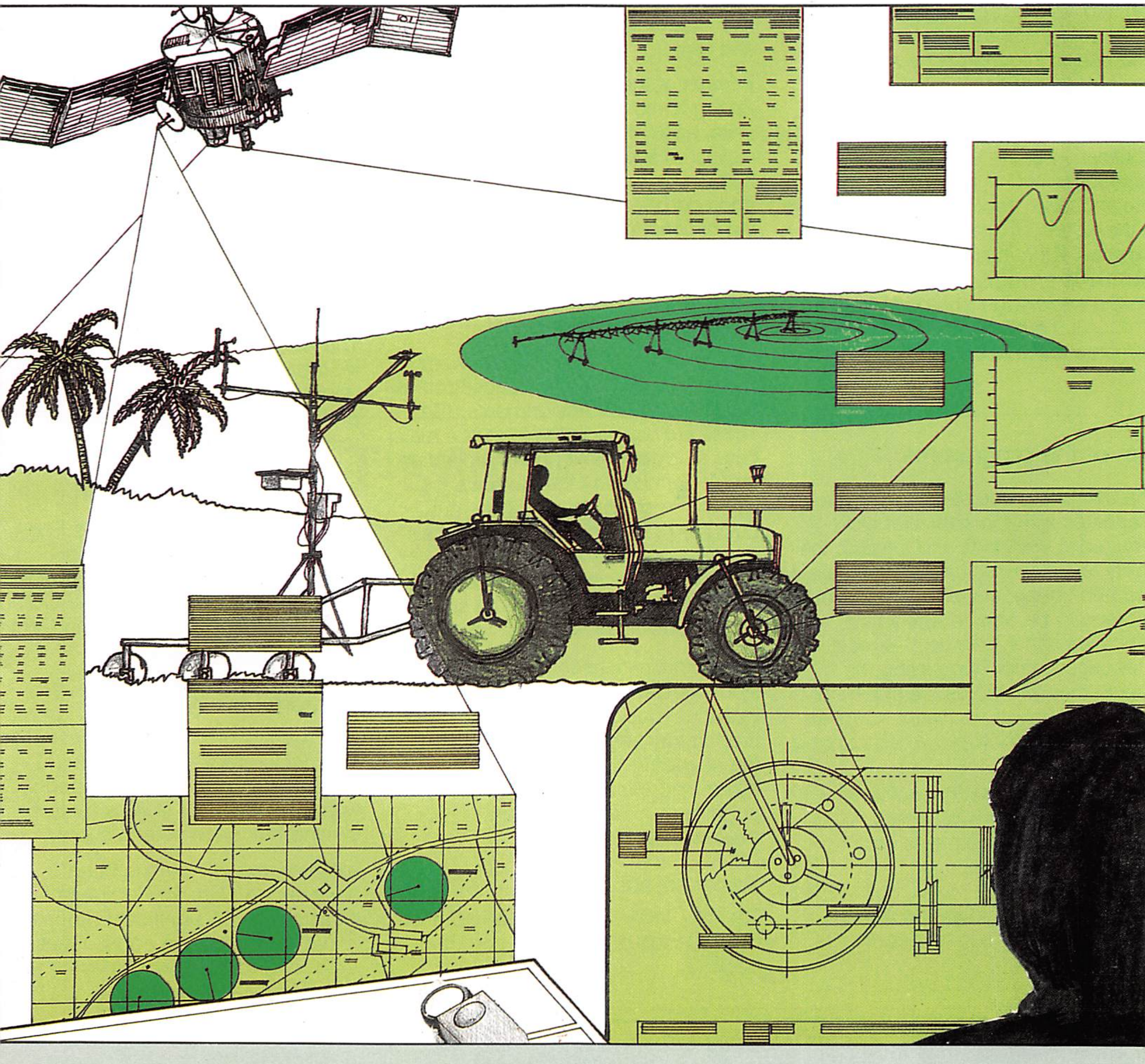
The Agricultural Engineer

Incorporating **Soil** and water

Volume 47 Number 3 Autumn 1992



Electronics/Livestock

The Agricultural Engineer

Incorporating Soil and water

Journal and Proceedings

Volume 47 No.3, Autumn 1992

THE AGRICULTURAL ENGINEER incorporating Soil & Water is published quarterly by the Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU. Tel: (0525) 861096.

Price £9.00 per copy, annual subscription £35 (post free in UK).

Front cover: Information technology for the rural sector – a montage of electronic applications (courtesy of Silsoe College, the Faculty of Agricultural Engineering, Food Production and Rural Land Use of the Cranfield Institute of Technology.

Regular Features

CONTENTS

COMMENT

Barry Sheppard
Hon Editor

The decision made last year to feature two lead subjects per issue has proved to be a great success both from attracting copy and from the potential authors' point of view in knowing which issue to aim for.

At a recent Editorial Panel meeting the 1993 programme was agreed:–

1992	Winter	Alternative energy/Quality Control
1993	Spring	Crop storage/Pollution
	Summer	Amenity engineering/Irrigation & Drainage
	Autumn	Harvesting, Handling & Processing
	Winter	Cultivations/Instrumentation
1994	Spring	Horticulture/Crop protection

We also agreed that we would welcome papers on relevant aspects of Environmental Engineering. However as this is such a wide ranging subject we felt it best to cover this on a continuous basis rather than in a specific issue. A comment from overseas "that more drainage/irrigation reports would be welcomed" has been taken on board (see summer '93). Please give us a call if you have further suggestions as to topics we should feature.

The overall presentation of the journal is kept under review by the Editorial Panel. Further changes could be made but there is always the question of cost. I have more to say about this on page 79.

ISSN 0308-5732

New 'stockman's tractor' from Renault

Designed with the smaller mixed stock or hill farmer in mind, a new 52 hp tractor, available in either two- or four-wheel drive, has been introduced by Renault Agriculture Ltd.

Designated Renault 55-12 LB (or 55-14 LB in four-wheel drive form), the tractor has a compact design and a 52 hp direct injection, three-cylinder air-cooled diesel engine. Dimensions are 1.68m (5.50 ft) wide and 2.28m (7.48 ft) high.

The new model is said to be particularly fuel efficient with consumption rated at 257g/kWh and it comes with a 62 litre fuel tank.

The transmission is fully synchromesh and has 12 forward and 12 reverse speeds with a dashboard mounted, synchronised hand reverser for rapid shuttle work. Forward speeds range from 0.42km/h to 27.0km/h.

Category I linkage is fitted with offset lower links, internal swayblock stabilisers, a screw top link and adjustable lift rods with a levelling box on the right hand lift arm.

The hydraulics incorporate position, draft and response controls. With a pump flow of 36.5 litres/min at a working pressure of 180 bar, the maximum lift capacity is 3.4 tonnes.

The specification also includes 540 rpm and groundspeed PTO (750 rpm or 1000 rpm is optional), oil immersed brakes acting on the differential shafts, a pivoting towing clevis and hydrostatic power steering. The front axle on the four-wheel drive 55-14 LB is adjustable.

The price complete with two-door ventilated cab and standard tyres, is £14,895 for the two-wheel drive 55-12 LB and £17,110 for the four-wheel drive 55-14 LB.

Renault Agriculture Ltd, Shipston House, Darlingscote Road, Shipston-on-Stour, Warwicks CV36 4DZ. Tel: (0608) 662727.

Keeping stock off field plots

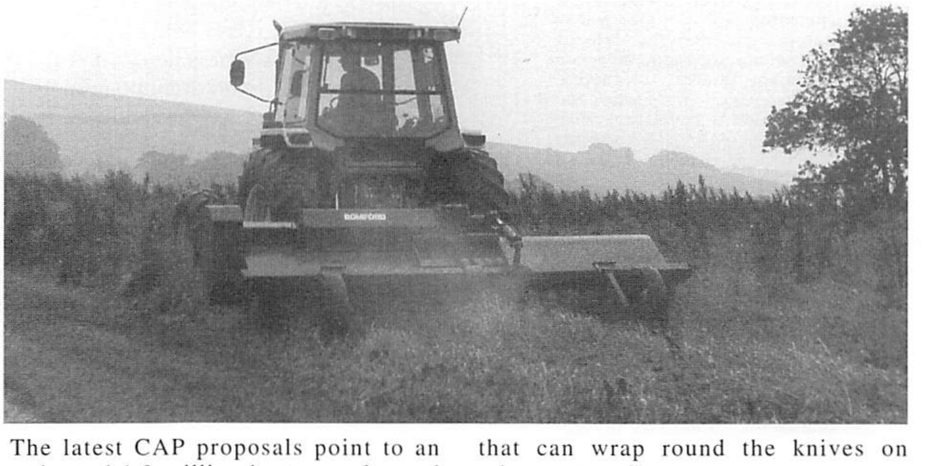
The 'NIPPER 20' is a new British electric fence aimed specifically at the small farmer for use in strip grazing or as a temporary enclosure.

Operating from any 12 Volt car or tractor battery, the 'NIPPER 20' has a stored energy 0.2 Joules and an output of 6000 Volts in pulses of 1 cycle per second. It is capable of electrifying up to 3 miles of control wire and, tested under conditions of heavy vegetation, still gives out a 1000 Volt discharge.

The 'NIPPER 20' is available by mail order only, direct from the manufacturers, Nipper Products, FREEPOST (No PT1204), Havant, Hants PO9 2YZ.

Price is £42.00 each plus VAT and £3.00 package and carriage charges.

Managing set aside – the Bomford Turner solution



The latest CAP proposals point to an estimated 1.3 million hectares of cereal producing land being taken out of production with the majority being put into set-aside. Regular mowing is an essential part of a set-aside regime and Bomford Turner have used their 30 year experience of verge mowing to provide a low cost and effective machine for this task.

"Flail mowers", says Clive Fowkes, Director of Bomford Turner UK Sales, "are preferred to rotaries as they cut and mulch the materials over the full working width rather than leaving long material in swathes that can wrap round the knives on subsequent cuts".

The new Bomford Turner flail mower range is offered in cutting widths of 2.75m (9'), 3.7m (12') and 4.6m (15') with outputs of 3.5, 5 and 6 acres per hour, depending on height of cut. Three point linkage and trailed models are available with prices ranging from £4,949 to £9,125.

The heavy duty construction makes these mowers particularly suited to contractor usage, say Bomfords.

Bomford Turner Ltd, Evesham, WR11 5SW (Tel: 0789-773 383).

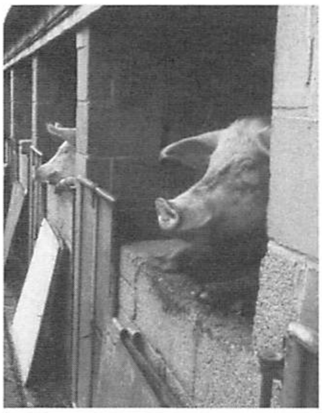
Fendt fits seatbelts as standard

Fendt's tractor range now provides operators complete safety by being the first in the field to fit seat belts as part of the tractor's standard UK specification. The belts are adjustable and of the 'aircraft type' designed to prevent operators from being thrown out of their cabs in the event of the tractor overturning.

Paul Bassett, Managing Director of Fendt Tractors which is based at South Cave, Brough, North Humberside, says: "As far as we are aware, there has been no accident, fatal or otherwise, involving a Fendt tractor. However, we feel that seat belts should be fitted and existing Fendt tractor owners will now be able to retro-fit the lap belts to their tractors at a cost of around £45, depending on the type of seat previously fitted. On new Fendt tractors, the seat belts will be part of the standard specification."

New Creetex polymer for silage clamps and animal housing

Surface Maintenance Systems, the Burnley based manufacturer of agricultural refurbishment products, has introduced an upgraded version of 'CREETEX POLYMER'. The new formulation has a far greater resistance to the highly corrosive water borne chemicals normally found in silage clamps and animal pens.



The product has been independently tested by a number of authorities. Product tests on water absorption and water vapour transmission and on 'silagic' acid which is the complex mix of chemicals formed as grass, straw and animal matter decomposes.

'Creetex Polymer' has been used for more than 8 years as an additive to cement mortar screeds, toppings and renders on silage clamps and for general concrete repair. The new formula increases the variety of uses, to which the product may be applied, including high strength applications such as 'structural' toppings to withstand heavy static loads. A free technical survey service is offered for clamp resurfacing and repair throughout the UK.

Surface Maintenance Systems, Dagenham, Essex RM8 1QL. Tel: 081-593 7621.

New professional range from McCulloch

McCulloch, one of the world's leading chainsaw specialists, has launched a series of new products under the Titan brand. Aimed specifically at semi-professional and professional users, the Titan range includes chainsaws, trimmers, brushcutters, petrol powered hedgecutters, water pumps and drills.

Special features of the new chainsaws include electronic ignition for easy starting and minimal maintenance, ergonomically designed easy-grip handles, chainbrake safety device and full anti-vibration system. In addition, the adjustable, automatic, mechanical oil pump ensures the chain is correctly lubricated for optimum performance.

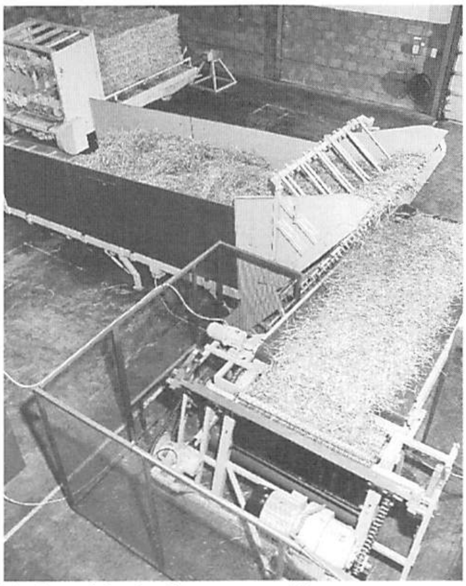
Also new to Titan is the range of petrol-driven stringtrimmers and brushcutters designed to offer all the convenience of electric models without the limitation of an electric cable.

McCulloch Titan products are distributed by Goblin Limited, Cross Green Approach, Leeds, LS9 0SX Tel (0532) 488994.

Straw slicer developed for paper-making plant – Silsoe research into crop utilisation for industry

A novel straw slicing machine designed and constructed by Silsoe Research Institute is to be used in a pilot scale pulping plant being commissioned this year.

The complete project forms part of the EC ECLAIR programme (European Community Linkage of Agricultural & Industrial Research). Funding for the work on the straw slicer includes contributions from the EC and ETSU (Energy Technology Support Unit).



Wide-scale adoption of the technique for preparing straw for a range of potential industrial users could lead to the establishment of an important outlet for surplus straw from farms faced with the ban on straw-burning after this year's harvest. In addition, the energy-saving aspects involved will offer major environmental advantages.

A team from the Crop Mechanics Group of Silsoe Research Institute, led by Andrew Knight, has produced a straw slicing system based on Silsoe technology originally developed in the 1980s to reduce the power requirements of forage harvesters.

The machine uses a conveyor to deliver 0.5-tonne square Hesston bales, which are broken and metered through to the straw slicer. The all-electric drive has a safety cut-out in case of obstruction.

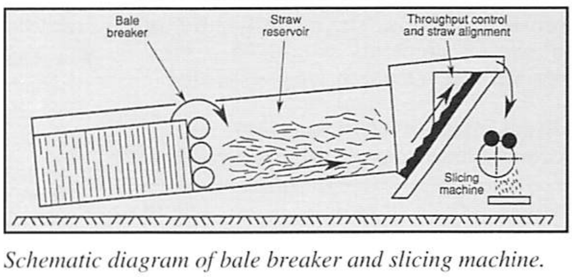
A bank of slowly rotating discs engages with slotted feed rollers to provide a continuous slicing action. This produces straw particles of 30mm median length for pulping, or feeding to any other suitable treatment process. Major advantages include extremely low power requirements (4kW when working at 2 tonnes/hr), greatly reduced dust content of the sliced straw, and higher throughputs (up to 10 tonnes/hr with the 1.2m wide machine), compared with conventional chopping.

This project is linked to other current research into the utilisation of crops for industrial use, including the processing of linseed straw for textile and pulp applications, and compaction of cereal straw to reduce transport and handling costs for use as a fuel or industrial feedstock.

Environmental Services Consultancy for UK

Geraghty & Miller, Inc., announces the appointment of Dr. Brian V. Crook to the position of Managing Director of the firm's operations in the United Kingdom. With this new base at Cambridge the firm plans to become a major provider of environmental services in the UK and eventually to establish a Pan European environmental consultancy through acquisition and growth.

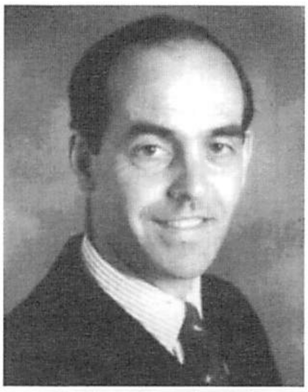
Geraghty & Miller, Inc. is one of the oldest, largest, and most experienced environmental consulting firms in the United States. The firm specialises in the development, management, and protection of ground-water resources, and the assessment and correction of ground-water contamination problems. In addition, Geraghty & Miller services include engineering design, construction management, hydrocarbon recovery, air-quality evaluation, soil and ground-water remediation, computer modelling, pollution prevention, geophysical studies, risk assessment and long-term operation, monitoring, and maintenance at hazardous waste remedial sites.



Schematic diagram of bale breaker and slicing machine.

Computer aided pesticide application (CAPA) – a spraying system for the future?

Increased pesticide legislation and falling margins have resulted in farmers looking for ways to reduce pesticide use on farms. Andrew Landers sees the advent of direct injection crop sprayers, combined with information technology, as offering a solution to the problem. *(Paper presented to the Annual Convention of the Institution, May 1992.)*



Farmers are under great pressure when applying pesticides. The increasing awareness of environmental pollution, along with worries about pesticide residues on food has resulted in increasing legislation concerning pesticide use.

The Governments of Sweden and Norway aim to reduce pesticides by 50 percent states Nordby (1989); the Swedish Government levies a tax on each pesticide treatment. In Denmark the Government aimed at a reduction of 25 percent of active ingredients in pesticides by 1990 and further 25 percent cut before 1997, (Thonke, 1988). In the Netherlands there is a similar move to reduce pesticide use by 50 percent.

Table 1. Average pesticide costs (£/ha) for arable crops in Eastern England 1989/90 (1988/89). *Source: Murphy M (1991)*

Farm size (ha) and type		*Crop*				
		winter wheat	*winter barley*	*potatoes*	*sugar beet*	*oilseed rape*
40-400	upland	103.8 (90.7)	76.6 (70.2)	190.7 (87.3)	126.4 (115.0)	77.7 (70.5)
40-400	mixed	103.3 (92.9)	89.0 (77.4)	139.3 (75.8)	171.6 (116.3)	54.3 (55.8)
40-400	fen	92.0 (88.4)	67.8 (62.8)	291.9 (303.0)	141.4 (125.8)	74.8 (66.2)

Table 2. Average pesticide costs (£/ha) for field scale vegetables in Eastern England.

Crop	*86/87*	*87/88*	*88/89*	*89/90*
Carrots	134	228	280	156
Onions	193	213	264	251
Parsnips	163	353	359	514
Brussels sprouts	189	130	227	150

The decrease in profit margins requires closer attention to the production costs such as pesticide cost/ha, (Table 1 and Table 2).

