The Agricultural Engineer

Incorporating Soil and water

Volume 44 Number 1 Spring 1989

Welcome to Soil and Water Management Association Members

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Journal and Proceedings

Front cover:
Continuous plastic pipe drainage being laid on land farmed by the School of Agriculture of the University of Edinburgh (SCAE photograph)

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Contents

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I Agr E ANNUAL CONVENTION

9 - 10 MAY 1989

at

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FOCUS ON QUALITY

DAY 1

PLENARY SESSION

The fresh food chain
Machinery management
The single European market

CONVENTION LUNCH and PRESENTATIONS
Young Engineers' Section

PARALLEL AFTERNOON SESSIONS

Sparing the spray
Crop gantries
Machine vision

Tractor power management
Intelligent vehicle suspension systems
Dynamic stability of vehicles

EVENING EVENTS

Poster Session, Meetings of Specialist Groups on:-

Electronics
Forestry engineering

DAY 2

Full day Technical Visit to Manufacturing Companies, or

Meeting of the Vehicle Specialist Group followed by a half day visit to SCAE.

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Annual costs of farm machinery ownership

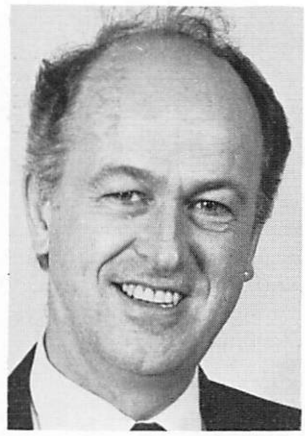
B D Witney and T Saadoun

Summary

THE procedure for calculating present annual machinery ownership costs from the discounted cash flows of the mortgaged capital cost, the repair and insurance charges and the resale income, is extended to include the effect of loan rate and loan period on interest charges, the effect of capital allowances taking account of the actual balancing charges at the end of the period of ownership, and the effect of tax relief on the interest charges, repair costs and insurance premiums. The concept of marginal holding cost is applied to determine the optimum ownership period.

The resale values of eight makes of two-wheel drive and four-wheel drive tractors available in the UK and of combine harvesters are predicted by means of a second order exponential function. As well as providing a better correlation with available data than that with the standard logarithmic depreciation, the advantage of the revised approach, called decremental depreciation, is that the resale value of a new machine, at age zero, is identical with the current purchase price.

Sensitivity analysis is used to explore the effect on present annual ownership costs of changes in input data. Over-estimation of initial depreciation defers machine replacement. High repair costs through over-estimation or through heavy usage encourages earlier machine replacement. High tax liability decreases the annual ownership cost and also encourages earlier machine replacement, whilst high inflation has no effect provided that real interest rates remain constant.



Brian Witney

Tahar Saadoun

1 Introduction

A simple estimate of machinery operating costs can be obtained by averaging the annual cost over the full period of ownership. This average cost, however, does not reflect any variation in annual operating costs with age of the machine, nor does it account for the changing value of money over the period of ownership. For a more accurate appraisal of complex agricultural machinery management problems, the present annual machinery ownership costs can be calculated using the actual cash flows which occur each year. Three types of cash flow are involved in the calculation of the annual cost of a machine:

(1) the capital cost with interest charges repayable by equal mortgage instalments;
(2) the recurring annual repair and insurance charges;
(3) the income from selling the machine.

These discounted cash flows form the basis of a machinery cost model devised by Audsley and Wheeler (1978) and further developed by Witney (1985, 1988) and Elbanna (1986).

The Edinburgh Machinery Cost Model includes the effect of loan rate and loan period on the interest charges incorporated in the mortgage payments; the effect of capital allowances, taking account of the actual balancing charges at the end of the period of ownership; and the effect of tax relief on the interest charges, repair costs and insurance premiums. These refinements provide a more accurate annual cost, which, in turn, facilitates the calculation of the optimum ownership period. Machinery replacement is most economic when the present annual ownership cost reaches a minimum value which is numerically equal to the marginal holding cost. Although this characteristic ensures the precise identification of the optimum replacement time even where the present annual ownership cost curve is very flat with respect to the age of the machinery, it also serves to emphasise the critical importance of accurate input data. In view of the paucity of information on depreciation and repair charges, the effect of their variation on the ownership period is investigated by means of a sensitivity analysis.

2. Costing procedures

Discounted cash flows are used to determine the current total cost in money of the same value. The essence of the discounting procedure is that present money is worth more than future money; the further ahead that the money is to be received in the future, the less it is worth in present-day terms. The reasons for this are two-fold: firstly, the further ahead that money is promised, the more risk that it may not materialise; secondly cash received today can be invested to be worth more in the

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Refereed paper.

future. These reasons are valid even when the purchasing power of money remains constant but the effects of inflation can also be included in the calculation of actual cash flows.

2.1 Annual repayment of loan capital and interest

The capital cost of a machine, PP, may occur as a payment (outward cash flow) at the beginning of ownership at time zero, or else the machine may be bought by borrowing the money and paying a series of equal annual mortgage payment, M:

$$M = PP i_l (1 + i_l)^N / [(1 + i_l)^N - 1] \qquad \text{... 1}$$

where i_l is the loan interest rate and N is the period of ownership (Audsley and Wheeler, 1978). It is assumed that the period of the loan is the same as the period of ownership. Payment of one's own capital may be thought of as borrowing from oneself at an interest rate which is usually lower, but which occasionally could be higher compared with special rates offered by machinery companies to promote sales. Thus, the concept of opportunity cost of capital may also be included.

The discounted cash flow or present annual cost of a cash flow, CF, in the year, n, is the amount of money, NPV, which must be invested now to pay for the cash flow in the n^{th} year. If the interest on investments is i_i, then:

$$NPV = CF_n/(1 + i_i)^n \qquad \text{...2}$$

For a series of equal annual cash flows, M, over the life of the machine, the total present mortgage cost, NPV_m, is:

$$NPV_m = M \sum_{n=1}^{N} 1/(1 + i_i)^n \qquad \text{...3a}$$

By rearranging terms and combining with Eqn 1, the total present mortgage cost becomes:

$$NPV_m = PP \frac{i_l (1 + i_l)^N [(1 + i_i)^N - 1]}{i_i (1 + i_i)^N [(1 + i_l)^N - 1]} \qquad \text{...3b}$$

This is the investment needed at the start of ownership which pays for all the annual payments. If the interest rate on investments is the same as the loan interest rate, the total present mortgage cost is equivalent to the purchase price.

