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Forestry harvesting

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Front cover: A whole tree chipper operating in Corsican pine at Rendlesham Forest (*photo:* Department of Forestry, University of Aberdeen.)
See also page 106.

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An economic analysis of slurry treatment and spreading systems for odour control

N L Warner, R J Godwin, M J Hann

The control of offensive odours arising from the landspreading of livestock slurries is becoming an increasingly important consideration for many farmers.

In this report the authors compare the costs of various treatment and spreading systems. For full odour control the cheapest option is shown to be soil injection of untreated slurry.

This paper considers the economics of various slurry treatment and spreading systems for odour control, using a computer spreadsheet package established to assess the most cost-effective slurry management system.

It should be noted that this analysis shows comparative costs between the alternative techniques and whilst absolute costs may vary in time, it is likely that the comparative differences between treatments will remain similar.

The following treatment and spreading options are considered:

i) Conventional surface application of untreated slurry.
ii) Conventional surface application of aerated slurry.
iii) Conventional surface application of anaerobically digested slurry.
iv) Injection of untreated slurry using both tanker mounted and umbilical hose equipment.
v) Low-level surface application of untreated slurry using both tanker mounted and umbilical hose equipment.

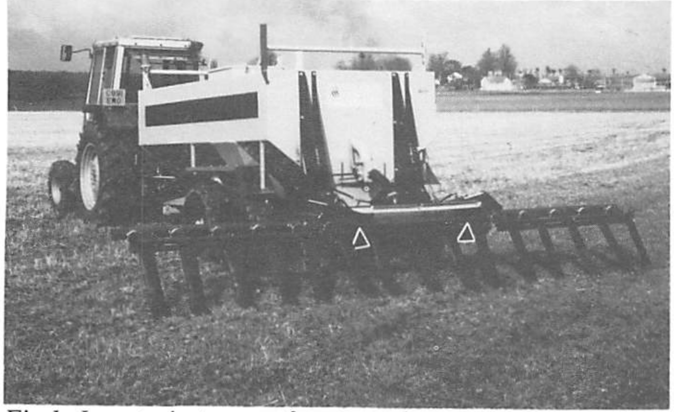

Fig 1. Low trajectory surface spreader.

Earlier work reported by various authors has shown that the pre-treatment of the slurry by aeration (Evans and Thacker, 1985; Williams *et al,* 1986), or by anaerobic digestion (Demuynck *et al,* 1985; Phillips, 1985), can reduce the offensiveness of the slurry prior to conventional surface spreading. Alternatively, the untreated slurry can be injected directly in to the soil (Warner and Godwin, 1988), thus significantly reducing the odours produced (Phillips *et al,* 1988).

As a further alternative, the slurry can be surface applied by a low-level applicator, such as that identified by Stroud and Phillips (1987) (Fig 1). Such equipment can prove valuable in situations where complete odour control is not required, but where a reduction in the aerial spraying of slurry is necessary.

Cattle and pig enterprises both considered

The analysis considers both pig and cattle enterprises producing varying quantities and consistencies of slurry. Details of individual farm practices, such as slurry application rates and storage periods are required, as are the levels of inflation and interest rates on borrowed capital. Machine work rates are also required which can be calculated using the following formula (Hunt, 1979):

$$C = (SWLE)/(K_1L + DSWLE + K_2ST) \quad (1)$$

Where:
- C = Effective machine capacity (ha/hr)
- S = Spreading speed (km/hr)
- W = Rated width of machine (m)
- E = Effective width of machine (decimal of W)
- L = Length of field passes (m)
- T = Turning time at headlands (sec/turn)
- D = Unproductive time (hr/ha)
- K_1 = Constant = 10: K_2 = Constant = 2.7778

The unproductive time (D) includes transportation and filling times of tankers, and the setting up and dismantling of umbilical pipelines.

Table 1. Comparison of typical spreading rates for machines applying 50m³/ha of slurry (After Godwin *et al,* 1990).

Machine	*(ha/hr)*
Conventional splashplate tanker	0.31
Tanker mounted injector	0.28
Umbilical hose injector	0.75
Tanker mounted low-level applicator	0.30
Umbilical hose low-level applicator	0.80

Nigel Warner (left), formerly at the Department of Engineering for Agriculture, Silsoe College, is now at the Department of Farm Mechanisation, Royal Agricultural College, Cirencester, Gloucestershire. Professor Dick Godwin (centre) and Mike Hann (right), are at the Department of Engineering for Agriculture, Silsoe College, Cranfield Institute of Technology, Silsoe, Bedford (refereed paper).

Typical figures of machine capacity for all slurry application systems considered are shown in Table 1, the data being obtained from detailed time and motion studies of machines in operation (Godwin *et al,* 1990).

Major assumptions used in the analysis

– Slurry storage

The slurry will be stored in an above ground glass-lined steel tank for a period of 140 days for all tanker supplied distribution systems, in accordance with current ADAS recommendations.

However, Godwin *et al,* (1990) has shown that the required storage period for umbilical injection systems (Fig 2), could be significantly reduced, as a result of the increased trafficability of such light-weight systems. As a consequence, storage capacity amounting to 90 days production of slurry has been assumed for such systems. Such plans assume the operation does not cause water pollution throughout the winter and gives provision for storage when soils are saturated or frozen.

Cost of storage tanks is given by the formula (SAC, 1988):

$$\text{Cost (£)} = 174\ V^{0.667} \qquad (2)$$

Where V is the slurry tank capacity, (m^3)

– Aeration

It was assumed that the slurry was stored in the usual way, and then separated using a belt press separator before passing to a separate aeration tank. The separator produces a solid material of 20% dry matter and a thin liquid which can be aerated efficiently in a continuous-flow reactor with a residence time of one day (Williams *et al,* 1986) immediately prior to land spreading.

The specific power requirement of the aerator has been estimated at 25w/m^3 for piggery slurry, to ensure adequate mixing of the material in the aeration tank, (Cumby, 1987). For the aeration of cattle slurry, a 20% increase in aerator power has been assumed in order to maintain mixing efficiency in a material containing higher levels of solids and fibre. Consequently, a specific power requirement of 30w/m^3 has been used for the analysis. The cost of aerators has been estimated using the following formula:

$$\text{Cost (£)} = 2500 + 550 \times \text{power (kw)} \qquad (3)$$

– Anaerobic digestion

The anaerobic digestion systems considered are based on preformed glass reinforced plastic vessels ranging in size from 70m^3 to 400m^3 capacity. The required size is estimated using data supplied by Farm Gas Ltd (1989) from which it was assumed that each cubic metre of digester capacity could successfully treat 5.5kg of solids per day. This may often lead to residence times of only 10-12 days, but ensures that benefits in terms of BOD reduction and gas production are optimised.

A proportion of the gas produced each day is used for heating the digester, and also for gas recirculation mixing, leaving a volume equivalent to the digester vessel capacity available for external use. The biogas was assumed to have a calorific value equivalent to 5.6 kWh/m^3 or 20 MJ/m^3 (Meynel, 1982).

Using the data supplied by Farm Gas Ltd, the cost of the digester vessel, including gas recirculation and heating equipment and the necessary control equipment can be estimated by the equation:

$$\text{Cost (£)} = 3527\ V^{0.507} \qquad (4)$$

Where V is the volume of the digester vessel, (m^3).

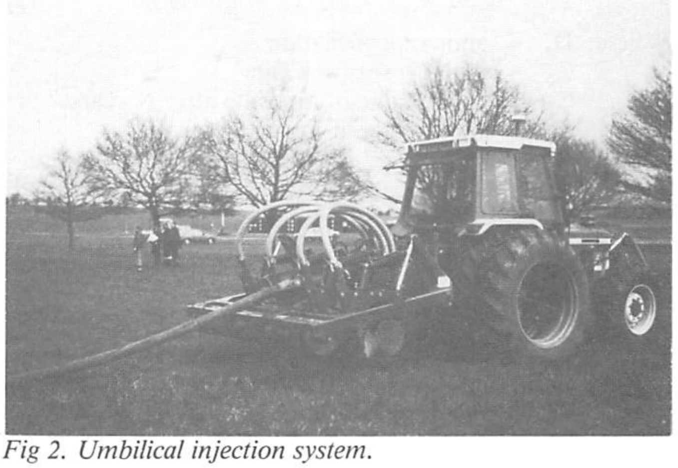

Fig 2. Umbilical injection system.

– Slurry spreading

It was assumed that:

i) Slurry will be applied at a maximum application rate of 50m^3/ha, in accordance with MAFF guidelines, to fields which surround the slurry store, thus keeping transport distances to a minimum.

ii) Surface spreading will be conducted with a 60 kW (80hp) two wheel drive tractor and a 7m^3 (1500 gal) slurry tanker. The same machinery will be used for the low-level application, with the addition of a multi-tube applicator (Stroud and Phillips, 1987).

iii) Injection will be conducted with similar tankers (as above), with a four-tine winged injector unit mounted on the back and powered by a 90 kW (120hp) four-wheel drive tractor.

iv) Both umbilical systems will involve the use of a 37.5 kW (50hp) two-wheel drive tractor for operating the pump and laying out the pipelines. The injector will be pulled by a 75 kW (100hp) four-wheel drive tractor and the low-level applicator by a 60 kW (80hp) two-wheel drive machine.

v) The tractor sizes detailed above have been selected following several years of operating slurry spreading equipment (Godwin *et al,* 1990). The given power requirements will ensure efficient machine operation under a wide range of soil conditions.

vi) All tractors up to 75 kW will operate for 1000 hours on all farm duties, with those in excess of 75 kW operating for a total of 750 hours per annum.

vii) The umbilical pipelines used consist of rigid galvanised irrigation pipes for all but the last 400m of their length. The pipeline will be completed with 400m of flexible lay-flat irrigation hose to the applicator.

viii) The spreading of solids produced by the separator will be conducted using a conventional 5m^3 capacity muck spreader operated by a 60 kW (80hp) tractor, applying a maximum application rate of 10 tonnes/ha.

ix) Loading of solids in to the spreader will be conducted using a tractor fitted with a fore-end loader. The loader will be fitted to either the same spreading tractor or to a second tractor which already exists on the farm. Consequently, the only costs included are those associated with the purchase of the loader and the additional operating costs of the loading tractor.

– Finance

It was assumed that:

i) The annual depreciation of machinery is a straight line, given by the formula (Boyce *et al,* 1976):

$$D_a = (C_O - C_N)(1 + g)^N/N \qquad (5)$$

Where: D_a = annual depreciation
C_o = initial cost of machine
C_N = resale value of machine after N years
and g = annual rate of inflation

ii) All equipment was purchased using borrowed capital, thus incurring interest on the amount outstanding. If the borrowed capital, plus interest, was repaid over the life of the machine in equal instalments, then Boyce *et al*, (1976) estimate the annual repayments to be given by:

$$I(£) = C_o i(1 + i)^N/((1 + i)^N - 1) \qquad (6)$$

Where: I = annual repayment on borrowed capital
C_o = initial cost of machine
i = interest rate on borrowed capital
and N = life of machine

The major analysis was conducted without considering the effects of grants available under the current Farm and Conservation Grant Scheme. However, the effect of the grant on the final cost figures, is shown in Table 3 for the 'standard' farm situation.

The values of repair and maintenance, labour and fuel costs are estimated from appropriate sources of farm management data (Nix, 1988; S A C, 1988).

Tractor tax was assumed to be £16.00 per vehicle per year, and insurance costs are estimated at 1.0% of insured value (Witney, 1988).

– Biogas utilisation

The biogas produced from the anaerobic digestion process was assumed to be used in one of three ways:

i) Direct substitution for natural gas in domestic heating systems where it is costed as a direct replacement at equivalent calorific values,

ii) Use in separate gas boiler for the production of hot water and heat for animal housing, where it is costed at 2p/kWh, assuming a boiler efficiency of 80%,

iii) Use in a combined heat and power unit, converting 30% of the input energy to electricity at 4.92p/kWh and 60% to hot water at 2p/kWh.

The value of biogas was determined for each of the above, and the most cost effective method used to offset the operating costs of the anaerobic digestion.

Costs of the alternative systems

An example of the output from the economic analysis for a given 'standard' livestock enterprise (Table 2) is summarised in Table 3. The enterprise considered is a mixed farm producing $10m^3$ pig slurry and $6m^3$ cattle slurry per day, corresponding to herd sizes of 1500 pigs and 100 dairy cattle.

Table 2. Values of input variables assumed for the 'standard' livestock enterprise considered.

Daily slurry production (m^3)	Pig	10
	Cattle	6
Machine capacity (ha/hr)	Conventional tanker	0.31
	Tanker injector	0.28
	Umbilical injector	0.75
	Tanker low-level applicator	0.30
	Umbilical low-level applicator	0.80
Slurry storage period (days)	Tanker systems	140
	Umbilical systems	90
Annual rate of interest (%)		14
Annual rate of inflation (%)		7

Table 3. Operating costs of alternative disposal options, both with and without grant aid.

System	*Slurry condition*	*Cost (£/m^3) without grant*	*50% grant*
Conventional spread	untreated	3.83	2.86
Conventional spread	aerated	6.36	4.97
Conventional spread	digested	8.26[2]	6.06[2]
Tanker injected	untreated	5.19	4.22
Umbilical injected	untreated	4.64	3.90
Tanker low-level spread	untreated	4.01	3.04
Umbilical low-level spread	untreated	4.25	3.51

1. Grant per Farm and Conservation Grant Scheme (FCGS).
2. With efficient Biogas utilisation, costs for conventional spread digested slurry become respectively £6.93/m^3 (without grant) and £4.73/m^3 (with 50% grant).

The following sections of this paper consider the effects of changes in input variables on the final cost of the slurry management systems. In all cases the individual variables are adjusted from the standard figures shown in Table 2. All variables not considered in each individual situation revert back to those shown in Table 2.

Influence of daily slurry production rate

Figs 3 and 4 shows the effect of varying daily productions of pig slurry on the total operating costs of the different slurry management systems. The maximum daily output considered is $40m^3$ which corresponds to a pig herd of 5500.

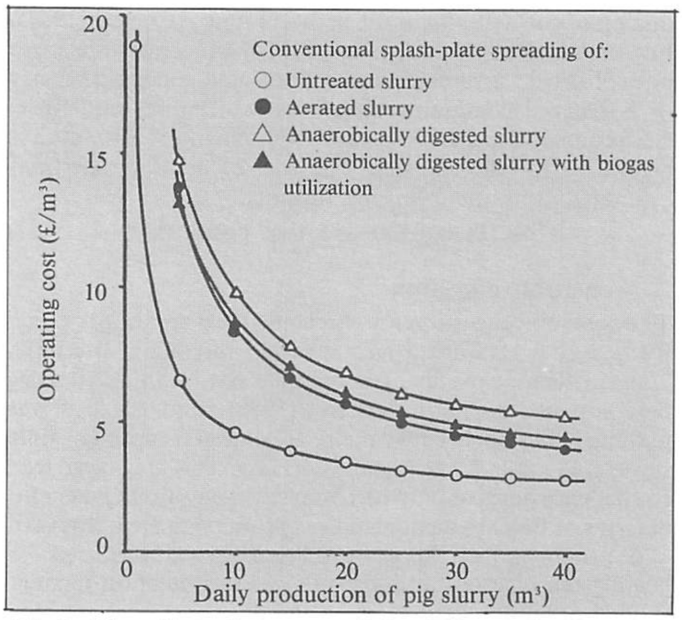

Fig 3. The effect of the rate of the daily production of pig slurry on the operating costs of conventional splash plate spreading following alternative pre-treatment systems.

The treatment of the slurry prior to conventional surface spreading, (Fig 3) shows very little difference in costs between aeration and anaerobic digestion where efficient use has been made of the biogas produced. Anaerobic digestion systems where the biogas is not fully utilized generally result in increased costs of approximately £1/m^3 of slurry produced.

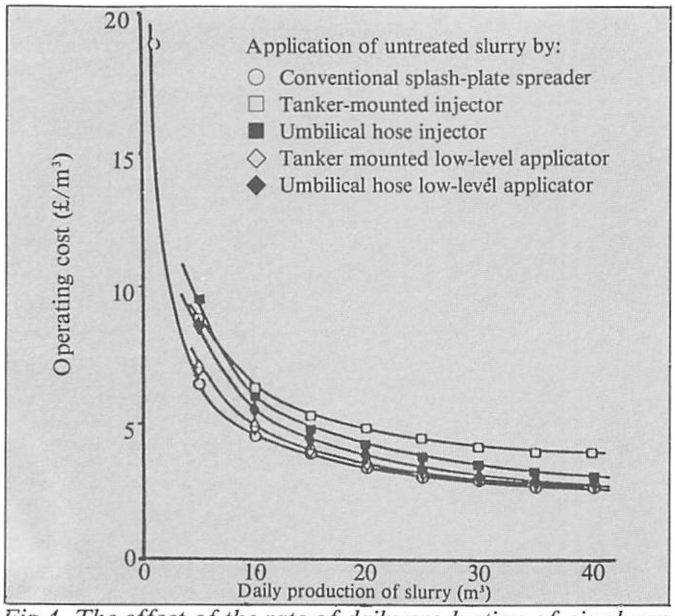

Fig 4. The effect of the rate of daily production of pig slurry on the operating costs of various slurry application systems compared to the conventional spreading of untreated slurry.

The use of low-level surface spreading and injection practices (Fig 4) shows the cost of both low-level application systems and umbilical injection to be similar for large livestock enterprises, and are similar to the costs of conventional surface application when slurry production approaches 40m³ per day. The injection of slurries using tanker mounted equipment, however, remains £1-£2 more expensive than conventional spreading as a result of the need for larger tractors, although the system proves cheaper than umbilical injection when slurry output is less than 10m³ per day due to the higher capital value of umbilical equipment.

Comparing pre-treatment costs, Fig 3, with those of injection and low-level surface application, Fig 4, shows that both treatment systems are generally £2-£3/m³ more expensive for enterprises producing between 10 and 30m³ slurry per day. Outputs of less than 10m³ per day results in pre-treatment costs increasing to over £4/m³ more expensive than injection or low-level surface spreading. For very large enterprises, however, there is little difference between the costs of aeration, anaerobic digestion and tanker injection of slurry, but umbilical injection and both low-level systems remain approximately £1/m³ less expensive.

Comparison of pig and cattle slurry

The type of slurry has no effect on field applications, since it is the volume of whole slurry rather than the type or thickness which affects these systems. However, aeration and anaerobic digestion systems are affected by the differences in dry matter and fibre contents of the slurries.

Fig 5 shows the effects of varying outputs of both pig and cattle slurry on the total cost of spreading aerated and anaerobically digested slurry. The maximum slurry production considered being 40m³/day for pigs, as in Fig 3, and 20m³/day for cattle, corresponding to a herd size of 350 dairy cows.

The figure shows treatment costs for cattle slurry to be generally £1/m³ higher than for pig slurry reflecting the need for larger aerators, longer separation periods and larger capacity digesters to treat the higher solids content of the slurry.

The efficient use of biogas is even more important when digesting cattle slurry, as shown in Fig 5(B) where costs are generally £2/m³ lower when gas is used to produce heat and hot water for heating and parlour washing. The highest gas production is as a result of the higher solids and fibre content of the cattle slurry.

Loan interest rates

All slurry management systems show a linear relationship between interest rates and unit cost, with increases of between 35 and 40% as interest rates rise from 5% to 20%. The higher increases applying to those systems involving high capital investment.

Influence of machine capacity

The work of Godwin *et al,* (1990) showed the major influences on work rates of slurry application machinery to be the distance from field to slurry store, field size and capacity of slurry tankers. They showed work rates typically varied from a minimum of approximately 0.1 ha/hr to a maximum of 0.8 ha/hr for the majority of machine systems and conditions.

The effects of such variations in machine capacity is shown in Fig 6 for all slurry management systems.

The results show significant reductions in operating costs as machine capacity increases, up to a rate of 0.4 ha/hr. Above this rate, whilst the cost of most options continue to fall at a reduced rate, the cost of aeration begins to increase.