Traditionally, farmers have used pesticides to 'blanket' spray the whole field. The advent of direct injection sprayers and computer based information systems will allow them to spot treat patches of weeds or disease. Cussans *et al* (1987) suggests that many fields are treated at weed levels far lower than the economic threshold due to poor herbicide performance and differing infestation levels. The quantification of these risk elements would be a vital practical step in rationalising pesticide use.

Direct injection crop sprayers

A conventional crop sprayer is fitted with an injection system comprising one to four pumps which will dispense pesticide at a known rate into the water stream in the sprayer pipeline. The main tank of the sprayer holds clean water only. The pesticide is mixed with the water, either in the manifold or at the main water pump and the resultant mix flows to the booms and nozzles.

An electronic controller adjusts the pesticide injection pump according to changes in operating requirements, e.g. changes in application rate and pesticide required. Fig 1 shows the basic concept of a direct injection system. There are four systems commercially available in Europe and six systems under development. Landers (1988 and 1992a) states the major advantages of injection sprayers are:-

- the reduction in environmental pollution due to the elimination of tank and pipeline washing;
- a reduction in the operator contamination which occurs with conventional sprayers. Ideally the pesticide would arrive on the farm in large 35 litre containers and be connected directly to the pesticide injection pump, resulting in a closed system;
- an electronic controller which allows each pesticide pump to deliver each product. The injection pumps can be switched on/off as and when required to spray a patch of weeds;
- the amount of pesticide applied (dose rate) can be adjusted on the move, allowing a higher dose rate to be applied to a high infestation of weeds or disease and vice-versa.

A Landers is Senior Lecturer in Agricultural Mechanisation at the Royal Agricultural College, Circencester.

Computer-assisted information gathering

Fig 2 shows the role of information technology for a computer aided application system.

Information technology can be used to help the farmer gather information about the health status of his crop and compare field conditions with a computer model. The resulting farm management information can be used to develop a crop spraying programme. A computer aided pesticide application system (CAPA) comprises the following:

Computer based information systems

There are several new information based programmes available to the farmer using human logic to help solve problems such as planning strategy, pesticide application and machine selection. Information technology can be used to record data from field observations on soil type, crop response to pesticides and crop yield.

Computer models can be used to simulate crop production, allowing the farmer to

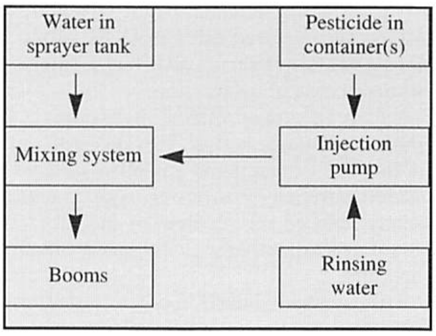


Fig 1. The basic concept of direct injection crop sprayers.

compare the model with the field information, (Baandrup and Ballegaard, 1989). Smith and Webster (1986) concluded that simulation models should display more than just 'spray' or 'don't spray', they should include monetary values of alternate strategies e.g. the opportunity cost of labour. Farmers are more interested in the expected loss rather than the variability of loss.

Green and Straszweski (1991) developed the 'Cleaver Calculator' for use by advisers to determine the cost-effectiveness of various treatments for the control of cleavers *(Galium aparine)*. Cleavers are the most competitive broad-leaved weed with the potential to significantly reduce cereal yields if left untreated. Prompts are used to input a number of agronomic variables which influence the competitive index value of 7.2 as well as several financial values, which enable a direct comparison of the cost effectiveness of the treatments.

Machinery selection models are available for comparing spraying systems. Landers (1992b) devised a model to examine the effect on sprayer output of changes in the operating parameters of a spraying system eg increasing tank or boom size and filling time.

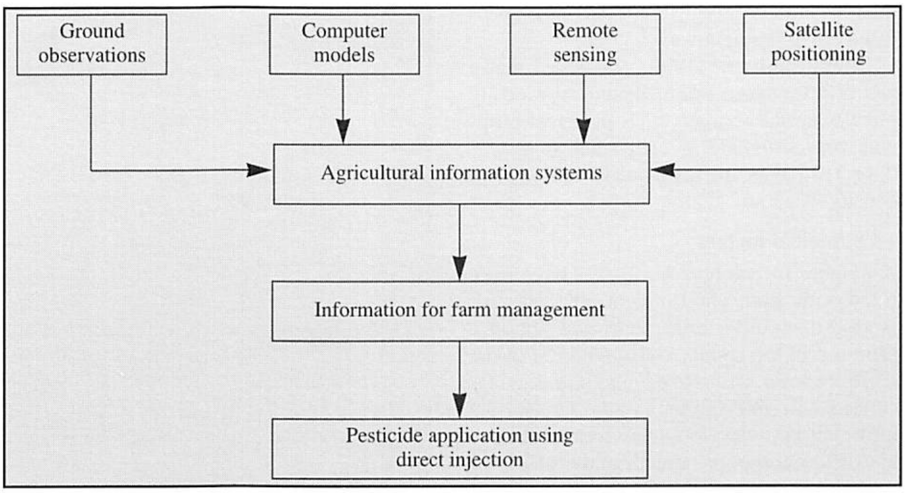


Fig 2. Computer-aided pesticide application.

opportunity to review assessments immediately and cut down time delays between information collection and the final report, greatly reducing costs. An integrated approach to information technology was reported by Dickson and Talbot (1985).

Table 3. Examples of pesticide rate changes according to soil type.

Product		*Crop*	*Application Rate l/ha*	
Trade name	*Chemical name*		*light soil*	*med-heavy soil*
Albrass	propachlor	Brassicas Leeks Onions	9.0	13.0*
Gesatop 500FW	simazine	Maize Beans	2.3 1.7	3.4 2.3
Nortron Venzar	ethofumesate lenacil	Sugar beet	5.0 0.5	10.0 1.0
Opogard 500FW	terbutryne terbuthylazine	Peas Beans Potatoes	1.6 2.3	3.4* 3.4
Pyramin	chloridazon	Sugar beet	1.7kg†	5kg†

Notes * These rates apply to soils high in organic matter † These rates expressed in kg/ha

Data acquisition in the field

There are a number of systems available for data capture and retrieval.

– Soil mapping

Detailed soil maps can be constructed for the farm. A soil survey will result in a detailed plan of the various soil types so that the farmer can appraise the land, cropping and fertiliser policy. Pesticide requirement varies from one soil type to another, see Table 3. Certain pesticides are used at different rates on organic soils compared to sand soils, and weed growth is often more vigorous on organic soils compared with other soil types.

– Crop reporting

Hand held data capture systems are being developed by a number of manufacturers. The introduction of a data logger will eliminate transcription errors, provide the

The hand held data logger can be used with a position indicator, Fig 3, so that weed or diseased patches can be identified and located for spot treatment. For example, the crop walker logs in the beginning of a patch of wild oats *(Avena fatua)* and presses the location switch on. When the patch finishes the walker presses the location switch off; the spot treatment injection sprayer will then carry out the instructions when it passes over the recorded positions. The data can also be downloaded into an office computer.

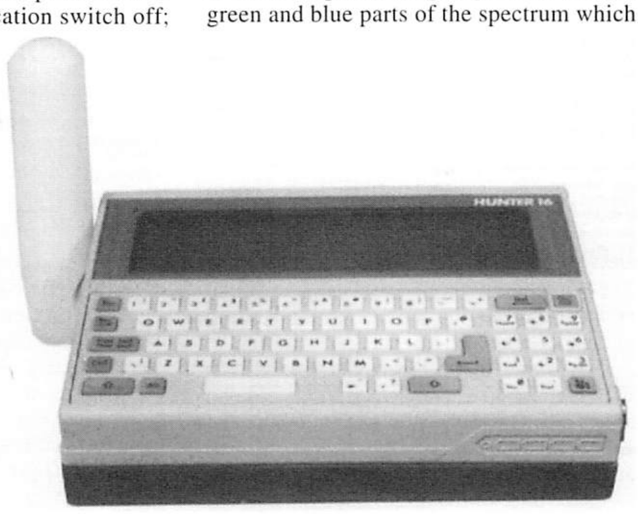


Fig 3. The Navstar XR4, a Husky portable computer fitted with a GPS receiver.

– Down the row identification of soil organic matter

Gaultney *et al* (1989) and Shonk *et al* (1991) developed a real-time soil organic matter sensor which used a narrow band light source and measured reflectance from the soil with a photodiode. Sudduth *et al* (1990) developed a prototype sensor using near infra-red reflectance techniques to determine the organic matter content of the soil surface.

The application rates of soil acting herbicides must often be increased on high organic matter soils because the cation exchange capacity of the organic matter increases the absorption of a herbicide and decreases its effectiveness. A microprocessor can be developed to interface with the controller of an injection crop sprayer.

– Down the row identification of weeds

Petry and Kuhnbauch (1988) developed a technique for the discrimination and quantative registration of a weed population. Different spectral information of the plant and soil was used. A video camera was used to deliver separate image signals for the red, green and blue parts of the spectrum which then became digitised in a video card and a weed cover gradient was devised.

Thompson *et al* (1990) concluded that a weed detection system based on finding plant material between rows of cereal crops was very sensitive to crop canopy cover; detection was only possible when crop density was low.

– Crop yield meters

A number of combine harvesters have been fitted with grain yield meters. The operator is able to monitor crop yield and obtain a print out of the results. Selected areas of the field can be monitored and farm trials carried out. The farmer is able to use this information in developing a cereal model on his office computer and thus the effect of pesticides applied to any particular part of the field can be closely monitored.

– Satellite positioning

The position of a crop walker when recording data on the health status of a crop is very important for the spot treatment of weed patches. Similarly the position of the combine harvester is also important when measuring grain yield from trial plots. As the injection sprayer drives towards the patch of weeds or disease a vehicle position indicator can inform the sprayer controller and switch on a particular injection pump and spray pesticide as and when required.

Shmulevich *et al* (1987) and Gorham and MacLeod (1991) developed a field machinery guidance system using a scanning laser based upon triangulation geometrical positioning. Choi *et al* (1990) described an automatic guidance system based upon two position sensors designed to follow a predetermined path.

The use of satellites for marine use has enabled sailors to find their exact position anywhere in the world. Satellites are used extensively for military purposes and systems exist which give pinpoint accuracy.

As more systems are made available by the military and as other systems are developed, so satellite positioning will become affordable.

Satellite positioning may also be used to locate the position of a tractor and grain drill, a tractor and fertiliser spreader and a combine harvester, Fig 4. The cereal seed rate and the drill coulters may be adjusted according to changes in the soil-type/seedbed condition; the application rate of fertiliser may be adjusted according to changes in soil type and the grain yield monitored as the combine harvester crosses the field.

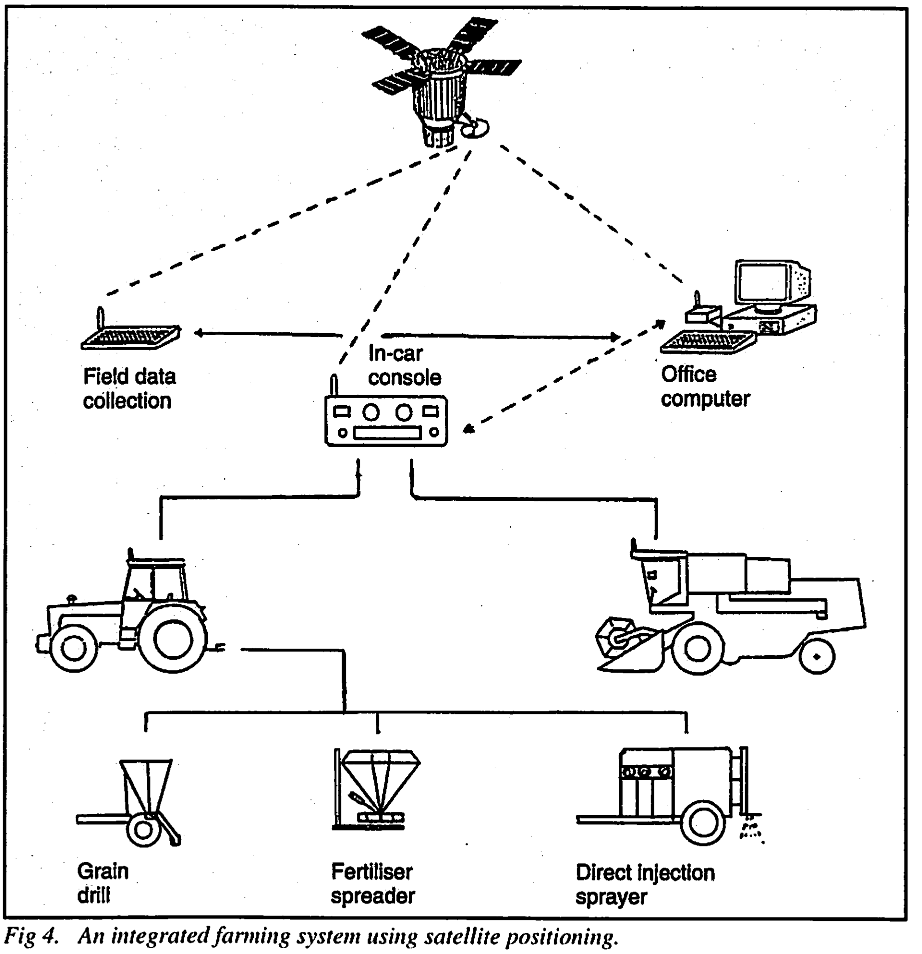


Fig 4. An integrated farming system using satellite positioning.

Information processing

The farmer is able to use the data acquisition systems information to help in the decision making process.

The farmer can compare the ground data with the computer simulation and decide on a pesticide strategy based upon a number of agronomic variables. The revised information can then be downloaded into the in-cab controller of the direct injection sprayer via a hand held computer or a 'smart card' (RAM card).

The 'smart card' would contain information about the weeds and disease status and its position in the field. A patch of weeds or disease could be spot treated with pesticide as the sprayer passes. As the weed infestation is passed the sprayer could be switched off. Satellite positioning would indicate the grid reference.

The 'smart card' could also contain information on the level of infestation, allowing the pesticide to be applied at varying levels according to the degree of infestation.

The controller of the injection sprayer enables the farmer to carry out these functions manually at present, but the development of a control board to allow automation is quite feasible. A printer could be installed to allow the farmer to know the exact quantities of pesticide applied and the area sprayed which would enable precise financial control to be retained.

Conclusions

- Direct injection sprayers enable the farmer to rationalise his pesticide use, reduce environmental pollution and reduce operator contamination.
- Computer aided pesticide application (CAPA) will result in more appropriate use of pesticides and rates being used, with an overall reduction in application rates, thereby satisfying environmentalists, legislators and farmers. CAPA will enable the farmer to be better informed regarding his pesticide application strategy and enable him to improve his decision making skills.
- Information technology systems already exist to allow computer aided pesticide application technology to be developed.
- Computer aided pesticide application is part of an integrated farming system, besides its use for crop spraying it provides the user with information such as the location of grain drills, fertiliser spreaders and combine harvesters, enabling the costs of production to be reduced and crop yields to be measured.

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The re-establishment ofwetland habitats – a search for guidelines

After the decades of support for land drainage and programmes to increase crop production, the time is now ripe, says John Sheail, to consider the restoration of some selected farmland areas back to wetlands.

'Agriculture and the Environment' was the theme taken by the United States Department of Agriculture for its 1991 Yearbook. The Secretary of Agriculture wrote of how . . .

"Prospects for protecting the environment have never been greater. As a Nation, we have moved far beyond environmental slogans".

The Yearbook covered such topics as soil conservation, water quality protection, renewable yields, wildlife preservation, and trash recycling. Above all, it explored the advances in research and technology that enabled resources to be measured and used more efficiently and wisely (US Department of Agriculture 1991).

Whilst it would be irresponsible to suggest that all relevant measures have been taken in the United Kingdom, there are similarly grounds for confidence in asserting that a more positive approach has emerged over the last few years to tackling environmental issues in what is still a predominantly agrarian countryside.

The concept of Environmentally Sensitive Areas was introduced in 1988; Countryside Stewardship schemes have been promoted. There has been much comment as to which parts of the country and which types of land holding have taken advantage of the grant aid. In making such analyses, it is important to distinguish between factors that are likely to bulk large in land-holders' minds, whatever the purpose and type of grant aid offered, and those factors which are intrinsically related to new environmental objectives.

J Sheail is a Senior Principal Scientific Officer in the Institute of Terrestrial Ecology at Monks Wood, Huntingdon, and External Professor of Geography, Loughborough University of Technology.

Past support for field drainage to raise food production

At a time when so much attention is focussed on moves to sustain or re-establish 'wetland' conditions in furtherance of conservation objectives, it is salutary to note in the files of the Ministry of Agriculture and Fisheries (preserved in the Public Record Office) the disappointment and frustration felt at the patchy and slow adoption of grant aid for drainage work, first for arterial drainage schemes under the Agriculture Act of 1937, and then for drainage of individual farms and fields under the Agriculture (Miscellaneous War Provisions) Number 2 Act of 1940. The Ministry undertook to pay the cost of tile drainage schemes up to a limit of £7.10s per acre, on condition that this would raise food production by the ensuing harvest.

Resolutions were soon received, pointing out that little would be achieved until the limit was raised. Whilst there was a clear case for increasing the limit in some parts of the country, the Ministry's officials were afraid that, if publicity was given to the availability of higher discretionary grants, it would 'rule out the incentive to do the job economically'.

By the time the powers were extended under the Agriculture Act of 1947, serious consideration was given to removing an upper limit on grants that represented only a third of actual costs. The change was never made. Not only were there doubts as to whether the Minister could use his discretionary powers to introduce what was, in effect, a two-tier system, but the more expensive schemes were fast becoming the rule.

As officials argued, a more economical and practical course was to find ways of reducing costs. There was enormous scope for introducing new drainage techniques, particularly through making greater use of machinery (Public Record Office, MAF 218, 12).

Impact of more intensive management

Whatever the precise part played by grant aid in the extent and timing of drainage activity, the lowering of water tables, and the associated changes in agricultural land use and management combined to degrade the value of significant parts of the countryside for amenity and wildlife. In the Romney

Continued from page 70

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Considerable experience in the management of plant and animal communities for nature-conservation purposes has been gained on the Woodwalton Fen National Nature Reserve, in the otherwise intensively-farmed Cambridgeshire fenlands. Heavy investment has been required in managing the soil-water regimes and controlling scrub growth in order to sustain a distinctive wetland wildlife.

(Photo: Cambridge University Collection, © copyright reserved)

Marsh, grant-aided drainage schemes affected 6% of the area in the 1940s, 19% in the 1950s, 44% in the 1960s, and 31% in the 1970s.

Whilst Trafford (1978) argued that such drainage activity made little impact on the environment, in as much as it was designed to improve existing farmland, rather than reclaim new areas for farming, the consequent impact of the more intensive forms of grassland management, and of cultivation, became so extensive as to leave few, if any, refugia for the distinctive wild species of the pastures and pasture-dykes (Sheail and Mountford 1984).

Restore selected wetland habitats?