2.2. Recurring annual repair and insurance charges

For an annual repair cost, R_n, in the n^{th} year of machine ownership, and insurance charged at one per cent of the resale value of the machine at the end of the previous year, $S_{(n-1)}$, the present annual cost for repairs and insurance, NPV_r, is:

$$NPV_r = \sum_{n=5}^{N} [R_n + 0.01 S_{(n-1)}] w^n \qquad \text{...4}$$

where the inflated discount factor w, is:

$$w = (1 + j)/(1 + i_i) \qquad \text{... 5}$$

and j is the rate of inflation. For the calculation of all the present annual values, the rate of inflation and the interest rates for loan and investment are assumed constant throughout the period of investment.

2.3 Income from selling the machine

When the machine is bought new, the current resale value of an equivalent, 'N' year old machine is S_N, so the resale value in 'N' years time will have changed with inflation. The present resale value, NPV_s, after discounting is:

$$NPV_s = S_N w^N \qquad \text{... 6}$$

2.4 Tax relief

Various machinery costs are eligible for tax relief, namely, annual capital allowances, interest payments, repair and insurance charges, and fuel and oil costs. These allowances only benefit those farmers who make sufficient profit to pay tax — the more profitable the business, the higher the marginal rate of tax and the greater the financial advantage from the allowances.

For taxation purposes, the annual rate of capital allowance in 1987 is 25 per cent on a diminishing balance basis, that is on the written-down value of the machine. Thus, the annual capital allowance for an 'n' year old machine, CA_n, is:

$$CA_n = 0.25 \; PP \; (1 - 0.25)^{(n-1)} \qquad \text{...7}$$

When repaying the purchase price by means of a mortgage in equal instalments, the initial instalments largely comprises interest while later instalments are mainly repayment of the principal. The annual interest charge, I_n, is given by the interest on the outstanding balance of the loan after repayment of the mortgage instalments in the preceding period of the loan:

$$I_n = PP \; i_l \; [(1+i_l)^N - (1+i_l)^{(n-1)}]/[1+i_l)^N - 1] \qquad \text{...8}$$

Repair and insurance costs have already been determined previously (Eqn 4) and fuel costs can be considered separately as they are already in present value terms.

Once the machine is eventually sold, or traded in, the total capital allowance must be adjusted to equate with the actual loss in value of the machine during the period of ownership. If the resale value exceeds the written-down value used for tax assessment, then it is necessary to have a balancing charge on which tax must be paid. This balancing charge in the last year of ownership, BC_N, is:

$$BC_N = \sum_{n=1}^{N} CA_n + S_N - PP \qquad \text{... 9}$$

Alternatively, if the resale value is less than the written-down value, then there is a balancing allowance (i.e. a negative balancing charge) on which additional tax relief is available.

The net present value of the capital allowances, the interest charges and the balancing charge, NPV_r, is given by:

$$NPV_t = \sum_{n=1}^{N} (CA_n + I_n)/(1 + i_i)^n - BC_N/(1 + i_i)^N \qquad \text{...10}$$

In practice, the tax relief on capital allowances, interest payments, repair and insurance charges, and fuel and oil costs accrue in the year following that to which they apply and the balancing charge or allowance is deducted from or added to the capital allowances on other machines within the farm equipment 'pool'. For the appraisal of an individual machine, however, it was considered expedient to allocate these adjustments to the year to which they refer, so that the calculation of machinery cost remains within the ownership period.

The various tax allowances are multiplied by the marginal tax rate, t, to give the tax relief. There is a series of taxable income bands, each with its own tax rate, ranging from the standard tax rate of 27 per cent in 1987 up to 60 per cent at higher levels of taxable income. The annual tax relief is deducted from the gross cash outgoings to give the net amounts for discounting.

2.5 Present annual ownership cost

The present annual ownership cost with tax relief, A_t, is the value in today's money of 'N' equal value, annual payments made during the ownership of the machine. These annual payments are again influenced by inflation and discounting, so that combining the three cash flows from Eqn 3a, 4 (adjusted for tax), and 6, together with the tax allowances from Eqn 10:

$$A_t = \sum_{n=1}^{N} NPV_m + (1-t)NPV_r - NPV_s - t\ NPV_t \qquad ...11$$

Since it can be shown that:

$$\sum_{n=1}^{N} w_n = w(w^N - 1)/(w - 1) \qquad ...12$$

the final form of the equation for the present annual ownership cost is:

$$A_t = [NPV_m + (1-t)NPV_r - NPV_s - t\ NPV_t]\ (w-1)/[w(w^N-1)] \qquad ...13$$

2.6 Marginal holding cost

The marginal holding cost represents the extra costs incurred by keeping a machine for an additional year. For a period of ownership of only one year, the marginal cost is equal to the present annual ownership cost. For longer periods of ownership, however, the extra cost is not solely derived from the additional year of ownership because the change in the term of the mortgage alters interest payments in earlier years as well. Thus, the determination of the marginal cost involves the calculation of two sets of annual cash flows, CFN and CFM, for two different periods of ownership both including and excluding the additional year, respectively. The marginal cost, MC_N, for the year N comprises the present annual value of costs for that year, together with the sum of the present annual values of the extra costs for each of the preceding years:

$$MC_N = \frac{CFN_N}{w^N} + \sum_{n=1}^{(N-1)} (CFN_n - CFM_n)/w^n \qquad ...14$$

3 Machinery costs

Machinery costs have been traditionally defined as fixed costs and variable costs. Fixed costs include depreciation, interest, insurance and shelter — all more readily determined and analysed than variable costs. Hunt (1956) defined the variable costs of a machinery system as 'those costs which increase proportionally with the amount of operational use' and included repairs and maintenance, fuel, and labour costs in this category.

3.1 Depreciation

Even before a machine has been purchased, it is necessary to estimate its resale value so that the investment costs can be identified. Depreciation is defined as the loss in value and service capacity arising from wear in use, obsolescence, accidental damage and corrosion. Although depreciation is commonly estimated by the straight line method or by the declining balance method, neither technique adequately represents the rapid depreciation which occurs in the early years of the ownership period. The accuracy of the declining balance method is improved by adopting a logarithmic function but it is proposed that the residual discontinuities are effectively eliminated by an approach which Witney (1985) identified as 'decremental depreciation'.

3.1.1 Logarithmic depreciation

Peacock and Brake (1970) predicted the trade-in values of some machines by means of both linear and logarithmic functions of their age. Using the logarithmic form, the current resale value of an 'n' year old machine as a decimal proportion of the current initial purchase price is:

$$S_n/PP = SA\ SB^n \qquad ...15$$

where: SA = first year correction factor
SB = annual depreciation factor.