The increased cost of aeration is due entirely to the significantly increased power and electricity consumption required to aerate the much larger volume of material prior to the daily spreading operation. In such situations, it may be more feasible to aerate a smaller volume for a longer period prior to spreading, thus reducing the size of aerator and

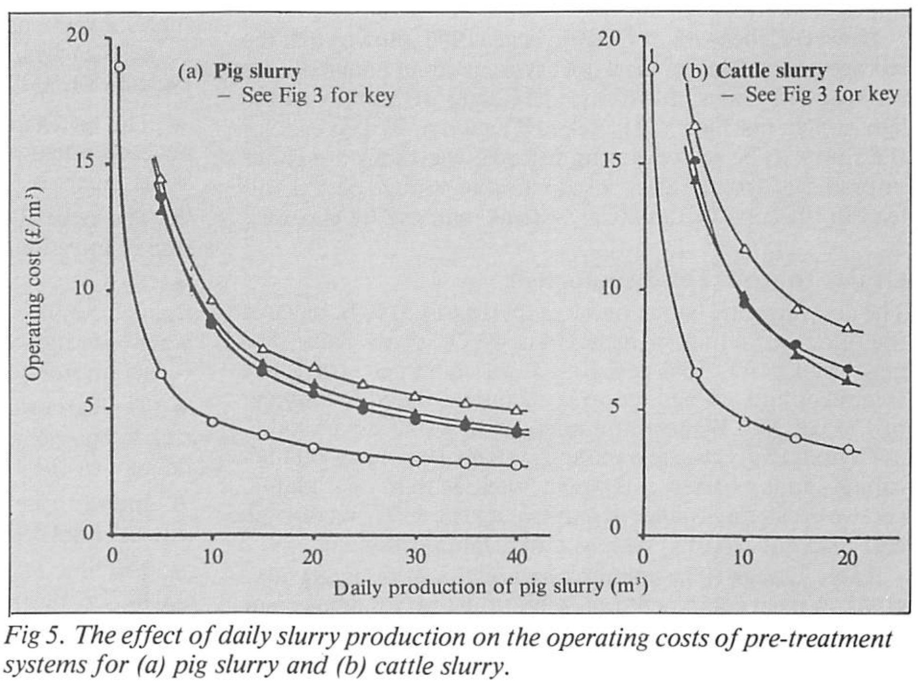

Fig 5. The effect of daily slurry production on the operating costs of pre-treatment systems for (a) pig slurry and (b) cattle slurry.

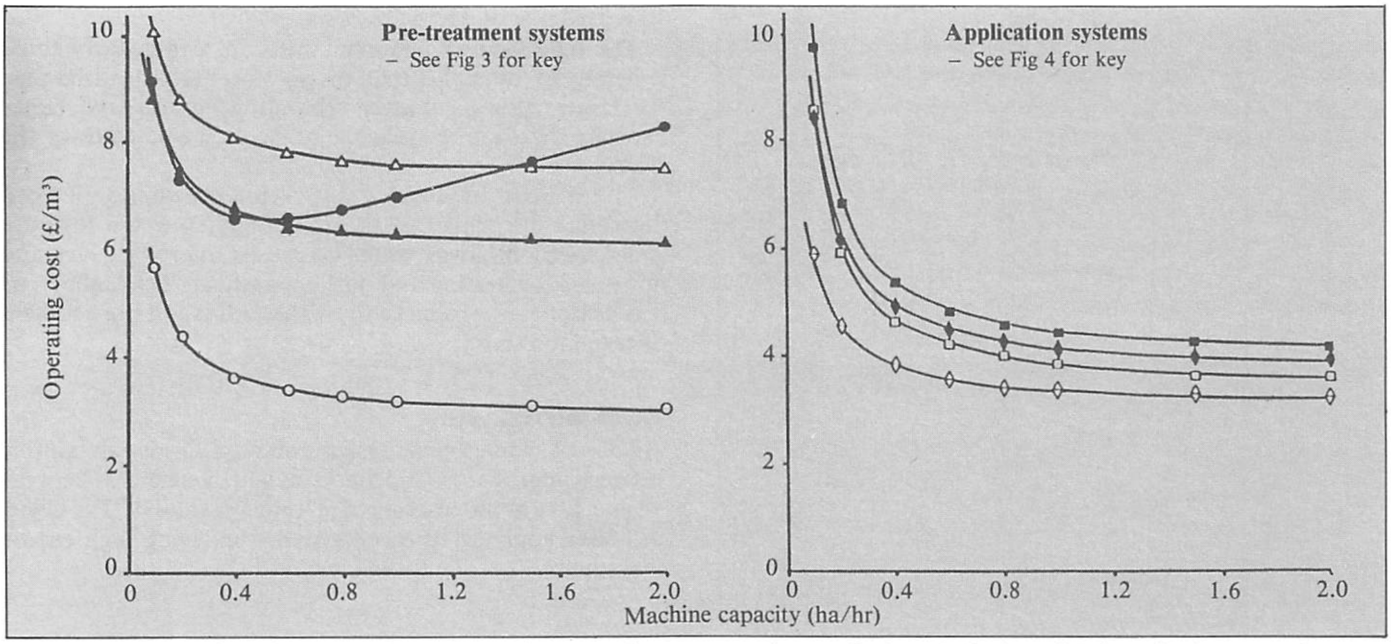

Fig 6. The effect of machine capacity on operating costs for an enterprise producing 10m³ pig and 6m³ cattle slurry per day.

aeration tank required. It is unlikely, however, that in practice machine capacity for tankers would greatly exceed 0.4-0.5 ha/hr so the problem is unlikely to occur.

The unit costs of the two umbilical systems may appear to be higher than the equivalent tanker-mounted systems, but it must be remembered that, due to the much lower unproductive time involved with such systems, the machine capacity for umbilicals will generally exceed twice that of tankers for any given situation, hence leading to the reduced unit costs observed previously.

Storage requirements – less with umbilical hose injection

The current ADAS recommendations are for storage of approximately 140 days throughout the winter. If the situation arose whereby storage for a whole year was required, for instance due to land restrictions due to cropping patterns, then all systems would experience an increase in costs of approximately £1.50/m³.

However, the work of Godwin *et al,* (1990) showed that the storage period for umbilical hose systems could potentially be reduced to 90 days, due to the increased trafficability of the light-weight machinery. The selected period of 90 days enables the slurry to be stored during periods when soils are either saturated or frozen. Such a reduction in storage period will lead to the costs of umbilical systems reducing by 60p/m³.

Grants towards fixed equipment

The new farm and conservation grant (MAFF, 1989), replaces the Agricultural Improvement Grant previously available. The new grant offers 50% relief on fixed equipment for waste treatment and storage, up to a maximum initial investment of £74,000 (ie £37,000 grant max), in any six year period.

Consequently, waste handling systems dependent on high capital input of fixed equipment, such as treatment plants, receive greater assistance in grants than those relying on high cost disposal systems, such as umbilical injection.

Table 3, page 102, summarizes the effect of receiving 50% grant on fixed equipment for each of the slurry management systems considered.

The figures show a cost reduction due to the grant of £2/m³ for anaerobic digestion when efficient use is made of the biogas produced, making this option cheaper than aeration, where costs are reduced by £1.67/m³ with grant aid. However, if the biogas is not utilized efficiently, then digestion is still the most expensive option.

The remaining management options receive grant aid amounting to only £0.97/m³ for tanker systems and £0.74/m³ for umbilicals, reflecting the lower proportion of fixed equipment costs. These options, however, still have a lower operating cost than either of the two pre-treatment options.

Conclusions

- The cost of all treatment and disposal options decrease as the volume of slurry produced increases. However, costs are disproportionately high when slurry production is less than 15m³/day.
- Injection of untreated slurry typically costs £1-2/m³ more than conventional surface spreading, but the technique proves to be the cheapest option for full odour control, costing typically £1.50-£2/m³ less than aeration or anaerobic digestion.
- The efficient utilisation of biogas produced by the anaerobic digestion process can reduce the cost of this option by as much as £1.30/m³.
- The cost of umbilical injection proves to be less than tanker injection when slurry production exceeds 10m³/day.
- The costs of low-level spreading are only marginally greater than conventional surface spreading (typically 20 to 50p/m³ when production exceeds 10m³/day), and can achieve a reduction in odour produced, but not complete control.
- Typical costs of pre-treatment are £1/m³ higher for cattle slurry than pig slurry due to the higher dry matter and fibre content of the cattle slurry.
- Interest rate has a linear influence on costs. Increasing interest rates from 5% to 20% increases costs by 35-40%.
- Machine capacity has a large effect on unit cost up to 0.4 ha/hr. Beyond this, except for aeration system, unit cost is at a minimum irrespective of machine capacity.
- The cost of aeration increases with increasing machine

capacity above 0.4 ha/hr, as it is influenced by the power requirements for aerating larger volumes of slurry per day.

- Reducing the storage period reduces the cost of all disposal systems. A reduction in storage period from the ADAS requirement of 140 days to 90 days for umbilical systems can reduce costs by 60p/m^3.
- The farm and conservation grant scheme reduces the cost of systems requiring much fixed equipment but does not reduce the unit cost to less than those of injection.
- The effect of changes in any given livestock enterprise can be assessed by the use of a spreadsheet developed for the purpose, enabling the identification of specific components of the slurry management system which offer the greatest scope for further savings to be identified.

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Ministry of Agriculture, Fisheries and Food for financial support.

Trevor Cumby, Adrian Williams and Roger Phillips of AFRC Engineering for information on the aeration of slurries.

John Letcher and Charles Howard of Farm Gas Ltd for information on the anaerobic digestion of farm slurries.

Numerous farmers and contractors who allowed time and motion studies to be performed, in particular Chris Holt and staff at Severn Trent Water Authority's Stoke Bardolph estate.

Cedric Nielson and Alan Brewer of ADAS for their valuable help and advice throughout the study.

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Appointment of Secretary to the AFRC

The Agricultural and Food Research Council (AFRC) has appointed Professor Tom Blundell FRS to be Secretary to the Council from 1st January 1991. He succeeds Professor W D P Stewart FRS who has taken up an appointment as the Government Chief Scientific Adviser.

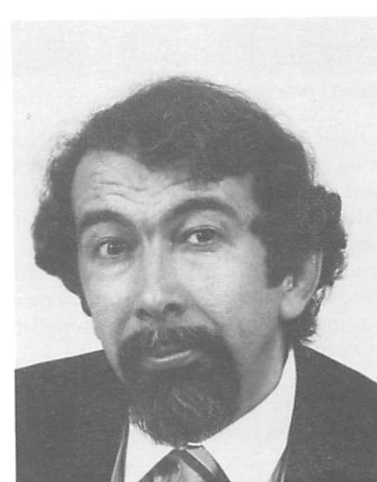
Professor Blundell is a molecular biologist who applies modern biochemical, crystallographic and modelling techniques to determine the 3-D structure of complex molecules such as enzymes, hormones and other proteins. These interests have led him into new areas of innovative research on drug design and protein engineering.

He graduated with First Class Honours in Chemistry at Brasenose College, Oxford University in 1964 and with a D.Phil in 1967. He was elected as a Fellow of the Royal Society in 1984.

In recent years Professor Blundell has been deeply involved with planning and reviewing science at national levels. He has been Chairman of the SERC Biological Sciences Committee (1983-87); member of the SERC Science Board (1983-87); and was appointed a member of SERC Council in 1989. He was involved in the planning of the Human Frontier Science Program.

He also has many connections with AFRC. During five years as a member of AFRC Council (1985-90) he was a member of the Council's Food Research Committee and of the Plants and Soils Research Grants Board. He has chaired a Visiting Group to the AFRC Institute of Plant Science Research and is a visiting research fellow at the AFRC Institute of Food Research.

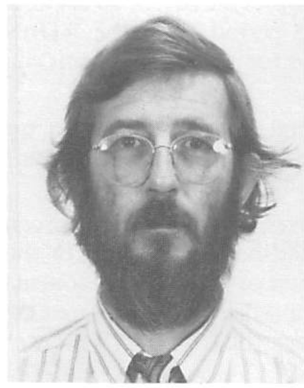
Professor Blundell is currently a member of the Government's Advisory Council on Science and Technology (ACOST).



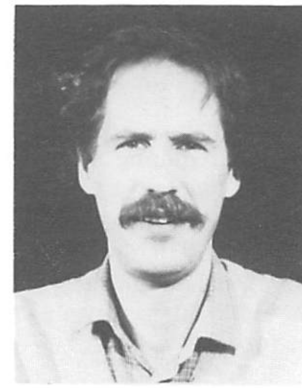
Professor Tom Blundell FRS.

Forestry harvesting systems in Great Britain

The annual volume of timber harvested from Britain's forests is predicted to rise by 50 percent by early in the next century. J B Hudson and C P Mitchell explain how harvesting operations are being increasingly mechanised and they review here the tree-length, shortwood and whole-tree harvesting systems. Particular potential is seen for whole-tree systems incorporating an energy element.



Barrie Hudson



Paul Mitchell

Britain is a relative newcomer to commercial conifer forestry in comparison with the European Community and Scandinavia. Also the present forest area of Britain – expressed as a percentage of total land area – is small at 10% when compared with 24% for the European Community as a whole and 52% for Scandinavia. Annual harvesting volumes are in the region of 6.5 million cubic metres overbark (Mm^3 ob), which is estimated to provide 12% of the total annual consumption of timber and timber products (Forestry Commission, 1989).

Mechanised processing at landing.

The short history of commercial forest harvesting and the relatively small volumes harvested per annum has restricted home based development and manufacture of forest harvesting equipment and with few, but steadily increasing, exceptions equipment is imported. The major influence on choice of harvesting systems and the major supplier of equipment is Scandinavia.

Britain's forest resource

The 2.1 million hectares (M ha) of productive woodlands in mainland Britain cover some 10% of the land area. Of this total some 1.5Mha are commercial conifer crops, producing 5.25 Mm^3 ob. This represents some 80% of the total timber production (including broadleaves) of 6.51 Mm^3 ob.

The conifer forest is located primarily in Scotland which has 62% by area – England having 26%, and Wales 12%. Predominant species in the conifer productive forest are Sitka spruce, 40% by area and Scots pine, 18%.

Of the total of 0.6Mha of productive hardwood woodland, 82% is situated in England, the predominant species being oak with 31% by area.

Woodland area by percentage of land area is illustrated in Fig 1.

Age distribution of the forests in mainland Britain is heavily weighted towards the lower age ranges with 65% of the standing volume being planted over the last 40 years. This concentration of younger age class crops will result in a rapid increase in harvesting over a short time span and production is predicted to increase by 50% to some 9.7 Mm^3 ob by 2004 (Forestry Commission, 1989).

Barrie Hudson is a research fellow and Paul Mitchell a Senior Lecturer, both in the Wood Supply Research Group of the Department of Forestry at Aberdeen University.

Four zones of productive forest

The distribution of the productive forest can be divided into four broad zones.

Upland spruce forest.

Large scale upland spruce plantations in higher rainfall areas of Wales, western Scotland and the border area of northern England and southern Scotland. The soils are characterised by peats, peaty podsols and gleys.

In these plantations the length of the rotation is often governed by the risk of windthrow which may preclude thinning. Any thinning that is attempted is often costly due to the difficulties of access caused by the high density of stems and to the soft soils, which are very susceptible to damage. Crops are often clearfelled prematurely short of optimum rotation length, the large numbers of small stems adversely affecting harvesting costs.

However, this is the most important forest resource, containing large areas of Sitka spruce crops, sought after for excellent pulping qualities and near to the wood using industry. The resource area contains large volumes of potential thinnings arising from intensive planting in the 1960s and 1970s.

Lowland plantations.

Smaller lowland plantations of mixed conifers in central and northern Scotland with a wide range of soil types and terrain.

These plantations tend to be in lower windthrow hazard areas, thinning can take place, subject to terrain, and longer rotation lengths to clearfell are possible. Harvesting is generally easier with better terrain and access and hence lower cost than in the upland spruce areas.

Pine forests.

Large and medium scale pine forests on the dryer sandy mineral soils on the east coast with gentle terrain and generally a low windthrow hazard classification. There are few limitations to harvesting.

Broadleaves.

The broadleaf forests of southern England, characterised by the diversity of species and small, scattered blocks.

The size of the blocks, lack of markets and often small tree sizes tend to act against economic harvesting.

Forestry practice influences harvesting

Silvicultural techniques and forestry practices used in the establishment and management of forestry plantations have an important influence on the means, methods and costs of harvesting.

Forestry plantations are established in Britain with trees planted at 2 metre centres (some 2,500/ha). When competition from the closely grown crop starts to limit growth then the crop is thinned by removing approximately 30% of the standing crop at five year intervals throughout the rotation starting at around age 20.

The stemwood from thinnings is used in the small roundwood processing industries (paper pulp and board products, with larger material going for pallet wood and small sawlogs).

At the end of the rotation, between 40 and 70 years of age depending on species, the crop is clearfelled to produce sawlogs, primarily for the construction industry, the smaller diameter stemwood going to the small roundwood processing industries.

The initial close spacing of the trees restricts access for harvesting. The first thinning is designed to provide access to the crop both for the first and later thinnings. Excessive opening of the forest canopy can allow ingress of wind with the potential of damage to the remaining crop, thinning patterns are thus designed to limit the potential for damage.

Increasingly, access is provided by the provision of strip roads by removing single or double rows of trees every, say, seventh row to allow machinery access, with the trees in the rows between strip roads thinned selectively at first and later thinnings.

Small machines, low ground pressures

Such methods place high demands on equipment for felling and extraction of thinnings, the limited width of the strip roads and the need to select trees in the rows either side of the strip roads necessitates that only small and highly manoeuvrable machines can be used.

A contributory factor to potential windthrow is that of damage to the ground and the root systems of the trees. Minimising ground bearing pressure of equipment and hence damage to soil and root systems is critical.

Clearfell at the end of rotation, in an open and unrestricted site, places fewer limitations on the choice of systems and equipment, other than the ability of the equipment to function for the task intended, to harvest within specific cost limits and to minimise ground damage for the subsequent crop.

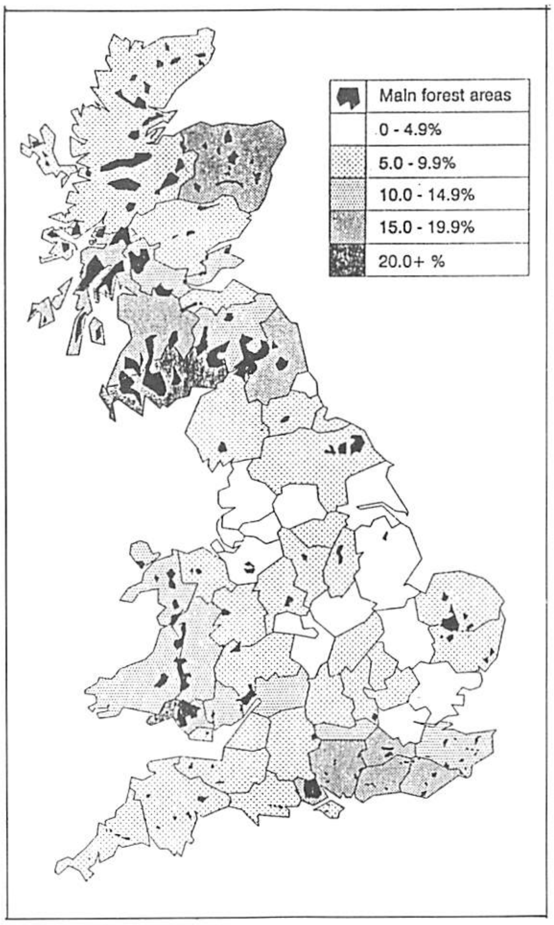


Fig 1. Woodland area by percentage of land area. (After Gardner 1989).

Harvesting systems

Harvesting systems are generally differentiated by the point at which processing, the removal of the branches and tree top (delimbing), and if appropriate, cross cutting of the stem, takes place. Processing can take place at the tree stump or at the forest road, or at a combination of the two.

The three main harvesting systems – illustrated in Fig 2 – are:

- Tree length.
- Shortwood.
- Whole tree.

Tree length (or pole length) systems

After felling, the tree is delimbed at the stump and the whole stem is extracted to the forest road where cross cutting if required takes place. Alternatively, the whole stem can be removed from the forest to the saw mill in its single length.

Tree length systems were historically the first harvesting systems used generally in Britain, using axe felling and horse extraction methods. The introduction of the chain saw in the 1960s improved efficiency in felling, and required improved extraction techniques. Modified agricultural tractors were introduced, equipped with winches for extraction, improved tractive power meant an increased length of tree was able to be extracted.

Tree length systems are used in large tree sizes but generally have been superseded by the use of shortwood systems. There is increasing interest in tree length systems, in crops of poor form, with the potential for improved utilization that can be obtained from cross cutting the stem on the controlled environment of the saw mill.