In the changing economic circumstances of farming, coupled with a marked growth of public interest in what are called 'environmental issues', the time may be adjudged ripe for considering the restoration of *selected* wetland habitats on agricultural land.

Drawing upon their respective fields of expertise and experience, the Institute of Terrestrial Ecology (Natural Environment Research Council), the Field Drainage Experimental Unit of ADAS (FDEU), and the Department of Land Economy in the University of Cambridge, combined in 1991 to carry out a review for the Ministry of Agriculture, identifying what might be the ecological objectives of wetland restoration, the technical feasibility of realising those goals in terms of soil and water management, and the socio-economic implications for the farmer. This article draws in part on their findings.

Proper management remains essential

The conservation of wildlife does not imply the withdrawal of management.

The value of the wetland habitat for plants and animals is determined by the dynamic interaction of management practices with soils, climate, and hydrology.

Whilst public interest may be particularly focussed on the birdlife, the conservation of individual bird species and populations can only be achieved through appropriate management of plant life, surface water and soil-water relationships. The structure and composition of the vegetation must, for example, be 'tailored' to the needs of whatever degree of abundance and diversity in bird- and insect-life is desired.

A fully-integrated approach must, therefore, be adopted, whereby the primary objective is defined (whether for amenity, wildlife, agriculture, or some other purpose) and as many secondary uses as possible are accommodated in so far as they are compatible with the main aim.

In theory at least, a hierarchy of objects may be identified. The main purpose may then be defined more rigorously. If nature conservation is the principle aim, decisions must be taken as to whether it is for birds, invertebrates or plants. If it is for birds, then the question has to be asked as to which species should receive most support. What suits one species or group may not be right for another.

Detailed study of life histories and habitats

In order to make informed decisions, a detailed knowledge of the life-histories and habitat requirements of the key species is required. The Institute of Terrestrial Ecology and Silsoe College of Cranfield Institute of Technology have sought to assist the Ministry of Agriculture by further developing German research into the relationships of different plant species to differences in water-table, and Dutch models as to their effects.

To develop guidelines of practical value for the farmer and drainage engineer, these and other models must be validated under the conditions likely to be encountered in different parts of the United Kingdom.

Supported by the Department of the Environment, the Ministry of Agriculture, and English Nature, the AFRC Institute of Grassland and Environmental Research and the Institute of Terrestrial Ecology have for some years been monitoring the impacts of different grazing and fertiliser regimes under replicated conditions at a trial grassland site in the Somerset Moors.

In a sense, these studies are endeavouring to bring the kind of scientific rigour to conservation management that J B Lawes and J H Gilbert had begun to develop for farm crops, when, in 1871, they published their paper on the effects of drought on the experimental crops at Rothamsted. As they remarked:–

> "It is only when crops are grown under precisely similar circumstances, as to manure and other conditions, for many years in succession, that we can obtain satisfactory data for studying the influence of variety of season on the amount and character of the produce."

Taking each crop in turn, they recorded 'the probable amount of water exhaled during growth', the source of that water, and differences in the effects of drought on different experimental crops.

Complexity of amenity management

In a fundamental way, the ecologist faces a task far more daunting than that of the pioneers of research into crop behaviour at Rothamsted. The farmer sought to grow one or at most a very small range of species in a field – everything else was to be eliminated or, at best, tolerated. In practice, the object of amenity or wildlife management is to produce not a single-species crop, but a community of plants and animals.

In developing protocols for establishing and sustaining floristically-rich plant communities, a further layer of complexity is introduced by the need to take account of intra- and inter-species competition among the species desired in the community. Species that might flourish individually in soils of a particular type, may be absent because of their failure to compete with another.

Whilst important advances have been made in developing seed mixtures, and such techniques as slot-seeding, in an effort to re-establish 'traditional' grasslands and other open habitats, much more strategic research is needed before such procedures can be applied in a cost-effective way to each habitat and substrate.

If a full understanding is to be gained of individual wild plant and animal species in, say, the Somerset Levels and Moors at the present day, and the relative effects of recent dry years (as opposed to concurrent agricultural and nature-conservation practices), a backlog of some hundred years in research has to be made up.

Inventories have been compiled of the wildlife distinctive of different types of habitat. Wetlands are important for fourteen of the 55 species of butterfly in the United Kingdom. Some of the foodplants are rare, and difficult to establish. It is known that the requirements of the early life-stages of butterflies can be highly specific, making careful management of the vegetation essential. There is a pressing need to test these theories and hunches of butterfly conservation through trials carried out on different types of restored wetland.

The habitat requirements of wetland birds are better understood than those of other animal groups or plants. There is considerable experience as to how the timing, duration, depth and frequency of flooding affect different species. Records have been kept of the direct effects of agricultural practices, say in endangering nests and chicks, and of the indirect effects of vegetation on birdlife. There is firsthand evidence from reserves managed by the official and voluntary bodies of the manner in which changes in technique can alter the size, species-richness and diversity of species. Much of the information is, however, anecdotal. A more experimental approach is required to identify crucial aspects of wetlands designed for birds.

Models to study the feasibility of 'reversing' drainage

Supported by the Ministry of Agriculture, an important step has been taken by the Institute of Terrestrial Ecology and ADAS Field Drainage Experimental Unit (FDEU).

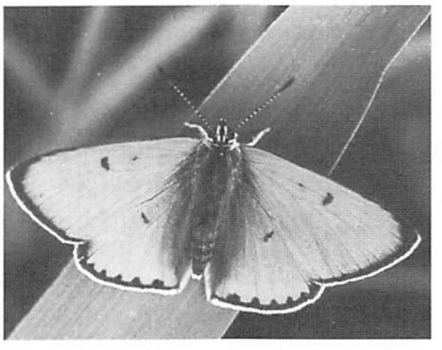
By reference to the soil/water-balance model developed by the FDEU, the feasibility of 'reversing' drainage on sites with an established drainage infrastructure has been assessed for certain hypothetical situations. The study has shown that it is possible to raise watertable-levels in restored wetlands by the manipulation of ditch levels.

Although such control may be easy to implement in peat soils, it will be much more difficult in clay soils. Moreover, the model suggests that large volumes of water will be required, and may have to be 'imported' to maintain water levels at the desired height for types of birdlife during the summer months.

As well as validation against field observation, the model requires further development to include detailed representation of consumptive water-use, together with consideration of variations in soil types and microtopography.

Financial inducements at farm level

The principal effects of wetland restoration on farm business would be to reduce agricultural output. Capital costs would have to be adjusted (but not necessarily increased). There might be limited scope for greater non-agricultural earnings. As the study made by the Department of Land Economy at Cambridge emphasised, changes at the individual farm level are likely to require financial inducements. Because there have been so few examples of wetland-maintenance projects, there is little information on which to build valid estimates of the costs likely to be incurred at different scales and patterns of wetland restoration.



Scientific programmes to re-establish the Large Copper butterfly have highlighted the difficulties of re-introducing species and their requisite foodplants and habitat.

Whilst many valuable wetland-habitats are 'man-made', and depend on agricultural activity for their maintenance, it is far from clear whether a 'traditional' wetland can be created simply by making conditions wetter, or by imposing 'traditional' management practices. Current knowledge of how wetland and other types of habitat function is still too rudimentary to enable management prescriptions to be drawn up with any certainty of success.

Rehabilitation, re-creation or creation?

For that reason, an important distinction has to be drawn between wetland rehabilitation, re-creation, and creation.

As well as retaining examples of habitat where they have survived to the present day, the priority should be to rehabilitate sites that are still in the early stages of degradation, and then to move onto examples where wetlands can be re-created on sites that have more intensive cropping.

Experience in other countries, and particularly the United States, emphasise the need for ecologists, hydrologists and land economists to be involved in the planning process at the earliest possible stage, so that detailed objectives can be identified and agreed by all parties.

The first major phase of strategic thinking on the management of land for amenity and wildlife occurred in the 1940s, in the years that led up to the establishment of the National Parks Commission in the planning sector, and the Nature Conservancy in the science sector, of Government. In an internal memorandum of 1942, Basil Engholm (who later became Permanent Secretary of the Ministry of Agriculture) recognised the important opportunities for the Ministry and farming industry at large to participate in such ventures. His view did not prevail. A pencilled note in the margin of his wartime memorandum emphasised that nothing must be done to deflect the industry from its central task (Sheail 1981). Agriculturalists distanced themselves from the research and practice of amenity and nature conservation. They had more than enough to do in meeting the nation's need to grow more food.

CAP reform a matter of urgency

Circumstances change. The farming industry now operates in a very different socio-economic climate. In their publication, *Our Farming Future*, the Agricultural Ministers for Great Britain and Northern Ireland remarked on how environmental concern made the reform of the Common Agricultural Policy (CAP) even more urgent. "Mechanisms had to be found for incorporating broader objectives than food production". "The environment must become a greater concern for farmers and agricultural policy-makers, both in Britain and across the whole of the European Community." The Government's approach has been to provide a framework of guidance, regulation and payments for positive environmental-management measures (Minister of Agriculture *et al* 1991).

Engineering new soil/water regimes

Recent discussions between agricultural scientists and wildlife ecologists on landscape ecology and how greater diversity and sustainability might be introduced to the countryside, have demonstrated the mutual benefits of a closer rapport.

If account is taken of the abundance of practical expertise that already exists for engineering new soil/water regimes, an exciting and highly relevant agenda of research and development can be foreseen as the countryside of the United Kingdom prepares for closer integration in Europe.

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The potential for applying machine vision to defect detection in fruit and vegetable grading

Following the success in the automatic grading of some fruits and vegetables according to their colour, size and shape, machine vision is steadily showing its potential for surface defect detection. In this paper Qingsheng Yang reviews literature on machine vision for surface defect detection in fruit and vegetable grading. He highlights various aspects in the process of defect detection and discusses possible approaches to further research on questions of defect identification and the requirements of real applications in terms of speed, flexibility and accuracy.

To meet the increasing demand for high quality produce, many fruits and vegetables are graded before being sent to market. Automation of the grading procedure will undoubtedly bring significant economic and labour saving benefits to the food industry. Grading standards usually specify the external quality requirements in colour, size, shape and extent of surface defects. While the automatic grading of some types of produce according to colour, size and shape has become a commercial reality, the selection on the basis of surface defects such as blemishes and injuries is still a manual task.

The automation of the defect detection is a key step to the full automation of the grading procedure.

It has long been recognised that only optical methods are practically feasible for automatic defect detection. The methods adopted by pioneer researchers mainly used spectrophotometry techniques[1]. This approach suffered from a lack of spatial resolution and was seldom employed by itself.

Owing to the advances in computing and electronic technology and the decline in the price of computing and imaging hardware, machine vision technology has been considered for many applications in agricultural and food production processes[2]. Machine vision is a machine eye-brain (camera-computer) system which provides some of the capabilities of human visual perception.

In automatic grading, machine vision is used as a tool for automated visual inspection, and has become a very active area of research in the last decade. In addition to being used in grading fruits and vegetables for colour, size and shape[3-21], machine vision is being applied to grading many products for the extent of defects[12-34]. Among the products are apples[21-26,34], citrus[14,15] and oranges[16], peaches[27], bananas[28], dates[29], dried prunes[30-32], tomatoes[12,13], potatoes[17,18], bell peppers[19] and processed vegetables[20].

Currently, most of the developments are at an early stage, using relatively simple image processing techniques and being studied under laboratory conditions. The reported performance of the most developed systems is, on the whole, still far below that of humans, and extensive research is required before these prototype systems can be brought to commercialisation.

Q Yang is a member of the Robotics and Control Group, Silsoe Research Institute, Silsoe, Bedford. (Refereed paper.)

Techniques developed for colour sorters using machine vision are sometimes applicable to defect detection. However, in most colour sorters the colour measurements are often global or average readings and are obtained by integrating over the whole surface of a product. This is inadequate for defect detection because defect detection requires both global measurements and a surface scrutiny.

This paper reviews the research work on the application of machine vision technology to surface defect detection in fruit and vegetable grading. Major aspects in the application of machine vision to defect detection are discussed. The emphasis of this review is on the identification of generic problems in these applications. The potential of implementing a real-time vision system for all-over external quality evaluation is considered. Some possible approaches for further research are suggested.

Process of defect detection with machine vision

A typical machine vision system is depicted in Fig 1. It consists of a camera, a computer containing a plug-in image processing card, a display monitor and a terminal for the computer. The camera generates an image in the form of analogue signals. The image is passed to the card where it is converted into digital form and stored in an area of memory. Once an image is 'frozen' in the memory, computer programs can be used to process it and information can be retrieved to interpret it. An image is typically digitised into 512x512 data, each of which represents a small picture element (pixel) and has a gray level between 0 and 255. The high spatial and gray scale resolutions of the digital image allow the vision system to discriminate details in very small areas.

In manual grading, the image processing and interpretation are of little difficulty to a human inspector if the product rate is low enough and the inspector is not too fatigued. While watching the products moving along a conveyor belt, he detects defects by looking for discolouration and other surface inconsistencies, and judges the importance of the defects against grading standards. Having gained experience through training and practice, he can complete the whole inspection process (including the inspection for colour, size and shape) at 'a glance'. A machine vision system carries out the process in a similar way. However, the image processing and interpretation tend to be very difficult to implement.

A machine vision system generally accomplishes the process of defect detection in a series of steps:

i. image generation;
ii. product location;
iii. scrutiny;
iv. measurement;
v. classification.

The product location and the scrutiny are two distinct steps of the image processing. The product location is the separation of a particular product from its background and from other products. Usually large numbers of pixels have to be scanned before the product of interest is found. Once the product is located, every pixel on it may need to be examined to detect defects. Normally some geometric measurements are made because grading standards specify defects according to size, shape and other geometric properties. These measurements may be then used as features in the classification step to yield a grading decision in terms of the degree of defects. Combining the decision with other evidence about colour, size and shape, a final grading decision is made, with output to a sorting controller.

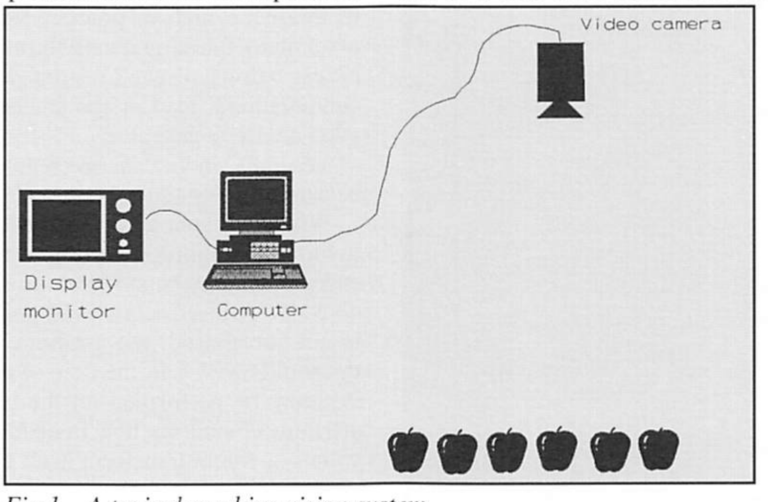

Fig 1. A typical machine vision system.

Image generation

Obtaining the proper images is vital if machine vision is going to be applied successfully to surface defect detection. The image generation includes the presentation of the produce, the use of the camera and the lighting design.

– Presentation of the produce

Ideally, products would be singulated, oriented and positioned in front of the camera(s)[13,19,24] so that most of the surface can be viewed and subsequent calculations can be greatly simplified. However, this increases the complexity of the handling mechanism and slows down the grading speed. Nevertheless, a mechanism for singulation greatly simplifies object location[15,18,26,27,30]. Singulation is assumed in some reported work[12,17,21,22] where single products are manually placed in the field of view.

For higher throughputs, flat belt conveyors may be adopted[18,27,30]. The produce is presented in one line and items may touch each other at both ends along the direction of movement.

Bulb shaped products must be rotated so that most of the surface is visible to the camera(s). One method of achieving the necessary rotation is the use of a conveyor belt with rollers[16], which are in rows perpendicular to direction of translation and linked by a chain and carry the produce along. The undersides of the rollers are in contact with a stationery bed which causes the rollers to rotate as they move forward. In this way several rows of produce are in the viewing field of the camera instead of just one line of products. However, the items can still touch each other in the same row. The singulation must be done later in image processing[9].

– Cameras

Most cameras used in defect detection are solid state video cameras. The sensor elements in the device are arranged either in a single array as in line-scan cameras, or in a matrix as in area cameras. Both types of cameras can be monochromatic or coloured. Line-scan cameras may be used if products translate through the field of view at a constant speed, such as in the case of the inspection of processed vegetables[20].

Generally, matrix CCD cameras are used, especially when the produce are rotated in the field of view. In this case the use of a line-scan camera is not appropriate because the scanned lines may not evenly cover the surface of produce of varying sizes.

The number of the images or cameras is determined by the given method of product presentation. Either several images are acquired by a single camera or multiple cameras are arranged at different viewing angles to allow the whole surface of a product to be analysed.

– Lighting

Lighting is dependent upon the application. For defect detection, front lighting is required. The light sources are often soft incandescent lamps[19,22,16,17,30,31]. The light should be distributed as uniformly as possible over the produce. Diffuse lighting[13,17,18,21,22,23,27,29,30] can provide quite uniform illumination, and also eliminate shadows and minimise specular reflection.

Owing to the surface geometry and smoothness of produce, specular reflectance is always present to a certain extent and in most cases needs to be eliminated. A pair of polarising filters may be applied[16,34]. One filter is mounted in front of the light source, and the other fitted in front of the camera lens and adjusted until the specular reflection is minimised.

A background can be chosen to make the image segmentation of objects from it easier[17,26,27,29,31]. However, in a real commercial installation, backgrounds can become dirty, which makes the segmentation more difficult.

To enhance the image contrast optical filters with narrow pass bands may be used. Spectrophotometric measurements can aid the selection of the filters[22,26,27,29,30]. If reflectance in the near infrared range (NIR) is desirable, a camera with the sensitivity peaked around the centre of NIR may be used without a filter[30].

Structured lighting using projected stripes, grids or other patterns is also very useful to get three-dimensional surface information[34].

Fig 2 illustrates a laboratory set-up involving structured light for blemish detection in apple grading. Examples of the images presented to the grading unit are shown in Fig 3.

Image processing for product location and scrutiny

The task of the image processing mainly consists of two segmentation stages. The individual product of interest is first separated from the background and from other objects in the image; secondly, defective surfaces are differentiated from

Fig 2. Blemish detection for automatic apple grading – structured light can be used to detect the stalk and calyx areas of an apple. (Photo: Silsoe Research Institute.)

normal surfaces and other natural features such as stalks and calyxes. Other types of processing are occasionally needed, eg texture analysis for non-homogeneous surfaces like oranges[3].

Before defect detection, images are often pre-processed through either hardware or software in order to enhance the contrast and to correct for non-uniformity of illumination[27]. Digital filtering, gray level scaling and pixel-to-pixel arithmetic are commonly used in this process. Individual objects may then be located by simple thresholding[29,30,34]. Consequently, only pixels on the product surface will be examined in the second stage of the segmentation.