American machinery is classified into four groups for estimating the resale value and the relevant factors are listed in table 1 (ASAE, 1986). The use of the first year correction factor is not the complete answer because the improved approximation in later years is offset by the error in the resale value of a near new machine.

Table 1 Values of the first year correction factor and the annual depreciation factor for calculating the resale value of various machines

Machine	*First year correction factor (SA)*	*Annual depreciation factor (SB)*
Tractors	0.68	0.920
Combine harvesters, self-propelled swathers	0.64	0.885
Balers, forage harvesters, blowers, self-propelled sprayers	0.56	0.885
All other field machines	0.60	0.885

3.1.2 Decremental depreciation

Ayres and Waizencker (1978) proposed that the resale value of an 'n' year old vehicle is related to the current purchase price of an equivalent new vehicle by an inflation proof expression:

$$S_n/PP = \exp(-k_1\ n) \qquad ...16$$

where k_1 is an exponent depending to some extent on vehicle type.

Based on this method, Hagger (1986) analysed resale prices of eight makes of two-wheel drive and four-wheel drive tractors available in the UK and combine harvesters. As only limited resale data is available for current models, preference was given to past models using prices from the Market Guide produced by the British Agricultural and Garden Machinery Association Ltd. The historical price data was updated to current monetary values by means of price indices (Elbanna and Witney, 1986). The values of the resale exponent, k_1, for two-wheel drive tractors, four-wheel drive tractors and combine harvesters are shown in table 2. Although there is some variation in the values of the resale exponents for the various machines and between different makes of tractors, a single value for the resale exponent, k_1, of 0.21 explains 97% of the variation.

Despite this high explanation of the data, close inspection reveals that the resale value tends to be over-estimated for one and two year old trade-in for data is sparse (figure 1.) Eliminating this error involves the inclusion of a second order exponent:

$$S_n/PP = \exp(-k_1 n + k_2 n^2) \quad ...17$$

where k_1 and k_2 are resale exponents (Witney and Saadoun, 1986). The individual values of the two resale exponents are also listed in table 2.

The age of the machine, n, can be adjusted to take account of level of use, a lightly used machine having a lower 'depreciation age' than a heavily used one. This depreciation age is the mean of the actual age and the operational age, the latter being the ratio of the accumulated use to the average annual use (Witney, 1985). If the average tractor use is assumed to be 1000 h/yr, for example, a four year old tractor working for 1500 h/yr is equivalent to an operational age of six years and the mean value or depreciation age is then five years.

As well as providing a better correlation with available resale prices than obtained by other methods, the advantage of decremental depreciation is that the resale value of the machine when new, at age zero, is identical with the current purchase price. This overcomes the discontinuities incorporated in other methods for calculating depreciation.

Table 2 Resale parameters for first order (k_1 only) and second order (k_1 and k_2) equations for two-wheel drive tractors, four-wheel drive tractors and combine harvesters

Machine type	*Resale exponents standard deviation* k_1	k_2	*Degrees of freedom*	*Explanation of data, %*
All 2WD	0.20[0.0017]	—	298	98.01
tractors	0.24[0.0070]	0.005[0.0010]	298	98.01
All 4WD	0.24[0.0031]	—	142	97.12
tractors	0.28[0.0108]	0.007[0.0016]	142	97.89
Combine	0.22[0.0024]	—	190	97.84
harvesters	0.26[0.0094]	0.007[0.0013]	190	97.90

3.2 Repair costs

Repair costs are a modest but significant portion of the total cost of machinery ownership. As repair costs tend to increase with machine age, they are important in influencing the optimal time for machinery replacement. Deterioration through normal wear is directly related to use, whereas component failures are more random with

Table 3 Values of the repair constant and repair exponent used in the calculation of accumulated repair costs for various types of machine

Machine type	*Av field speed, km/h* *Typical*	*Range*	*Estimated life, h*	*Total life repairs, % of list price*	*Accumulated repair cost index* *Repair constant*	*Repair exponent*
TRACTORS & TRANSPORT						
Two-wheel drive			10000	120	0.012	2.0
Four-wheel drive & crawler			10000	100	0.010	2.0
Trailer			3000	80	0.19	1.3
TILLAGE						
Mouldboard plough	7.0	5.0–10.0	2000	150	0.43	1.8
Heavy-duty disc	7.0	5.5–10.0	2000	60	0.18	1.7
Tandem disc harrow	6.5	5.0–10.0	2000	60	0.18	1.7
Chisel plough	7.0	6.5–10.5	2000	100	0.38	1.4
Field cultivator	9.0	5.0–13.0	2000	80	0.30	1.4
Spring tooth harrow	9.0	5.0–10.0	2000	80	0.30	1.4
Roller-packer	10.0	7.0–12.0	2000	40	0.16	1.3
Rotary hoe	11.0	8.0–16.0	2000	60	0.23	1.4
Rowcrop cultivator	5.5	4.0– 8.0	2000	100	0.22	2.2
Rotary cultivator	5.0	2.0– 7.0	1500	80	0.36	2.0
ESTABLISHMENT						
Fertiliser spreader	7.0	5.0– 8.0	1200	120	0.95	1.3
Grain drill	6.5	4.0–10.0	1200	80	0.54	2.1
Crop sprayer	10.5	5.0–11.5	1500	70	0.41	1.3
HARVESTING						
Combine harvester:						
trailed	5.0	3.0– 6.5	2000	90	0.18	2.3
self-propelled	5.0	3.0– 6.5	2000	50	0.12	2.1
Mower	8.0	6.5–11.0	2000	150	0.46	1.7
Mower conditioner	7.0	5.0–10.0	2000	80	0.26	1.6
Side delivery rake	7.0	6.5– 8.0	2000	100	0.38	1.4
Baler	5.5	4.0– 8.0	2000	80	0.23	1.8
Big bale baler	5.5	5.0– 8.0	2000	80	0.23	1.8
Forage harvester:						
trailed	4.0	2.5– 4.0	2000	80	0.23	1.8
self-propelled	5.0	2.5–10.0	2500	60	0.12	1.8
Forage blower			2000	50	0.14	1.8
Sugar beet harvester	5.0	4.0– 8.0	2500	70	0.19	1.4
Potato harvester	3.0	2.5– 6.5	2500	70	0.19	1.4

respect to time and become more predictable only as a cumulative trend over the service life of the machine. The logarithmic equation which best describes the typical trend in total accumulated repair and maintenance costs, TAR, was first proposed some 30 years ago and later modified by Rotz (1987) to include average operating speed compensation for accumulated machine use:

$$TAR/PP = RA[X\ V_l/V_0]^{RB} \qquad ...18$$

where: RA, RB = repair constant and exponent:

X = accumulated use, h x 10^3;

V_0, V_1 = typical and actual average operating speed, km/h.