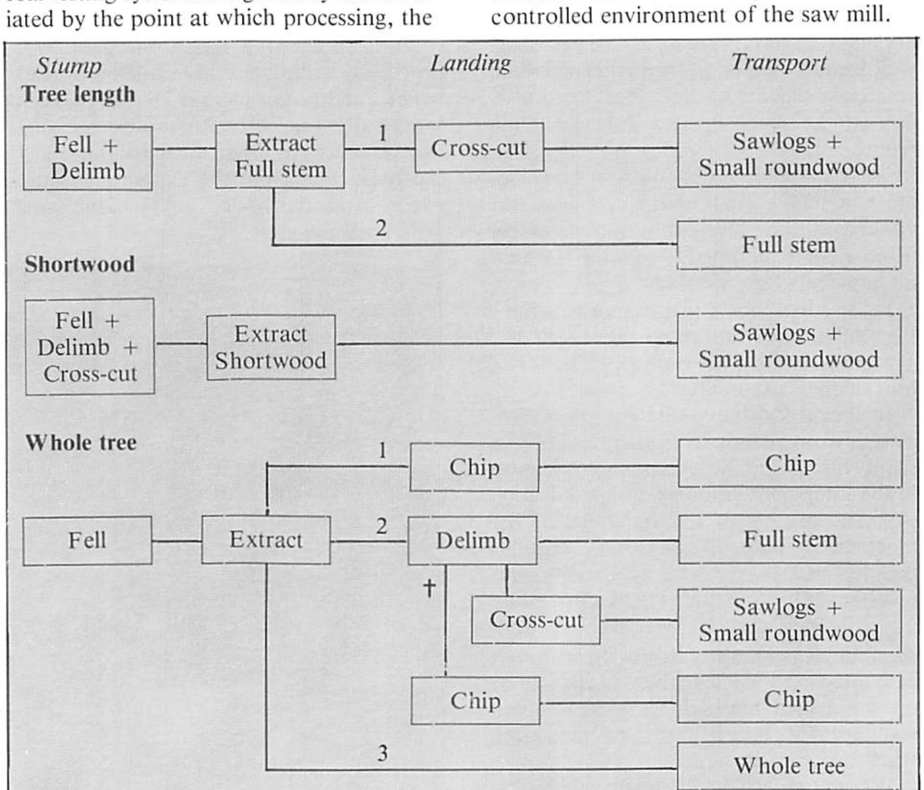


Fig 2. Harvesting systems.

Shortwood systems

All processing, both delimbing and cross cutting, takes place at the stump, the timber is then extracted to the forest road in short lengths.

Shortwood harvesting based on chain saw felling and processing, with extraction by purpose-built articulated-frame steered forwarder, was introduced from Scandinavia by the Forestry Commission in the 1970s as a solution to harvesting increasing volumes of timber in a standardised productive and efficient operation.

Valmet single grip harvester.

The shortwood system is the most predominant harvesting system in use today in Britain accounting for some 80% of all harvesting.

Increasing mechanisation has taken place in the felling and processing elements in shortwood harvesting systems. The delimbing element in processing was the first element to be mechanised followed in a later development by cross cutting. The next stage was the introduction of twin grip harvesters, where the delimbing and cross cutting is carried out as a separate function from felling.

More complex multi-function machines are now increasing in use, single grip harvesters, able to fell, delimb and crosscut using a crane mounted harvesting head on an all terrain base machine.

In Sweden, single grip harvesters have been introduced at a rapid rate (Freij and Tosterud, 1989), their use in British forest harvesting is expanding.

In shortwood harvesting equipment imported from Scandinavia, there has been a steady increase in the level of sophistication in the equipment including computerisation of many aspects of the functions of the machines. In many British forest conditions this has led to reduced availability and machine utilization due to the lack of back-up facilities. There has been the beginnings of a movement away from the complex Scandinavian base machines to the use of crane mounted single grip harvester heads on standard British built base machines, often tracked excavator bases.

In both tree length and shortwood harvesting systems, the stemwood only is harvested, branches and tops (residues) are left in the forest. Harvesting of the residues for fuel or additional fibre can be carried out in a second pass operation, during which the residues are collected and comminuted.

Whole tree systems

Whole tree systems are those in which all processing take place away from the stump. After felling, the whole tree is extracted to the forest road and either processed at that point or alternatively transported whole for processing at a centralised point.

Whole tree systems collect both stemwood and the residue material, potential fuel and additional fibre, in a single pass operation.

Whole tree harvesting, whilst common in Eastern Canada and the southern United States in particular, has not, with certain exceptions, been readily accepted into Britain. Whole tree systems do, however, attract interest for the potential of increased utilization, for use in difficult terrain where roadside processing has advantages over processing at stump, and in small tree sizes where multiple tree handling techniques can lower harvesting costs. Roadside processing has, however, the disadvantage of the loss of the brash mat from the extraction route, which is essential in some terrain to minimise ground damage.

In general, the use of whole tree systems allows a greater level of mechanisation and involves a move away from the use of complex machinery in the stump area to the more controllable environment of the landing or processing plant.

Whole tree systems can use multiple tree handling techniques in small tree sizes using feller/bunchers, and clam bunk skidders or grapple skidders for extraction. Processing can also be carried out using multiple tree handling techniques with the use of flail delimbers and at the processing plant, drum delimbers.

Choosing the harvesting system

The choice of harvesting system is influenced by the following factors that are often specific to a particular crop and set of site conditions:

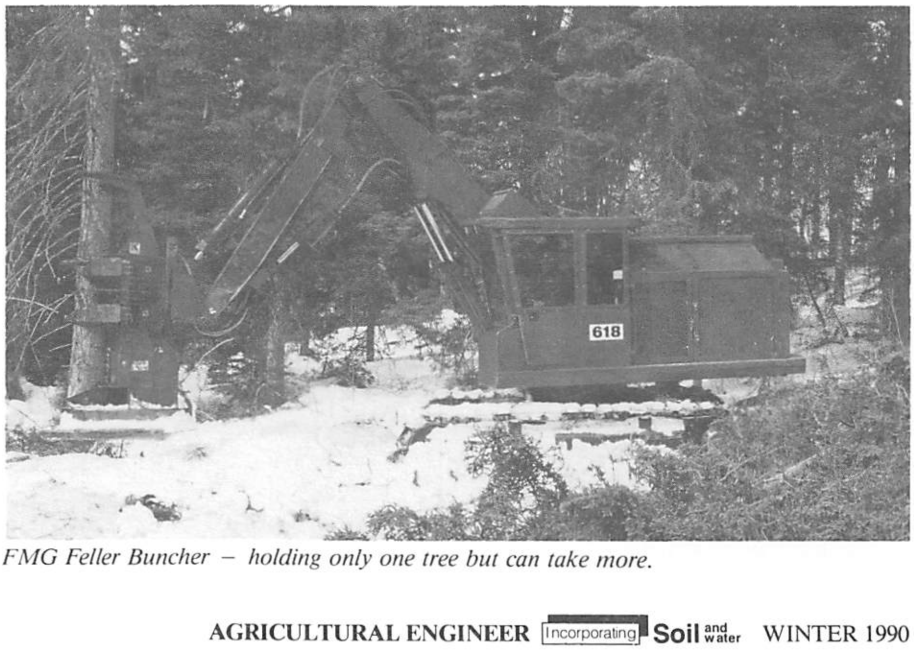
- tree size and species;
- silvicultural treatment – clearfell/thinning – intensity and treatment;
- terrain – ground conditions, roughness, slope;
- access roads and extraction routes;
- markets and product specifications;
- equipment availability;
- contractual relationships;
- scale of the harvesting operation;
- cost.

Cost is of major importance in timber harvesting in both thinnings and clearfell.

Wood as a raw material is of relatively low value and harvesting is a major factor in end product cost.

The largest single factor in determining the costs of harvesting is tree size, and to a lesser extent, tree species, followed by terrain conditions and extraction distance.

Generalised costs of the supply chain for harvesting and delivery of roundwood products from a first thinning, later thinning and clearfell are illustrated, based on a shortwood system of chain saw felling and forwarder extraction of Sitka spruce YC 16 (yield class 16 – $16m^3$/ha/annum), over an extraction distance of 150 metres on moderate upland terrain (Fig 3).



FMG Feller Buncher – holding only one tree but can take more.

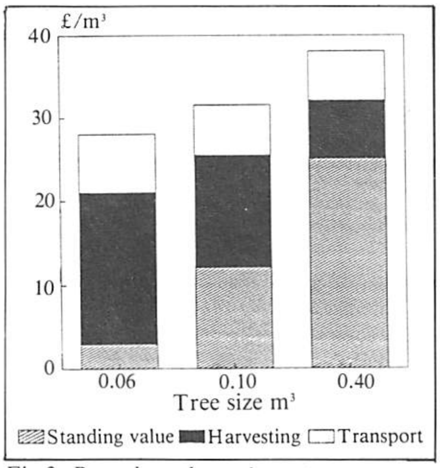


Fig 3. Roundwood supply costs.

The effects of increasing tree size in decreasing harvesting costs are clearly shown. The standing value of the tree is a function of market value of the products obtained less the costs of harvesting.

Advantages and disadvantages of tree length, shortwood and whole tree mechanised harvesting systems are summarised in Table 1.

Increasing timber supplies will demand more mechanisation

There are a number of factors that are combining to influence the future choice of forest harvesting systems, and harvesting equipment within those systems, in Britain.

An increasing raw material resource, some 3.2Mm³ ob additional raw material, is predicted in the next 14 years. This 50% increase in supply will strengthen the demand on the harvesting industry to improve long term harvesting capacity.

There is already a marked reluctance of chain saw operators to work in the often difficult and dangerous forest environment. Furthermore, health and safety legislation and increased insurance premiums are likely to contribute, as they have done in North America, to diminish the role of the chain saw operator in the forest. Increased mechanisation will be necessary to improve outputs.

However, the small-scale and fragmented nature of the harvesting industry, and the short term contracts that are often entered into, provide obstacles to large scale capital investment with its consequent need to secure income over long periods of time.

Notwithstanding the overall long term increase in supply, there is a potential short term imbalance predicted in the processing industry. Recent large scale capital investment has extended demand to a point where sufficient supplies over the next 2 to 3 year period are in doubt. This is having the effect of causing the wood processing industry to become actively involved in the procurement of wood supplies with investment in harvesting and management enterprises.

Such developments may well provide the impetus for longer term contracts for harvesting contractors to secure supplies. This in turn could provide the stability the harvesting industry requires for the longer term investment in mechanised systems.

Clam bunk skidder.

Table 1. Advantages and disadvantages of 3 mechanised harvesting systems.

Advantages	*Disadvantages*
Tree length	
Fewer pieces to handle. Simple extraction equipment. Improved stem utilization. Cold system, minimum machine balancing requirements. Brash mat available for extraction.	High breakages. Second pass for residue recovery. Low productivity in small tree sizes.
Shortwood	
Clean wood. Minimum rehandling for sorting. Compact loads. Cold system, minimum machine balancing requirements. High productivity in large tree sizes. Brash mat available for extraction.	Second pass for residue recovery. Decreased stem utilization. Low productivity in small tree sizes. Multi-function machines in stump area.
Whole tree	
Single function machines. Increased utilization. All processing at landing. Improved stem values. One pass operation for residue removal. High efficiency in small tree sizes.	Higher extraction costs. Large landings needed. Hot system, machine balancing essential. Nutrient losses. No brash mat.

Future mechanisation trends

Given that these trends will influence the speed of mechanisation, it is worth considering what direction the investment will take and what effect it will have on the choice of harvesting systems and, within systems, on the type of machinery.

Shortwood harvesting systems predominate in Britain, there has been considerable investment in capital equipment and infrastructures. Shortwood systems will continue but the gradual withdrawal of chain saw operatives will mean an increase in the use of mechanised systems. Single grip harvesters, mounted on both specialist and standard base machines, will be of increasing importance in the British forestry scene.

The use of feller/bunchers, felling and bunching the trees for delimbing by separate processors has occurred as a consequence of the move away from complex machinery. At the moment with little demand for the residues this processing is taking place in the stump area, but it could equally take place on landing thus converting the shortwood system to whole tree systems with few modifications to working practices.

The use of both tree length and whole tree systems, where the stem can be cross cut in the controlled environment of the saw mill, can lead to improved utilization of the stem. In addition, the use of whole tree harvesting

concluded on page 112

Meeting the timber indus

In this article C D Forsyth outlines the formation an He reviews the roundwood specifications required b implications these have for timber harvestin

The UK Wood Processors Association (UKWPA) was formed three years ago to provide a representative body for the major small roundwood and residue users. Currently the membership comprises: –

- Aaronson Bros
- Caberboard
- Caledonian Paper
- Pyrok Manufacturing
- Highland Forest Products
- Kronospan Ltd
- St Regis Paper Co.
- Shotton Paper Co.
- Iggesund Paperboard

In 1989 these companies took delivery of close to 2 million tonnes small roundwood out of a total UK production of some 2.7m tonnes – the difference being largely made up of exports and the stake market.

The forecast demand figure from UKWPA members in 1990 is some 2.2m tonnes, rising to 3m tonnes in 1994. The total UK demand figure in 1994 is estimated to be 3.5m tonnes.

The upward consumption trend is indicated by the annual figures presented in Table 1.

Influence of specifications on harvesting – processor preparation

Generally processor-prepared material causes few problems – for the chipboard manufacturers the additional bark removal is a definite advantage in that it aids drying and limits the bark percentage in the produced board. Small pegs or occasional retained branches which have not been cut off by the delimbing knives cause few problems.

St Regis and Iggesund also have no difficulty accepting processor-prepared material with a high percentage of bark removed.

Major users of small roundwood

CABERBOARD produce a range of chipwood and medium density fibreboard products. Thirty-nine percent of their current annual intake is small roundwood and two thirds of this is mixed conifer *i.e.* pine, larch and fir. Only very small amount of hardwood used.

Specification is: – Preferred length 2.0m, with tolerance 17.m to 2.1m. Diameter range is 5cm to 35cm and can be peeled or unpeeled. Wood should be of sound quality and reasonably straight.

The length specification is due to the design of the particular Hombak Flaking Units which Caberboard operate at both their Scottish plants. These units have a cutter head of 2.1m maximum width and with the roundwood being fed into the feeding units sideways it is imperative that the 2.1m is not exceeded in order to avoid logs becoming jammed with consequential downtime and lack of production on the Flaking Unit. The reason for the minimum length specification is due to the requirement to maximise the production from the Flaking Unit and also is due to the storage and infeed conveying system in that the wood really has to be in excess of 1.5m in order to be transported and singled efficiently.

The logs have to be "reasonably straight" which in practice means the logs require to be capable of being rolled.

A moisture content ideally of between 80-100% relative to dry weight is considered best – this compares with fresh wood intake of something between 120-140%. Caberboard's wood is dried down to a moisture content of between 2 and 5% and the savings in energy costs have to be balanced against the reduction in throughput and increase in knife changes caused through drier wood being processed. Additionally, with dry wood a further negative aspect is that a larger proportion of fines is usually generated.

IGGESUND have an intake requirement comprising 90% small roundwood which after July 1990 is 100% spruce. The end products are various grades of cartonboard.

The length range is 1.8m to 2.3m and diameter 6.5cm to 40cm. The length specification is due to conveyor constraints of just under 3m maximum length and logs less than 1.5m lengths are not carried on the cross transfer spikes on the conveyor. The roundwood has to be reasonable fresh felled to ensure efficient debarking in the drum debarker, easier chipping and refining and less resultant fines. The species specification change to 100% spruce is due to colour requirement from the customer – even dry spruce will meet the colour requirement but freshness as previously mentioned is essential for the pulping process.

The optimum chip size is 30mm and only sawmill chips from their own integrated sawmill are used to ensure this specification is met. The acceptable bark percentage is less than 1%.

SHOTTON PAPER COMPANY'S requirement is 80% roundwood and 20% sawmill chips. Species is predominantly spruce (90%) as this gives the best qualities of strength, brightness, colour and length of fibre for newsprint production. The remaining 10% roundwood comprises mostly pine as this species has most of the required qualities for newsprint but it does cause more "pitch" problems and as a result chemical additives are required to disperse the resins.

The length specification originally (1985) was to be the normal Scandinavian 3m. However, representations were made by suppliers to have a shorter length to help yields from early thinnings and to give flexibility in selection of harvesting machinery. As a result the length specification today is 3m plus or minus 20cm, or 2.3m plus or minus 20cm the length selection being at the discretion of the suppliers. Both lengths go into the debarking drum together so there is no advantage to Shotton in production. It does, however, slightly complicate storage in the log yard where the wood is used in strict rotation. The diameter range is 6cm to 40cm. The debarking drum contains 200 tonnes of logs rotating and even with 6cm minimum diameter, some logs are broken and this can jam the feed chute to the chipper.

Moisture content is very important as in the thermo mechanical pulping (TMP) process the chips are forced between one static and one rotating disc. Dry wood burns in these circumstances and discolours the pulp. It is therefore important that the wood is "fresh felled" which is defined as no more than 6 weeks from felling. A better indication is by taking a knife to the bark and it should be white under the bark. Mottled brown spots indicate that drying is well advanced and complete browning under bark is not acceptable.

The logs have to be reasonably straight but as they are in the debarker for 20 minutes, most shapes of logs are well debarked during that time. Chip size is important in the TMP process with the optimum size being between 18 and 24mm. The chip size from the Shotton chipper is mostly over 18mm; chips from a chipper canter saw are mostly under 18mm – thus a mix of 80% roundwood and 20% peeled sawmill chips gives an overall acceptable size distribution. Debarking of logs at the sawmill leaves around 1% bark in the chips. Shotton chips normally contain 0.25% bark and the combination gives an average bark content of under 0.5%. Anything over this figure gives a mottled effect on the newsprint sheet.

It is important to know that the pulp is the only constituent of Shotton's paper.

Colin Forsyth is General Manager, Forest Management, with Shotton Paper Company Limited.

tries market specification

**ctivities of the UK Wood Processors Association.
ıe member companies of the Association and the
echniques and equipment.**

However, Iggesund do require the wood to be fresh. Similarly Shotton and Caledonian accept that large scale harvesting has to be done with processors but it is crucial that the material is "hot logged" into the mill to avoid moisture loss.

Dry weather is a problem with processor-prepared material particularly in the spring and can cause problems with stock rotation in the log yards.

Generally pegs and the occasional retained branch do not cause undue problems although branches can jam conveyors.

– log splitter for large diameters

An interesting development at St Regis is a Botex log splitter which can quarter large diameter hardwood logs – 2.4m long and up to 1m diameter – with a predicted capacity of 200 tonnes per day.

This will mean an increase in the log diameter specification and the available log volume in the mill catchment area will

products, processes, specifications

CALEDONIAN PAPER produce lightweight coated paper from almost exclusively spruce roundwood. No chips or other residues are used at this mill.

The length requirement is 2.7m to 3.0m and the logs are crosscut to 1.5m lengths which is the width of the grindstones. The shortest grindable length is 1.2m. Logs longer than 1.5m produce waste. Diameter range is 6cm to 40cm. As with the other processors, small diameters break in the debarking process. Regarding straightness, since the logs are crosscut a swept log is acceptable.

Freshness is essential and the criteria are similar to Shottons. Dry logs will not debark easily and they overheat the grinding process. The woodyard has a spray system to ensure the logs retain moisture to the level at which they were delivered.

ST REGIS PAPER COMPANY'S roundwood intake is 100% hardwood. They have two main products – waste based fluting and semi-chemical fluting, manufactured at their Kemsley and Sudbrook mills. Waste based fluting has 50% virgin wood fibre input whereas semi-chemical fluting has 65% virgin fibre.

The length specification is mostly 1.8 to 2.4m lengths to suit cross stacking on articulated lorries. However, they will accept 1.2m log lengths. The maximum length for the chipper infeed is 2.7m. Diameter range is 5cm up to 40cm – as with the other processors the minimum diameter specification is to minimise breakage. The moisture content has to be reasonably high to ensure a clean cut on the chip edge to assist liquor penetration at digester stage, to reduce the percentage of fines generated by the chipping and to maximise fibre recovery.

Roundwood is preferred for: – the constant size produced by the mill chipper (essential for digester controlled "cooking" of the chip since short chips overcook, long chips undercook due to the difference in time taken for the liquor to penetrate to the centre of the chip); consistent moisture content; lower bark percentage, and higher fibre percentage recovery.

HIGHLAND FOREST PRODUCTS intake is exclusively roundwood with at least 83% pine, the balance made up of other, non-spruce, conifer. The reason for the intake being only roundwood is the flake dimension of 75mm × 20mm × 0.7mm can only efficiently be produced from roundwood. The product is oriented strand board (OSB) with thickness range 6mm to 25mm.

The length specification is 3m with a tolerance of 2.8m to 3.1m. This specification is set by the conveyor widths and by the size of the Bezner Waferizer. The 3m long billets break down into 0.75m bolts. The minimum diameter is 5cm although efforts are being made by HFP to increase this to 7cm. The small diameter material snaps under stress with resultant operational problems. Also small diameter material does not yield correct wafer dimensions and has a higher proportion of sapwood which when dry tends to be excessively brittle. No top diameter is specified, but logs over 45cm diameter cannot go through the ring debarker. Logs of this diameter are rarely delivered, however.

The preference is for fresh cut timber as this provides better wafer dimension, less waste in fines percentage and fewer breakages. However, dried timber, especially heartwood can give a higher fibre yield as less water is being purchased.