– Problems in image segmentation

Spectrophotometric studies[1] show that many defects present some differences in reflectance from normal surfaces when illuminated properly. It is these differences that allow the defects to be detected by a machine vision system. However, the segmentation is generally difficult for the following reasons:

i. many different kinds of defects can be present, and their locations, orientations, sizes and shapes are often unpredictable;
ii. the reflectance contrast between defective and normal surfaces is often small;
iii. the boundaries of defective areas may not be well-defined, which can present problems to an edge-based method;
iv. natural variations in colour over a product surface or among objects of the same product may also cause differences in reflectance;
v. the shape of a product surface may lead to uneven variations in reflectance, especially near the boundary of the product and at surface concavities.

– Image segmentation techniques

There is a broad range of techniques available for image segmentation[35]. Some of the techniques are quite complicated and computationally intensive, and therefore only suitable for off-line inspection.

A typical example is the region splitting and growing technique, which in practice will iteratively examine each pixel many times, gradually refining a hypothesis about which pixels belong to each region. Methods which involve low computational load or are amenable to real-time implementation are more desirable.

Generally, more than one segmentation technique is required because different defects present different features in images.

With high contrast images collected under well controlled lighting conditions, simply thresholding the intensity level of every pixel may be sufficient to segment out most of possible defective points or clusters of points[17,26,27,33]. Where the contrast is not substantial, the gradient image may be used for the thresholding[12,18,30]. In the case of a colour image the thresholding may be performed on the image of transformed colour attributes[20] such as hue instead of the original tristimulus values (a colour transform itself could be a segmentation technique[16,19]). The thresholds can be set manually[20,26,30,33] or calculated from histogram analysis, global or local statistics[12,27,32], or other methods[29].

In many cases, more complex methods are required. If the contrast is poor, edge-based techniques are frequently appropriate[27]. Because segmentation is a process of pixel grouping, discriminant analysis may be applied[21,22], in which a discriminating function is trained and used to map each pixel into the proper group. The segmentation can also be carried out by using artificial neural networks.

The first stage of the segmentation may be unnecessary in some cases such as the use of the background subtraction technique[25,34]. In this example, defective points or areas are associated with sharp and inconsistent variations in reflectance, and are segmented out by subtracting the original image from its background image, which only contains very low frequency variations and results from heavily smoothing the original image.

– Identifying stalks and calyxes

The results of the segmentation are pixels or small areas which may be associated with either defects or some natural features like stalks and calyxes, since they look very similar to defects in the image, especially in the case of grading non-orientated produce[26]. Distinctions between them must be made.

If a stem appears as a protrusion from the product outline in the image, it can be detected by the analysis of the outline[36]. If an intensity image is regarded as containing depth information, ie two-and-half dimensional image, the distinctions can be made by analysis of the intensity values within the segmented areas[27].

As many defects occur on the flat or convex surfaces of a product while the surface around a stem or calyx appears concave, the three dimensional information about the produce surface shape can be used. Such information may be obtained either by stereo imaging or by the use of structured lighting[34].

Measurement and Classification

Once the defective areas have been recognised and segmented out, the consequent measurement and classification are relatively straightforward.

– The grading standard

In the simplest situation, pixels associated with defects may be counted for size measurement. If the total area of the defect is larger than a threshold, the item will be downgraded[16,17,20,23,26,29,30,33]. The threshold is specified by a grading standard.

Sometimes a grading standard, in addition to size, also specifies shape[37], texture and other criteria for different types of defects; the quality requirement for a specific class is the combination of these different criteria. Consequently, all these specified quantities may need to be measured. Here, further image processing, mainly working on the binary image, may be needed, such as pixel connection, locating segmented patches and perimeter following[25].

Alternatively, some equivalent features which are not specified by a grading standard may be measured because they are more suitable to be extracted from the digital images[18,27].

– Classification and the grading decision

In the process of classification, the list of those measured features defines a pattern and is fed into a classifier to produce a grading decision. Both deterministic[25] and probabilistic[27] classification approaches may be used. The use of traditional statistic classifiers (Bayesian) sometimes gives unsatisfactory results. There are several factors which may affect the accuracy of these techniques. Among them are:-

i. some features selected are actually correlated to some extent;
ii. the training set of samples is often not large enough to cover all possible blemish patterns;
iii. the class-conditional probability densities are not well-known.

As an alternative, an artificial neural network can be used[38,39], which can overcome above problems i and iii because it makes no assumption about input data. A neural network is a parallel computing architecture – inspired by the structure of the brain – that has a large number of simple processing units for local computations and many interconnections between them. It learns by example.

Typically, a neural network is presented with a training set consisting of different patterns, and in response to the examples, it adjusts the strength of the interconnections. The network information is actually encoded among the interconnections in a distributed fashion. After training, it is able to classify new input patterns that are similar to the training examples.

Other important properties of a neural network include graceful degradation and fault tolerance due to its characteristic of the distributed information representation.

Neural networks are quite powerful and particularly excel at classifying biological objects which have highly variable images.

Discussion and conclusions

– Speed

In the application of machine vision to automatic produce grading, high speed is a basic requirement. Most of the research work so far has emphasised the development of algorithms for defect segmentation and the evaluation of the classification accuracy based on the algorithms, using laboratory systems which are not suitable for real-time application. For those aiming at real-time application, multiprocessor systems are used[8,26,31], which are very application-specific. Further research work is needed to develop flexible high-speed systems for grading a range of produce.

Vision algorithms, especially sophisticated ones for defect segmentation, demand a large amount of computational power to achieve results in a reasonable time. Parallelism, in which data processing is distributed among multiple processors, appears the only economical ways to achieve the speed. There are different methods of parallelism. For instance, many low-level image processing techniques such as edge detection are characterised by local computations for each pixel and are suitable for geometric parallelism, in which processors execute the same program on their own sub-regions of an image; at an intermediate level, different tasks of grading for colour, size, shape and extent of defects require different operations and lend themselves to a form of event parallelism, in which each processor executes its own programs independently.

Multiprocessor systems for fast processing can be constructed cost-effectively from an array of transputers which can operate concurrently and communicate through links. With electronic link switches, a transputer-based image processing system can be reconfigured easily by software so that the system is capable of being adapted to meet different requirements of parallelism as data changes from localised image data to global data about features in the image. With the inherent parallelism in neural computing, the use of a trained neural net working on programmable parallel hard-

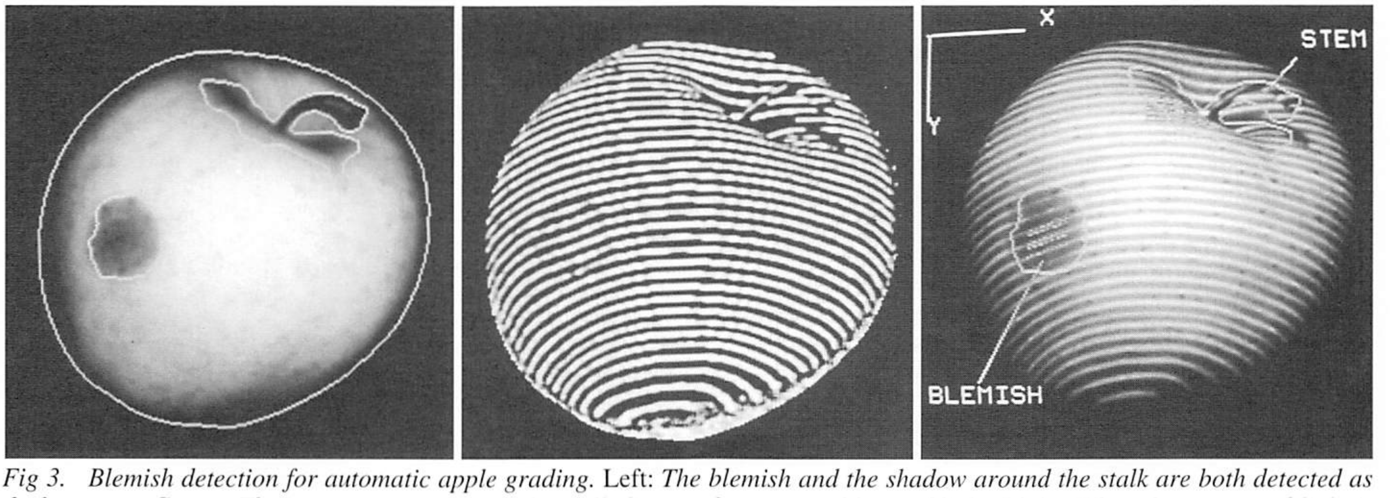

Fig 3. Blemish detection for automatic apple grading. Left: *The blemish and the shadow around the stalk are both detected as darker areas.* Centre: *The concave area around the stalk distorts the projected lines of light.* Right: *When the structured light is added the stalk area is correctly identified.* *(Photo: Silsoe Research Institute.)*

ware will speed up the information processing tremendously.

Speed of the mechanical handling systems should be borne in mind at the early stage of the development of a whole inspection system including optical configuration and processing hardware. Hardware pre-processing may be used to do some common low level image processing at very high speeds[8].

– Colour

The use of colour in defect detection[16,20,21,27] is very helpful sometimes, and critical in the cases where defects are very diffuse and may not be detected at all by monochrome processing. In fact, human inspectors depend heavily on colour to differentiate defects. The inclusion of colour increases the information content of images, enables the analysis to incorporate chrominance, in addition to luminance, and may make the segmentation of defective areas possible in some cases and simpler in others.

Traditionally, colour images are generated by a colour camera or three monochrome cameras with three different filters. The red-green-blue outputs are digitised by a multi-channel analogue-to-digital converter and stored as three separate images. This means that the colour image processing requires three times as much memory. For fast processing, special hardware that is closely integrated with the framestore may be needed.

Alternatively there are several techniques for adding the colour processing capability to existing monochrome vision systems, either for relatively low cost implementation or for high speed operation. The use of optical filters is an obvious one, in which all colours that are not of interest to a particular application are blocked out by the filters. Another example is the look-up table method[16,20], in which a look-up table (LUT) is set up by off-line interactive assignments, and in the grading operation the R-G-B signals are used to generate addresses to access the LUT so that the tristimulus values of a pixel can be directly mapped into either good or defective categories.

– Further research and development

It should be possible to develop a fully automatic produce grading system with machine vision. In fact, some tasks of grading for colour, size, shape and extent of defects require common or similar processing functions, eg product location and outline following. The same structure of software and hardware design may be used for over-all external quality evaluation[13,18,21].

However, a lot more research work is required to meet the speed, flexibility and accuracy requirements in real applications.

Careful design of the lighting and imaging system in co-ordination with a produce presentation mechanism is essential. More robust segmentation algorithms and approaches, including the distinction of real defects from natural features of produce, are needed. For high speed, algorithms should be selected so that they can be efficiently implemented by parallel processing. In the classification process, a rule-based system for grade decision-making is required to combine all information from colour, size, shape and extent of defects[13,18]. In more complex situations, artificial neural nets may be more appropriate for the information combination.

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concluded on page 79

Drying and storage of grain and oilseeds by D B Brooker, F W Bakker Arkema and C W Hall.

Publ: Van Nostrand Reinhold, NY (1992).
ISBN 0-442-20515-5.

At the outset the authors state that this is not a mere revision of their earlier book "Drying Cereal Grains". Indeed the first chapter gives a very broad definition of grain and proceeds to summarise the position of the commodity in world trade. In particular, reference is made to the position of harvested grain in the USA, and to the developing technologies and energy requirements (60% of total energy requirement is used in drying).

Inevitably a comprehensive account is given of the properties of moist air and the use of the psychrometric chart in interpreting changes during the drying process. This is followed by a fairly standard account of the Equilibrium Moisture Content models; but unusually, although the standard approach is taken to the calculation of latent heat of vapourisation, no acknowledgement is made of the work of Othmer.

The importance of grain quality criteria is discussed and a very brief account given of the means used to determine numerically the quality properties of moisture content, test weight (hectolite weight), foreign matter and such 'non-standard' properties as breakage susceptibility, milling quality and viability. These last receive considerably more attention than the standard properties; an understandable expedient since 'standard' measurements are well described in a wealth of other literature.

The importance of airflow measurement, system design and an understanding of fan characteristics is emphasised as it must be in such a book. Surely a unique section in the airflow chapter, however, is that which discusses the anisotropic nature of some grains (e.g. *canola*), showing that horizontal airflow experiences less resistance than vertical flow.

From this point on, the book appears to be rather illogically ordered. An 'introductory analysis of fixed bed systems' points to the limitations of Hukill analysis, but then leads on to the modelling of single kernel drying and, thence again, to deep bed drying. This section includes mention of the various continuous flow models which are reintroduced in a later chapter under 'high capacity off-farm systems'. A special chapter on rice drying is followed by conventional descriptions of grain handling and management techniques, including a discussion of pests and fungi. A short chapter on automatic control systems is little more than an introduction to the subject, but attention is drawn to fairly recent research on the subject and, from what is not said, the authors make it plain that the subject of control (of continuous driers) is not yet satisfactorily understood.

Throughout the book, plentiful numerical examples are given, indicating ways in which calculation can help the understanding of the drying process. Imperial (or 'English') units are used in some cases; SI in others. There is very little reference to that favourite US measure, the 'bushel', which in earlier publications, was always a source of confusion to this reader!

The book ends with eight very useful appendices giving numerical data useful to a serious student of grain drying or a potential designer of systems.

Overall the book is a welcome addition to the shelves, the print style is clear and the diagrams well presented and annotated. Maybe the claim of the authors, that the book is 'more than a revision' is justified. Certainly there is some interesting new material – but in spite of the title it is difficult to find much specific reference to oilseeds.

BCS

Journal costs pegged

Barry Sheppard, Hon Editor

In a previous issue I was pleased to report that we were receiving more favourable comments on the recent changes in the Journal's appearance (including colour on the front cover) and its readability than we were receiving "brickbats". This is still the case, I am pleased to say.

With these improvements in mind and the tough economic situation we as an Institution and an industry find ourselves in, I thought I had better look at how we have been doing financially over recent years. Four years seemed about the right time to look at, as this period spans the change from the black and white covered previous format, to what we have today. I was amazed to find that despite the improvements, the nett cost to the Institution has remained exactly the same.

Journal Production Costs and Revenue 1987-1991

	1987	*1991*	*% increase*
Production and postage costs	18.1	22.3	23
Sales and advertising	6.7	10.9	63
Nett costs	11.4	11.4	0

. . . but more advertising will help – please spread the word

Taking inflation into account, a zero percentage increase in costs is a good performance but I am sure we could do better on the advertising front, even in these difficult times. There are few, if any publications in our area, that accept advertising and go to as many countries and as many specialist advisers/consultants as we do. We are doing our best to get this message across to the marketing people in our industry but a personal approach from their own colleagues is bound to be more effective. Perhaps some of our readers can help in this respect as they will have the success of their own organisations and the future of the Institution at heart.

Future of publications – your ideas welcome

Talking of the future, the Journal Editorial Panel which includes Denis Cartmel the Newsletter Editor, also discussed the future of publications in general at the recent meeting. Many revolutionary scenarios were proposed and discussed at the meeting, but as time was limited we decided that what was really required was for a sub-committee to look at this subject in greater depth and come up with some firm proposals. We have now put forward this idea to the President and Executive Committee. If you as members have any thoughts on how you would like to see our publications develop in the future, then please let me know as soon as possible as we live in rapidly moving and interesting times!

continued from page 78

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Electronics in Agriculture

Guidelines for training:

The discussion forum created by the Electronics and Computing Systems Specialist Group (ECS) has provided a valuable meeting point for those interested in electronics and the use of computers in agricultural engineering and has created a centre of expertise within the Institution as a whole.

Simon Blackmore is Lecturer in Information Technology at Silsoe College. He is the current Chairman of ECS.

The ECS specialist group became concerned that the uptake of electronic monitoring and control systems in agriculture and horticulture was slower than it should have been. The needs of farmers and growers for more precise and timely information, to remain competitive, coupled with close control of production – particularly on the quality of their products, has become more important. It was therefore decided to set up a Working Party to develop a syllabus for training purposes in electronics for agriculture.

Undoubtedly, two of the main barriers to progress are still a lack of awareness of the capabilities of electronic systems to meet these needs, together with a feeling that

Agriculture and Horticulture User

Duration of Course

Twelve hours, either as a single two day event or in separate modules of two, four or six hours on an extended basis (NOTE: It is recommended that users complete a preliminary training course in farm electrics, such as the ATB's 2-day Farm Vehicle Electrics course 246.1C).

Objectives

On completion of the course members will have achieved the following:

- Awareness of the areas and types of application of electronics in agriculture and horticulture.
- Understanding of the basic concepts of electronic systems.
- Awareness of the design features that are important for reliable operation of electronic systems in the agricultural and horticultural environments.
- Understanding of the safety procedures relating to the use, checking and service of electronic equipment.
- Ability to install, set up, check and operate typical electronic systems.
- Ability to perform simple fault diagnosis with the aid of a basic test meter.
- Ability to report the results of fault diagnosis to supply and repair agencies and to log routine checks and calibrations.
- Ability to relate available equipment to requirements.

Course Elements	*Time (hours)*	*Content*
Review of basic electrical principles	1	Review AC; DC; voltage; current; resistance; insulation; analogue and digital signal; safety.
Application of electronics in agriculture and horticulture	2	Awareness of potential (costs and benefits). System modules (sensors, processors, displays, controls).
Electronic components	1	Recognition of basic units (resistors, capacitors, integrated circuits, etc.).
The agricultural and horticultural environment in relation to electrical and electronic equipment	0.5	The effects of heat, moisture, dust, etc.; interference; matching equipment to needs and environment.
Power supplies	0.5	Mains; battery management; fuses; safety.
Sensors	1	Principles of common sensors (temperature, load, pressure, flow, etc.); reliability; maintenance.
Signal processing		
Control principles	0.5	Basic concepts of control (logic, closed loop); speed of response.
Actuators and displays	0.5	Recognition of basic units (solenoids, relays, motors, LEDs, etc.); safety; reliability.
Calibration and testing	1	Concepts of calibration and errors (practical).
Installation and commissioning	0.5	Use of manuals; common pitfalls; safety.
Fault finding and diagnostic techniques	1	Logical approach using manuals; practical tests with meters; fault description; causes and effects; safety.
System design Construction methods and reliability	0.5	Concepts of compatability and standards.
Software	0.5	Basic concepts of what it can and cannot do.
Servicing and maintenance	0.5	Key areas; log books.
Selection, procurement and assessment of equipment	0.5	Matching equipment to requirement; assessment of quality.
Manuals and other technical writing	0.5	What to look for in manuals; warranties; performance figures; etc..

In 1987 the Institution formed the Electronics and Computing Systems Specialist Group (ECS), spear-headed by Sidney Cox, to create a forum for discussion on the aspects of electronics, and information technology that affect agricultural engineering. A Working Party of the ECS has drawn up guidelines for training. Simon Blackmore gives us the details.

operation of these systems is beyond their capabilities. Unfortunately, these attitudes extend into the farm services sector, including many parts of the agricultural engineering industry.

Therefore, one of the aims of the Group has been to identify, develop and promote suitable training syllabi for non-specialists, through which they may acquire better understanding of electronics systems. To that end the Working Party on Training was set up, under the chairmanship of Professor Dick Godwin at Silsoe College, and with co-opted members from AEA, BAGMA and ATB, as well as individual farmers and specialists in electronics systems.