Speed compensation ensures that the fewer hours of accumulated use for a high speed operation do not result in lower repair costs than for a slower speed operation with the same machine. When the actual average speed is the same as the typical average operating speed, the speed ratio is equal to unity and has no effect on accumulated repair costs.

The values of the repair constant and the repair exponent for various types of machines are given in table 3, together with average field speeds, estimated machine life and total repairs over the expected life of the machine (ASAE, 1986).

3.3 Fuel and oil costs

The fuel consumption of a diesel engine in a tractor or self-propelled farm machine is governed by the amount of energy demanded at the drawbar or at the power take-off. Fuel efficiency varies with engine loading and reaches a maximum at about 90 per cent of full power. In order to compensate for this variation in fuel efficiency (ASAE, 1982), the specific fuel consumption of a diesel engine is related to the power utilisation ratio, RU, such that:

$$FC = 2.64\ RU + 3.91 - 0.2\sqrt{(738\ RU + 173)} \qquad ...19$$

where: FC = specific consumption, l/kW h

$$RU = \frac{\text{equivalent pto power requirement, kW}}{\text{maximum pto power, kW}}$$

For tractor operations throughout the year, the average power utilisation ratio is 0.55.

Applying the average power utilisation rates of 0.55 for tractor operations throughout the year, however, the specific fuel consumption of 0.55 l/kWh is almost double the actual performance data quoted in tractor test reports. Although minor adjustments to Eqn 19 have been published (ASAE, 1986), it is considered that a more radical change to the equation could result in a significant improvement in the correlation between actual and predicted specific fuel consumption values for different power utilisation ratios.

Oil consumption is defined as the volume of engine crankcase oil replaced at the recommended change intervals. For simplicity, the oil consumption, OC, is related to the rated engine power, P_{max} without any adjustment for engine loading (ASAE, 1986):

$$OC = 0.2169 + 0.00059\ P_{max} \qquad ...20$$

4. Financial analysis

The annual ownership costs were calculated for a 60 kW two-wheel drive tractor with an initial price of £16,000. This price was derived from the 1984 purchase price trend equation, with index-linking from September 1983 to September 1987 (Elbanna and Witney, 1986). The accuracy of the projection over four years, which was confirmed by reference to a recent tractor price guide (Anon, 1987), is also significant for the appraisal of the decremental depreciation technique (see Section 3.1.2). A sample of the pro-forma output is shown in table 4 for a

Table 4 Standard input data with a sample of the pro-forma output of annual ownership costs

Input data for 2WD tractor

Purchase price £ = 16000		Annual use, h = 1000	
Loan rate =0.113	Interest rate = 0.0815	Inflation rate =0.05	Tax rate = 0.27
Fuel cost, £/l = 0.14	Labour cost, £/h = 5.00	Shelter, % = 0.01	
Repair coefficients:	RA = 0.012 RB =2.0		
Resale coefficients:	k_1 = 0.237 k_2 =0.005		

Output cost data for 2WD tractor

Age Yr	*Inflation factor*	*Investment factor*	*Repair cost* £	*Insurance* £	*Actual repair & insurance* £	*Actual capital allowance* £	*Actual interest charge* £	*Total tax allowance* £	*Actual cash outgoing* £	*Discount cash flow* £	*Inflated discount factor*
1	1.050	1.082	192	177	387	4000	1808	6195	1465	1355	0.971
2	1.102	1.170	576	146	796	3000	1701	5497	2063	1764	0.943
3	1.158	1.265	960	122	1253	2250	1583	5085	2631	2080	0.915
4	1.216	1.368	1344	104	1760	1688	1451	4898	3188	2330	0.888
5	1.276	1.480	1728	89	2319	1266	1304	4889	3750	2535	0.863
6	1.340	1.600	2112	78	2935	949	1140	5025	4329	2706	0.837
7	1.407	1.731	2496	68	3608	712	958	5279	4934	2851	0.813
8	1.477	1.872	2880	60	4343	539	755	5633	5573	2978	0.789
9	1.551	2.042	3264	53	5143	400	530	6076	6256	3091	0.766
10	1.629	2.189	3468	47	6019	300	279	3483	3813	1742	0.744
										23432	8.53

Actual salvage value = £4017		Present annual cost = £2747
Mortgage payment = £2751	excluding	(Fuel cost = £2541
Actual balancing charge = £3116	tax	(Labour cost = £5000
	allowances	(Shelter cost = £ 160

set of input data which includes the standard values of the repair and resale coefficiencts. The ownership period was taken as 10 years and the annual use 1000 hours. The repair costs increase with the age of the machine by levying an increasing percentage of the purchase price, whilst the insurance charges decline with machine age by applying a fixed percentage to the written-down value. Note, however, that instead of the fixed percentage of the written-down value described in Section 2.2, the insurance premiums in table 4 were based on a minimum charge of £25 up to a current value of £1000 and thereafter on a sliding scale of £1.20 per £100 up to £5000, £0.95 per £100 for the next £10,000 and £0.85 per £100 above £15,000. As the salvage value at the end of the tenth year is more than the written-down value, there is a balancing charge for tax adjustment. The equal annual mortgage repayments have a declining interest component eligible for tax relief. In addition to the present annual cost, fuel, labour and shelter are also listed in current values but were not included in the financial comparisons as their present annual costs are constant.

The annual ownership costs for ownership periods from 1 to 10 years are shown in figure 2. These costs rapidly decline as the ownership period is extended to three years, but, thereafter, the annual cost curve flattens out. The annual ownership cost for *each* year of a two year ownership is £3120 compared with £2700 for *each* year of a seven year ownership period. The minimum point on the annual cost curve is located at its intersection with the marginal holding cost curve for an ownership period of seven years.

