of cut. This preserves the crop stubble, which in turn promotes better regrowth and crop quality.

To provide optimum performance, the impeller is located low and behind the cutterbar. This reduces the power needed and means the crop is cut before conditioning starts, which also reduces losses and prevents soil getting into the harvested crop. Windrow width is adjustable from 0.7 m to 1.3 m on the 1355 and from 0.8 m to 1.8 m on the 1365. This can be increased to 1.7 m or 2.1 m respectively using an optional wide swath deflector, which spreads the crop to the full width between the mower wheels.

This adjustable deflector is compatible with John Deere's windrow Grouper, and it is very easy to switch from one to the other. The Grouper can be used in combination with the front mower conditioner, or on every second windrow when used on its own with the pull type machines. In this operation, each second windrow is offset to the left hand side, and laid beside the first. Combined windrow widths are 1.8 m with the 1355 and 2.3 m with the 1365, depending on the crop.

A double windrow can be picked up in a single pass with a 3 m wide self-propelled forage harvester pickup, considerably reducing operating time and costs. Moreover, with the increasing power of new foragers, it is important to feed the machine properly, which improves the quality of cut for silage production.

The Grouper's carrier frame has been reinforced for 2000 to increase reliability and durability in tough conditions. Both mower conditioners feature a heavy duty main gearbox and a new larger input shaft to withstand heavier loads. The cutterbar and the conditioning system are also fully protected by a slip clutch.

There is a choice of two new drawbars. The linkage version is recommended for users who do not change their mower tractor too often, and allows a turning angle of up to 900 without any risk of damaging the pto shaft. The swivel hitch is more manoeuvrable, and allows faster U-turns for higher productivity, especially in demanding conditions. For extra convenience, both drawbars may be fitted with an optional toolbox.

An optional constant velocity joint on the swivel hitch allows the user to correct the mower on the move on slopes. This also makes it easier to mow around obstacles, with no loss of time or crop. Detachable wear skids protect the cutterbar and help glide over most field obstacles, reducing wear, preventing damage and resulting in lower maintenance costs.

The new John Deere 1355 and 1365 pull type mower conditioners require 41.25 kW and 52.5 kW respectively at the pto, or 59.25 kW and 71.25 kW when equipped with the Grouper attachment.

- John Deere has also introduced a new 2.2 m wide pickup for the 580 and 590 variable chamber round balers for 2000. This is in addition to the existing 1.8 m pickup and 2 m unit plus pre-cutter. The new wider version is designed for higher productivity in the widest windrows, and features a heavy duty front shield to improve and regulate the flow of crop into the baler.

Contact: **David Hart, John Deere Ltd, Langar, Nottingham NG13 9HT. Tel: 01949 860491. Fax: 01949 860490.**

New Cranab 720 punches above its weight capacity

The new 10 tonne capacity Cranab 720 is fitted with the same slewing motor as the 8 tonne-metre crane, giving it greater power

Partek Forest has introduced the 10 tonne capacity Cranab 720 to its range of forwarder cranes. Offering a choice of 7.20 m reach in its Tele variant and 9.1 m in Combi format, the new unit is fitted with the same slewing motor developed for use on the company's larger 8 tonne-metre crane. This gives the 720 greater power for slewing up hill so maintaining high levels of productivity in the most demanding of conditions.

To further increase performance, the Cranab 720 also operates on a high pressure, low hydraulic flow system. This speeds load cycle times and is critical in ensuring the unit can deliver maximum productivity in relation to its capacity.

Partek Forest has also paid particular attention to making the Cranab 720 smooth in operation. This is achieved not only by the hydraulic controls offering excellent feedback to the operator but also by the linkage geometry to the outer boom section.

This has been developed so that the boom extension and retraction speed remains constant throughout the working arc. This critical development reduces stress on the crane, cuts load swing and improves working accuracy for greater productivity.

In line with all Cranab cranes, the 720 benefits from robust hose routing to avoid operational damage, high strength close grain steel boom sections and oversize slew bearings for maximum durability. The Cranab 720 Combi features a patented outer boom section with internal hydraulic hose routing. This provides additional protection and is recommended for use in extremely difficult conditions.

'The Cranab 720 crane combines power and strength with smooth and precise control,' says Stewart Paul of Partek Forest. 'This enables operators to really make full use of the crane's capacity. With increasing pressure on operators to reduce overall equipment operating costs, the Cranab 720 will help speed forwarder loading times'.

Contact: **Kenny Paterson, Partek Forest Ltd, Longtown Industrial Estate, Longtown, Cumbria, CA6 5TJ. Tel: 01228 792018. Fax: 01228 792388. email: partek@globalnetco.uk**

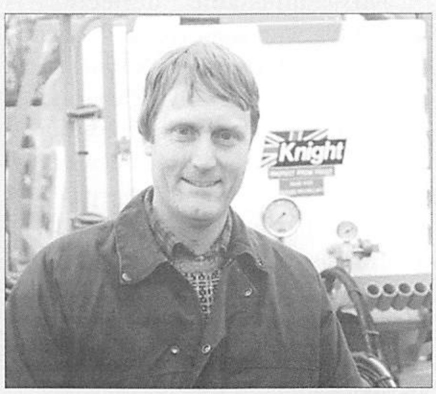
Internet shopping for farm equipment on new website

One-stop internet shopping for farm equipment has arrived with the opening of a new website: *www.agri-part.com* Agri-Part is an independent division of Knight Farm Machinery Ltd.