The Working Party has drawn up the following suggestions of topics common to training at three broad levels – Users, Technician and Professional grade. The idea is that electronics should be dealt with largely in 'black box' terms at all three levels (leaving detailed circuit design to the specialist) but with a graduated level of theory from Ohm's Law for the user through to unit selection, interfacing and feedback loop analysis at the most advanced levels.

Technician

About thirty-two hours – either as a five day course (comprising one half day, three full days, with evenings hand-on experience and another half day), or a series of four hour modules.

- Awareness of the areas and types of application of electronics in agriculture and horticulture.
- Understanding of the basic concepts of electronic systems.
- Awareness of the design features that are important for safe and reliable operation of electronic systems in the agricultrual and horticultural environments.
- Understanding of the safety procedures relating to the use, checking and service of electronic equipment.
- Ability to install, set up, check and operate typical electronic systems.
- Understanding of the basic concepts of fault-finding and ability to perform and record routine diagnostic tests with simple meters.
- Ability to interpret and utilise technical literature for users, servicing and commissioning engineers.
- Ability to instruct users in the operation and maintenance of their electronic equipment.

Professional Engineer

Forty hours, spread over one or two terms for full-time students, or five full days for in-career training (i.e. Short Course).

- Awareness of the area and types of application of electronics in agriculture and horticulture.
- Understanding of the fundamentals of electronic instrumentation, data processing and control systems.
- Awareness of the design features that are important for safe and reliable operation in the agricultural and horticultural environments, and of the construction methods employed to meet the requirements of these environments.
- Ability to undertake system design of instrumentation and control equipment for agricultural and horticultural use, based on the selection of components appropriate to the requirement.
- Ability to commission, test and rectify faults in equipment of this type.
- Ability to write clear documentation for manufacturers, service and maintenance engineers, and for users.

Time (hours)	*Content*	*Time (hours)*	*Content*
4	AC; DC; voltage; current; resistance; Ohm's Law; insulation; wiring specifications; analogue and digital signals; motors (continuous and stepper); use of meters and other test equipment. Safety procedures, including fuses and circuit breakers.	4	As for Technician but more emphasis on theory and use of more advanced instrumentation.
2	Awareness of potential (costs and benefits). Product awareness; practicalities.	2	Awareness of potential; farmer's requirements(costs and benefits). Farm visit.
2	V, C and L; measurement of these quantities; identification of components; printed circuit boards and wiring.	4	As for Technician but more on the characteristics and interpretation of technical specifications.
1	Heat, moisture and dust, etc.; EMI; protective measures (incl standards). Safety considerations.	4	Physical components of the environmental protection, serviceability and modularisation. Safety.
1	Mains; batteries and their maintenance; voltage and current limitations; the use of backup power units. Safety.	2	As for Technician but with more on technical specifications.
4	Principles of common sensors; environmental limitations; fault conditions; maintenance requirements.	4	Principles of sensing; characteristics of common transducers; selection; alternative techniques.
2	Conditioning of sensor output; op-amps, ADC, DAC, VTF conversions; multiplexing.	3	As for Technician plus microprocessors; noise problems and their treatment.
2	Basic concepts of logic and closed loop control, where employed; simple algorithms (on - off, PID); concept of user tuning.	3	As for Technician plus treatment of stability; ergonomics of man machine interface. Safety.
2	Solenoids, relays, motors and interfacing. Safety.	2	As for Technician, but more on the technical specification.
2	Concept of calibration; instrumentation standards; calibration and test equipment.	2	Calibration and standards; sources of error; calibration methods.
2	Use of manuals; pitfalls; safety; instruction of users.	1	Design for ease of acceptance.
4	Logical approach using manuals; practical diagnosis with test equipment; reporting. Safety.	1	Design for accessability and ease of checking. Reliability and safety.
2	Standards for inter-connection. Reliability.	3	Interfacing and standards. Documentation for users, etc. Computer capacity, memory, control rates, I/O. Safety.
1	Checking of programs and instruction books; pitfalls of modification and change.	3	Design for safety and simplicity; good documentation; specification and testing.
2	Key areas; recording; routine problems.	1	Documentation for servicing agents and users.
1	Key features; matching the equipment to the requirement.	2	Components and basic building blocks; specification; pitfalls.

Computers for arable farm management – the future

Bruce Eglington

To make sound management decisions, good information is vital. This information must be up to date, accurate and relevant to the decision process in hand. It must also be accessible in an easily interpreted format.

On an arable farm, many daily decisions are based on the experience and knowledge of the manager or his adviser. However, access to external information may also be required.

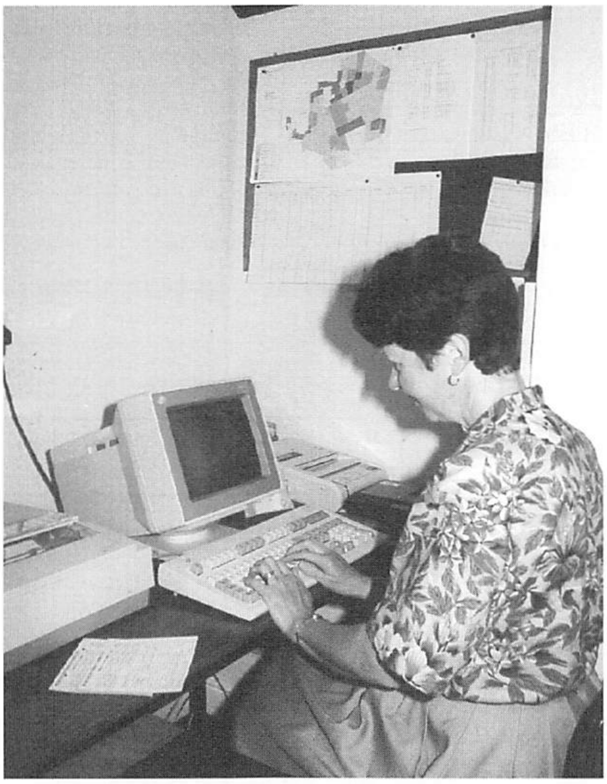
Decision Support – or Decision Making?

A number of computer programs have evolved for arable farm management. They can broadly be divided into two types. First, **recording and analysis** programs and secondly, **decision support** systems, sometimes "Expert Systems". This paper will focus on the former, but it is worth noting that the more advanced crop recording and management programs already contain interactive elements to assist with daily management decisions and such facilities are likely to become more common in the future. Preferably, these will be integrated with the overall management systems. As this process takes place, it should be remembered that most managers do not want the decision process to be taken out of their hands, they simply want support systems to assist in the more complex elements.

Current Field Recording and Management Systems

The use of computers in arable farming has increased considerably over the past few years from the early days of farm computing where the emphasis tended to be on intensive livestock applications.

Most field recording programs provide a means of maintaining individual field records, often including some form of stock control and costing facility for inputs (seeds, fertilisers, sprays). Thus they combine technical and fincancial information. Some address aspects of legislative monitoring (COSHH, FEPA etc). Programs are also available for forward planning and budgeting, as well as more detailed daily work planning to control field-work, staff and materials more effectively.



More recent developments include mapping programs to display information in a geographical and therefore often more immediate manner. The advent of more sophisticated electronic instruments in field equipment provides an opportunity to link directly to such in-cab devices for electronic data transfer. Software also exists to help advisers or agronomists and integration between these and the on-farm programs enables the maximum advantage to be gained for all concerned in the production process.

Common recording facilities enhance the information from individual farms and comparison of data from many farms can provide considerable additional performance analysis. The more successful programs seek to address the needs of everyone involved in the food production process – the farmer, the adviser, the workforce, not forgetting the customer.

The advantages of a good computerised crop recording system over a manual system or a more general purpose management accounting program include:

- more immediate and relevant information;
- ready access to both physical and financial details;
- providing practical assistance to the daily management tasks of planning, organising, instructing and so on.

Experience has shown that data recording must be fast and straightforward and that it must be flexible enough to accomodate individual recording requirements.

For the information to be of management value a ready means of data validation, normally some form of physical and financial reconciliation, is essential. Commitment on the part of the software provider to develop and enhance programs to suit the changing needs of arable farming is also very important.

What of the future?

Factors likely to affect crop management programs include:

- increasing financial pressure on farming businesses;
- increasing importance of environmental and safety considerations;
- likely reduction in labour force with fewer but more highly qualified staff;
- continuing rapid development of computer and electronic technology both in the farm office and in the field.

As well as influencing the likely content of crop software in the future, these factors are likely to encourage further integration both between computer programs, (eg accounting and enterprise management programs) and electronic equipment (eg in-cab instruments). As computers become more powerful, the user interface is also likely to change to a more intuitive, perhaps geographically based system.

Integration with other software

It may no longer be appropriate to consider arable systems, or indeed other enterprise management systems, in isolation from

Paper presented at the Institution's Annual Conference "Alternatives", May 1992.

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overall business management systems.

Agricultural computing in the UK has developed to a stage where it may soon be realistic to progress into fully integrated information management systems. Previous attempts at such systems, mostly outside the UK, have often been unsuccessful either for commercial or technical reasons. To be successful, it seems likely that these systems must be modular and therefore *integratable* rather than *integrated*.

The specialist enterprise program must provide an interface between financial and technical information, referring directly to the central accounting element, in addition to covering as many aspects as possible of daily enterprise management – ie it must be a practical management aid. Each element should be capable of operation in its own right, as well as alongside the other modules, and each should be designed primarily with the needs of the main users in mind, whether it be the manager, secretary, adviser, owner. In addition there must be a common user interface and data structure.

In this way the computer becomes a fundamental part of daily management and data entry is minimised.

Integration with electronic equipment

There is currently considerable interest in treating crops on a variable basis within each field, to take account of different performance potential and optimise the use of resources.

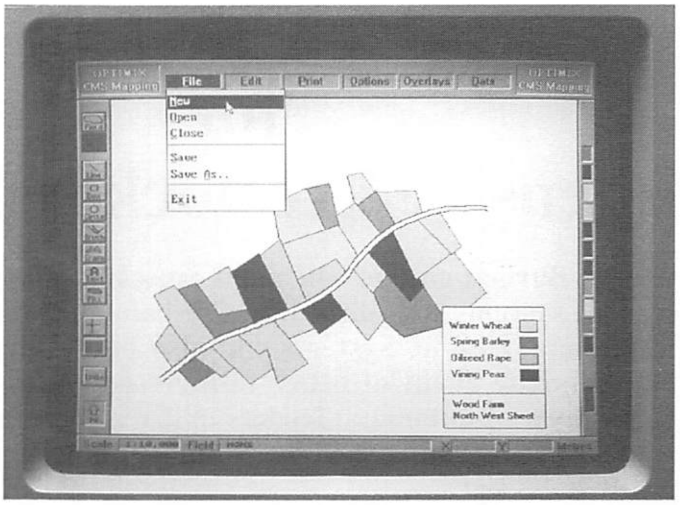
Whether or not spatially variable treatment systems will become common will depend on potentially complex, and ever-changing, cost-benefit equations. Environmental and legislative pressures are likely to become more significant factors, with more accurate control and monitoring of fertilisers and pesticides becoming ever more necessary.

Many farmers are already treating their fields on a differential basis, albeit rather crudely compared to the techniques possible under the developing technology. Much work and research is going on currently but many factors need to fall into place for such systems to become accepted practice.

There are perhaps five main stages:–

1. Data logging of spatially variable information (eg yield, soil information, weed or pest problems);
2. Analysis of this data to determine appropriate treatment policies;
3. Co-ordination into electronic instructions to be passed to control equipment;
4. Execution of these instructions by the field equipment;
5. Recording this variable treatment information for subsequent re-analysis.

The first, third and fourth stages depend mostly on hardware or closely related software and developments are taking place in this area. Reliable, cost-effective positioning systems of appropriate accuracy are required, along with a suitable means of measuring the variable information. Some measurements (eg yield) are likely to be mechanised, but other factors (eg weed distribution) may be logged manually, or remotely sensed.



The cropping plan on screen.

The second stage requires suitable software. While ultimately there will almost certainly be computer based algorithms for determing optimum treatment strategies based on a detailed layered analysis of spatially variable information, this requires a multi-disciplined approach and in the forseeable future most of this work is likely to be undertaken as academic research.

While decision making systems may become more common as better information is available, the starting point of commercial systems will perhaps be decision support systems which rely on the manager or agronomist's experience coupled to the spatial information available to determine treatment instructions. This will take faster advantage of the technology which is either already available or very close indeed.

Geographical user interfaces

To be of practical benefit in crop management software, geographically based interfaces represent a considerable development investment. Existing mapping programs mostly take the form of additional modules, accessing the main recording and analysis program as required. They provide an opportunity to re-display existing information already recorded in a different and perhaps more immediate manner, as well as allowing geographical information (eg roads, paths, ditches, drains etc) to be recorded. Other uses include convenient area and distance measurement, operator or contractor instruction etc.

With recent advances in computing power and software technology, it is possible that this type of interface could become the primary one for crop recording programs of the future. Meanwhile, more immediate developments may form the bridge between the collection and display of spatially variable information, and instruction of machinery according to the manager's wishes.

REVIEWS

The Ivanhoe Guide to the Engineering Profession – 1991

Edited by Linda Parkin

Publisher: Ivanhoe Press (1991)

On the whole I found this book very interesting, although sixth formers need to remember that the guide is obviously aimed at a wide audience – right up to professional engineers - and therefore some parts are more relevant to them than others. For instance, I found particularly interesting the sections on Working Overseas, CV and Interview Preparation, Life as an Engineering Student, Working in Large/Small companies, CET, Women in the Profession, the European Engineer, and the History and Structure of the Profession. I felt that these articles would help me to decide whether or not engineering is for me. For instance, they describe what opportunities there are for women, what further training is available, and so on.

Several of the articles such as those on CV's and Working Abroad were of wider value as they seemed to be relevant to many different careers.

Part III was fairly interesting as general reading – but not as relevant to six formers as others.

As I am studying Maths, Physics and German A-level, engineering is a very real possibility as a career. I thought that the first paragraph of each article, giving the author's background, was particularly useful as it helped the reader to understand the perspective from which the author was writing. This book has certainly given me a much clearer insight, into working in engineering than I previously had.

DJ

Year 12, Aylesbury High School

Safe use of Electricity

Aimed at encouraging safe working practices amongst farmers and horticulturists, a 52 page, full colour handbook, "Safe Use of Electricity in Farming and Horticulture", has been produced by Farm Electric. It is available, without charge, from Regional Electricity companies.

Alarm systems for intensive livestock buildings

George Burnett outlines the main causes of failure in ventilation control systems and describes the range of alarm equipment which is available. Systems can also be designed to raise the alarm in the event of other failures or emergencies such as breakdown of automatic feeders or fire. The majority of alarm systems have facilities to activate fail-safe devices if fitted.

From 1 January 1992 in the UK the Welfare of Livestock regulation (HM Government, 1978, 1990) require that automatic ventilation systems in intensive livestock units must have an alarm to give adequate warning of failure. The alarm system must operate even if the main power supply to it has failed.

The livestock welfare codes (MAFF, 1983-87) are worded more broadly and say that where failures of any automated equipment could endanger the welfare of stock an alarm system should be fitted which will warn the stock keeper of the failure.

System failures

The reasons for failure of ventilation systems are of three types:

- electrical failure caused by interruption to the power supply from blown fuses, broken wires, power cuts etc,
- equipment failures such as burned out motors, mechanical breakages, and faulty thermostats,
- human failure when a switch is accidentally switched off or a thermostat is incorrectly set.

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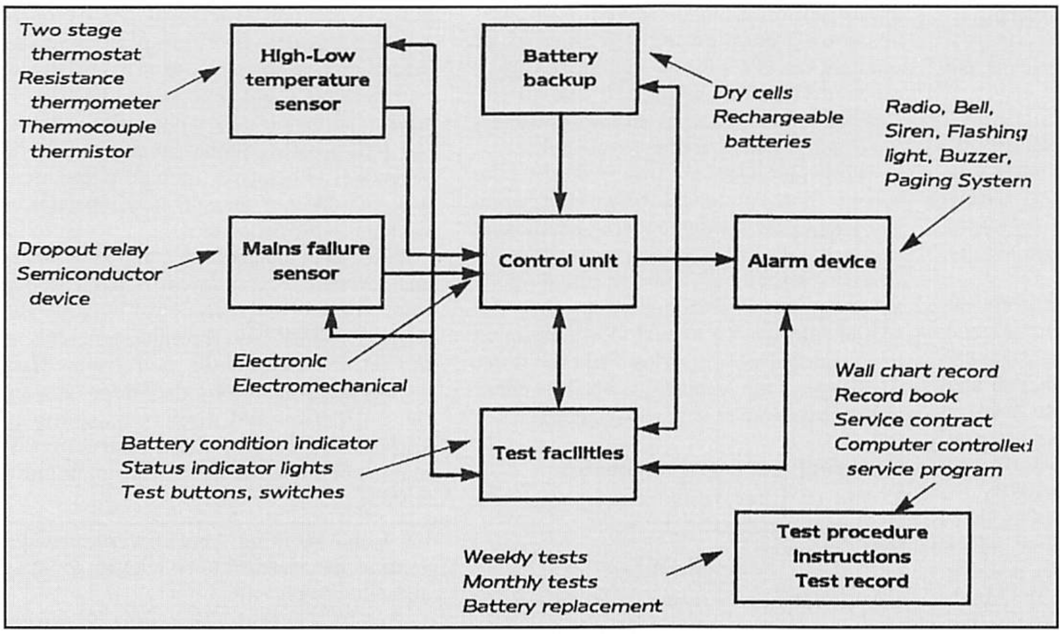

Fig 1. Alarm system minimum requirements: block diagram.

Both fan ventilated systems and automatically controlled natural ventilation (ACNV) depend on electricity for their operation. However, the effects of failure usually results in an unacceptable rise (or occasionally fall) in temperature within a short time in intensive livestock buildings.

Essential requirements

The alarm systems must respond to:

- a temperature which is above or below the limits for the housed stock,
- a loss of electrical power to the ventilation systems.

In some cases both needs will be met adequately by sensing temperature alone.

The alarm system must have:

- the means to communicate the fault to a responsible person,
- test facilities for the vital components in the alarm system: i.e. bell, siren, lights, batteries etc,
- a backup power supply with the capacity to power the system for a sufficient length of time,
- a well-defined test procedure with adequate instructions,
- a main switch system with fuse protection, constructed and installed to comply with the IEE wiring regulations, fitted to isolate the system from the mains supply.

Fig 1 shows the minimum requirements for an alarm.

– Temperature monitor

Temperature sensors are generally of two types.

1. Thermostat-type switches with either one high-temperature contact or two contacts, one for high and one for low temperature. Adjustments of set temperatures are made at the sensor with these types.
2. Electric sensors. In this case temperatures are set at the main control centre.

In both cases the controls for adjusting temperature should be constructed so that they are inaccessible to unauthorised persons. The sensors should be placed in an accessible position for ease of inspection and sited where they are exposed to representative air temperatures in the building.

– Power failure monitor

If a device to give warning of an interruption to the electrical supply is included in the alarm system, it is advisable to have the warning signal delayed for a short time. Short interruptions ranging from a few seconds to a few minutes pose little threat to temperature stability within the building but can be a nuisance when they always cause the alarm to sound. Devices giving a delay, typically of one minute, can be fitted to remove the nuisance.