Ideally, machines should be replaced before their age exceeds the period of ownership for which the annual cost is a minimum. The extra costs of not doing so can be obtained by summing the differences between the marginal cost curve and the annual cost curve for each

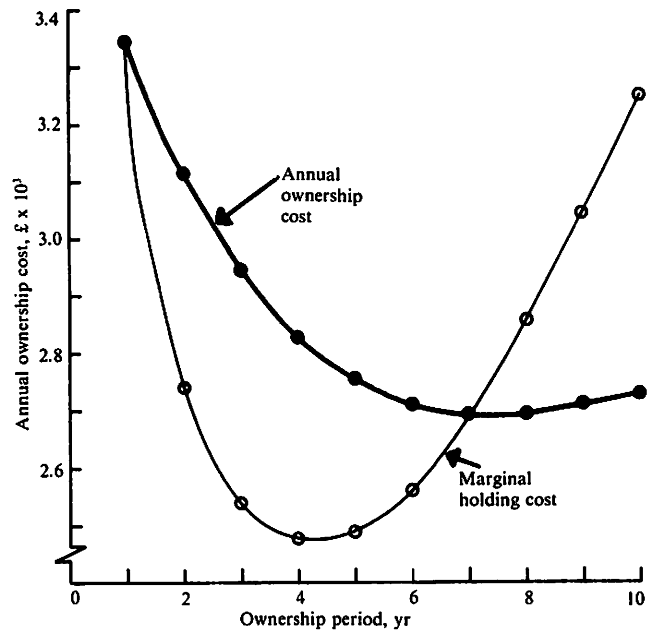


Fig 2 The optimum period of machine ownership is when the marginal holding cost is equal to the annual ownership cost using discounted cash flows

year of additional ownership. There are also the penalties of untimely operations which may accrue through poorer reliability of an older machine.

5 Sensitivity analysis

Sensitivity analysis was used to explore the effect of inadequacies in the evaluation of resale data on the credibility of the costing procedure and the viability of the replacement policy. The sensitivity of present annual ownership costs to changes in repair costs and in tax rates was also examined. The range of values included in the sensitivity analysis is given in table 5, standard input

Fig 1 Depreciation of two-wheel drive tractors, together with the calculated values of logarithmic depreciation and of decremental depreciation for first order and second order exponential equations

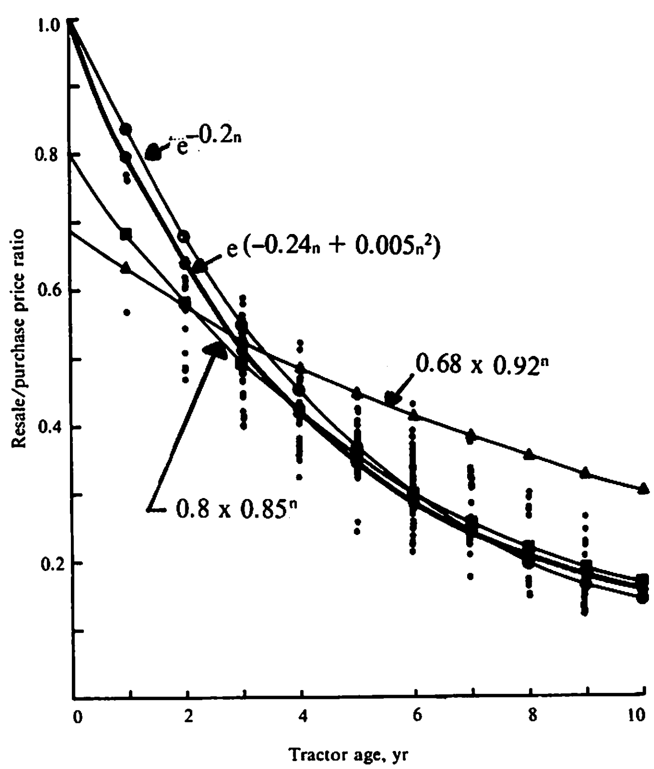


Table 5 Range of values of the variables in the sensitivity analysis

Variable	*Values of the input data* Low	Standard	High
First year correction factor, SA	[0.8	—	[0.68
Annual depreciation factor, SB	0.85]	—	0.92]
Resale exponent, k_1	[0.20	[0.24	—
Resale exponent, k_2	0]	0.005]	—
Repair constant, RA	0.008	0.012	0.016
Repair exponent, RB	1.9	2.0	2.1
Annual use, h	750	1000	1250
Tax rate	0	0.27	0.40
Inflation rate	0	0.05	0.10
Investment interest rate	0.03	0.0815	0.133
Loan interest rate	0.06	0.113	0.166

[Brackets indicate values in combination] values being adopted for all variables other than that under scrutiny. The only exception to this procedure was for the investigation of the effects of inflation in the absence of taxation on present annual costs; the loan interest rate was assumed equal to the investment interest rate so that the total present value of the mortgage became the same as the purchase price.

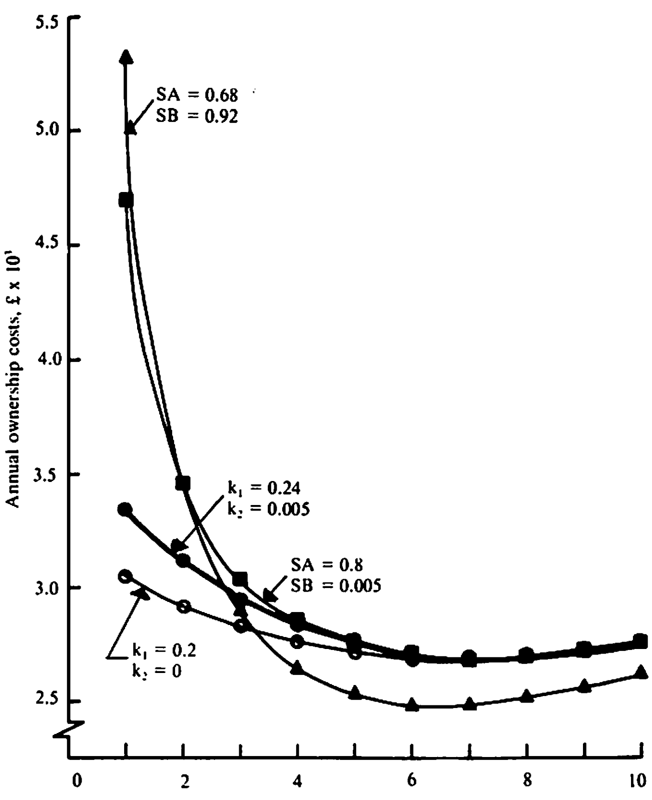
5.1 Variation in resale value

Four depreciation curves are illustrated in figure 1, the standard logarithmic equation which does not fit the British data, the 'best fit' logarithmic equation, and the 'best fit' first order and second order decremental equations. The resultant annual cost curves are shown in Figure 3.