The roundwood must be reasonably straight otherwise two problems can be encountered: – timber which is not straight is difficult to convey on the in-feed decks as it is conveyed sideways. There is also a potential problem at the ring debarker and excessively misshaped roundwood can create downtime at this point. A drum debarker would be more beneficial in that swept timber could be handled, but the minimum diameter would have to be increased to 7cm.

KRONOSPAN produce chipboard from 5 presses at their plant in Chirk. Fifty percent of their intake is small roundwood. The species preference is for pine and Douglas fir. There is only a small proportion of spruce as it tends to have a higher moisture content, and a similar proportion of larch as it has undesirable springback characteristics and does not compress as well as other species. Hardwoods comprise 15% of the roundwood intake but conifers are preferred on the basis that the greater the volume you can compress, the better the board.

Length specification is 1.0m to 6m, but in practice the roundwood is cut to length for ease of handling – mostly between 2m and 3m. The diameter specification is between 6cm and 40cm. (The maximum diameter was 1m in 1986 and this has progressively been reduced to 40cm over the last 4 years.)

The moisture content requirement is similar to Caberboard – with fresh wood the moisture content is approximately 130% relative to dry weight although last summer this dropped to an average of 60%. The roundwood must be reasonably straight and clean. Mud and stones as a by product from skidder extraction in wet weather are not acceptable as no debarking is done.

be increased significantly. Shaken oak and chestnut, and all wood below fencing and furniture specifications can be very efficiently handled through this industrial log splitter although the wood has to be reasonably fresh as dry logs tend to snap when passed through this splitter.

– accuracy of cross cutting

There is a fairly common criticism of processor material and that is the accuracy of crosscutting.

As mentioned earlier, material in excess of the preferred length can cause considerable operational problems and also leads to waste.

What suppliers appear not to be fully aware of is the tolerance in terms of length up to the maximum length. Invariably men or machines cut to fixed length and in small thinnings this naturally puts more pressure on the minimum top diameter. More flexibility could be introduced into this length specification although it is accepted that cross loading on lorries could become more difficult as a result. It is also interesting to note Caledonian are currently assessing the potential of a 4.2m-4.5m length specification.

Table 1. Timber delivered to wood processors ('000 tonnes)

Category	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*
Chipboard	185	252	294	380	654	757	1,020
Fibreboard	36	30	15	15	20	15	20
Paper and paperboard	283	303	433	592	788	860	953
Totals	504	585	742	987	1,462	1,632	1,993

Source: Forestry Commission.

The research at Caledonian perhaps indicates a trend for the future of longer length material prepared at stump or at roadside. Many sawmillers would prefer to have more control over crosscutting by extracting in tree length and crosscutting at roadside or in the sawmill. Small roundwood users may well similarly develop harvesting systems to enable whole tree extraction and roadside processing on a much bigger scale, with perhaps the lop and top chipped for fuel.

A Bruunett processor 678P. The machine is seen with one tree length being snedded and crosscut and one tree length being lifted by the grap arm from the waiting row. Photo: *Forestry Commission, Edinburgh.*

– limited prospects for chippers until screening perfected

In low value crops – for example coastal provenances of Lodgepole pine or scrub hardwoods – chippers will be developed as the most economical way of dealing with these difficult crops. However, it is not easy today to see widespread use of this quality of chip in the wood processing industry. For example Highland Forest Products do not use any chips in their board manufacture. Shotton and Iggesund's tight specification on bark percentage would appear largely to discount their use of material prepared by whole tree chippers.

St Regis operated in wood-chippers for three years up to 1989. This was stopped because the high content of leaves, twigs and fines made the acceptable percentage of chip too costly compared with roundwood and sawmill chips.

If the screening of chips can be perfected to produce substantially bark free chips then this would be a major advance and could well provide part of the solution to the potential wood fibre shortage in the mid 1990s.

How to mechanise without risk to site

In commercial thinnings it is difficult to see a dramatic move away from shortwood working with extraction by forwarder but the major research and development requirement in this area is how to mechanise effectively without damaging the generally fragile site conditions which pertain in Britain. Most of the mechanised systems developed to date are much too heavy for upland thinnings and there is a substantial market for the right machine.

Tracked low ground pressure forwarders are only just coming into Britain although they have been operational in Scandinavia and Ireland for many years.

continued from page 109

systems, where the residue material is harvested can increase utilization by 30 to 100% depending on the crop and stand parameters providing additional raw material for both fibre and fuel.

A large proportion of the increase in supplies will come from the young upland spruce areas. Thinning in these crops is problematic and perhaps difficult to achieve with traditional shortwood harvesting systems. If extraction problems can be overcome, then whole tree harvesting, with the use of multiple tree handling techniques, could reduce the costs of first thinnings and release the resource.

Acknowledgements

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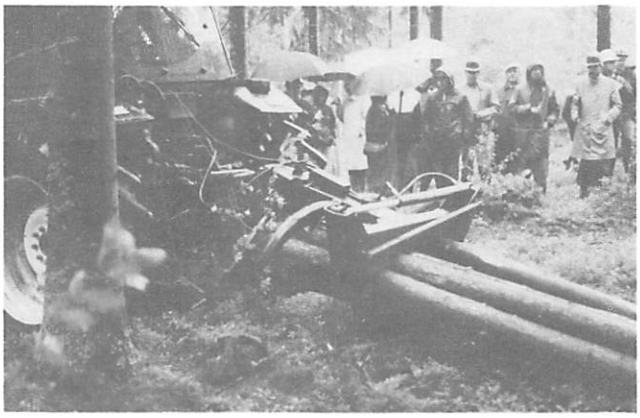
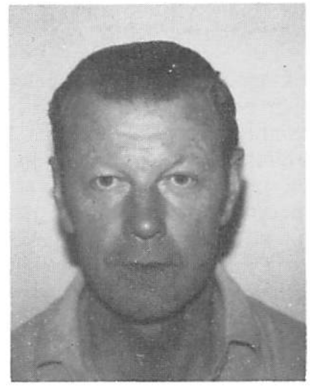


Grapple skidder

Installation of computer-aided engineering

In this paper presented at the 1990 Annual Convention, C Reed, speaking from personal, practical experience, describes the procedure adopted at Standen Engineering for choice and installation of a computer-aided engineering system. Above all, he stresses the need first to consult all those likely to be involved and then to draw up a precise specification of what the system will have to achieve.



Standen Engineering started their venture in Computer-Aided Engineering (CAE) five years ago. At that time the company was part of a multi-disciplined engineering group, and it was group policy to investigate the justifications of introducing CAE.

At Standens we specialise in the design, development and production of harvesting machinery for potatoes and sugar beet, as well as manufacturing a wide range of narrow tractor wheels for rowcrop work. We are a medium sized company employing around 100 people in the various administration and production disciplines. Around 25% of the company's turnover of £4.5m is on sub-contract work which can involve design and manufacture in a diversity of disciplines in both mechanical and construction industries.

Consult all involved

Without a detailed specification of precisely what the needs of a company are, it is virtually impossible to select the correct system. We started totally incorrectly. Myself as Technical Director and two other engineers felt a visit to a design exhibition at Birmingham would be the ideal platform from which to start. How wrong we were – that visit should have been made much later, when we knew what we wanted!

At Birmingham we were greeted with dozens of computer screens all showing different detail and many sales representatives on the stands far too busy to explain in detail exactly what was what on each display. With our total lack of knowledge of what we really wanted to do, we left the exhibition not one ounce the wiser as to what system we should select. It did, however, emphasise the need to define our requirement and to this end we set up a team to do just that.

It is surprising how many people within the company needed to be involved in the drawing up of a detailed requirement and it is vitally important that all these people have their say. In order to make the system a success everyone involved must be behind the final decision with an eagerness to make it work.

As the learning curve on introduction has proved extremely long, this has needed the dedication and commitment to the project of all concerned.

Prepare a precise specification

When setting out the specification, consider carefully precisely what is required in your working environment.

For example, in our case the need for three dimensional graphics and parametrics was not seen then or in the future as a requirement and as such this was eliminated as part of our specification.

We did, however, see a requirement for operating our existing tape-driven numerically controlled (NC) machinery and this rated in the eyes of both foremen and operators of these machines as extremely important.

It is therefore essential not to buy a system that can do a lot of things you do not require and fail to satisfactorily achieve the most important.

The CAD/CAM Exhibition at the NEC, Birmingham. A good source of information but sort out first what it is you need. Photo: *EMAP, London.*

Select prospects and arrange demonstrations

Having completed what was felt by all concerned as a suitable overall specification, we then needed to establish who provided what we needed.

I suppose, in hindsight, the Birmingham exhibition did provide us with a carrier bag full of glossy brochures. It was from these we selected three companies that appeared to sell packages to suit our needs.

We have found, without doubt, that the practical demonstration is extremely important in comparing systems and finding out whether those who have to drive the system are likely to feel comfortable with it.

In the first instance two of the three companies we selected gave us demonstrations at their premises. This proved a major plus as we had a complete day with their total attention to answer questions and allow us to 'play' with their system.

One of the companies was prepared to bring their equipment to our factory and spend a day showing us how their version of CAE could carry out what we do every day. What excellent value this proved, as it showed all concerned what can be done. There is no doubt that an individual, once it is proved to him that the system will work, is extremely keen to show he can be as good as the 'expert'.

Visit existing users

A third element to the demonstration is, I feel of the greatest importance. Do ask your supplier for contact companies who are using the same system and using it the way you intend to. We visited two companies, spending complete days discussing implementation and operation with their engineers. This experience has proved extremely valuable. If you are prepared to be a guinea pig and try out a new product that's fine but, when first installing the system, go for proven and accepted software and hardware. It is not easy to introduce a CAE system. To have to endeavour to develop it with your supplier at the same time spells disaster.

Ensure training and back-up service available

As I have outlined previously let no one be under the illusion that introduction is quick and simple. It is not. When choosing your

concluded at foot of page 114

C Reed is Technical Director, Standen Engineering Ltd.

Soil erosion on agricultural land

Edited by J Boardman, I D L Foster, J A Dearing
Publisher: John Wiley & Sons
ISBN: 0471 926027 Price: £65

The book represents the papers presented at a workshop on Soil Erosion on Agricultural Land as the contribution of the British Geomorphological Research Group to the Annual Conference of the Institute of British Geographers.

The book contains some 45 papers and posters given at the workshop which had the aim of bringing together erosion researchers from different disciplines including soil science, agronomy, geology and agricultural economics.

Perhaps at this stage I can make one major criticism, that the list includes no engineers either Agricultural or Soil and Water. This tends to lead the work to concentrate more on processes, assessment and rather less on conservation measures. This is reflected in the list of contents which are arranged into three sections:

- Erosion processes, past and present; (19 papers).
- Assessment and predictions (13 papers).
- Conservation and policy (with 9 papers relating to conservation practices).

This particular gripe aside the papers are of a very high quality. As to recommendations of such proceedings it is difficult to be objective. As with all good quality scientific conferences a group of experts have come together and presented their latest work. It therefore must be a most valuable reference work and for those researching in the area will appear on their shelves. For the rest it will be in the university, poly or college library or consultants etc will provide a copy. In this context, this is a most useful extension of the literature. **MJH**

Trees as a farm crop
by E G Richards, J R Aaron, G D D'A Savage and M R W Williams

Pub.: Blackwell Scientific Publications
ISBN 0-632-02321-X Price: £10.95

With Britain still importing 90% of its requirements of wood and wood products and a substantial overproduction of food in Europe, it is not surprising that our thoughts turn again to forestry. In fact this text reminds us that Britain's marine climate provides good growth conditions for trees, with rates several times that of Scandinavia, one of our main suppliers of timber.

It is therefore timely that this book, written by a group of experts including consultants, teachers, trainers, who have had experience in senior posts with the Forestry Commission and private companies, has recently been published. It is mainly aimed at the farmer and provides a practical guide on the various steps to be taken in establish ing woodland. However, as with so many such guides it forms an excellent practical reference to students whose curriculum includes components related to forestry or anyone else with either a professional or general interest in the subject.

The text is written in an easy style and is punctuated with well illustrated diagrams and informative graphs and tables. The book guides one to further references where appropriate, but these are rather spread in the text and would have been better placed in a special reference section.

The appendix section is very comprehensive with a range of useful data including specifications, contact addresses, sales agreements and methods of timber measurement.

The main text is presented in a logical husbandry sequence with chapters on selection of trees, land preparation, planting, practices, harvesting and marketing.

It aims and succeeds in providing a comprehensive coverage but it inevitably fails to provide much depth to the subject. Nevertheless as a 'first primer' on growing trees on the farm as a commercial venture, it can be strongly recommended.

MJH

continued from page 113

system, question in great depth the training and, even more importantly, the back-up advice system your supplier can give.

Our engineers attended a three day familiarisation course which taught them little more than the raw basics of operating the system. The learning continues for many months. It was only with the constant help via a telephone hotline to the support desk of the company (on a daily basis in the early months) that we were able to proceed forward and understand how not to make the errors that one invariably does with something as different and complicated as this.

We sent two of our four draughtsmen on the basic training course – at that time we had only purchased two units and there seemed little point sending more draughtsmen. What transpired was quite a revelation. The other draughtsmen showed continual interest once the two trained personnel were using the system and these two have fully trained all our other draughtsmen far better than any training course could have possibly done.

Be prepared to replace and update

So far so good – we now have installed our glossy new CAE system.

Where do we go for the future?

As we have found literally to our cost, systems do not stand still and software is being continually upgraded. It is very important not to assume once you have the system that it can be treated like many machine tools and written off over a seven to ten year period.

As programme updates add more and more facilities, the computer you have so proudly bought is no longer capable of handling them, and the software houses will happily tell you as the next major update comes along that to get the best out of it, the new standard of hardware should be purchased.

We have already changed all our computers and have already been informed that should we want to take advantage of the latest software levels under development, a further change within two years will be necessary.

Of course, it is not necessary to be continually upgrading if you are totally happy with what you have got. We have, however, found that each new level of software and certainly the hardware has increased our speed of output and the flexibility of the system.

I would be extremely reluctant to take on any system where the supplier did not operate a maintenance system for continually investigating the needs of customers and raising his software levels to comply.

System costs have dropped considerably since we first ventured into the market. As I have stated previously, in order to budget, discussions should be held with suppliers well in advance of issue of updated software, to establish whether you want it and if so what the total costs of incorporating it are.

Successful CAE reduces errors, improves productivity, enhances company image

I have tried to outline some of our experiences and the potential pitfalls in entering the world of CAE.

Approached correctly the system has tremendous benefits and has certainly enabled us to produce more with less. The actual gains in draughting productivity vary considerably depending upon the type of components. Obviously items such as wheels show tremendous gains whereas a complicated casting much less so.

The major benefit is accuracy. Providing the computer is fed the correct information it will provide a drawing which is guaranteed precise. The major spin-off from this of course is less drawing office errors and much improved quality in assembly.

Presentation of drawings is extremely good and consistent and eliminates the variables which must occur with each draughtsman regarding legibility of text. For tendering presentations it enhances the professional image of the company, which is extremely important in today's competitive world.

It has to be a benefit to all companies in manufacturing so go for it but go carefully and the results can be nothing but pleasing to all involved.

Fresh water ecology
by M Jeffries, D Mills

Publisher: Belhaven Press
ISBN: 1 85293 021 7 h/b 1 85293 127 2 p/b
Price: £27.50 hardback, £8.95 paperback

For those of us who design water storage or conveyance structures an improved knowledge of the physical and chemical characteristics of water related to the ecological structure of fresh water environments is a must if we truly are interested in environmentally friendly development.

This book, a rewrite of an earlier 1972 work "Introduction to fresh water ecology" by D Mills will be a great help to the aforementioned designers in that it is a comprehensive outline of the scientific principles of fresh water ecology written in a clear and comprehensive manner. It provides the engineer with a first class guide into the subject and it develops the application of ecological techniques to better design, management and conservation of lakes, ponds, rivers, streams and ditches.

I recommend all involved in Soil and Water Management to read this book. It is an excellent publication on a most important area, much neglected in the past.

MJH

Irrigation theory and practice

Proceedings of the International Conference held at University of Southampton, 12th-15th September 1989.
Editors: J R Rydzewski, D F Ward
Publisher: Pentech Press, London.
ISBN 0-7273-0904-8

The conference was held to celebrate 25 years of teaching and research in irrigation at Southampton University. As most engineers are now able to appreciate the success of irrigation development depends upon the irrigation of a wide diversity of disciplines and groups. The aim of this conference was to call on this wide diversity to identify the successes and limitations in the application of theory into practice.

It is of course impossible to consider all of the material in detail in such a report as this. However, it can certainly be recorded that a comprehensive list of world authorities has been drawn together and their combined papers give a most complete picture of the present "state-of-the-art" together with a most interesting insight into future fundamental improvements in development.

The publication is very well presented and I would certainly recommend it to anyone who is likely to require a reference work on the latest research work in the discipline.

MJH

Earth roads (a practical manual for the provision of access for agriculture and forestry projects in developing countries)
by John M Morris MBE

Publisher: Cranfield Press
ISBN 0-947767-93-2

Really the title says it all! This is a practical manual but it has much more than that to offer.

It provides a real insight into the problem of providing access in developing countries in the form of earth roads. As would be expected from a practitioners handbook it is pitched in the words of the author at the blacksmith rather than the mechanical engineer. But please do not feel that this in any way detracts from the main quality of the book. It deals most superbly with many of the major problems in a most professional way and therefore has much to recommend it as a "design code" for those with projects to create in tropical and sub-tropical conditions.

Indeed in my opinion the planning and specifications phases of the book are particularly good. The author's experience shines through and should help the designer avoid many basic errors, commonly found in access development.

As suggested, the design and construction component of the work is practically based but serves two important purposes; for those with an engineering background it points out important issues relating to what is practically possible to achieve in the conditions expected: to the manager of projects it provides the outline of what to expect in the designs submitted and how to check that they include all his practical requirements.

The book would not be complete without sections on maintenance and rehabilitation and these are presented in a clear, concise and easily followed form backed up with plenty of well selected illustrations.

This is an excellent work which I can thoroughly recommend. It will be of particular value to all students studying transportation and land improvement in developing countries.

MJH

Advances in range management in arid areas

Edited by R Halwagy, F K Taha, S A Omar
Publisher: Kegan Paul International Ltd
ISBN 0 7103 03602 Price: £65

This book contains the proceedings of the first International Conference on Range Management held in Kuwait in April 1985. The objectives of the conference were to analyse the state of knowledge in range management in arid regions, bring into focus the needs for the role of range research and formulate priorities, highlight advances in management of rangelands and develop improved communications within the discipline.

Seventeen of the twenty-one papers presented at the conference are published in these proceedings in five sections. The sections are in rangeland ecology, rangeland improvement, present status of rangelands, forage production and range ecosystems, and finally range animals.

As with so many conference proceedings they will predominantly be considered as reference works except by a very select few. In this case the price may well further influence choice.

It is of course also extremely difficult to provide a balanced critique of such a wide range of papers. Suffice it is to say that the subject areas selected are extremely relevant to extensive agriculture in arid land. They have been prepared by people researching predominantly in the Gulf region and hence are up to date, practically significant and convey the latest practices.

For anyone who intends to study, research or practice in arid zones this work will be a useful reference. Make sure your library has a copy.

MJH

Machine condition monitoring

Papers presented at a Seminar organised by Solid Mechanics and Machine Systems Group, Institution of Mechanical Engineers, Jan 1990
Pub.: Mechanical Engineering Publications.

A bound copy of the papers from the above Seminar has come across my desk recently. It contains the following papers:

Effects of coupling errors and misalignment on the dynamic behaviour of a multi-shaft system;

Joint study on the computerisation of in-field aero engines vibration diagnosis;

Condition monitoring of borehole submersible pumps;

Centrifugal gas compressors – method for rotor stability assessment;

Machine condition monitoring via stress wave sensing;

Condition monitoring of rolling element bearings using the enveloping techniques;

Pump drive failure investigation using condition monitoring techniques;

The use of expert systems in advanced condition monitoring.

Condition based monitoring is a developing science and despite continued costly machinery failures little attention has been devoted to an understanding of this science.

The aim of these papers is to bring to the attention of practising engineers some of the current techniques employed by larger industry, ie pump industries, aerospace and power generation. It will be to agricultural engineers' good if those involved in machinery development pay attention to the content of this publication.

MJH

Using sea water for irrigation

K Ruess and H Federer describe a novel technique in which sea water is evaporated to provide water vapour for sub-surface irrigation.

Hot air has a higher water vapour capacity than cold air. In a bathroom for example, air takes up vapour from the water, until the water capacity is reached. The cold mirrors and windows cool down the humid air and if the water vapour capacity is exceeded, the air has to give up water vapour as condensation.

The same procedure occurs in meteorology. In the Red Sea and the Persian Gulf the hot air takes up a water layer of over 3.5 metres deep each year. This moist, warm air rises. Air pressure differences between the equator and the poles, as well as other forces then move it around the world. In a higher degree of latitude the subtropic air is cooled down by polar air and if this lower water vapour capacity is exceeded, the vapour condenses, resulting in rain.