– Communications devices

The equipment for raising the alarm must be sited in a position that ensures that the responsible person receives the alarm message without delay. It may take the form of a bell, a siren or a flashing light. The alarm device may, for example, be sited outside a building, in the farm office, or in a stock-keeper's house.

It is important to have visual indication on site of which building or room has the fault: it can be surprisingly difficult to locate the source of the problem when a siren sounds on a large site.

For remote sites equipment is available which operates through the telephone system or by radio.

– Test facilities

Test facilities for the battery backup and the alarm device are essential. They must be readily accessible and clearly labelled. Confidence lights to show that the system is working should be included.

Fig 2. Components of a simple alarm system for livestock housing – control box; bell; high and low temperature thermostat; mains failure unit.

Test procedures

The Welfare of Livestock regulations require that the alarm and associated additional equipment for use in the event of ventilation system failure be tested by the stock keeper or other competent person not less than once every seven days. Particular circumstances may require more frequent testing of parts of the alarm system.

A clearly defined procedure should be set up for each site with clear instructions detailing what has to be done and how often. The minimum requirement would include:

- testing the alarm system every seven days,
- testing backup battery condition every seven days,
- inspecting backup equipment to be used in the event of ventilation system failure every seven days,
- changing replaceable backup batteries at least once a year, and recording when next routine replacement is due,
- testing the complete wiring system every three years in accordance with the IEE wiring regulations,
- recording all checks made in a log book, with the date and signature of the person conducting the test.

It should be made a condition of contract that instructions and test procedure must be included when a system is supplied.

Response to an alarm

The action taken following an alarm will depend on the nature of the failure. However, immediate steps must always be taken to safeguard the welfare of the stock. These may include:

- calling out the first person on the stand-by list,
- checking that fail-safe devices, if fitted, have operated,
- opening doors or windows,
- adjusting ventilation flaps manually,
- starting an emergency generator,
- organising frequent visits to the building to check stock,
- organising frequent visits to the building to check stock,
- introducing an alternative heating supply,
- repairing the fault.

The stock keeper or other person on call should be fully familiar with the required procedure. Alarm systems for large or remote sites with radio or telephone links operated by a commercial security company require a well-defined call-out procedure to be set up on the company's computer.

Choice of alarm system

Various different types of alarm systems are available commercially. Choice of the best system for a particular application will depend on:

- number and type of events that are to be safeguarded,
- size and layout of the site to be monitored,
- suitability of the equipment for livestock buildings,
- technical skills available for installation, testing and maintenance, or the back-up service provided by the manufacturer.

– To suit building layout and livestock

The type of livestock and the number and type of events that are to be safeguarded can influence the choice of alarm system.

For example, poultry units usually have relatively few but large buildings with automatic ventilation, automatic feeding and water supplies. The production cycle for poultry means that all the buildings have the same temperature requirements. Because of the nature of production, a fault in any of these could endanger the welfare of the birds in a short period of time. In selecting the alarm system to alert to ventilation failures it may be sensible to consider systems that can be linked to the other services.

In contrast, most pig units have some small rooms containing few pigs while other rooms are large and are well stocked. Different ages of pigs have different feeding requirements with different types of floor, so that different temperatures are required.

The layout of the site can affect the efficient operation and cost of the installation. The building in some livestock units are close together, while in others buildings may be hundreds of metres apart. On some units all the stockpersons live close by, whilst on others they may live off site.

Where the buildings are close together a hard-wired system, where all the buildings are linked to common wiring could be appropriate. On scattered sites buildings may be linked by radio transmitters to a receiver in the farm office. Radio signals pass through wood easily, through brick and concrete with some loss, and through metal with considerable loss or not at all. If a transmitter is mounted inside a metal-clad building an appropriate external aerial may be required.

Fit temperature sensors in an accessible position. Mains failure detectors should be as far down the line as possible and preferably on the final electrical circuit supplying the ventilation. In some situations, for example farrowing rooms, it may be wise to fit mains failure devices on the circuit supplying the heater lamps. Where a three-phase supply is used to power ventilation, a mains failure detector must be fitted in each phase.

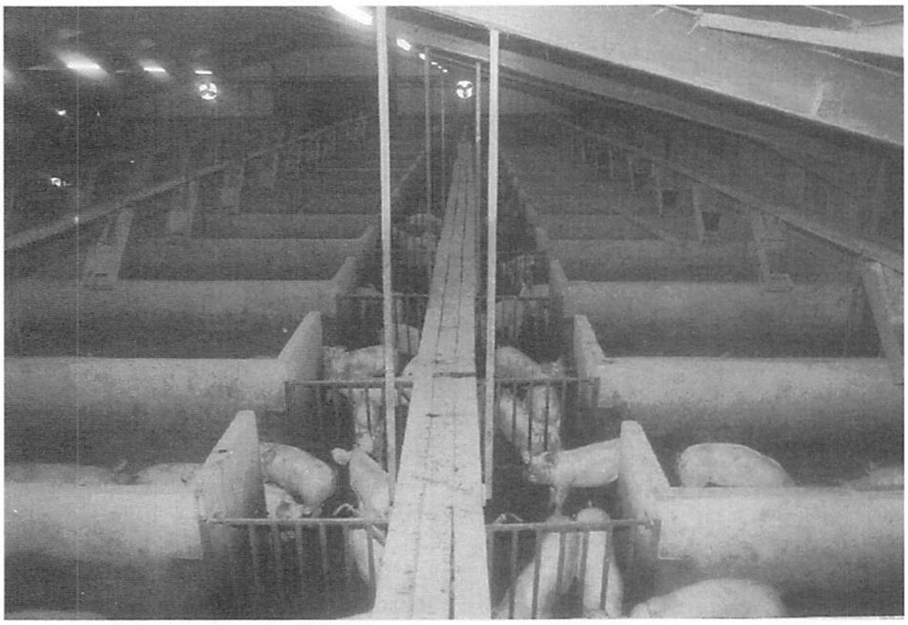

Fig 3. Fan ventilated rearing house for pigs.

Clearly, care must be taken to ensure that not only does an alarm system monitor for conditions that could result in livestock suffering unnecessary stress, but also that somebody knows about it even if the site is unattended. On units where a stockperson is always within earshot of the unit an audible siren may be adequate. For remote sites an auto-dialler connected to a telephone exchange line or a radio pager would be more appropriate.

– Costs

Cost is an important factor for any part of a livestock production system. For alarm systems, the cost of the installed system is most important, not the price of individual components. For example, the cost of components of an alarm system for a pig unit with 42 rooms on a large site with widely spaced buildings was £3280 and £3250 respectively for a hard-wired system and a radio alarm system. However, when installation costs were included the radio alarm system was around half the cost of the hard-wired system. In another case, where the buildings were close together, the hard-wired system was much cheaper.

– Skilled installation

Generally, stockpersons are more interested in husbandry than complex electrical gadgets. Therefore, an important factor when choosing alarms, or any other equipment for that matter, is the technical skills available to install, test and maintain the equipment.

Many electrical installations in livestock buildings are ruined because the installer is unaware of the hazards. All cables and fittings must be out of reach of livestock, and protected from attack by vermin, dust and condensation and from mechanical damage by machinery. Always choose good quality fittings with a minimum electrical protection rating of IP55 (BSI, 1990).

The welfare regulations require that the alarm system be tested every seven days and any faults repaired 'forthwith'. The alarm system should be capable of being tested quickly: unnecessary time spent testing is time lost from animal husbandry. Ideally the system should be capable of being tested by one person. On large sites, a radio pager carried by the person carrying out the test can provide this facility. Alternatively, two-way radios can be used, one transmitting from a buzzer or siren on the controller while the receiver is carried by the tester.

– Repair facilities

Like any electro-mechanical system alarms can break down. Prompt repair is required. As a general rule, only consider systems that can be repaired locally. Never purchase a system that can only be repaired by specialists who may be located at the other end of the country.

At least one manufacturer of alarm equipment has established a very effective backup service. They operate a registration system for all their controllers. Once the installation is complete, registration documents are returned to the manufacturer. If a fault occurs, a telephone call to the manufacturer will secure immediate despatch of a replacement. Once the new part is fitted the faulty part is returned as part exchange.

On some systems inexpensive plug-in thermostats are appropriate. When a fault occurs a new thermostat is fitted and the old one discarded.

In most cases it pays to seek advice from an independent consultant who has no ties with specific manufacturers or suppliers.

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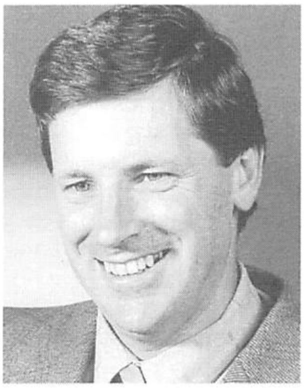
Design and management of automatic milking systems



by Toby Mottram

In this review – to be presented in three parts – the economic, welfare and social justification of increasing automation in dairying are discussed and the principal features of milking systems examined in detail. The development of automation for the physical and information gathering activities of milking are discussed. The principal areas for new research are shown to be gathering and positioning the animals for milking, preparing the teats, attachment of teat cups and getting animals to leave the milking area. Information about the animal can be detected from change of activity to determine oestrus and change of conductivity used to diagnose some mastitis infections. The rate of flow of milk from the animal can be used to monitor the successful progress of milking. Research is needed to identify decision making techniques for determining the health status of a cow from a combination of sensor inputs.

Dairying is one of the most important agricultural enterprises. It allows a monogastric human population to obtain food energy and protein from cellulose material via the digestive processes of ruminant animals.

In the UK there are 3.14 million dairy cows, sales of dairy produce have a value of £4 billion and provide 18% of the nutritional energy in the UK diet (Milk Marketing Board, 1991). The total number of dairy cows in the UK remained static from 1965 to 1990, whilst the number of registered producers fell from over 120,000 to below 30,000 (Milk Marketing Board, 1991). There has also been a reduction in the labour employed on dairy farms. Average herd size in the UK is now over 100 cows. At the same time the average yield per cow has risen from 3500 l/ann to 4880 l/ann (Milk Marketing Board, 1991).

The principal recurrent costs of milk production are feed and labour (Nix, 1991).

Trends in dairying – reduced labour; higher yields

The two main trends in the management of dairy cows have thus been increasing numbers of cows per unit of labour and an increasing yield of milk from each cow.

The reduction in the labour demand has been achieved by mechanisation of handling systems for forage and waste products and by improvements in milking system design.

The increase in milk yield per cow has largely been achieved through an increase in the feeding of concentrates (Webster, 1987) and also through simple recording and management techniques.

Mechanisation has been stimulated by both economic and social considerations. Even with the most modern labour saving devices the herdsman still has many tasks to perform at unsocial hours. There is a high staff turnover (Gasson, 1991, Holt, 1989). Average earnings for dairy cowmen are the highest in the agricultural sector, £220 per week (Nix, 1991), the hours worked, 53.9 per week, are the longest.

Monotony and often harsh work environment

The addition of labour saving devices in the milking parlour has tended to make the work monotonous with a small number of tasks having to be repeated frequently. Unlike most employment the whole task of milking has to be completed every time and cannot be left to another day or time.

In the design of the milking parlour there is sometimes a lack of attention to the needs of the worker, extremes of temperature are experienced, relative humidities are over 90%, noise from vacuum pumps and feeders is high and lighting levels are poor (Belt and Zegers, 1984). This neglect of the employed worker's needs is shown by the divergence of perception between employer and employee demonstrated by Davies and Seabrook (1988). A study of the mobility of dairy workers by Gasson (1975) demonstrated that dairy personnel move jobs frequently and that herdsmen were younger and more ambitious than other agricultural workers. It was also concluded that the fact that "not inconsiderable numbers of workers obliged to leave for personal reasons, ill health or disability casts some reflection on the increasing pressures to which dairy cowmen are being subjected".

There is thus an argument on the grounds of both labour productivity and motivation to remove the routine tasks of milking.

The skills of the herdsperson can be deployed in non-routine tasks such as identifying oestrus, handling stock at calving and treating sick animals, many of these tasks can be carried out during socially acceptable hours.

Automation – could lead to improvements in management and to higher yields

Milking is carried out at either end of the day to attempt to meet the animal's physiological needs of an even interval between milkings. Reducing the interval between milking removes an inhibitory protein which appears to be a natural feedback to suppress surplus milk production. The milk yield of cows milked four times a day increases by 15% compared to twice daily milking (Hillerton *et al*, 1990). More frequent milking has been attempted with conventional milking systems but places a heavy demand on staffing and has proved economic only in special circumstances.

It seems likely that frequent milking will only become viable when automatic milking systems become available. The model developed by Parsons (1988) needs updating in the light of changing technologies and prices but showed that such systems would probably be viable for herds larger than

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60 cows. Such systems are becoming possible with current sensing and computing methods.

A further application of electronic sensing techniques and information processing is for monitoring animal performance.

The quantity of feed consumed by the modern dairy cow increases the risk of metabolic disorders due to feed imbalances. By monitoring metabolic indicators such as food intake and linking this to other data such as milk output, an improved quality of management has been suggested (Webster, 1987).

Similarly, animals are bred to increase milk yields and there is some evidence that this can make them more susceptible to production diseases such as mastitis (Grindal and Hillerton, 1991). Constant monitoring of milk parameters such as conductivity has potential as a reliable method of diagnosing diseases such as mastitis at an early stage.

Technology has already outmoded these traditional stalls in which cows spent much of their lives.

These techniques are likely to be an essential part of any milking system which reduces the time spent by a milker examining each animal. In addition, they offer the potential for reducing the time spent on healthy animals and allow a better focussing of the scarce resource of labour.

Grant (1980) showed that milking routines occupied 50% of a herdsman's time and that increasing the number of labour saving systems on dairy farms would allow the herdsperson more time for husbandry tasks whilst automatic data collection and processing would assist in identifying problem animals. The ultimate objective of automation in dairying is the elimination of all routine manual tasks and a precise deployment of the skills of the herdsperson to non-routine tasks associated with animal management.

Dairy goats and sheep – greater mechanisation essential

The management of dairy goats and sheep is less advanced than that of dairy cows, probably as a result of their relative lack of importance in the agriculture of the developed world.

The demand for a greater range of dairy products, particularly of cheese, has grown (Mottram, 1986). This has led in recent years to the establishment of a number of herds (and flocks) in the UK. Mottram (1986) estimated that the current output of produce from dairy goats was equivalent to 0.01% of the output of cow's milk produce in the UK, there is thus much potential for growth in the market before it reaches the level of 4-5% attained in France (La Chevre, 1987).

The chief way that the husbandry of goats and sheep differs from cows is that the volumes of milk produced are substantially less. Mottram (1986) showed that the ratio of margins for goat versus cow dairying implies that a farmer must keep at least four times as many goats as he would cows for viability. This throws an even greater burden on the milking system to handle large numbers of animals rapidly.

It seems inevitable that future development of dairy enterprises for small ruminants will depend on the economic feasibility of developing highly mechanised systems.

Features of milking systems

This review examines the milking system with a view to reducing the labour input in the routine tasks of dairying and developing techniques to improve management of dairy animals. Tasks such as cleaning milking equipment which do not involve animal contact have been excluded as have husbandry tasks that can be performed without milking, such as automatic weighing.

The sequence of operations which an animal undergoes during milking are listed in Table 1. Most of these tasks have had some degree of mechanisation but this has mostly been to aid rather than supplant human input. The *physical actions* performed on the animals are carried out in parallel with *information gathering actions*.

Table 1. Operations to milk an animal.

Physical actions	*Information gathering*
Gathering	Animal behaviour
Positioning	
Preparing teats	Teat condition
Inspecting foremilk	Mastitis detection
Attaching teat cups	
Milking	Milk yield, conductivity, temperature
Removing teat cups	
Teat disinfection	
Animal exit	
Return animal	Animal behaviour

The information gathering activities are principally related to livestock management, such as identifying oestrus, monitoring milk output and diagnosing mastitis. These activities are carried out at milking principally because that is the only time under current management at which the milker can be sure of seeing each animal.

Each element of the milking system will be reviewed to identify the current state of the art and where work is required to further the aim of automation.

The amount of data that can be derived, even with manual recording, from an average dairy herd is substantial. For example, in the 'brinkmanship' system reported by Webster (1987) the yields and feeds for each cow are recorded weekly. The complete data set for each cow per annum is at least 500 bytes. Decisions about the management of the cow referring to the data are therefore taken at leisure in the farm office rather than in haste in the milking parlour. When automatic recording of other factors such as conductivity are added, the amount of data can only be analysed by a computer.

The current state of the art is reviewed in the light of the potential for some of the decisions to be made automatically.

Gathering the animals

In the UK, the yard and parlour system has almost entirely displaced the round-the-shed milking systems which developed from the stall-fed systems associated with hand milking. In the yard and parlour the cows are milked through a parlour system detached from the housing for the animals. The animals to be milked are gathered into a yard adjacent to the parlour by the herdsman, sometimes with the aid of a dog. The amount of compulsion applied by the herdsman to motivate the animals to move depends on a variety of factors, such as whether they are housed or at grass, how much feed is to be offered, the weather conditions, the distance to be walked and so on.

The benefits of the yard method are its efficiency in the use of labour, flexibility and superior hygiene. With the cowshed where cows are tied by the neck, mechanisation of the tasks of feeding, mucking out and milking was difficult. It was also more difficult to maintain good hygiene in a building inevitably contaminated by the continual presence of cows and feedstuffs (Clough, 1979).

– Novel methods necessary

With the automation of the milking process novel methods of bringing animals to the milking stall are necessary. Rossing *et al* (1985) and Ipema *et al* (1988) demonstrated that housed dairy cows would visit a station where they were both fed and milked by a researcher. It has been suggested that the principal motivation of the cows to visit the stall was to obtain concentrated food.

The hypothesis that cows visit a stall to be milked voluntarily has yet to be tested, but it seems certain that cows will attend a stall for feeding with concentrates. This method of attracting cows to be milked has limitations, for example, animals in later lactation can obtain virtually all their nutritional requirements from forage (Webster, 1987) and concentrate feeding becomes unprofitable. It is also unlikely that cows can be motivated to leave grazing, particularly in early summer, when they are surrounded by nutritious and palatable grass.

Wierenga and Hopster (1989) attempted to train individual cows to be summoned by an acoustic signal generated for each animal by an ear tag containing a radio receiver and tone generator. Many of the cows proved liable to forget their training and it seems unlikely that such a method is practical on a farm scale. Albright (1978) has shown that cows and heifers can be trained to respond to a variety of signals suitable for summoning them to milking, it remains to be seen whether the effect of these stimuli would diminish through lactation unless they are reinforced by positive reinforcement, such as feeding.

A practical method of gathering housed cows for automatic milking has been suggested by Ketelaar (1991) and by Mottram and Street (1991a). A stall which identifies cows by means of a radio transponder is placed to intercept a cow moving between the lying and forage eating areas, once held, the animal can be released either into a milking parlour or direct into the feeding area. Metz-Stefanowska *et al* (1989) have shown that cows will normally eat forage six times daily and this suggests that regular attendance of cows can be ensured by such a scheme. Research is currently in hand at several centres to test the attendance of dairy cows for automatic milking.

– Robotic husbandry operations?

Street (1985) suggested a system where cattle at grass would have access to a number of milking stations distributed around the farm. As yet there has been no research to determine the potential for ensuring regular attendance at automatic milking stations for grazing cattle.