Described by managing director Brian Knight as 'a virtual dealership', *www.agri-part.com* already has 1500 items for sale, including wearing parts for cultivation equipment, sprayer components and workwear. The site is expected to grow rapidly as other products are added to it.

'We believe the Internet is set to change the way the agriculture industry operates', said Brian Knight. 'Agri-Part offers something that farmers and manufacturers have both been waiting for: an on-line spare parts service where prices are low and which operates within a framework that people will quickly find familiar.'

Using a unique new database system, the website has a comprehensive search facility which makes finding products quick and simple. The net prices of all products are stated. The site includes facilities for secure on-line payment by credit or debit card, and customers can also open a monthly account.



Brian Knight, Managing Director, Knight Farm Machinery

'For farmers, the site combines convenience and economy', said Mr Knight. 'They can see on the computer screen what is available and what it costs. Also, the web operates 24 hours a day, making it ideal for today's busy farmers.'

'There are obviously savings to be made in distributing products in this way, and this is reflected in the prices. It also means farmers can find what they want in one place and pay for it in a single transaction. Most products will be delivered within one to three days of order.'

Contact: **Knight Farm Machinery Ltd. Tel: 01780 722200**

Four combines do the work of six in the same time

When it comes to harvesting, two neighbouring farming companies in Norfolk have devised a novel system that is practical, efficient and labour saving.

The wet autumn of 1993 that resulted in reduced time available for harvesting brought about discussions on the pooling of combine harvester resources between G W Harrold Farms at Stanhoe and Salle Farms Company, owned by Sir John White, at Reepham. This proved to be not only a successful temporary solution to the problem, but also the basis for a more permanent collaboration. Since the crops grown by the two organisations each require the major use of combines at different times of the harvest season, this arrangement was conducive to the concept of combine sharing.

The reasoning behind this system of combine sharing is that the land types vary on the two farms. Salle Farms grow 45% of their total area as wheat (720-800 ha) with 100 ha to spring barley, 140 ha to winter barley and 120 ha for beans, whereas G W Harrold Farms grow 800 ha of winter barley, 320 ha wheat, 240 ha spring barley and 80 ha linseed.

Therefore, over the winter of 1993, Salle Farms Manager Poul Hovesen and Melton Harrold, who runs G W Harrold Farms, came to an agreement whereby they would each loan the other a like-for-like combine and driver with the cost of fuel and oils incumbent on the farm using the machine. The other costs of a driver, parts and servicing would rest with the farm owning the combine. The idea was that at the end of a season the hours worked on each other's farm would be more or less equal, leaving each farm needing one less combine to own, maintain and store when not in use.

Further efforts in achieving cost efficiency meant that in 1998 both farms decided to buy two identical models each, giving a total fleet of four, but still retaining the capacity of the previous joint fleet of six combines. The then newly opened branch of Ernest Doe & Sons Ltd at Fakenham offered the solution by supplying four New Holland TF78 Elektra Plus combine harvesters, each with a 9.15 m cutter bar.

Five-year statistics kept by Poul Hovesen had shown little difference in the running costs of a large combine compared to a smaller one. Melton Harrold and his Farm Manager, Bruce Lockhart, confirmed that the operators took to the new sized headers with no worries and they are adamant that the 9 m header is 'the right width for the combine's size.'

'Twenty one days out of the first 25 in August this year it rained, but we managed to combine over 800 ha of wheat and beans in just 10 days,' stated Poul Hovesen. 'We have cut down on the number of units we own, and therefore on our labour requirements and running costs, without any change to efficiency,' he added. Both farms are pleased with output levels for this year's harvest, with Salle Farms reporting an hourly average in excess of 40 tonnes on wheat and also 'good averages on beans'.

'With a harvest season that started well and then changed to a race against time, the combine sharing concept with the larger capacity machines has certainly proved worth the investment. This arrangement has allowed us to do more when we want and enabled us to finish earlier,' said Melton Harrold.

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GreenStar system

Agricultural software specialists Farmade Management Systems have signed an agreement with John Deere to provide full software support for the established GreenStar precision farming system.

'We are very pleased to announce this partnership between John Deere and Farmade, linking our expertise in machinery and hardware with theirs in software management,' said Peter Leech, John Deere's customer support manager. 'This is a new approach to customer service, designed to meet the rapidly changing demands of new technology in an area where neither we nor our dealers have the necessary experience.'

GreenStar precision farming systems are optionally available with John Deere's CTS and 2200 Series combines, for simple monitoring of crop yields and other harvest data, or for both monitoring and GPS mapping applications. As precision farming practices are adopted more widely, these systems will also be available for use with the company's drills and sprayers.

Under this new agreement, John Deere dealers will continue to be responsible for everything 'up the combine steps'. This includes all GreenStar related parts, components, wiring and controllers installed on the machine, as well as all equipment diagnosis, calibration and repair.

Farmade will be responsible for all customer support activities connected with the JDMap software used in analysing the GreenStar mapping data. This effectively covers everything in the farm office, including the delivery, installation and operation of software, on-site training, and 12 months' on-line software support.

GreenStar data is transferred from the combine cab's mapping processor to the farm computer using a durable 8 Mb PC card (PCMCIA), which can hold up to 400 hours of information. Using JDMap software, the system can produce easy to read colour maps showing yield or moisture data for areas as small as 4 m^2.

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