Application in classical times

Man's use of this process is not new. In the past the Greeks have built heavy condensation wells made of stone. On their walls, the moist air was cooled down to obtain water. These wells were not only functional, they were also artistic, often with dovecots along the top. With the excrement of the pigeons and the water produced, plants were fertilised and watered.

King Herod built the most famous condensation well in Masada. In his time Roman Baths were very fashionable. Besides the great baths and pools for the people a condensation well supplied the King's bath with water. Calculations have shown that these wells and the condensated water around the rock of Masada provided a few thousand cubic metres of water a year, enough to survive a siege. In peace time there were other water sources too.

Providing water for irrigation

Thus, as already explained, it is not new to obtain water from the air. However, the idea of heating and moistening air with solar energy and sea water and condensing water vapour directly by the roots of plants, is probably new. The schematic representation in Fig 1 outlines the technique we have now developed. This procedure enables cultivation of plants in hot, arid zones near a salt water source without the need for fresh water irrigation.

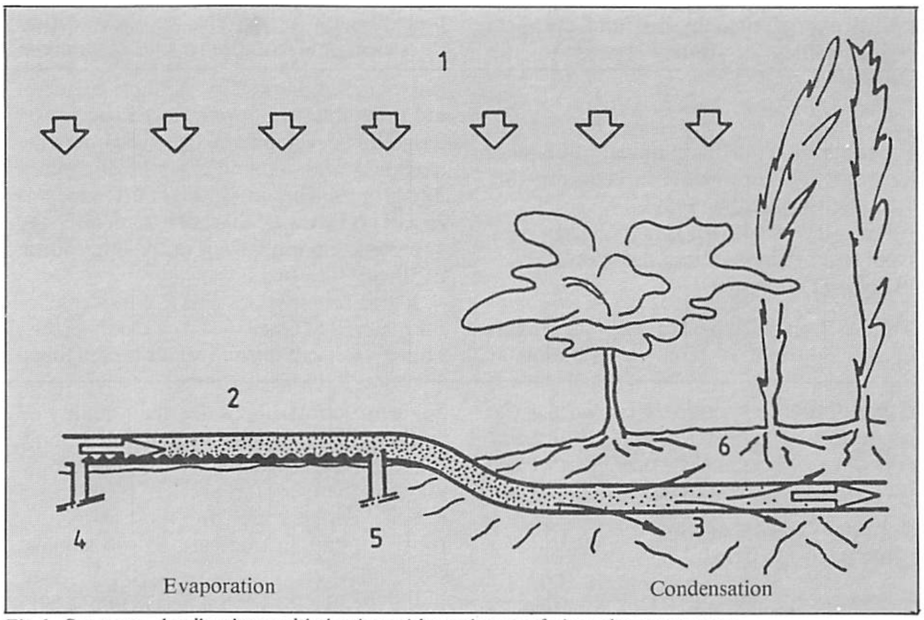
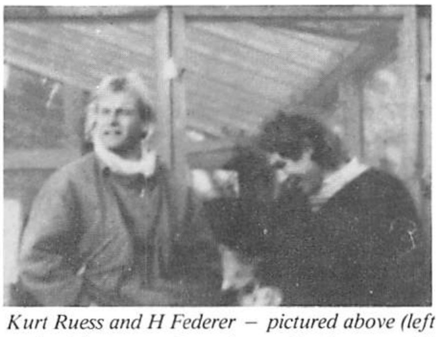


Fig 1. Sea water desalination and irrigation with a mixture of air and water vapour.

Sea water and air are drawn into the same evaporation tube (2). The sun's rays (1) heat up the air and salt water (input 4, output 5). The water evaporates and a mixture of air and water vapour is fed into the soil. The soil cools the saturated mixture and water vapour condenses in the tubes. The water is then made available to the roots of plants (6) through porous drain pipes (3).



Kurt Ruess and H Federer – pictured above (left and right) are Consultant Engineers with Ingenieurbüro Ruess and Hausherr, based at St Gallen, Switzerland.

In our patented system, air and salt water pass through sun-exposed evaporation tubes. The sun's rays are absorbed, so heating the air and the water (Fig 1). Supposing the air reaches a temperature of 40°C and is saturated with water vapour at the end of an evaporation tube, its vapour capacity is then 50g of water per kilogramme of dry air (air density = 1.293kg/m^3, normal conditions).

After the evaporation process the saturated mixture of air and water vapour is led under the soil, close to the roots of plants. The soil temperature decreases drastically after the first few centimetres from the surface. Supposing that the soil cools the mixture down to 20°C, the water vapour capacity is now reduced to 15g/kg. This means that we gain 35g of water by cooling each kilogramme of mixture. The water arrives at the roots through drains or porous pipes. Water vapour diffuses widely throughout the soil. Experiments have shown this effect.

The desalination and irrigation plant can be built as an air circulating system. Instead of the proposed air moistening system other systems can be used (eg water vapour from industrial processes). It is a question of economy and planning whether natural convection or ventilation is employed for the air circulation. In the presented method condensing and distributing the water occurs together.

An important advantage of our system is that the water arrives at the roots without loss by evaporation into the air (a sprinkler system often has an efficiency of less than 50%). A further point is that other irrigation systems such as sprinkler plants and open water channels have partly contributed to the recent increase in malaria, the open water being a breeding ground for the mosquitoes causing the disease. With subterranean irrigation the soil surface is dry, so that there is no breeding ground for the malaria-causing mosquitoes.

Practical trials in pilot project

Since July 1986 a pilot plant has been running in St Margrethen (Switzerland). In a sun energy collector field the air is heated and moistened (Fig 2). In Fig 3 the subterranean condenser tubes are shown. A solar generator provides the electric power to drive ventilators and the sea water pump (Fig 2) hence the plant works without batteries and without regulation. If the sun is shining, the system starts and produces water. Even if the sun is not shining, water is stored because of the humidity of the soil.

The general layout is shown in the small-

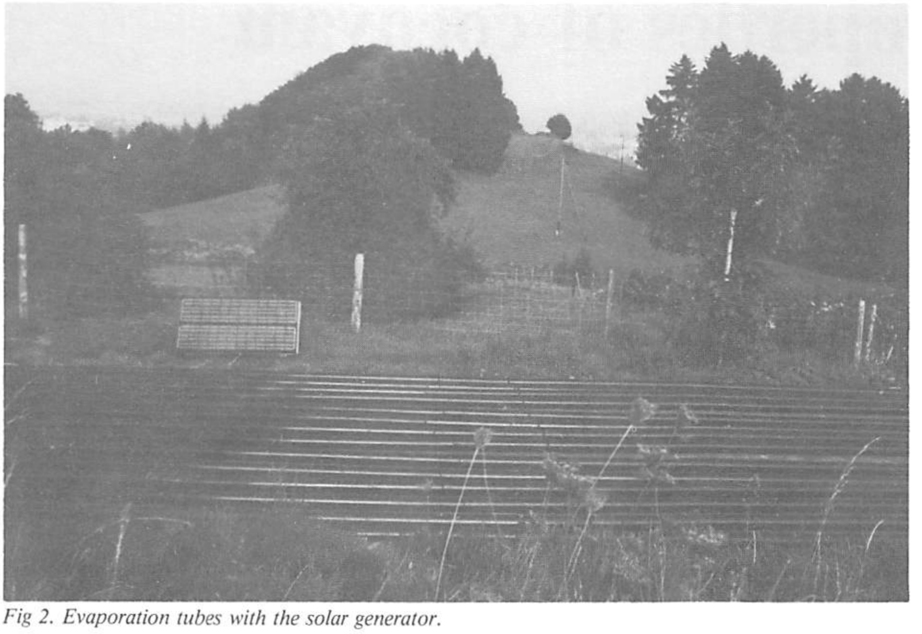


Fig 2. Evaporation tubes with the solar generator.

water vapour is more effective than either sprinkler or drip irrigation. The plants need the most water at high temperatures and with strong sun radiation (also with less humidity, wind, etc). With these conditions the desalination and irrigation process has the best efficiency and produces the most distillate. Plants search for the water sources and build their roots around the condenser.

As the pilot plant 1986 and 1987 has shown plants grown with this irrigation system needed only half of the water quantity expected. Therefore the water consumption is very low when compared to the amount needed with traditional irrigation plants. Additionally, the quality of the distillate was high. Mineral salt for the plants has to be given as required.

The large surface of the evaporators has one further advantage. During rain the evaporators act as water collectors and lead the water directly to the plants. The condensers act as a drainage system and lead off the excess rain water.

scale model, Fig 4.

Besides the quantity, the quality of the obtained water is important. If irrigation water is too salty, the soil becomes unusable after some years because there is not enough water to wash out the salt accumulation. In our system we achieve high quality irrigation water – the distillate.

Cress is a very salt sensitive plant and served as the salt or quality indicator. Tomatoes need plenty of water and served as the quantity indicator. As a light indicator we planted lettuce. A greenhouse and a damp border in the soil was built to protect the pilot plant from rain water.

In the pilot plant cress and lettuce were grown with success. Conventionally watered tomatoes need more than 600 litres of water per square metre. With the mixture of air and water vapour irrigated tomatoes needed half this amount. This shows the high degree of efficiency of the irrigation system. Fig 3

Fig 3. Young tomato plant between the condensation tubes.

Table 1 Estimated construction costs and annual energy costs for two sizes of plant.

Cost element		*Cultivation area*	
		600m²	*3000m²*
Investment			
– engineering, planning, materials	SFr	23500	96000
	£	9400	38400
Annual energy costs			
– for pumps and ventilators	SFr	290	1450
(@ SFr 0.10 per kWh)	£	116	580

Note In practice, for any given size of plant the realisable cultivation area will depend on the local climatic conditions and the water requirements of the crops being grown.
(Rate of exchange £1 = 2.55 Fr.)

shows a young tomato plant between the condensation tubes. In Switzerland, the tubes are laid near the surface to simulate high soil temperatures. In arid soil the tubes lie deeper.

Costs

Two sizes of irrigation plant have been assessed. A general indication of costs is given in Table 1.

Conclusions

Subterranean irrigation with condensing

In summary, the function of the condenser is to:

- condense the mixture of air and water vapour
- distribute the water to the roots
- lead off the excess rain water (drainage system)
- heat the soil.

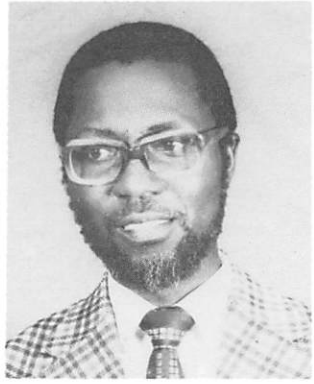
Absorbation of the condensation heat into the soil allows an early cultivation in spring and thus the prospect of an earlier, better-priced harvest.

Fig 4. Model of sea water desalination and irrigation plant.

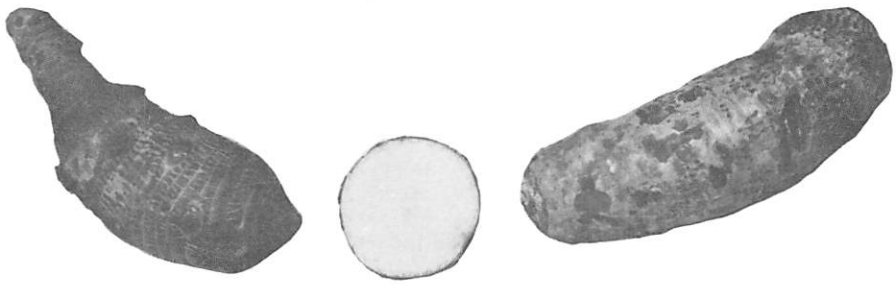
Rheological properties of cocoyam

E A Baryeh here describes how the tensile strength, compressive strength, shear strength, degree of elasticity, hardness and resistance to cutting of cocoyam corms were studied at various moisture contents using an Instron Universal Testing Machine, a parallel plate shear apparatus, a penetrometer and a vertical band saw.

The results revealed that the lower the moisture content of the corms, the higher the tensile, compressive and shear strengths and the harder and more resistant the crop is to cutting. The crop was found to have a high degree of elasticity at 48 to 62% moisture content (wb). The degree of elasticity reduced rapidly with decreasing moisture content for moisture levels below 48% and with increasing moisture content for moisture levels above 62%.



Cocoyam *(Xanthosoma* ssp. and *Colocasia esculenta)* is a tuber and is one of the major sources of calorie intake in West Africa and other tropical countries. In West Africa, it is pounded to make 'fufu', boiled, roasted, fried or mashed before consumption. In Hawaii, it is used to prepare 'poi', a national dish (Purseglove 1976). It compares with potatoes nutritionally (US National Academy of Science 1978) – it contains 2-3% protein, 0.2-0.4% fat, 13-29% carbohydrate, 1.0% fibre and is rich in minerals and vitamins B and C (Purseglove 1976). Hence a knowledge of the rheological properties which will help in the design of machines to work on cocoyam will be useful.



Examples of the cocoyam, together with a cut section through one tuber. (Photo: *Natural Resources Institute.*)

Cocoyam has a central corm surrounded by smaller edible corms shaped roughly like cocoa pods; hence the name cocoyam. The central corm is usually planted, either whole or chopped, 100 to 150mm in the ground. It grows well in reasonably rich, loamy soil in low to medium altitudes with 1500 to over 2500mm of evenly distributed annual rainfall. A hectare of cocoyam can yield an average of 45 to 50tons of edible corms within 6 to 15 months depending on species (US National Academy of Science 1978).

Despite the large amount of cocoyam consumed and its recommendable nutritional qualities its cultivation and processing are still done purely manually.

Edward Baryeh is Professor of Agricultural Engineering at ENSIAAC, BP455, Ngaoundere, Cameroon.

Rheological studies to help machine designers

Rheology is the study of the manner in which food materials respond to an applied stress or the science that deals with deformation of matter. It provides information that is useful in the handling of raw materials and their processing in relation to the quality of the final product and can be used as a guide in designing machines to work on such materials. Other reasons for rheological studies have been outlined by Sherman (1974) and Szczesniak (1977).

The studies presented here evaluate the tensile, compressive, shear and hardness properties of cocoyam with the hope that they will help designers in producing suitable machines for planting, harvesting, handling, storing and processing the crop.

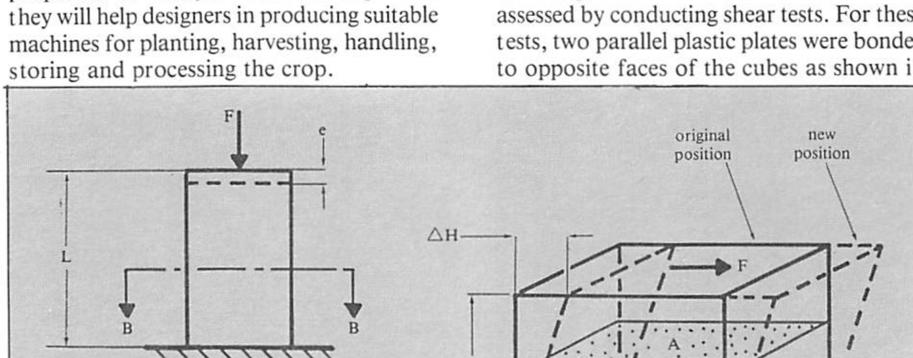


Fig 1. Normal and shear stress and strain.

Methodology

– Strength and elasticity.

Elasticity is a basic materials property. Elastic deformation is one which disappears entirely, when the force which caused it is released. Otherwise the deformation is plastic or visco-elastic.

Cocoyam corms, initially at the harvest moisture content of 70% (wb), were cut into cubes of side 20mm. The cubes were oven dried at 90°C to different moisture contents.

To evaluate the strength, the cubes were tested at different moisture contents using the Instron universal testing machine. Tensile and compressive tests were conducted on fifteen samples at each moisture level considered. To assess the degree of elasticity, the samples were compressed to 90% of their original height using the Instron universal testing machine. The degree of elasticity was calculated using equation (4). Other samples were also extended to 110% of their original height using the same machine. The degree of elasticity was then calculated using equation (5).

– Toughness and resistance to bruising

The toughness and resistance to bruises were assessed by conducting shear tests. For these tests, two parallel plastic plates were bonded to opposite faces of the cubes as shown in

Theoretical considerations

In materials testing, the deformation of the material under test resulting from the applied force, is a function of the force itself, the area over which the force is distributed and the length or height of the material being tested (see Fig 1). The effect of the force, in mechanical terminology, is stress and strain. The stress (σ) is given by:

$$\sigma = \frac{F}{A} \quad (1)$$

where F = applied force
A = area over which the force acts
Fig 1 (a) illustrates normal or direct stress while
Fig 1 (b) shows shear stress.

When the material is stressed, it deforms as shown in Fig 1. Fig 1 (a) and 1 (b) illustrate direct or normal deformation and shear deformation respectively. The deformations combine with the length or height of the material to give direct or normal strain (ϵ) and shear strain (ϕ) as follows:

$$\epsilon = \frac{e}{L} \quad (2)$$

where e = extension
L = original length

$$\phi = \frac{\triangle H}{H} \quad (3)$$

where $\triangle H$ = reduction in height
H = original height

From force-deformation measurements, the degree of elasticity (D) may be defined as (Mohsenin 1970):

$$D = \frac{D_r}{D_c} \quad (4)$$

where D_r = distance recovered by sample after the load is removed
D_c = distance the sample is compressed.

The degree of elasticity may also be defined as:

$$D = \frac{D_r}{D_e} \quad (5)$$

where D_r is as stated above and D_e is the distance the sample is extended.

Fig 2. The bonded faces were roughened lightly with emery paper to strengthen the bond. Forces were applied to the plates through spring balances without slippage at the bondage. A deformation gradient was then created across the thickness of the sample. This movement was measured by optical techniques based on principles similar to the principles of the Marten's Extensometer (Warnock and Benham 1967). A small mirror attached to the top plastic plate was viewed through a telescope mounted 2.0m from the mirror (see Fig 2). The movement of the mirror was viewed in the telescope and read on an attached scale. This displacement is equal to $\triangle H$ in equation (3).

– Hardness and resistance to cutting

Hardness was determined at different moisture contents using a penetrometer furnished with a vernier scale. The penetrometer had a steel cone as an indenter at the end of a 50mm diameter rod having a length of 150mm. The angle of the cone was 15°. The cocoyam samples were placed on a marble table. The conical end of the penetrometer was placed on the sample. A 2N force was maintained along the length of the penetrometer for 5 seconds. The hardness was then measured as the depth of penetration. This was repeated for forces of 5, 10 and 20N. After this, the load for a constant penetration depth of 5mm was measured for the samples at different moisture contents. Next, the penetration for a constant load of 10N was measured at different moisture contents. Fifteen samples were used for each moisture content.

The resistance to cutting, another measure for hardness, was evaluated by cutting the samples with a vertical band saw. A force of 5N was maintained between the samples and the saw. Resistance to cutting was assessed as the time taken to cut through the samples. Robson (1966) used a similar technique to assess the crumb strength of cake samples by measuring the force developed when a rotating blade cut a spiral path in the cake. Wade (1968) also used the time required to cut into a stack of biscuits with a circular saw blade as a measure of hardness. A vertical band saw was used in this study instead of a rotating blade or circular saw because for the samples used, the vertical band saw cut points in the sample along the same vertical line simultaneously.

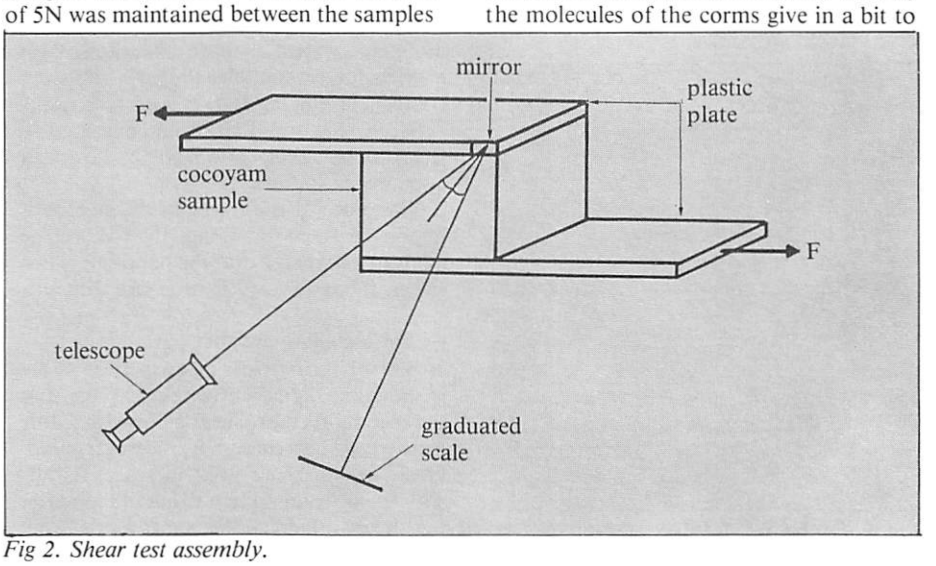


Fig 2. Shear test assembly.