For logarithmic depreciation, the resale to purchase price ratio close to the time of purchase is entirely dependent on the value of the first year correction factor, SA. There is an immediate loss of value of 32% and 20%, increasing to more than a third and a quarter of the inital purchase price at the end of the first year for the standard and 'best fit' equations, respectively. After this initial drop, the annual depreciation factor governs the annual loss in value. Thus, a high value of the first year correction factor and a low value of the annual depreciation factor both over-estimate depreciation of nearly new machines. This results in excessively high annual costs for one and two year periods of ownership. Although the error declines as the period of ownership is extended, a high initial depreciation can lead to a steadily declining annual cost curve and a totally misleading replacement policy.

The annual cost curves for decremental depreciation present a less dramatic variation with period of ownership. As the value of the first order resale exponent

Fig 3 Annual ownership costs for different levels of depreciation, the heavy line representing the most accurate prediction of resale values by decremental depreciation



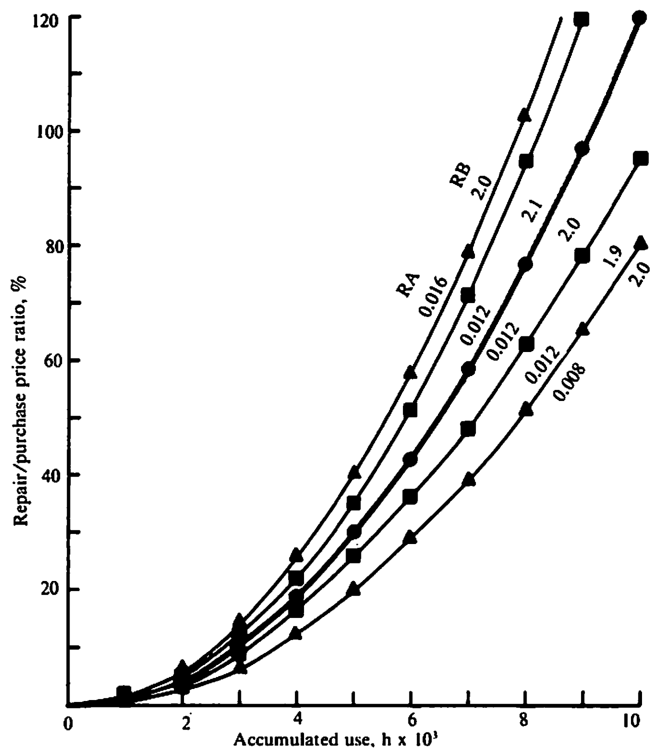
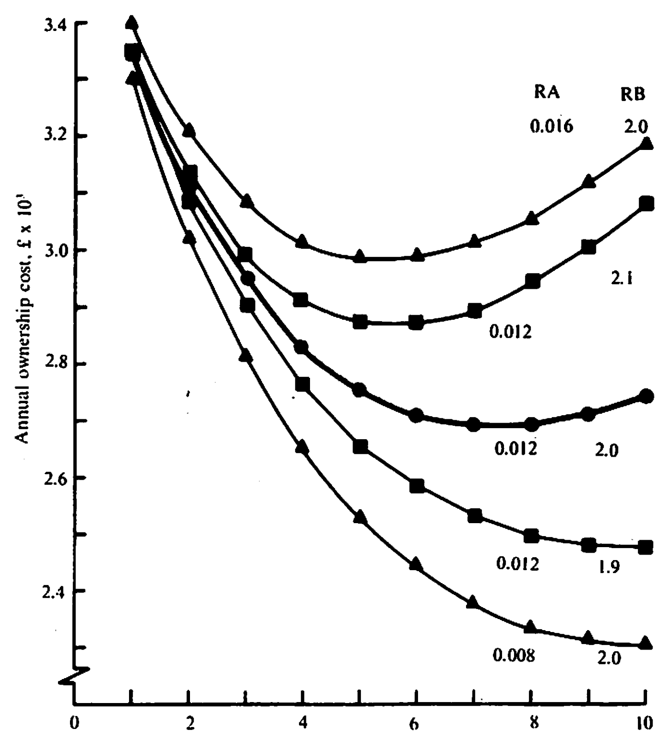


Fig 4 Repair/purchase price percentages for different values of the repair constant, RA, and the repair exponent, RB, the heavy line representing the repair costs for two-wheel drive tractors

becomes more negative and is compensated by a larger value for the second order resale exponent, the initial depreciation is increased to give a higher annual cost and to extend the optimum replacement period. Whilst this trend is the same as for logarithmic depreciation, the magnitude of the effect is smaller and within realistic limits.

Fig 5 Annual ownership costs for different values of the repair constant, RA, and the repair exponent, RB, the central curve being based on the standard repair costs for two-wheel drive tractors



5.2 Variation in repair cost

Repair and maintenance costs are highly variable and unpredictable as to time of occurrence and, even though they do show consistent trends in relation to accumulated use, a standard deviation equal to the mean is a typical variation in these data (ASAE, 1986). The magnitude of the logarithmic repair function (Eqn 18) is governed by the values of the repair constant and the repair exponent. The repair constant, RA, causes a proportional change in the accumulated repair and maintenance cost for each and every year throughout the life of the machine. The repair exponent, RB, controls the distribution of the repair costs over the life of the machine, a higher value of the repair exponent shifting a greater proportion of the costs onto older machinery. The standard values of 0.012 for the repair constant and 2.0 for the repair exponent for two-wheel drive tractors are used to demonstrate the relative effect of varying these two coefficients (figure 4). For a tractor life of 10,000 hours, the total accumulated repair costs is 120% of the purchase price using the standard repair coefficients, whereas the lowest curve gives 80% and the highest curve gives 160%.

Varying the level of the repair costs alters the replacement period (figure 5). For example, increasing the value of the repair constant from, 0.008 to 0.012 and to 0.016 brings forward the minimum annual cost point from a ten year period of ownership to seven and five years, respectively.