Evidence from work on automatic feeders (Wierenga & Hopster, 1989) indicates that cows will not walk more than 200 m from pasture.

It is hard to see how cows at grass in summer can be encouraged to attend milking.

The operation of intelligent machines with free ranging animals remains one of the most challenging areas for ethologists and engineers as it opens the possibility of robotic husbandry operations on domesticated and non-domesticated animals.

Positioning the animals

The layout of cow milking parlours has been well researched and reported (Clough,1979, ADAS,1983, Smith, 1985). Efficient parlour systems have evolved rather than been designed, with working farmers often the principal innovators. The role of the research community has been to assess the effectiveness of installed designs. This is principally because the stallwork is simple to modify and develop with farm tools.

The emphasis in the sixties and seventies was to improve the ergonomics of the operator and this led to designs such as the static herringbone and rotary parlour (Clough, 1979). However, the emphasis in the eighties has been on improving the cow entry to and exit from the stalls (Loyd, 1991).

– Controlling entry and exit

The change of emphasis to improving the efficiency of the movement of the animals was inspired by the realisation that the efficiency of the operator's movements could hardly be improved by further parlour automation short of robotisation. The largest element of the work routine was found to be supervising the entry and exit of animals (Clough, 1979).

The movement of a group of animals under the supervision of an operator is reasonably assured, however new research is needed to ensure that unsupervised animals in automated systems move in a way which enhances the milking operation.

Smith (1985) discusses the use of backing gates to encourage groups of cows towards the parlour. Automation of some of these might be possible although determining the response of cows when there is no operator present will need some research. Such research will need to be a combination of anatomical measurement particularly of the moving animal, behavioural response to stimuli, and animal welfare.

For example, in the author's experience of using the automated milking system under development by Silsoe Research Institute (Mottram & Street, 1991a), cows will only queue for entry into the milking system for a few minutes before they wander away. In the same establishment cows are apparently dissuaded from leaving the parlour by aggressive cows wishing to re-enter.

Solving such problems is unlikely to be achieved by traditional methods since these always depend on the presence of an operator to ensure compliance. The most attractive layouts for installing automatic milking systems are based on the tandem stall where the cow is enclosed by barriers on which sensor systems can be deployed (Mottram & Street, 1991a). When sensor systems for robotics become more sophisticated then it may be possible to deploy teat cup attachment devices in herringbone and side by side configurations but this is not likely to happen in the near future.

– Teat cup attachment requires accurate positioning and posture

Since the current generation of robots have limited degrees of freedom and few sensors, the positioning of the cow for teat cup attachment is of critical importance. An operator attaching teat cups has, in robotic terms, many degrees of freedom, and is fully equipped with a sensory system to control them. The limited capabilities of current robots make it desirable to improve their chances of locating teats and attaching teat cups by modifying the cow's normal posture.

Farmers Weekly (1991) reported a prototype automatic system developed by Gascoigne which attached teat cups by forcing the cow's legs apart and preventing any liberty of the cow to interrupt the milking process. No experiments were reported to indicate the success of the system nor whether cows returned to the system voluntarily. Ordolff (1987) demonstrated that a cow, when touched by a simulated robot, would increase the frequency of movement of her rear legs. Wesselink (1991) reported a Duvelsdorf prototype with a system of sliding plates in the floor of a stall which, it was claimed, would cause the cow to move her legs apart. Montalescot (1988) overcame the problem on the CEMAGREF system by raising robot arms through a floor which folded apart restraining the cow's legs in the process.

The data presented by Mottram (1990, 1992b) are the only reported experiments on methods of improving the posture of cows for automatic teat cup attachment. The objective was to encourage the cow to stand with her rear legs in a rearward position, separated from the teats by at least 50 mm, and to minimise the amount of leg movement. It was felt desirable to achieve this with passive features of the milking stall. Treatments of angled floors, areas of slatted bars to discourage foot placement, asymmetric ramps were all tried, in addition to variations in the height of feed trough. The most successful experimental treatment was the use of a step upon which the cow placed her front feet. This was shown to increase the accessibility of the teats without causing excessive movement.

This work has led to a patent application (Mottram & Street, 1991b). The work was an example of how a complex robotic problem could be simplified by organising the environment around the robot.

Once the animal has been positioned, the next task is to prepare the teats for milking. This and the further physical actions involved in milking will be considered in the second part of Toby Mottram's review, to appear in our next issue.

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Which angle of pull? The mechanics of pulling and carrying with draught animals

In the use of draught animals, says Ross Macmillan, one of the major variables that is open to user selection (to some extent) is the length of the chains and hence the angle of pull. The question "which angle of pull?" is therefore a very practical one, but judging from the answers that are given, frequently on the basis of intuition, it is one that is difficult to answer.

The difficulty in deciding 'which angle of pull' is partly because the question is not sufficiently clear and also because the answer depends on the mechanics of what is being pulled and on the energetics of the animal doing the pulling. As the animal pulls the load at a general angle it both supports part of the weight of the load and pulls the load along against the horizontal draught.

The question must therefore be decided by two factors:

(a) The extent to which the horizontal draught will be reduced by having a vertical component, i.e. by the animal 'carrying' part of the load.

(b) The relative energy costs to the animal of providing draught loads and of carrying vertical loads.

If the horizontal pull (equal and opposite the draught) is constant, irrespective of the angle of pull, then any angle of pull greater than zero is a disadvantage because it just causes the animal to use up energy carrying this 'load' to no advantage. If, however, the existence of a vertical component of the pull reduces the horizontal draught by, for example, reducing the normal reaction between load and the ground, then an angle of pull greater than zero might be an advantage. But the choice of angle will vary with the operation being performed (a, above) and with the animal (b, above).

This paper is concerned with the type of load where the draught resistance depends on the normal reaction between it and the ground. Hence the findings will apply at least approximately to trailers, sledges and similar vehicles. They may also apply to animal drawn cultivation implements, but this will depend on how the vertical component of the pull is reacted by the soil forces on the implement and by the implement weight.

Pulling a trailer or sledge – calculation of energy cost

If we consider the pulling of a wheeled vehicle or a sledge type vehicle, the draught resistance may be considered to be proportional to the ground reaction at the wheels/skids. Fig 1 shows the force analysis for a vehicle carrying material (weight W) with an angled pull.

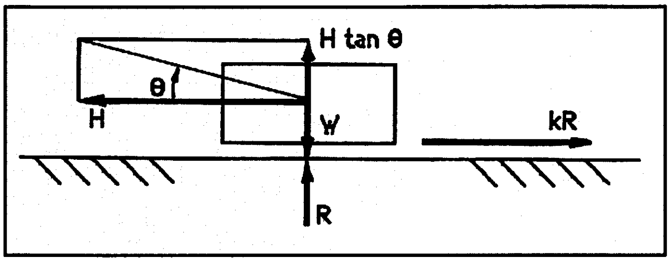

Fig 1. Force analysis of load vehicle.

With an angled pull, the ground reaction will be less than the weight; the draught force will therefore be less than for a horizontal pull. The penalty for this is that the animal must carry the vertical component of the angled pull and this has an energy cost associated with it.

Assume there is draught resistance coefficient,

$k = H/R$.

Resolving horizontally:

Horizontal pull $H = \text{Draught resistance} = kR$

Resolving vertically:

Ground reaction $R = W - H\tan\theta$

Horizontal pull $H = kW - kH\tan\theta = \dfrac{kW}{1 + k\tan\theta}$

Vertical load $V = H\tan\theta = \dfrac{kW\tan\theta}{1 + k\tan\theta}$

The total energy cost of moving this material one (1) metre horizontally is expressed as:–

Total energy cost T = pulling energy cost + carrying energy cost + walking energy cost

$= H.1.p + V.1.c + 1.w$

Where p, c and w = specific cost of pulling, carrying and walking respectively.

$$T = \frac{kW}{1 + k\tan\theta}.p + \frac{kW\tan\theta}{1 + k\tan\theta}.c + w = \frac{kW}{1 + k\tan\theta}(p + c\tan\theta) + w \qquad (1)$$

Differentiation of this equation with respect to θ does not give a minimum cost, but we can simplify it further as follows.

Expressing the energy (above the walking value) and on a per kg moved basis gives:–

$$\text{Total unit nett energy cost } T = \frac{k}{1 + k\tan\theta}(p + c\tan\theta) = \frac{kp}{1 + k\tan\theta}\left(1 + \frac{c}{p}\tan\theta\right) \qquad (2)$$

In the foregoing equation (2),

kp = energy cost of pulling one kilogram, one metre for angle of pull = 0

$= T_o$

Then

$$\frac{T}{T_o} = \frac{1 + \frac{c}{p}\tan\theta}{1 + k\tan\theta}$$

To show the effect of various angles, we need to use realistic values of c/p, the specific carrying/pulling cost ratio, and the draught resistance coefficient, k.

Carrying and pulling costs

The specific energy cost ratio c/p may be obtained from data published by Lawrence and Stibbards (1990) on the energy costs of Brahman cattle and swamp buffalo carrying and pulling loads on flat surfaces. These have been converted to a force basis (N) and are shown in Table 1.

R H Macmillan is Senior Lecturer in Agricultural Engineering, University of Melbourne; he is old enough to have worked draught animals on the family farm near Melbourne.

Table 1. Specific energy cost for animals.

Animal	*Specific energy cost* Carrying (c) J/N. m	Pulling (p) J/N.m ($=\frac{1}{\eta w}$)	*Ratio* c/p
Brahman	0.26	3.3	0.08
Buffalo	0.39	2.7	0.15

Draught resistance

The value of k, the draught resistance, corresponds to the rolling resistance for wheels and the towing resistance for sledges.

For wheels in agricultural operations, values of k range from 0.025 to 0.3 and represent operation of pneumatic tyres on various surfaces, from concrete to soft soil, for typical non-driving agricultural wheels, and to sand, for larger diameter wheels (Taborek, 1957; Onafeko and Reece, 1967).

For sledges, data from Foster, Knight and Rula (1958) suggest that the minimum values of draught resistance may be equal to those for wheels on soft soils and six or more times those for wheels on firm soils.

Total cost

Using values of k from 0.025 to 0.3 for illustrative purposes, the values of the total cost ratio, T/T_0 obtained are as shown in Fig 2 (a) and (b) for two values of carrying/pulling cost ratio, viz. 0.075 and 0.15 respectively.

It will be seen that for c/p = k, the total cost is independent of the angle and equal to the corresponding pulling cost.

For low draught resistance coefficients (c/p<k, easy pulling conditions), increasing the angle of pull increases the cost; it is more energy efficient to pull the load than to carry it.

For high draught resistance coefficients (c/p>k, heavy pulling conditions), increasing the angle of pull decreases the cost; it is more energy efficient to carry part of the load than to just pull it.

Conclusions

The practical conclusion of this analysis is seen in Fig 3, where the total cost is plotted against draught resistance for various angles of pull. To achieve a minimum cost, use a horizontal pull for all draught resistance coefficients up to a value equal to the specific cost ratio applying for the particular animals. For greater coefficients, as great an angle as is practical is suggested. In the limit, of course, it would be cheapest to use the animal to carry all of the load.

If for simplicity we assume that all animals have specific cost ratios of 0.1, then a horizontal pull on roads and on firm agricultural soils would be appropriate. For soft soils, the use of as great an angle as is practical would be most energy efficient.

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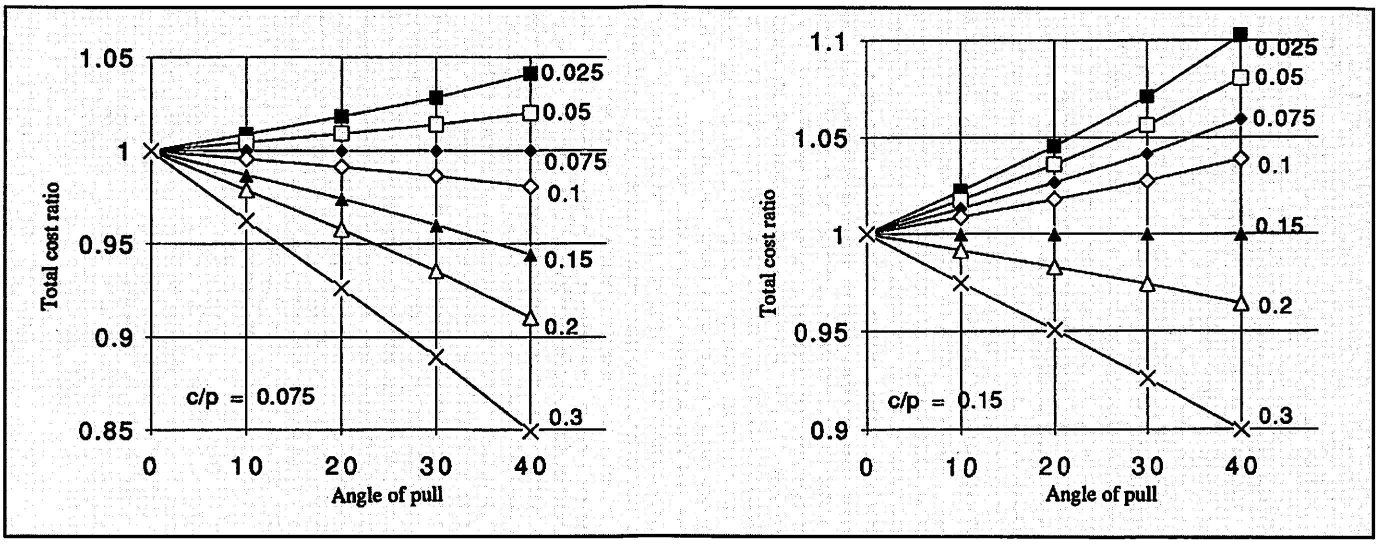

Fig 2. Variation in total cost ratio with angle of pull at draught resistance coefficients 0.025 to 0.3.

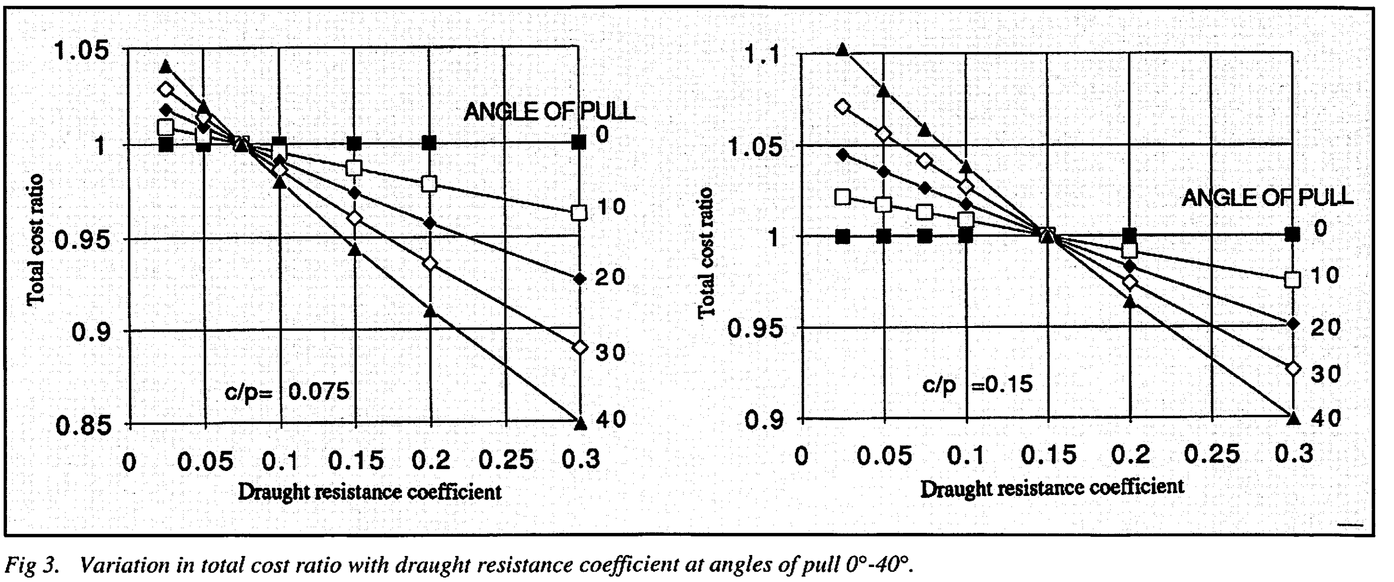

Fig 3. Variation in total cost ratio with draught resistance coefficient at angles of pull 0°-40°.

Developments in harvesting on soft ground

In Britain, particularly in the uplands, soft ground usually means peat – hill peat from a few centimetres to a metre in depth and also blanket bogs anything up to 20m in depth. Ken Buswell reports on Forestry Commission trials in assessing alternative harvesting and extraction machines and systems. The first essential, he says, is to have a thoroughly sound brash mat.

The harvesting of timber is a combination of several operations all of which are affected to some degree – either directly or indirectly – by working on soft ground. The constituent operations are:–

- Felling and debranching;
- Extraction } depending whether short-
- Conversion } wood or pole lengths;
- Stacking;
- Load and transport to customer.

It is the first three of these operations which interests this paper as generally the road construction deals with the last two. Harvesting systems and equipment will vary whether the operation is a thinnings or clear fell.

The majority of harvesting operations on soft ground will, in fact, be clear felling and often a premature clear felling when considering the normal age and tree size for the particular species. This early harvesting is to fell the crop before the wind does and so avoid a more expensive operation with reduced timber yields.

A no-thin regime is common on soft ground in windy Britain as thinning initially results in the crop canopy breaking up and increasing stem sway.

Motor manual harvesting is the traditional British system but mechanisation is increasing. Initially there were more processors than harvesters.

The quality of crop growing on soft ground can be very variable – swept butts and coarse branches as well as trees of better form. The motor manual system will handle nearly all conditions, but at a price. If the working is straightforward with little windblow, and a small tree size with good form, then the chainsawyer may be an option. He will cross the soft ground and, using organised felling techniques, produce well presented produce for extraction and a good brash mat to carry the extraction machine. Costs may be competitive with mechanical working.

However, as the tree size increases or if the crop is at all difficult, eg coarse branching, pockets of windblow etc, then mechanised harvesting will be cheaper and often safer.

K G Buswell was Deputy Head of the Work Study Branch, Forestry Commission, and is now Conservator for the West Country with the Forestry Authority.

Abridged text of paper presented to meeting of Forestry Engineering Specialist Group, Sept 1991, Newton Rigg, Penrith.

Skilled and *reliable* chainsawyers are becoming fewer and the trend to grapple harvesting for small to medium trees such as will be found on soft sites is evident.

Harvesting systems compared

During Work Study trials with LP harvesting on peat, undertaken by the Work Study Branch of the Forestry Commission, several

Fig 1. A thoroughly sound brash mat is essential for soft ground harvesting operations.

harvesting methods were tried. The equipment was chosen as typical of current practice, namely:–

Tapio 400: single grip reciprocating feed harvesting head of lower cost and output with simple maintenance. 60 cm is the maximum diameter handled.

Kockums 822 GP Processor: reciprocating boom with 3m stroke. Again simple and sturdy with basic maintenance but requiring pre-felling. (The Skogseric range is the currently available example of this type).