The results and their interpretation

– Greater strength in compression than tension – implications for handling and harvesting machinery

The results of the tensile and compressive tests are shown in Fig 3. It is clear from the figures that the relationship between stress and strain for both the tensile and compressive tests is non-linear. At any given strain, the tensile and compressive stresses the crop can support increase as the moisture content decreases, meaning that the crop strengthens as it ages. A comparison of the two figures reveals that at any given strain, the crop can stand a higher compressive stress than tensile stress. Therefore it can support higher stresses at lower strains in compression than in tension. This is advantageous in handling and packaging when the crop is likely to undergo more compression than tension.

There are implications for harvesting in that a machine which will uproot the crop by pulling the stem is likely to put the edible corms under tension during uprooting while a machine which will uproot by scooping the soil and corms together is likely to put the corms under compression.

For the tensile test, there is a rapid increase in strain for strains between 0.10 and 0.18, with very little increase in stress at all the moisture levels considered. After a strain of 0.18, there is again a rapid increase in stress with rapid increase in strain. This indicates that for strains from 0.10 to 0.18, the molecules of the corms give in a bit to

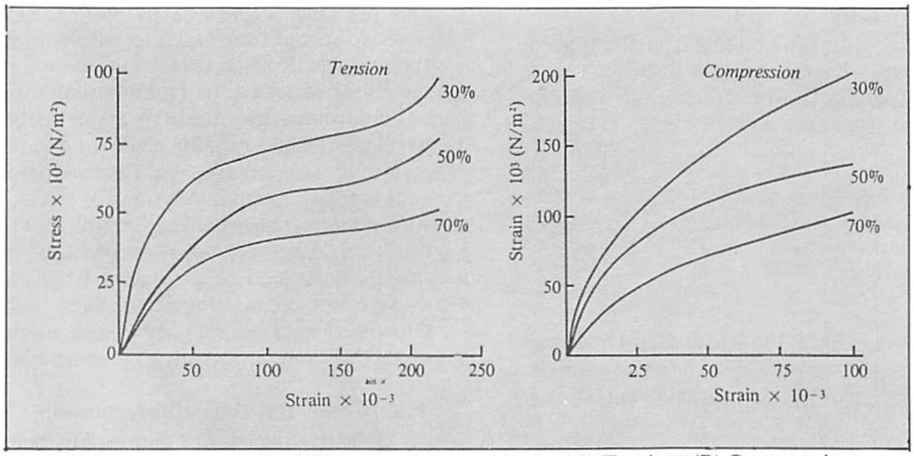


Fig 3. Stress-strain curves for different moisture contents. (A) Tension; (B) Compression.

rearrange themselves to offer more resistance to increased stress and strain. The beginning of this region will thus correspond vaguely to the yield point of the crop. This phenomenon is not apparent in the compression test. At about 0.20 tensile strain, the specimens show cracks and easily rupture.

When the portions of the tensile test graphs between zero and 0.10 strains are approximated to the linear portions of a Hooke's law graph for an elastic body, average modulus of elasticity values of 400,000, 550,000 and 730,000 N/m^2 are obtained for the crop at 70, 50 and 30% moisture contents respectively. This again indicates that the crop strengthens with decreasing moisture content.

In the compressive tests, cracks begin to appear at 0.10 strain, followed by rupture. The stress corresponding to rupture is higher in compression compared to tension for a given moisture content.

– Optimum moisture content for greatest elasticity – of benefit in handling

Fig 4 displays the results for the degree of elasticity. The figure reveals that cocoyam is not very elastic at low moisture contents in both the tensile and the compressive situation.

The crop exhibits different degrees of elasticity in the tensile and compressive situations at all moisture contents considered. It is, in general, more elastic in the tensile situation than in compression. The degree of elasticity in the tensile situation is remarkably higher than in compression when the moisture content is above 50%. The increase is at least twice as much as the increase for moisture contents below 50%. In both the tensile and compressive situations, it is more elastic between 48 and 62% moisture contents.

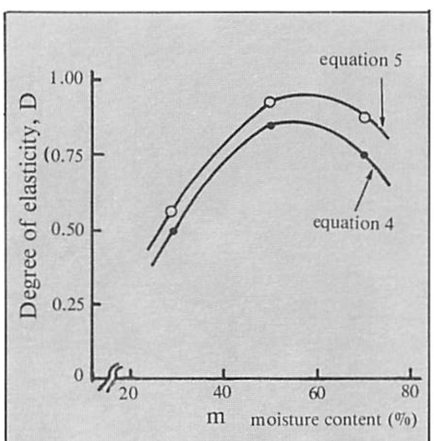


Fig 4. Degree of elasticity versus moisture content.

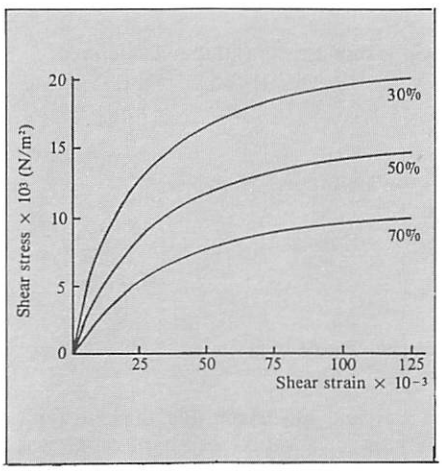


Fig 5. Shear stress versus shear strain for different moisture contents.

The peak degree of elasticity is at 55% moisture content in both situations. This may be the reason why the 50% moisture content curve in Fig 3 (A) is closer to linearity between zero and 0.10 strain compared to the others. This, however, is not very apparent in Fig 3 (B).

Therefore, if the elasticity of the crop is important in its handling, then it will be advisable to do most of the handling, when the crop has 48 to 62% moisture content.

– Peeling characteristics

A plot of shear stress against shear strain is shown in Fig 5. These results show that the crop resists more shear at lower moisture contents. The relation is, however, non-linear and the shear stress increases rapidly with shear strain up to a strain of 0.06 after which small increases in shear stress result in large increases in shear strain.

A machine designed to peel the crop would therefore operate best at the harvest moisture content when the resistance to shear is low.

Results of the hardness tests are displayed in Figs 6, 7 and 8. In Fig 6, it is clear that for a given moisture content, the load increases non-linearly as the penetration increases. Conversely, for a given load, the penetration increases with increasing moisture content. This indicates that the higher the moisture content, the more tender the crop is.

This also confirms that the crop is stronger at low moisture contents.

Machines for harvesting and handling will normally operate on the crop at 50 to 70% moisture content while machines for processing dried cocoyam into cocoyam flour (Baryeh 1982) will normally handle cocoyam pieces at 10 to 15% moisture content. At this low moisture content, the crop becomes so brittle that loads greater than 10N applied to the penetrometer break the samples.

When the penetration is held at 5mm, it is seen from Fig 7 that the load decreases with increasing moisture content indicating that the higher the moisture content, the more tender the crop is, as indicated above.

The results of the penetration for the

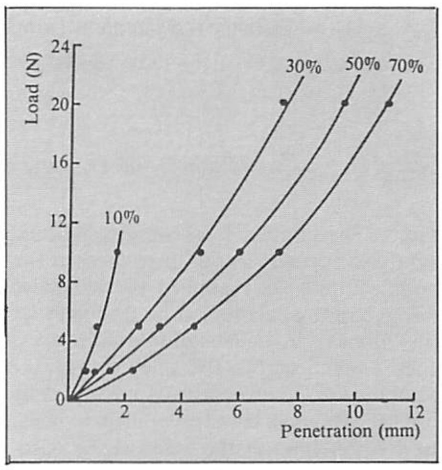


Fig 6. Load-penetration curves for different moisture contents.

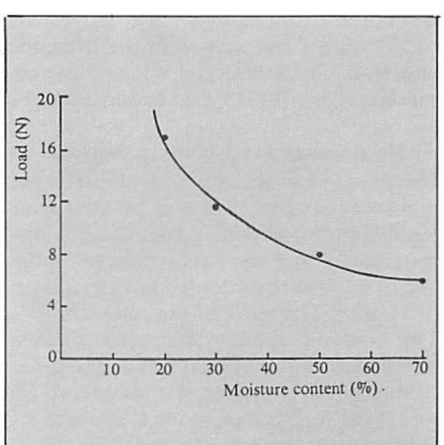


Fig 7. Load variation with moisture content for 5mm penetration.

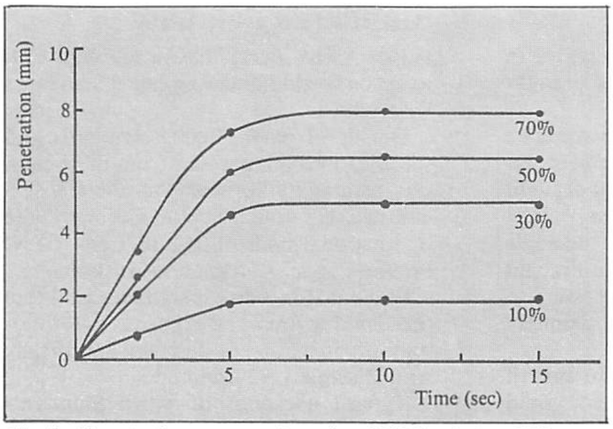


Fig 8. Penetration versus time for 10N load for different moisture content.

application of a constant load of 10N (see Fig 8) show that at all the moisture contents considered, the penetration increases as the load application time increases up to a time of 6 to 8s. depending on the crop moisture content. After this, there is very little increase in penetration with time and the

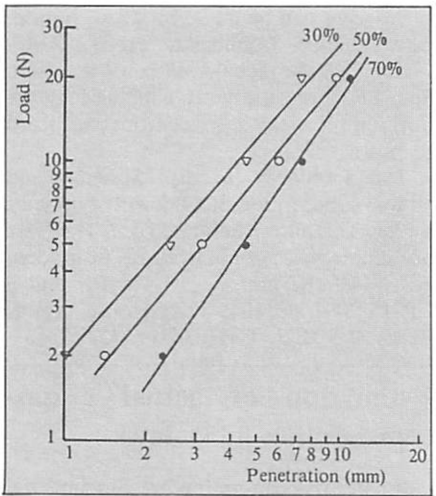


Fig 9. Load versus penetration on log-log sheet.

curves become assymptotic. Also at any given load application time, the higher the crop moisture content, the higher the penetration.

Up to a load penetration time of 5s, the penetration varies almost linearly with the load application time. This test also confirms the relative tenderness of the crop at high moisture content.

The load-penetration curves (see Fig 6) plot linearly on log-log sheet as shown in Fig 9. This indicates that the following relation exists between the load (F) and the penetration (p):

$$F = Ap^a \qquad (6)$$

where A = a constant given by the intersection on the load axis

a = a constant given by the slopes of the lines.

The load versus moisture content for 5mm penetration (see Fig 7) also plots linearly on log-log sheet as indicated by Fig 10. This also suggests that the relation between the load (F) and the moisture content (M) is given by:

$$F = BM^b \qquad (7)$$

where B = a constant given by the intersection on the load axis

b = a constant given by the slope of the graph.

– Slicing, cutting – best results on crop soon after harvest

Fig 11 shows the results of the resistance to cutting tests. It is seen from the figure that the higher the moisture content, the less resistive the crop is and hence the faster it can be cut. This means that if an engineer wishes to design a machine to slice the crop for drying or frying either for storage (Buryeh 1982) or for eating, it is better to design one that will slice it as soon after harvest as possible when it is still tender. Slicing at low moisture contents will require more time, more energy and a stronger cutter.

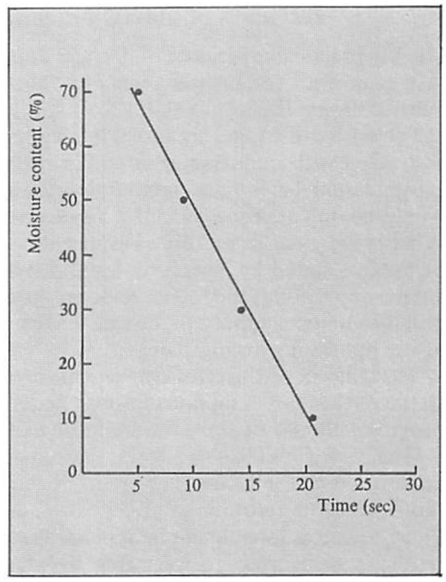


Fig 11. Moisture content versus cutting time.

These hardness and resistance to cutting results also suggest that during handling and conveying, parts of conveying and handling machines that touch the crop should be cushioned whenever possible. This will reduce the damage to the crop, thus improving quality and reducing losses in storage.

Bowls of dasheen and cocoyam on offer at a local market in Bamenda Province, Cameroon. (Photo: Natural Resources Institute.)

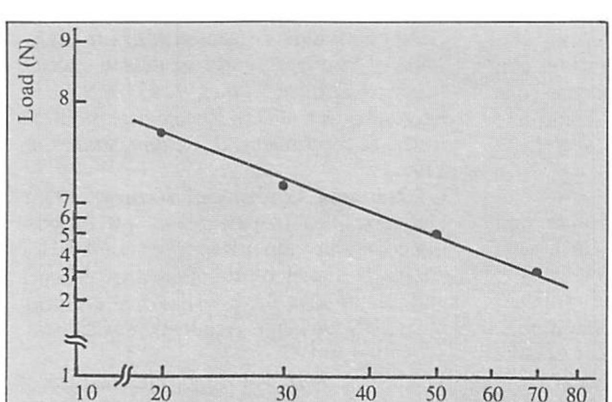


Fig 10. Load variation with moisture content on log-log sheet.

Conclusion

The studies have shown that the tensile, compressive and shear strengths of cocoyam increase as the moisture content of the corms decreases. The degree of elasticity, however, decreases as the moisture content of the corms decreases.

It has also been found that the lower the moisture content, the harder the crop is and the more it resists cutting and abrasion.

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Mechanics of animal-draught cultivation implements

Sir, My practical experience of draught animal power at AFRC Engineering causes me to take issue with certain statements in your article on the mechanics of animal-draught cultivation implements (Vol 45, No.1, pp 13-17).

Table 1 is misleading because it implies that a purely horizontal draught force would be associated with an infinitely large horizontal resistance to motion of an implement. By extrapolation Table 1 also implies that for an angle of pull of 85° the implement draught would be only 0.087 × effective vertical force and draught would be zero at $\alpha = 90°$! What is not clear from Table 1 is that the effective vertical force changes with the angle of pull, as stated by equations 4 and 5, *viz* $V = P\sin\alpha$ and $V = H\tan\alpha$. In draught animal applications the force vector polygon is determined by H, the draught necessary to pull the implement through the soil, and by α, the angle being dependant on the geometry of the harnessing arrangement.

The concept of the effective vertical force is confusing since, by definition, the sum of all the vertical force components must be zero (on average) otherwise the implement would progressively rise or sink. Furthermore this is not the same as V in equations 4 or 5.

Finally, I would like to suggest that much of the confusion has arisen through invalid application of the second version of equation 5, *viz* $H = V/\tan\alpha$. As α tends to zero, $\tan\alpha$ tends to zero but so also does V, as confirmed by equation 4, *viz* $V = P\sin\alpha$. Thus, equation 5 should not be applied, as zero divided by zero does not yield a determinate result. It is incorrect to infer that V (whatever it represents) divided by zero gives an infinitely large value.

D H O'Neill
Overseas Division AFRC Engineering, Silsoe, Bedford.

Our apologies to Dave O'Neill, as this letter should have appeared in last month's issue but was temporarily mislaid en-route to me. **Ed.**

Working of restored land – views sought

Sir, I am involved in a research project into opencast coal mining, the long-term aim being to alter legislation. I address this letter to anyone with experience of farming land that has been mined by opencast methods.

All mining has an adverse environmental impact, but opencast, it seems, is responsible for the worst damage. Mining operators insist that the land affected by the industry is restored to its original condition, or better. While I understand that in cases of dereliction there may be cause for improvement, I have difficulty in believing that cosmetic returfing is acceptable for what was previously mature meadow or active agricultural land. When natural strata has been devastated can the land be fully fertile in the conceivable future, if at all?

I am interested to hear farmers' views about problems or benefits of working on mined land. What is the quality of the soil? Is excessive investment in fertiliser necessary, is water drainage difficult? Or is the land as good or better than ever? Comments from tenants of companies such as British Coal are also welcomed.

Rebecca Wright
111 Dalmeny Avenue, Norbury, London SW16 4RR.

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Hence, depending on the operation being performed on the crop, a compromise has to be made between the tenderness level and the degree of elasticity.

In general, most machine operations can be performed at 48 to 62% moisture content when the crop is most elastic and has medium tenderness.

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Standards database

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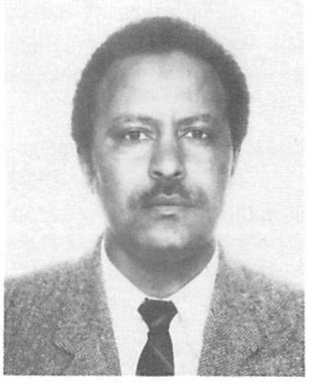
Estimation of actual evapotranspiration in Malawi

Estimates of evaporation are fundamental in assessing the water resources of Malawi, whose economy is so dependent on hydropower and fish stocks in Lake Malawi. The majority of previous evaporation studies in the area have been directed towards estimating open water evaporation and potential evapotranspiration. Actual evapotranspiration has not been examined in any detail.

In Report No.110, published by the Institute of Hydrology, six methods of determining regional values of average annual actual evapotranspiration from a mixed vegetation surface are applied to observations from 20 climatological stations in Malawi. Three of these methods are recommended for practical use in Malawi: catchment waterbalance, soil moisture recharge and a new empirical approach expressing actual evapotranspiration as the difference between the values of the constituent energy and aerodynamic terms of the Penman formula for short grass potential evaporation.

'Estimation of actual evapotranspiration in Malawi' is available, price £7, from: The Librarian, Institute of Hydrology, Wallingford OX10 8BB.

Land use planning using an energy approach



T G Tekie points out that traditional land use planning is aimed at improving the management of an existing land use and does not give consideration to the fulfilment of the daily energy and protein needs of the users. In this article he describes an exercise to devise a land use plan for a specific area by using the energy required both in terms of food and firewood as well as the protein needs of the community. Daily intake of energy, protein and firewood are then converted into the land area that is required to produce them.

A land use plan was drawn out for the Nyamzue watershed, in Zimbabwe using energy calculations of 2300 calories of energy and 39.3 grams (g) of protein per person per day.

Taking sequential air photos for 1955 and 1966, the population increase was studied. The population increased by 28% in 11 years or 2.5% annually, implying an increase in energy needs by the same margin. The total energy computed was converted into yield in terms of crop and animal produce. Similarly the fuel needed from natural woodland and eucalyptus plantation was estimated and the size necessary to produce it derived.

The land use for the watershed was estimated at 142 hectares of arable land, 1210 hectares of pasture and 97 hectares of forest or tree plantation. The size of land needed for 1966, which was 28% more than that of 1955, was found to be 1855 hectares.

At prevailing levels of production and including contingency crop and animal production, the watershed can sustain its inhabitants up to the year 1989.

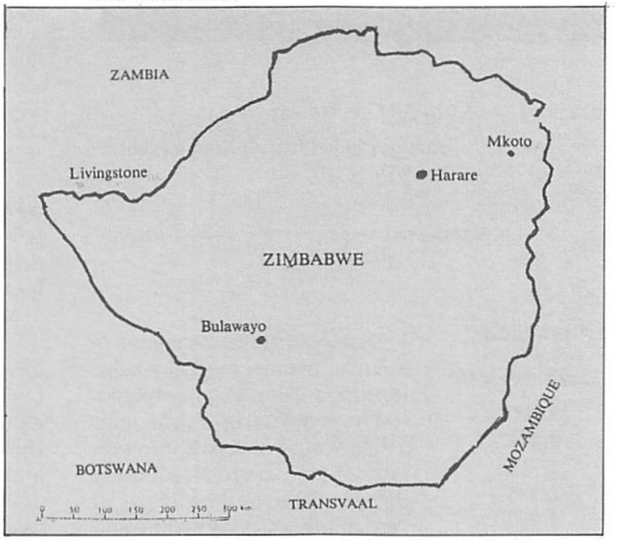
The study area of Nyamzue watershed after the river Nyamzue) is located in Mtoko region, Mashonaland South, Zimbabwe (Fig 1). It is situated between latitudes 17° 15′ and 17° 15′ 34″ and longitudes 32° 9′ 43″ and 32° 12′. Its size is 27 km² or 2700 hectares (Fig 2) of which 10 km² is suitable for crop cultivation while the remaining 17 km² is mainly mountainous woodland and rocky waste. Almost the entire population lives in huts.