5.3 Variation in annual use

The level of annual use has a substantial effect on repair costs and on the annual ownership cost curves (figure 6). For an annual use of 750 hours, the minimum annual

Fig 6 The effect of annual use on the annual ownership costs for a two-wheel drive tractor

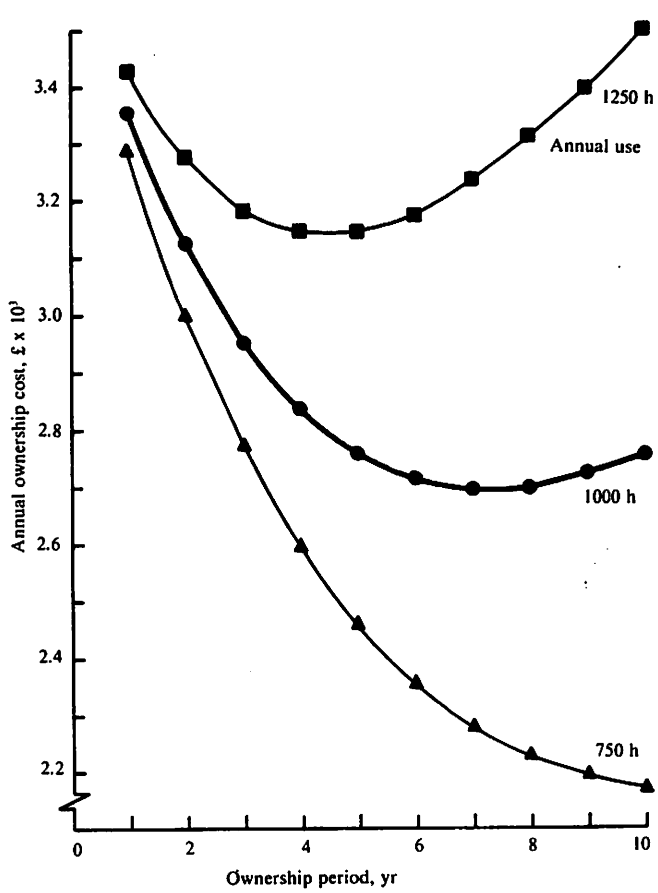


Table 6 The effect of annual use on the optimum replacement age of two-wheel drive tractors and the duration of the replacement decision-making period when annual costs deviate less than five and ten per cent above the minimum

Annual use h	Optimum replacement age, yr	Minimum cost, £	Period over which costs deviate less than 5% from minimum, yr	10%
750	12	2145	5	6
1000	8	2701	4	5
1250	5	3155	3	4

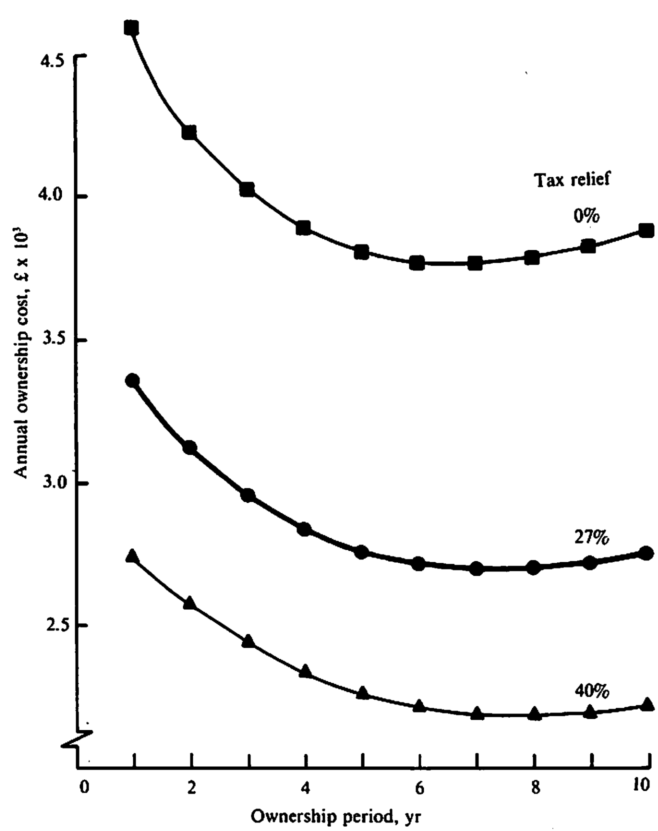
ownership cost is only two thirds of that for an annual use of 1250 hours and the optimum replacement age alters from twelve years to four (table 6). As the optimum replacement age falls, there is also a shorter decision-making period over which the annual ownership costs deviate less than five per cent above the minimum.

5.4 Variation in tax rate

The effect of three tax rates (0, 27, and 40%) on the level of annual ownership costs is shown in figure 7. The annual costs fall in proportion to the tax liability and this encourages earlier machine replacement, even though the minimum costs relate to similar periods of ownership.

Accounting for tax relief a year in advance of normal practice (See Section 2.4) leads to a small underestimation of the annual costs. This can be compensated by assuming that the tax relief has been 'borrowed' for one year at the loan rate of interest to give a further cash flow (net of tax) which leads to a small overestimation of the annual costs.

Fig 7 The effect of tax relief on the annual ownership costs of two-wheel drive tractors



The extra complexity was not considered justifiable in relation to the modest improvement in accuracy.

5.5 Variation in inflation rate

When the real investment interest rate is held constant at different levels of inflation, the annual ownership costs are unaffected in the absence of any tax liability and assuming that the loan interest rate is the same as the investment interest rate. Tax liability and higher loan rates do cause minor changes to the annual ownership costs but the variation is only of the order of ±2% for the range of input data under investigation.

6 Conclusions

Variation in the rates of depreciation, repairs and taxation has a significant effect on the annual costs of owning and operating farm machinery.

A high initial rate of depreciation leads to unrealistically high annual costs during the early period of ownership and defers replacement.

A new analytical procedure, called decremental depreciation, accurately predicts the loss in value with age of self-propelled machinery. The inclusion of the appropriate resale values not only advances the optimum time for machine replacement but also makes variation in annual costs over the period of ownership much less sensitive to age of machine.

Higher repair costs through over-estimation or heavy usage encourage earlier machine replacement. The introduction of average operating speed compensation for accumulated machine use represents a major improvement in the accuracy of assessing repair costs.

High tax liability decreases the annual ownership costs and encourages the earlier machine replacement, even though the minimum costs relate to similar periods of ownership.

High inflation has no effect on the total discounted cash flows provided the real rates of interest remain constant.