Lako 60: roller plus track feed grapple harvesting head with 2 sturdy single edged moveable knives plus a fixed knife above, plus clamping arm below the feed rollers. Fell/debranch capacity is 60/55 cm.

Osa 746: roller feed grapple harvesting head with 4 double edged moveable knives plus a fixed knife. Fell/debranch capacity is 45/40 cm. Unfortunately only limited time was available to test this head.

A limited study was carried out of a motor manual operation.

The usual products cut by all machines were 3m chipwood (2.8m-3.1m, including tolerances) but a sample of both 2m and 3m was taken from each machine. Where tree form and size allowed 2.3m and 2.5m pallet logs were cut.

The Tapio 400 delimbed most types of stem adequately with the operator able to 'float' the front part of delimbing knives over and around sweeps and coarse branches. However, output was low and a slightly ragged product resulted. Length measurement was reasonably accurate and product presentation was good. A satisfactory compact brash mat was produced.

Outputs from the Kockums 822 GP Processor were excellent and standard of debranching good. A brash mat could be produced to support it on the soft ground by delimbing in front of the machine. The mat was of a different type having a long top laid side to side, but given care developing and using it, its life was reasonable. The base machine would need to be adapted for regular soft ground working. Length measurement was basic but within the product tolerances.

The Lako 60 performed well with a good output and satisfactory delimbing and accuracy. An excellent brash mat was produced and working techniques could be varied to produce the width or depth required. One problem is the depth of the chain saw housing which results in high stumps being left. Product presentation was good.

Insufficient data was collected to provide accurate outputs for the Osa 746 but they were low and delimbing standard frequently poor as the head struggled to delimb the coarser trees. Although only a limited trial, this head clearly was in difficulty with these crops. With less demanding crops this is a good head.

After adjustment for tree size and operator skill comparative performance for harvesting 3m chipboard is shown in Table 1.

As the 822 GP is a processor, the felling operation, including brashing and stump treatment, also has to be paid for. Output from the sawyers was approximately 4m^3, indicating two would be required to keep the 822 GP operating. However, another later trial in a more difficult crop saw the sawyers' output fall to less than half this.

Table 1. Harvester/Processor outputs in lodgepole pine (LP).

Tree size	*Harvesting system*			
	Tapio 400	*822 GP*	*Lako 60*	*Osa 746*
$0.1\ m^3$	4.0	8.1	5.9	3.3
$0.2m^3$	5.8	9.8	7.8	–

Note 1. Outputs are measured in cubic metre end product per standard hour (1.4 x basic time to allow for rest and other work).
Note 2. Outputs include the unmarketable and unmeasurable elements in the crop.
Manual harvesting gave output of $0.9m^3$ per standard hour (0 x $1m^3$ tree size).

The LP were classified by quality which proved useful when analysing the effect on output of the various harvesters. When the time element for debranching alone was considered it was seen that working coarse rather than medium/fine trees invoked a time penalty of 4% with the Tapio 400, 25% with the 822 GP and 39% with the Lako 60.

The effect of form is also significant with the Lako. Medium and poorly formed trees show an increase in fell and process time of 20% over those of good form. This appears to be additive to coarseness effects.

Importance of sound brash mat

On soft ground the ability to produce a sound brash mat without reducing output is an essential feature for the harvester/processor. The harvester may survive without a sound brash mat (though very unlikely on peat) but it will be essential for the subsequent extraction operation. For security of operation and to avoid the problems of debogging a mat should be planned for.

Fig 2. Lako 60 grapple harvester in lodgepole pine.

The base machines for our trial were a JCB 812, JCB 814S, 4-wheeled Kockums 822 with frame steering chassis, and a 6-wheeled Osa 250. Track widths on the JCB excavators were both 700mm. All base machines crossed the ground satisfactorily given a sound brash mat. This was particularly essential for the 822 which would punch through into the peat given any weakness. With the excavators the brash needed to be built up to ensure that the base did not snag on any stumps, but if there was too much then it would be pushed forward in front of the machine.

Cost comparisons

Costs for the trial operation (see Table 2) are tentative because of its limited nature but provide an interesting comparison. The tree size is $0.1m^3$ and product is 3m chipwood. As the 822 GP is no longer available the Skogseric 380 with reconditioned base has been estimated for as an alternative capital cost. The costs are per m^3 end-product.

Table 2. Harvesting costs in LP

Harvesting system	*Cost/m^3–£*
Tapio 400/JCB 812	8.50
Skogseric 380/Recond Base	7.60*
Lako 60/JCB 814S	8.00
Motor manual	9.80

*Includes £2.50/m^3 for manual felling but later trials in more difficult LP gave a cost of £6.0/m^3 which indicates the variation found in LP.

If conducting early *thinning* on soft ground, as well as manoeuvrability and output, the main machine requirement will be avoiding root damage to ensure a sound crop develops for the future. This will apply particularly with extraction. Tracked vehicles are acceptable given a skilled operator and sufficient brash but wheeled vehicles even with chains and band tracks have more flexibility in operation and are less likely to injure root systems.

Conversion and extraction

Production of shortwood after whole pole or long length extraction involves conversion at roadside following extraction. With soft ground, skidding is not usually a practical option because of the damage it would cause to the site and because bogging would soon occur without balloon tyres or large tracks.

A cable crane may be used where a particularly difficult piece of land is to be crossed. This may mean the brash is not required in which case brash disposal may be a problem. However we have worked a roadside processor on a heap which ended up 2 m high and the machine remained safe and stable. Nevertheless it is a practice to be avoided if possible.

Cable cranes suffer from small loads, a limited field of operation plus high takedown/set up times when moving the equipment. Developments in Norway with Owren Variokran winch and similar are producing safer and faster running winches plus much faster movement times. Electro hydraulic controls are simple to operate and enable the operator to stand away from the winch line.

However a shortwood working system with forwarder extraction in some form will be common practice on most sites. It is a flexible system to manage and avoids bringing much unutilisable timber off the site. Most contractors are equipped in some form and could adapt their equipment for soft ground working.

Extraction systems compared

Finnish and Swedish research work has demonstrated that for soft ground 8-wheeled forwarders are generally better than 6-wheeled, but there were great differences between vehicles in the same class. Finnish trials showed that while a 2-wheeled driven farm tractor has poor performance on soft ground, a 4-wheeled drive tractor with powered trailer can do well. This may be of interest to small contractors or estate owners but we did not have resources to include this option in our trial. For extraction we considered what machines would be available in Britain and also those with minimum gross weights, while able to extract an economic load.

Our first trial included the Farmi Trac 5000, Bruunett 678F and Valmet 828 with rubber tracks. These machines have 3.5, 7.5 and 8.0 tonnes quoted capacities respectively. The Bruunett 678 was equipped with standard flotation tracks (weighing a total 1 440 kg) on both front and rear bogies. Details are presented in Table 3.

All forwarders were weighed to determine their static ground pressures (SGP) and also the load when ground pressures on front and rear bogies are equal. This assures uniform pressure and optimum ability to cross soft ground. If the loader on the machine can be positioned at both front and rear, then there will be 2 loads' capacities when the machine is in balance. The Farmi Trac is actually in balance when unloaded and was tested with a full load (3.6 T).

The actual ground pressures will of course vary with slope and movement but we had no means of measuring dynamic values.

Tests for rutting and for durability of brash mat

The Farmi Trac and Bruunett forwarders were subject to two types of test; rutting of peat soils and durability of brash mat on peat. The Valmet 828 was tested at a later date but on a similar site.

The rutting test included ground with both heather and rush *(Juncus)* vegetation, the Juncus area having soft clay present as well. It was not intended to bog the machines, rather investigate the resilience of the surface vegetation horizon and the speed of development of the ruts.

A uniform brash mat produced by motor manual harvesting across ploughed ground was used. Approximately straight 30m

Table 3. Forwarder balanced loads and minimum ground pressures.

Forwarder	*Loader position*	*Load capacity (T)*	*Weight empty front (kg)*	*rear (kg)*	*total (kg)*	*Balanced load (T)*	*SGP (kg/m²)*[1]
Farmi Trac 5000	rear	3.5	5260	3260	8520	(2.0/3.6)[1]	(0.30/39)
Bruunett 678F	front	7.5	9170	2370	11540[2]	6.8	0.39
Bruunett 678F	rear	7.5	7620	3920	11540	3.7	0.33
Valmet 828 (tracked)	front	8.0	8200	3020	11220	4.8	0.35
Valmet 828 (tracked)	rear[3]	8.0	6880	4340	11220	2.6	0.30

Notes: 1. Front/rear respectively – for comparison with other machines as in fact balanced at nil load.
2. Including tracks at 1440 kg. 3. Clamped to the load for travelling.

lengths were selected across plough, and the machine driven repeatedly backwards and forwards loaded until the mat broke down such that the machine would shortly become bogged. The furrows were 70cm deep before brash accumulated and 2.6m apart. Generally the forwarders could select routes, which avoided most stumps while remaining on the mat.

The point of mat breakdown was clear such that if it had been normal operational conditions the operator should have had time to patch the weakness with more brash and continue without becoming bogged. This was confirmed with later trials but was also probably a function of being tracked vehicles, a normal wheeled forwarder without tracks would punch through a weakness in the brash mat and become bogged very quickly.

These tests were repeated with mats produced by the Lako harvester on plough with 55cm deep furrows, 2.0m apart.

Forwarder performance

For comparison of the extraction systems, the output figures have been converted to a uniform extraction distance with 3m chipwood as the product. See Table 4.

Table 4. Forwarder outputs (200m wood/ 50m road travel)

System	*Output*[1]
Farmi Trac	5.7
Bruunett	8.2
Valmet	7.9[2]

Notes 1. Output measured in m³ per standard hour, full loads.
2. Operator still becoming accustomed to forwarder, add 10-15% for skilled operator.

If the in-wood travel distance is increased to 400m outputs fall by 28%, 27% and 26% for Farmi Trac, Bruunett and Valmet respectively.

For the Bruunett, the trial indicated that with the lighter balanced load the brash mats lasted longer such that total volume extracted was greater. In two tests 155T and 133T compared to 106T were extracted. Individual crop and site characteristics will influence this figure greatly. The Farmi Trac did not do very well across the plough in comparison with the Bruunett, only producing 69T from the brash mat. We felt this to be due to the effect of crossing furrows which caused the trailer to fall heavily into the furrow bottoms. On the second trial where the furrows were less severe this problem did not occur and the Farmi produced significantly more per brash mat than the Bruunett (65T compared to 23T). Interestingly, in a subsequent trial on deep peat, the Valmet did not follow the same pattern as the Bruunett. It extracted 178T with the 4.8T load compared to 96T with the 2.6T load.

The main stump free extraction route from the trial site was produced by brash from the Lako harvester and carried a total of 106T before patching was required. Usage stopped after a further 189T, but the track was still able to support extraction. Given regular patching as weaknesses develop, but before complete mat breakdown, it certainly seems possible to continue extracting over these soft peats.

Unfortunately overnight rain interfered with the rutting trials. The Farmi Trac on a wet day with 3.6T performed very similarly to the Bruunett with 3.7T on a moist day. Making allowance for overnight rain the evidence suggests that if you have a very wet, soft site to harvest, the Farmi should perform better. Nevertheless the Bruunett with tracks performs surprisingly well and further trials are underway at present.

Most of the rutting with the Farmi Trac came from the rear section, as one would expect with unloaded SGPs being the same between front and rear sections. The implication is that Farmi flotation should improve if the rear SGP is reduced, or a better balance arranged when loaded. Also the machine often rocked when travel-ling which aggravated the rutting, while the Bruunett was very stable.

Observations with the rubber tracked Valmet 828 indicate a very stable machine, well balanced while moving but lacking the traction the other two machines possess.

Subsequent trials of the tracked 828 on flatter sites with less variability of slope and roughness have clearly demonstrated its ability to extract over flat soft ground, the brash mat taking almost 200T before beginning to break down. When it did, again it took several passes so the operator has plenty of warning to patch the weak area.

Fig 3. Band tracks are usually essential for soft ground working.

During these later trials the Bruunett was again equipped with flotation tracks front and rear and, although the data is not fully worked up, indications are that the Bruunett was superior to the tracked 828 in terms of total quantity of timber extracted before brash mat break down, 275T compared to 200T. It would be interesting to compare the Bruunett with the wheeled 828 equipped with flotation tracks as this combination would have both flotation and traction.

Overall cost comparisons

The harvester and forwarder costs for 3m chipwood from 0.1m³ tree size can be combined to give an overall harvesting cost to roadside. Details are given in Table 5. The Skogseric is used as a substitute for the 822 GP. All costs are per m³ end-product.

Total costs to roadside range from the cheapest Skogseric (822 GP)/Bruunett combination to the most expensive manual/ Lokomo.

It is difficult in the relatively restricted nature of trials to produce accurate costings

Table 4. Harvesting and extraction costs summary.

	Farmi Trac 5000	*Bruunett 678F*	*Valmet 828 (tracked)*	*Lokomo 910*[1]
Tapio 400/JCB 812	15.15	13.73	14.38	16.41[1]
Skogseric 380/Recond base[2]	14.25	12.83	13.48	15.51[1]
Lako 60/JCB 814S	14.68	13.26	13.91	15.94[1]
Motor manual	16.45	15.03	15.68	17.71[1]

Notes: 1. Only a brief exercise and not recommended for soft sites.
2. Includes motor manual felling at 2.50/m³.

but it is clear that the Bruunett and Valmet forwarders, in combination with Skogseric processor and Lako 60 harvester are producing the cheapest costs. However as has been mentioned already, the manual felling element for the processor can increase significantly and the brash mat it produces needs care by the operator at expense of output. In this respect the Lako 60 produces a solid brash mat in the normal course of operation while presenting the produce neatly for extraction. The Skogseric has a larger capacity than the 822 so outputs may be slightly different (cheaper).

Access

Access across soft ground, as with any harvesting can be assessed in three phases.

a. Full 38 tonne road access for timber transport.
b. Regular forwarder, or even light vehicle access routes.
c. In-wood access for extraction of the harvested timber.

Access can be provided from a combination of factors, either providing the bearing capacity (flotation) by the road itself or by reducing the pressure from the vehicle. I will restrict myself briefly to the forest side. Work Study Southern Team Report 175 deals with 'Road-side Facilities for Harvesting' generally, including soft ground.

As can be deduced from our trials so far, machine access across peat with a well maintained brash mat is remarkably good. It is essential that the vegetation layer is maintained intact, particularly retaining any stumps (ie root systems) within the ground.

Access to both landings for timber and the forest road can be difficult if the road construction has left damaged soft ground on either side of it. Forester and road engineer must discuss each other's requirements at the time of road construction.

With soft ground roads it is important to anticipate the problem and prepare for it, not solve the problem once it occurs.

To cross ditches and streams we have successfully used land drainage pipes protected with tops and brash. One must consider the requirements of likely flood water as well as the normal flow or the resultant wash out could prove a problem to cross again. The main problem with pipes is blockage and ensuring sufficient protection to avoid bending or being pushed into the bed of the ditch below water level. Alternatively pipe fascines are commercially provided in various sizes to fill various sized ditch/stream crossings. These are groups of substantial plastic pipes connected so the whole bunch can be lifted together by a forwarder. They can be re-used many times and need little or no protection by brash.

Portable bridges have been used with success. The Forest Engineering Institute of Canada (FERIC) is conducting research into portable bridges of varying lengths and strengths. Although the pipe fascines type of approach will solve many of the ditch crossing problems of peatland sites, portable bridges are straightforward to use and allow the crossing of more substantial streams.

Machine ground pressure reduction

For the forwarder itself the ground pressure can be reduced by various means but a degree of aggression will always be needed to grip and pull the loaded machine across damp vegetation. On relatively small side slopes (10-15%) machines with smooth tracks may slide sideways when moving forward.

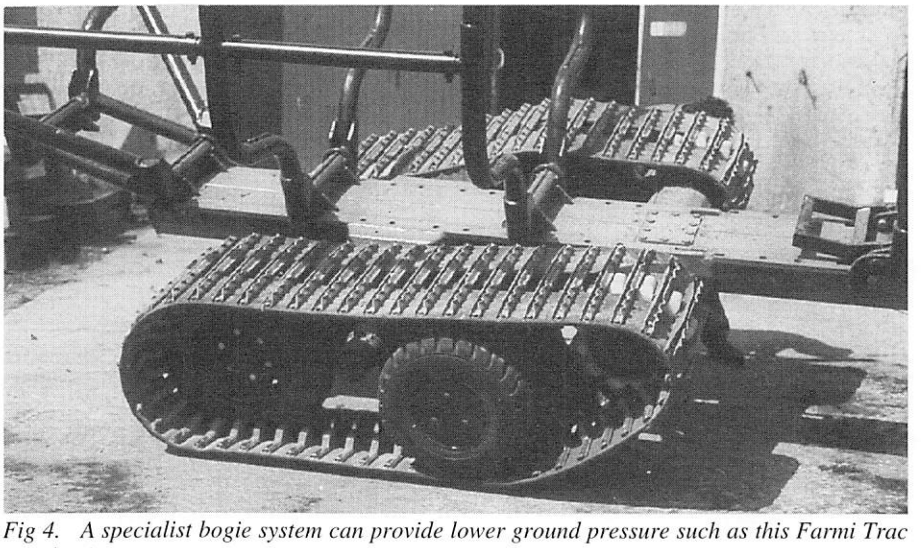

Fig 4. A specialist bogie system can provide lower ground pressure such as this Farmi Trac rear bogie.

Terra-tires, produced by Goodyear, have an extremely wide cross section and large air volume at low pressure. The ground contact area is claimed to be 2½ times the equivalent conventional tyre. The result is much greater flotation characteristics and less site damage. They are expensive but may outlast the machine. As an option to enable a 4 or 6-wheeled machine to operate on soft ground they should be considered, but check with the machine manufacturer that the axles and bearings can tolerate the additional loading these tyres provide.

Gislaved Moccasin tracks are made from a special urethane rubber and are claimed to shape themselves to the contour of the ground. They are attached around the pair of wheels of the forwarder in the usual manner and with each section of track having a large surface area they have good flotation characteristics.

The machine manufacturers and specialist companies such as William Clark of Parkgate produce a range of bandtracks to fit on forwarder wheels, including models for soft ground working. Clark have recently produced a mid link flotation version which fits snugly round the tyre shoulder rather than projecting outwards for the attachment of the connecting links. This reduces the additional stress tracks can cause for the axles and removes any clearance problems.

In summary

- A thoroughly sound brash mat is essential for both harvesting and extraction and the grapple harvesting head can produce one in the course of its normal operation with no loss in output.
- Forwarding is the most practical option, possibly with the use of cable cranes for sensitive or particularly difficult sites. Current trials indicate that the Farmi Trac 5000 remains the option for the softest wettest conditions, especially if brash is on short supply, but machines such as the tracked Valmet 828 and Bruunett 678F with full bandtracks are suitable for most conditions using brash mats.
- Access, particularly continued access, demands careful planning and vigilance, but it is possible. Modern geotextile can aid this but old-fashioned brash remains the key factor.

Acknowledgements

The bulk of our soft ground work has been carried out by our Northern Team under Michael Wall. To them must go the credit for this investigative and development work and much of this paper is extracted from their reports. Various FC Civil Engineers have done their best to pass on their hard won experience to me.

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