Measurement of population and food/energy requirement

FAO (1979) considers that in Zambia the amount of energy required per person per day is 2300 calories and 39.3 g of protein. Adopting these figures for neighbouring Zimbabwe especially Mtoko which is close to Zambia, energy computations for the Nyamzue catchment can be done.

Although there is a range of energy requirement, in that children and women need less than these averages, adults and working men also need more than this. Thus the daily energy need is an average quantity. Table 1 lists recommended daily intake of energy and protein for various age groups and sexes in Africa. Similarly the protein amount is an average figure.

Using a pair of stereoscopes and air photos of 1955 and 1966, individual huts were counted to estimate the population of the watershed.



Zimbabwe, indicating Mtoko and the area of the Nyamzue watershed.

Discussions with Zimbabweans has revealed that a family in Zimbabwe typically, consists of 8 members and owns 5 huts. One hut is for the parents, one for boys, one for girls and the remaining two are kitchen and store.

From this it can be calculated that the mean occupancy per hut is 1.6 heads. The total number of huts counted from air photographs of the area in 1955 were 369.

The population in 1955 therefore was:

$$369 \text{ huts} \times \frac{1.6 \text{ heads}}{\text{hut}} = 590 \text{ heads}$$

Energy required

$$= 2300 \times 365 \text{ days} \times 590$$
$$= 4.95 \times 10^8 \text{ calories per year}$$

protein required

$$= 39.3 \times 365 \text{ days} \times 590$$
$$= 8.46 \times 10^6 \text{ grams per year}$$

Food sources

Again, discussions with people who worked in Zimbabwe revealed that the diet in Zimbabwe consists of *sadza* (combination of maize, millet and sorghum), *usava* (cooked vegetable, peanut butter and cow-peas) and cooked meat mixed with peanut. Meat actually

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is scarce. Some fruits and vegetables are available during the dry season.

From this it follows that maize, groundnuts, sorghum, soya, meat and animal products can be taken as the main diet

Table 1 Recommended daily intake of energy and protein for populations in Africa.

Population group	*energy (cals)*	*protein (g)*
Adult man active (55kg)	2530	31
Adult woman active (47kg)	1880	24
Boys: 10-12 years	2600	30
Boys: 13-15 years	2450	30
Boys: 16-19 years	2580	30
Girls: 13-15 years	2120	29
Girls: 16-19 years	1970	29
Children: below 1 year	820	14
1-3 years	1360	16
4-6 years	1830	20
7-9 years	2190	25

Source: FAO (1979)

which can be produced in the area.

It is assumed that 90% of the food requirement can be produced locally within the watershed while 10% must be imported.

Farming in the region of Nyamzue.

Among the crops and foodstuffs that are imported are sugar, oil, coffee, tea, fish, spices and millet. Vegetables and fruits are partially imported and partially produced in the catchment.

In Table 2, a breakdown of crops and animal products is shown.

Spedding (1979) gives the following figures

Table 2 Breakdown of crops and animal products.

type of produce	*% of total*	*required cals × 10^7*
maize	60	29.700
ground nuts	5	2.475
sorghum	10	4.950
soya	5	2.475
animal products	10	4.950
others	10	4.950
Total	100	49.500

as world sources of energy intake; grains, roots and tubers 62.7%, fruits, nuts and vegetables 9.6%, sugar 7.3%, fats and oils 8.9%, livestock products 10.8% and fish 0.7%. He also indicates the balance of grains, roots and tubers may exceed 70% while livestock products may fall to 5% in less developed countries. This was borne in mind in the derivation of Table 2.

Cereals accounted for 70% because sorghum is used additionally for local brewing. The consumption figure for animal products is slightly above that for developing countries but was done deliberately to improve the nutrition hence the energy of the watershed people.

Crops required

FAO (1979) gives a list of calories and protein derived per 100 gms of diet as shown in Table 3.

The total yield required to produce the needed energy and protein can be computed by dividing the energy required by the watershed population with the energy derived from each 100 kg of produce.

e.g. maize

energy required from maize

$= 2.97 \times 10^8$ cal

energy yielded from 100 kg of maize

$= 3.59 \times 10^5$ cal

$$\text{Total required} = \frac{2.97 \times 10^8}{3.59 \times 10^3} = 82.7 \text{ tonnes}$$

By repeating the calculation in a similar manner for the remaining crops Table 4 was prepared.

The production shown in Table 4 was converted into hectares of land to produce it using data furnished by the Ministry of Agriculture, Conservation and Extension in Zimbabwe (1980).

Figures for Mtoko are set out in Table 5. As there are wide fluctuations in yield the coefficient of variation (CV) is included. The higher the CV, the more unreliable the weighted average becomes. In this case the weighted average is for 7 years.

Table 3 Calories and grams of protein from 100g of produce.

crop	*cals*	*protein (g)*
maize	359	9.3
ground nuts	549	23.2
sorghum	347	11.1
soya	405	33.7

Table 4 Crop production needed to sustain energy requirement of the whole watershed inhabitants for 1 year.

crops to be produced	*tonnes*
maize	82.7
ground nuts	4.5
sorghum	14.3
soya	6.1

Allowance for drought years

From previous data, it is to be.expected that once every five years there will be drought hence farmers have to produce 25% extra production every year for 4 years to accommodate the drought. From Table 5, it can be seen that the arable land required was 63 hectares, therefore 25% extra land amounts to 16 hectares annually for the watershed. As there are no statistics available for crop losses in store no estimate was included for this.

Moreover, it is suggested that one family in the watershed should aim to support one family in town which implies that an additional 63 hectares of land is needed. From Table 6 it becomes obvious that the total area needed for arable farming was 142 hectares in 1955.

The number of people living in the watershed was calculated to be 590 in 1955. Since a family comprises of 8 members, the total number of families was estimated at 590/8 = 74 families.

Area per family was:

$$\frac{142 \text{ hectares}}{74 \text{ families}} = 2 \text{ hectares approximately}$$

Animal products requirement

It has been shown in Table 2 that animal products provide 10% of the energy required by the watershed people. This amounts to 4.95×10^7 calories.

Table 7 shows the breakdown of this 10% into various animal products. Spedding (1979) considers carcass weight of a beef animal as 55% of live weight. Lowering this figure to 50% to fit African situations and taking the live weight of 1 cow/ox as 200kg, a goat as 34kg and a chicken as 2kg (author's experience) Table 7 is derived. The weight of 1 egg is taken as 60g and a litre of milk approximately 1kg.

Table 5 Production per hectare and total area needed for production.

crop	*production*[1] *Q/ha*	*CV* *%*	*area needed*[2] *ha*
maize	20.0	–	41.0
ground nuts	13.0	33.8	3.5
sorghum	10.7	32.0	13.0
soya	11.0	90.5	5.5
Total			63.0

Notes 1. One quintal (Q) = 100kg.
2. The figures for area needed were derived by dividing the total production (as shown in Table 4) required to feed the resident population by the production per hectare.
Thirty percent more area for losses ought to have been considered but due to the smallness of the area needed, it is ignored.

Table 6 1955 arable area size.

land needed for	*hectares*
1955 production year	63
1955 contingency production	16
1955 support for town family	63
Total	142

The calories and protein per kilogram are also included in Table 7.

Stocking rate is taken as 5 hectares for 1 beef animal and 1 hectare for 1 goat, because there is overgrazing in Mtoko and forage yield is low.

Again, considering 'export' to town, double the size is required hence the total area for animal and animal products production is 2 × 605 ha = 1210 hectares.

Table 7 Breakdown of animal produce.

produce	*%*	*cals reqd.* $\times 10^6$	*cal/kg*	*prot/kg (g)*	*q*	*No. of animals*	*hectares*
beef	40	19.08	2370	182	84	84	340
goat meat	10	4.95	1450	160	34	200	200
eggs	20	9.90	1400	118	70	1170	–
poultry	10	4.95	1390	190	36	3600	–
milk	20	9.90	790	38	125	13	65
Totals	100						605

Ample protein available

The total protein required for the watershed was computed as 8.46×10^6 grams per year. Whether this protein is available from the crops' and animal productions should be checked to ensure the nutritional need of the inhabitants. This is shown in Table 8.

It becomes apparent that the protein produced, 16.4×10^6g, is almost double that required (8.45×10^6g). Therefore, the production derived to meet energy needs also meets the protein requirement of the inhabitants.

Fuel needs

According to FAO (1981) fuelwood required for Africa south of the Sahara is 1.2-1.5m³ per head per year for 1980. Adopting the figure for 1955:

Fuelwood needed for the 590 population of the watershed is –
$1.5\text{m}^3 \times 590 = 885\text{m}^3$ of wood per year.

Further, FAO (1983) gives the following yield from typical situations:
- Tropical high forest 80-100m³ of wood/ha.
- Savannah 20- 45m³ of wood/ha.
- Eucalyptus 12-15 yrs old 80-200m³ of wood/ha.

If eucalyptus which will grow in Mtoko is planted the system that might be adopted would be:
- first cut at 8 years after planting
- second cut at 6-7 years after 1st cutting
- third cut at 6-7 years after 2nd cutting

After 20-22 years it should be uprooted and a new plantation established.

Assuming 30% of the fuel is available from the natural woodland and 70% from eucalyptus planting the area required is:
woodland 30% of 885m³ = 265.5m³
eucalyptus 70% of 885m³ = 619.5m³
taking yield for woodland as 30m³/ha, the area required is:

$$\frac{265.5}{30} = 8.85 \text{ ha/year}$$

Assuming first cutting is carried out at 7 years, area needed is:
8.85 × 7 = 62 hectares.

Taking a yield for eucalyptus as 140m³/ha the area required is:

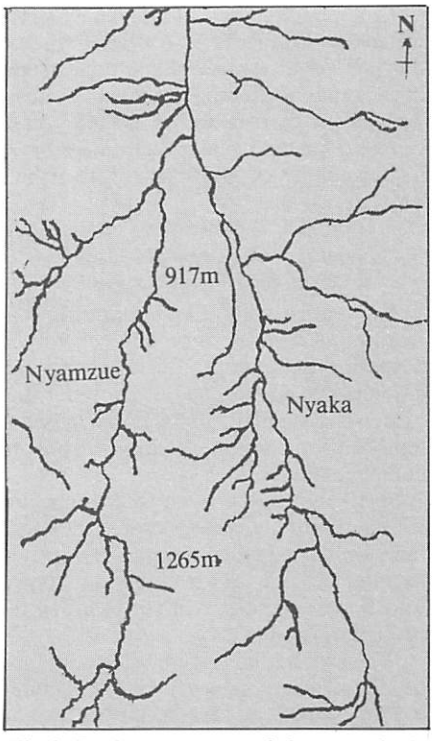

Fig 1. Drainage pattern of the watershed
Scale 1:50,000

$$\frac{619.5}{140} = 4.4 \text{ ha/year}$$

First cutting of eucalyptus will take place in 8 years time and in order to have a continuous cutting cycle the first 8 years should be planted at a yearly rate of 4.4 hectares. A total of 35 hectares of eucalyptus is therefore required.

Total forest area = woodland + eucalyptus = 62 + 35 = 97 hectares.

Since the area is prone to erosion as much land as possible should be under permanent vegetation hence the possibility of exporting fuelwood is discounted. If farmers want to make charcoal, the conversion is 7-11m³ of solid wood to a ton of charcoal FAO (1983).

Land planning

– Land use 1955

Total area used in 1955 was:

crops	142 hectares
grazing	1210 hectares
forest	97 hectares
Total	1449 hectares

Table 8 Protein derived from crop and animal produce.

Product	*Produce (q)*	*protein per quintal (g)* $\times 10^3$	*total protein* $(2 \times 3) \times 10^6$
maize	827	9.3	7.7
ground nuts	45	23.2	1.0
surghum	143	11.1	1.6
soya	61	33.7	2.1
beef	84	18.2	1.5
goat meat	34	16.0	0.5
eggs	70	11.8	0.8
poultry	36	19.0	0.7
milk	125	3.8	0.5
Total			16.4

The total number of animals for the watershed (Table 7) is: cattle (beef and dairy) 97 head, goats 200 and poultry (egg laying and meat production) 4770 hens. To convert each figure on a family basis can be done by dividing each figure by 74 *i.e.* the number of families in the watershed. This is equivalent to:

cattle 1.3 head per family
goats 2.7 head per family
chicken 64.0 head per family

As for afforestation 4.4 hectares per year requires 8800 holes to be dug per year at a spacing of 2.5m × 2m. For 1955 this amounted to about 120 holes per family per year. At a standard of 20 holes/man-day (author's experience), it takes 6 days to complete the job.

Furthermore, the family can contribute labour towards guarding protected woodland which increases by approximately 9 hectares per year. Each family can contribute 5 man days per year for guarding the protected woodland.

When all the above is considered, the size of land which remains for future planning is 2700 − 1449 = 1251 hectares.

– Land use 1966

The population increase from 1955 to 1966 was 28%. The implication of this was that the energy requirements also grew by 28%. The population structure can be assumed to have changed and by 1966 to have a majority of small children who need more protein. As was shown already (Table 8) there was enough protein to sustain such a growth.

– Future land use

Between 1955 and 1966, the increase in land area required for development was 406 ha. Even at the same level of population increase after 1966, the Nyamzue catchment area will only have sufficient development land for 22.5 years (834 ha./37 ha. per annum). Therefore, the Nyamzue catchment cannot sustain any more people as from 1989 onwards. However, to perpetuate the use of the catchment for the future, the following changes could be adopted:

- As the area suitable for cropping is 1000 hectares and only 142 hectares were utilised in 1955, further land could be used for the production of protein rich crops such as soya and groundnuts to replace protein derived from livestock which demand a large area of land.
- Crop yields are not high and with improved breeds and better husbandry significant increases could be achieved.
- Significant increases in animal products could be achieved with better breeds.
- Fast growing tree species could be adopted to improve the fuel supply situation, enabling less land to be occupied by forest.
- The export of crops and livestock to the urban centres could be abandoned.

If all the above changes fail, then resettlement of the people must be considered.

Area Calculation for Animals

Beef

$$\text{Amount needed} = \frac{\text{calories required}}{\text{calories/quintal}}$$

$$= \frac{19.8 \times 10^6}{2370 \times 100} = 84 \text{ quintals of meat}$$

Assuming 1 live animal weighs 2 quintals (author's experience) and net carcass weight is 1q, 84 animals will be needed.

Grazing area for 1 animal is assumed to be 5 hectares/year. Therefore, area = 84 × 5 = 420 hectares.

Goat meat

Using similar calculation as above 34q of goat meat is needed. Assuming net carcass weight of 17kg/goat, 200 goats are needed. If 1 hectare is allotted/goat, it will be 200 hectares.

Eggs

One egg weighs approximately 60g.

$$70q = \frac{7{,}000{,}000g}{60g/egg} = 117{,}000 \text{ eggs}$$

assuming one hen lays 100 eggs per year, then:

$$\frac{117{,}000}{100} = 1170 \text{ hens are needed.}$$

As hens need a small area, it is neglected from watershed area computations.

Poultry

Total poultry meat needed is 3600kg. Assuming net weight of one chicken to be 1kg. 3600 chickens will be needed.

Milk

125q. = 12,500 litres (approximately). Assuming a cow yields 3 litres of milk/day, for one year (300 days) it is 900 litres or approximately 1000 litres.

$$\frac{12{,}500}{1{,}000} = 13 \text{ cows}$$

13 cows × 5 ha/cow = 65 hectares

Energy approach planning – possible application in other countries

A plan using the energy approach has the advantage that it enables a farming family to produce food and fuelwood which are adequate for itself and for marketing if need be. Consequently, the size of the land that is allocated to the family is such that it is not small enough to starve the family and not large enough to be inoperative. It is just sufficient to sustain the family.

The approach can be extended to other countries such as Eritrea and could be very attractive for proposed settlements. The methodology is adaptable to take into consideration energy requirements of any country and the staple food of that country not forgetting the protein production which is vital for children.

Acknowledgements

The research presented in this paper was part of the MSc studies of the author at Silsoe College, England in 1984. The scholarship was financed by the FAO and supervised by M A Keech.

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ADAS grows apace

The latest ADAS brochure reports – in their words – a veritable explosion in the number and variety of the businesses they now serve.

With already over 85,000 clients, ADAS report that new clients are joining at the rate of some 1500 a month and there is a high proportion of repeat business. Significantly, they say they are finding themselves working more and more on a continuing, contractual basis, often in development of new ideas and new business strategies.

Wide range of ADAS services

Entitled 'The Progressive Resource', the brochure lists ten subject areas of ADAS expertise. These are:

Livestock · Cropping · Horticulture
Business management · Product marketing · Land management
Design services · Research and development and Special projects · Laboratory

Diversification

On the subject of diversification, it is recognised that, together with the need to eliminate European agricultural over-production there is a search for new land uses, new commercial ventures, greater 'added value' in existing enterprises. ADAS point out how their specialist knowledge has been, and is being, brought to bear in many such developments. Feasibility studies can be carried out, including the necessary level of investment in finance, premises, staff and marketing. Examples of recent diversification projects include:

- economic uses for farm woodland thinnings
- new wildlife habitats to add value
- redundant buildings converted to profitable holiday homes
- quality control procedures on a continuing basis
- designing a golf course.

New ultra-compact, integrated track drive gearbox and motor, for hydrostatic vehicles

To accommodate the new breed of miniaturised hydrostatically-driven vehicles, Brevini has launched two mini Compact Track Drive models, complete with integrated hydraulic motor and brake, which are claimed to be amongst the smallest on the market. Until now, the company supplied its planetary wheel and track drive gearboxes, with plug-in proprietary cartridge motors; the latest designs feature fully integral gear units and motors, both manufactured by Brevini.

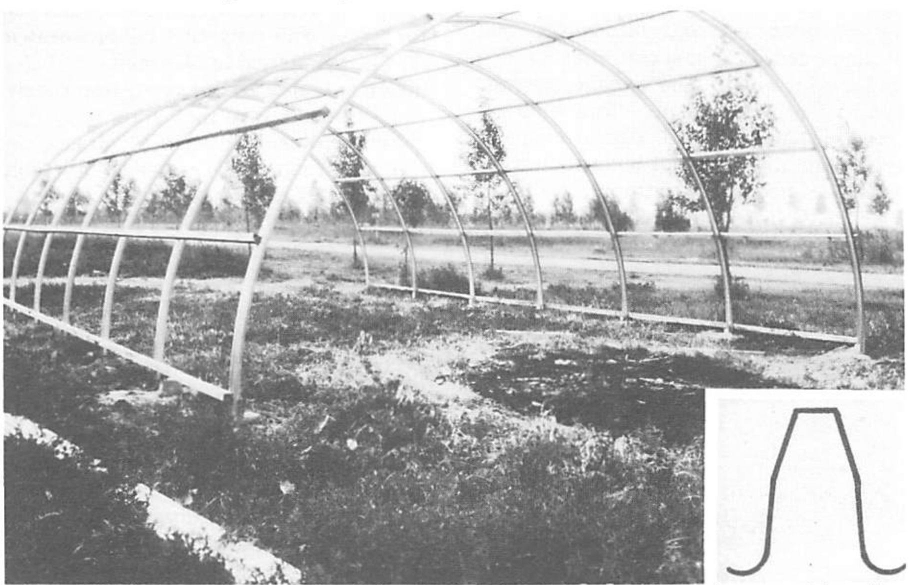
Two models are offered, CTD 1010 and CTD 1020, each with a choice of motor sizes. Apart from their exceptionally light weight and compact dimensions, they offer the traditional advantages of high speed motor/gearbox packages, over low speed hydraulic motors alone: lower motor cost, reduced downtime for maintenance and repairs, and less risk of damage from contaminated hydraulic fluid.

Typical applications include mini excavators, skid-steer loaders, small access platforms, ATV's, vibratory compactors, crop sprayers and other small-scale tracked or wheeled mobile plant, where low speed and high torque performance characteristics are required.

The CTD 1010 models, with nominal 1.2kNm maximum torque rating, weigh between 32.5kg and 34kg, according to motor capacity, and measure just 215mm wide × 220mm diameter; sister unit, CTD 1020, has 2.2kNm potential output, weighs less than 44kg and is equally compact at just 250mm × 215mm.

Further information from: Brevini, Planet House, Centre Park, Warrington WA1 1QX. Tel: (0925) 36682.

Haleco BV special profile



Haleco BV of Hoorn (the Netherlands) has developed and placed on the market a special profile intended for roof trusses for multifunctional tunnel-type buildings (Nissen huts and Romney-sheds). Viewed in cross-section, the new profile has approximately the shape of an inverted omega.

Compared with the traditional T profile, the new Omega profile is said to offer virtually identical bending resistance but with a very substantial saving in weight.

Haleco markets a complete range of galvanized steel and aluminium panels for external wall claddings, etc. The panels are produced by the cold-profiling process.

Deputy Director of SCAE

Henry Spencer

The Scottish Centre of Agricultural Engineering has announced the appointment of Henry Spencer as Deputy Director.

Henry – a Fellow of the Institution of Agricultural Engineers – joined the SIAE in 1968 and transferred to the new SCAE as Head of the Engineering Systems Dept in 1987. His early experience in aerodynamics, stress analysis and thermodynamics has more recently been applied to crop conservation, vehicle stability and solar radiation microclimates.

Following his appointment as a University Fellow by the Mechanical Engineering Dept, Edinburgh University, he has been involved in the supervision of honours projects undertaken by Engineering students, in addition to those taken by Agricultural students.

Henry has been particularly successful in attracting externally funded contract R&D work, perhaps partly because of his commercial engineering experience. He is most recently identified throughout the Scottish Agricultural College for his active role in the provision of a COSHH (Control of Substances Hazardous to Health) Service.

UK sales drive for Portuguese four wheel drive vehicles

Signalling the start of a major UK sales drive, the Portuguese UMM range of 4-wheel drive vehicles were shown at this year's Motor Show at the NEC, Birmingham.

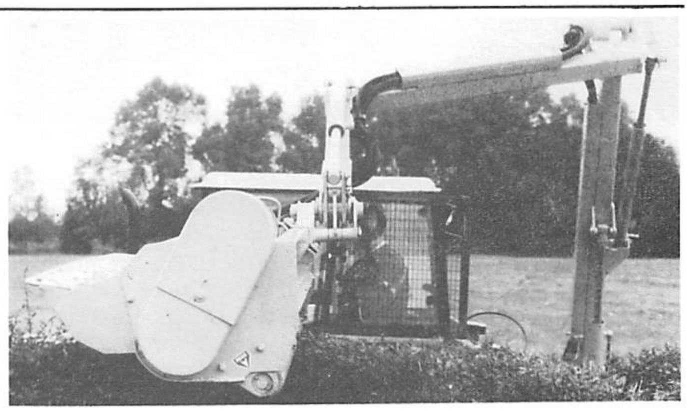
Peter Jones, Technical Director of SMC Products Ltd, the British concessionaires for UMM, comments: "SMC already has an initial network of UK sales and service centres. We are now keen to extend further the number and spread of dealerships".

Bomfords have introduced the new B53 XM hedgecutter specially designed for the UK market. A high first arm pivot height gives the correct geometry for cutting on both sides of the hedge and facilitates siding hedges in lanes not much wider than the tractor.

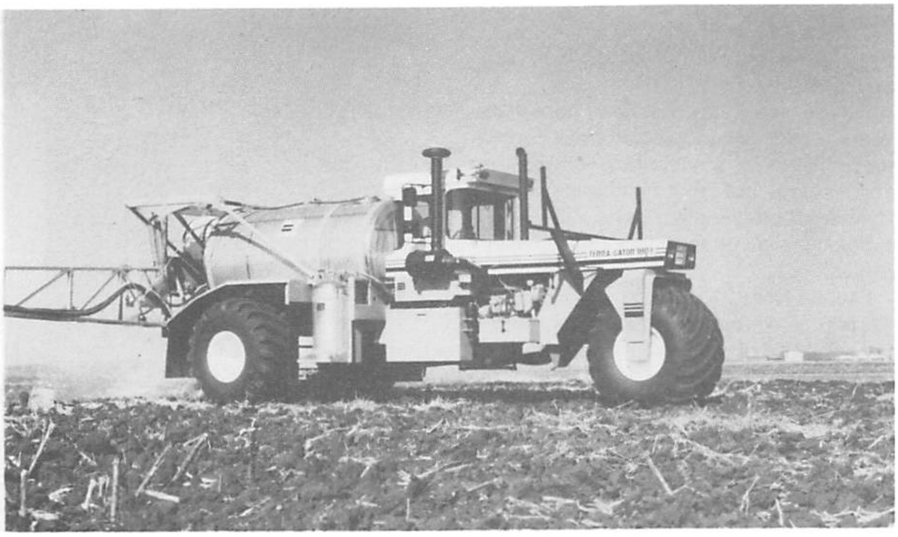
With 5.3m (17'4") reach arms and forward extension of 1.3m (4'4") the B53XM also has a wider than normal 1.25m (4'4") cutting head to give increased output and is fitted with the guaranteed unbreakable dual-purpose flail which will cut grass or timber up to 40mm (1½") thick. Rotor speeds of 3,000rpm or 2,400rpm can be selected for optimum performance on grass or hedges. The drive motor is mounted in-board to allow cutting right into corners.

Price of the standard model is £8850. Electric solenoid controls are available as an option to the standard well proven remote cable system.

Bomford Turner Ltd, Salford Priors, Evesham, Worcs WR11 5SW. Tel: (0789) 773383.



Specialist materials application vehicle



Flotag of Rugby (tel: (0788) 535891) have introduced their new model Terr-gator 1803, specialist materials applications vehicle. Features of this new model are the 275 HP Cummins engine, 18 speed gearbox and the new, quieter, flat-floored cab.

The Terr-gator 1803, like its stablemate the 1603, is a single front wheel steered vehicle, with single driven rear axle. All three wheels carry ultra wide, high flotation tyres, for minimum soil compaction and disturbance.

An important new option and also available for retro-fit to existing models of Terr-gator, Ag-gator and Big-A, is Syncro-3, a new electronic system for synchronising the vehicle forward speed and relative output of lime, fertiliser, chicken litter or dry sludge cake, with suitable spreader systems. Syncro-3 provides in-cab information on speed, distance travelled, area covered and application rate. A major innovation is in-cab adjustment of application rates up to 30%, in 2% increments, while on the move.

New recycling centre for Safety-Kleen

Operations have already started at Safety-Kleen's brand new Recycling and Distribution Centre at Dinnington, South Yorkshire.

The £7 million complex represents an important step for the company whose parts-cleaning operation now has over 33,000 customers in the UK. With nationwide distribution centralised, and a state-of-the-art recycling plant established, the company can offer an unrivalled service to industry through its 20 branches.

The greenfield site at Dinnington was chosen as it offered both the geographical location and the degree of space required for the project. With an excellent local pool of experienced workers, the company was able to have the centre up and running only 12 months from the start of construction.

Used mineral spirits (in tankers) and thinners (in drums) arrive at the plant ready for recycling. Following stringent testing to ensure that the solvents have not become contaminated with unacceptable matter, the products are recycled and returned to the branches for distribution to customers.

Ninety percent of the solvent is reclaimed for re-use, making the process exceptionally cost effective. Of the remaining 10%, 5% is sold on as a fuel with the 5% dry residue sent for off-site disposal.

The company is proud of its contribution to the environment through its preservation of the world's oil resources and the part it is playing in the control of pollution.

Research funding in Europe

UK lags behind

Research and development funding in the UK is compared with France and Germany in a recent report by Dr Harold Atkinson of the Science and Engineering Research Council.

Based on figures for 1987, the last year for which details are available, the UK lags well behind it's neighbours. In that year (public and industrial sectors combined) at normal currency exchange rates, Germany spent £19 billion, France £12.8 billion and the UK only £9.7 billion. Interestingly, each country has similar numbers of researchers with 130,000, 109,000 and 144,000 in the UK, France and Germany respectively. This results in funding per head of £73,000 in the UK compared to £128,000 in Germany. Support workers per researcher are quite different also at 1.77 in Germany, 1.55 in France and only 1.20 in the UK.

When one extracts the funding for defence from these statistics, the UK government-sponsored civil research sector comes out far worse with only £2.4 billion spent in the UK as opposed to £4.7 billion and £6.4 billion in France and Germany respectively. Even if one looks at the figures using purchasing power parities (PPP), France still spends 54% more and Germany 87.5% more than the UK. As a percentage of Gross Domestic Product (GDP), the picture is similarly bleak for the UK at only 0.58%, with 0.88% and 0.96% spent in France and Germany.

Although not easy to estimate, the report also tries to sort out what percentage of research expenditure is spent on 'basic and strategic' research in each of these three countries. Here the UK spends around half of that in Germany and two-thirds that of France at market rates.

Although the report does not in any way try to assess the quality or quantity of research output from these three EEC countries it does highlight the anomalies that exist between them regarding support for R&D by both industry and government and in the way R&D is controlled, leading up to 1992.

3CR12 mushrooming all over the world

Traymaster Ltd have seen the light and started to use 3CR12 from Cromweld Steels Ltd for the cladding of their Traymaster compost turners and other equipment which they manufacture for mushroom farming.

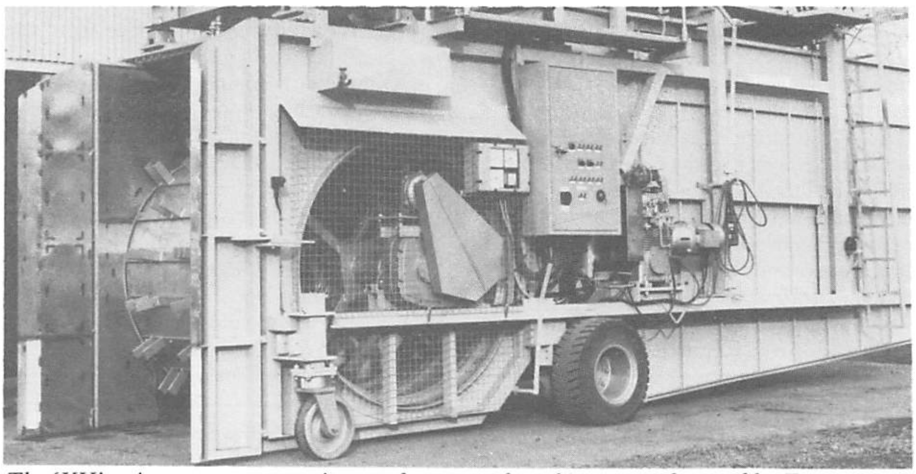
The range of compost turners includes machines capable of turning between 60 and 150 tonnes of compost per hour to prepare it for growing mushrooms. 3CR12 is being used for cladding and is attached to the mild steel structure of the machines to combat corrosion, which would be caused by the damp, acidic compost.

Paul Ellis of Traymaster Ltd explains that a conventional stainless steel was earlier used for the cladding but the transition to 3CR12 offers a considerable cost saving without detracting from the quality or reducing the life expectancy of the product. "Fabrication in 3CR12 has caused us no problems," he says.

Traymaster Ltd export their equipment to countries throughout the world including Canada, USA, USSR, Australia, Africa, Japan and the Middle East.

An 80-page User Manual prepared by Cromweld Steels gives detailed information on 3CR12-machining, welding and forming, etc, along with data on corrosion rates compared to other materials.

Cromweld Steels Ltd are at Stoke-on-Trent, Staffs ST12 9HD, Tel: (078139) 4139 and Traymaster Ltd at Great Yarmouth NR29 5BQ, Tel: (0692) 82100.



The 'XH' series compost turner is one of a range of machines manufactured by Traymaster Ltd, using 3CR12, the utility stainless steel, for cladding.

New Director of Business Devĕlopment for AFRC Engineering

William Henderson.

Dr William Henderson has been appointed Deputy to Prof Brian Legg and Director of Business Development.

Bill Henderson read Chemistry at the University of Glasgow and later gained his PhD in Organic Chemistry. After a period spent lecturing in California, he returned to the UK and has held a variety of positions in industrial companies.

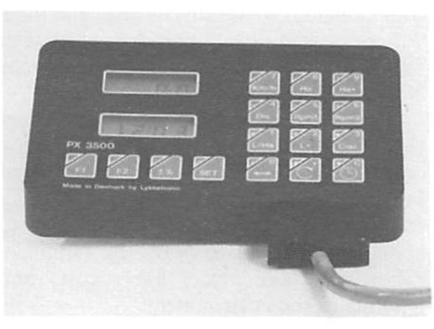
In 1979 he joined Cambridge Instruments as Sales and Marketing Director becoming Managing Director in 1985 and later, Group Executive Director. For the last two years he has been working with a Venture Capital company.

Mitsubishi launches second generation mobile vision system

Mitsubishi Electric UK Ltd (Tel: 0707 276100) is launching its latest mobile CCTV system, the C-Vision CV-654, with a wider and deeper field of view. The safety conscious mobile system eliminates the problems caused by blind spots at the rear or side of vehicles and enables drivers to manoeuvre their vehicles safely and accurately.

The system is available in the UK from Vision Techniques of Blackburn, Lancashire, who can also fit, as optional equipment, a washing system to clean the camera lens and a bullet-proof, polycarbonate cover which is said to be ideal for quarrying and mining applications. The CV-654 camera can also be supplied with a motorised, protective shutter which is activated at switch-on.

Electronic monitoring and control units by Farm 2000



Accurate monitoring and control of many farm applications is becoming an ever more critical requirement, not only for economic reasons, but also in the interests of a cleaner, safer environment.

The new Farm 2000 Lykketronic Computer-Line units are designed not only to cover current needs, but with the capacity to cope with additional future requirements.

There are eight models in the range, from the simple PX1000 Tractor Computer with functions covering: forward speed, partial and total areas, area time, running time, laps and actual time, distance, rotation and piece counter, up to the sophisticated PX3500 and PX5000 computers which have two displays and functions covering: forward driving speeds (wheel and radar), wheel slip, partial and total areas, area status programme, lift up and down, RPM, flow, area time, running time, laps and actual time, fuel consumption, fuel level, rotation control, application control, application total, piece counter and PC compatability for data aquisition and print-out. There are also alarms on certain functions.

Prices range from £285 for model PX1000 to £728 for the PX5000 with tractor and harvester computer complete with auto programme shift.

Farm 2000 Ltd, Droitwich Road, Bradley Green, Worcs B96 6RP. Tel: (052784) 621.

Food waste effluent problem solved at Eden Vale

Eden Vale, the country's leading branded chilled dairy products company, reports a major breakthrough in the control of Nocardia. This bacterium is particularly prevalent in plants where food type wastes are treated and prevents the effective treatment of effluent.

Eden Vale's Staplemead Creamery produces a range of products including cream, yogurt, soft cheese, fresh skimmed milk for bottling and skimmed milk powder. As a result, up to 280,000 gallons of effluent are produced on a daily basis and must be treated.

In 1983, the plant began to be troubled by a bright orange foam on the surface of the effluent ditches. The dense, stable foam was examined and found to consist primarily of a branched filamentous bacteria called Nocardia. This bacterium not only encouraged foam formation but also hindered the settlement of other bacteria in the plant. Thus prevented sludge from settling properly, resulting in an adverse effect on the final quality of the treated effluent.

Experts consulted world-wide

Eden Vale sought advice on how to deal with this phenomenon from a wide variety of experts including the Water Research Centre, U.M.I.S.T., Cardiff University, Birmingham University, the Cranfield Institute and four Water Authorities. Extensive literature searches were also conducted both in the UK and USA.

Although this extensive research revealed that the problem was not uncommon where the treatment of food type waste was concerned, there appeared to be no solution.

With no answer on the horizon and having tried all treatment methods suggested by the experts without success, Eden Vale set about tackling the problem from within.

Company laboratory found key to problem

Through Eden Vale's own on-site laboratory trials, it was found that Nocardia thrives best at temperatures of above 17°C and dies rapidly below 10°C. However, although useful, this discovery did not provide a practical solution, since the natural answer would have been to reduce the temperatures of the two 700,000 gallon ditches. This would have required an enormous refrigeration capacity and would also have hampered the operation of the other beneficial bacteria by reducing their activity.

These internal studies also highlighted one other factor which turned out to be the key to the problem – plants which had either a very high loading or very low loading did not seem to have problems with Nocardia.

This discovery led Eden Vale to an ingenious and simple solution. Instead of operating the two ditches in parallel, they were changed to operate in series. By pumping all of the waste into the first ditch, the loading rate was increased dramatically to outside the range suitable for Nocardia.

However, such a highly loaded system would not treat the waste adequately. By pumping the partially treated waste into the second ditch, the remainder of the treatment could be achieved and the ditch would be operating at a low loading rate, outside the range for Nocardia growth.

Once the system was operating fully, the Nocardia and associated foam in the first ditch disappeared within a week. Within ten weeks, the entire plant was free from the problem.

An additional bonus was the improvement in sludge settling properties. Previously, on a thirty minute test, a 10% settlement was the norm. After the change to series operation, this has improved to more than 70%.

The success of this project demonstrates what can be achieved through an extended period of effort. There is still more that can be learnt about Nocardia, but a method of control has been found at Eden Vale and has already proved its worth.

Training to conserve the countryside

A chemical manufacturer, a conservation organisation and a training board have combined to promote the awareness of conservation throughout the countryside.

This unique partnership, Rhône-Poulenc, the Nature Conservancy Council and the Agricultural Training Board, has produced a comprehensive guide to help trainers to integrate environmental practices into all agricultural and horticultural activities.

The 'Environmental Handbook for Agricultural Trainers' will be used by ATB instructors in all areas of training and is also being made available to agricultural colleges and other organisations involved in rural training.

Explaining the reasoning behind the partnership, John Smith, Chairman of the ATB, said: "For training to be effective it must be based on the expertise of specialists. The key to the success of every training course lies in the selection of the trainer and the quality of the training support material.

"To ensure that its instructors always have the best possible support the ATB works very closely with the specialists in all sectors of the industry. Our partnership with NCC and Rhône-Poulenc in this project has been a testimony to commonsense and practical co-operation for the benefit not only of the farming community but of everyone with an interest in the countryside.

"Although designed primarily for use by ATB instructors, we hope that the Handbook will prove invaluable to all those involved in every aspect of agricultural and horticultural training."

The Handbook is made up of three main sections:

– **farming,** which covers all agricultural and horticultural enterprises, with environmental guidelines cross referenced to all relevant activities;

– **habitats,** which gives details of the relationship between farming activities and the four habitat types (grassland, woodland, wetland and heathland); and

– **a reference section,** which summarises available grants and sources of help for landscape and conservation work as well as covering relevant legislation and regulations.

Copies of the 'Environmental Handbook for Agricultural Trainers' can be purchased from the ATB, NAC, Kenilworth, at an introductory price of £64 while stocks of the first edition are available.

Conferences

The new pollution legislation

The RASE is holding an important conference – "Pollution: the new standards" – Wednesday, 6th February, 1991, at the National Agricultural Centre, Kenilworth. Based around the new legislation which brings new standards for farmers to meet to avoid causing pollution from farm wastes, the conference – with NAC case study – will show that costs may be cut by closer attention to management integrated systems and better use of nutrients.

On the wider theme of "Integrated Pollution Control" (IPC) there is to be a two-day conference in London, 7th/8th February, 1991, organised by IBC Technical Services. (Tel: 071-236 4080).

IPC will be administered primarily by Her Majesty's Inspectorate of Pollution (HMIP) but with Local Authority control over emissions to the atmosphere, and there will be a significant interface with other regulatory organisations, in particular the National Rivers Authority.

The aim of the Conference is to explore the operation of this form of pollution control; the relationship between the regulators industry; what it means in practice to industrialists in plant design, and to sewerage undertakes; how the administration will take place; likely costs and benefits to the environment.

ADVERTISERS INDEX

Institution of Agricultural Engineers
Soil and Water Management Specialist Group

Provisional programme 1991
(firm details to be announced later)

February/March 1991
Joint meeting with UK Irrigation Association (UKIA) at Silsoe College – areas of joint interest in relation to soil management – with possibly some international perspective.

May 1991
Meeting at AFRC Institute of Engineering Research, Silsoe – field gantry systems.

September 1991
Meeting at Robinson College, Cambridge alongside the Institution's International Conference "Engineering the Rural Environment" – theme connected with the Conference.

BOOK NOW
the next
Soil Management Course
7th – 11th January 1991
Silsoe College, Beds MK45 4DT

Institution of Agricultural Engineers

Second International Conference

2nd – 5th September, 1991
Robinson College, Cambridge

Engineering the Rural Environment

The theme of the Conference will be the contribution which engineering can make to protecting the rural environment, while ensuring the continuation of a variety of successful enterprises within it.

There will be five half-days of papers and one afternoon of technical visits. Each half-day will begin with a Keynote Paper, after which the conference will split into three parallel sessions, to cater for a wide range of subject interests. There will also be poster sessions each day.

Conference fees (including papers and extended abstracts of posters):
Full residential .... £398 Institution members; £448 Non-members
Non-residential .... £272 Institution members; £307 Non-members
(but including all meals)
Daily and half-day rates will also be available.

Contact: The Conference Secretary, Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU. Tel: (0525) 61096.