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Notation

A_t = present annual ownership cost with tax relief, £
BC = balancing charge, £
CA = capital allowance, £
CF = cash flow, £
CFM, CFN = annual cash flows for two different periods of ownership excluding and including an additional year, £
FC = specific fuel consumption, l/kWh
i_i = investment interest rate, dec
i_l = loan interest rate, dec
I = annual interest charge, £
j = inflation rate, dec
k_1, k_2 = resale exponents
M = annual mortgage payment, £
MC = marginal cost, £
n = machine age, yr
N = period of ownership, yr
NPV = net present value, £
NPV_m = present total mortgage cost, £
NPV_r = present annual cost of repairs and insurance, £
NPV_s = present resale value, £
NPV_t = present value of tax deductible allowances, £
OC = oil consumption, l/h
P_{max} = rated engine power, kW
PP = purchase price, £
R = annual repair cost, £
RA, RB = repair constant and exponent
RU = power utilisation ratio
S = resale value, £
SA, SB = first year correction factor and annual depreciation factor
t = marginal tax rate, dec
TAR = total accumulated repair cost, £
V_0, V_1 = optimum and actual operating speed, km/h
w = inflated discount factor
X = accumulated use, h x 10^3

Centre pivot cultivation: power supply and control of a mains electric tractor

B Wilton, P Strange and H R Ghasemzadeh

1 Introduction

SOME six years ago, in a short article published in The Agricultural Engineer (Wilton, 1982), it was suggested that one day we may be able to distribute electricity over large fields in much the same way that we now pump water through irrigation systems. It was assumed that wherever water could be made to flow through pipes, electricity could be supplied through cables and it was argued that eventually our industry might well need to move away from a state of almost total dependence on liquid fuels. It was suggested that water distribution devices such as self-propelled irrigation booms might then be modified to carry a power supply, which in effect they already do as the boom wheels are usually driven by small electric motors.

In order to perform work at an acceptable rate by electrically powered tractors and other field machinery, the supply would obviously have to be considerably more substantial than that now provided to drive the boom when it is irrigating, however this would not present an insuperable problem. Using a boom to carry a power supply would have an added advantage in that it could also carry a series of reference points to be used in developing a system of steering and otherwise controlling any separate equipment. Electrically-powered equipment would also lend itself to automatic control.

By coincidence, another article

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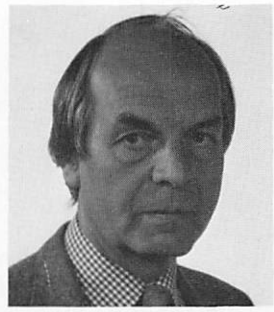
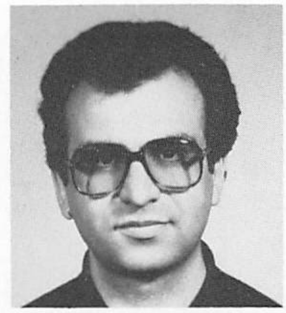
B Wilton


P Strange


H R Ghasemzadeh

was submitted to The Agricultural Engineer at about the same time on a related topic and the two were published together. In this second article, Matthews (1982), put forward his views about the way arable farming might look in the year 2030. Matthews predicted that the advantages offered by the gantry type of tractor would bring it into common use within 50 years. Now, after only one eighth of that time has elapsed, we see these machines beginning to appear in commercial farming and receiving considerable attention from research workers around the world. Anyone who has visited the Warwickshire farm of David Dowler — the farmer/engineer who has done more than anyone else in the UK to further the gantry tractor cause — cannot fail to have been impressed by the way his machine performs and by the effect its use has had on soil structure.

Matthews also had something to say about fuel supplies and electricity in the field, viz, 'although I do not believe that there will be in 2030 a critical shortage of primary energy, I consider that electrical energy will be much cheaper than remaining portable fuels, and that this will, therefore, influence the agricultural power unit'.

2 Previous work

The first major work on the possibility of using mains electricity to drive field cultivation equipment was carried out in the Soviet Union in the 1940s (Anon, 1950). It involved the construction of electrically-driven crawler tractors that took their supply from a mobile transformer substation fitted with a pantograph through which it drew high voltage current from overhead power lines. These tractors and subsequent ones were all supplied through trailing cables, which inevitably caused such severe problems that the development programme was eventually stopped. In more recent times, further work on the use of electricity in the field has been carried out in the USSR (Zhukov, 1986). In these rather futuristic studies, booms made up of sections 100 m and more wide are being considered to carry power and materials across the land automatically.

After the early Russian work the next published paper on this topic was by Reece (1968), who proposed a system based on the hauling of equipment across fields using electrically-powered mobile winches. This system could have been automated by indexing the winch and its equipment across the field. In many ways Reece's proposal was the forerunner of a system developed in the USA in the 1980s (Lepori *et al*, 1986); their Texas AMPS (Alternative Machinery Propulsion System) involved equipment that was winched along the ground from one end of a boom that spanned the width of the field. The functions of the boom were to guide the winched equipment and to support the cable. Although the first AMPS was powered by an internal combustion engine, this approach would obviously lend itself to electrification.

A feasibility study of Wilton's (1982) idea was later carried out by Rowland (1983); he considered both centre pivot and linear move booms, various patterns of work that might be followed and aspects of power distribution. Rowland ruled out power supply drums because of heating problems, but otherwise found no technical reasons why both types of boom should not be used to supply and control electrically-powered field equipment.

At about this time Alcock (1984) started preliminary experiments with a small mains electric toolframe, the supply cable reaching it via a rotating boom. Alcock used separate motors to drive the two traction wheels, switching them on and off to steer the toolframe along a spiral path. Microswitches placed around the supply cable indicated the position of the machine relative to the power pick-up carriage, the latter being slowly winched along the boom at a rate of one toolframe width per boom revolution.

The work on which the remainder of this article is based was started in 1985 and it is reported in full in an unpublished PhD thesis (Ghasemzadeh, 1988). A stage has now been reached whereby a small electrically-powered 'tractor' has been built and equipped in such a way that it can run automatically along either a straight line or around a circular path. At the end of the line or when the circle has been completed, it stops; its position can then be changed (at present under manual control) to an adjacent parallel run before it moves off in the opposite direction, again under automatic control.

3 Design and control

Although the linear move boom would have presented fewer problems, it was decided to work on a centre pivot installation as these are far more common, Soane (1985) having reported that more than 100,000 had been installed by that time. From a supply point-of-view the centre pivot arrangement is the simpler of the two in that it takes in its water and/or electricity through rotating couplings. The linear unit, on the other hand, is normally supplied with water by a trailing hose, although in an exceptionally flat location it can take it in through a suction hose from a channel running along the field boundary: the electrical equivalents are either a trailing cable or a pantograph picking up current from an overhead supply running along the edge of the field.

Having decided to work with a rotating boom, the decision was taken to follow a concentric pattern, rather than a spiral one, despite the fact that the former involved transferring the working equipment sideways by one width after each revolution. Had the spiral pattern been adopted, it would inevitably mean that the 'tractor' crossed the boom tracks at an oblique angle; taking the long-term view this was considered to be highly undesirable, both for subsequent passes of the boom and for the equipment working across consolidated tracks. A linear move boom would not be able to work on the linear equivalent of a spiral pattern.

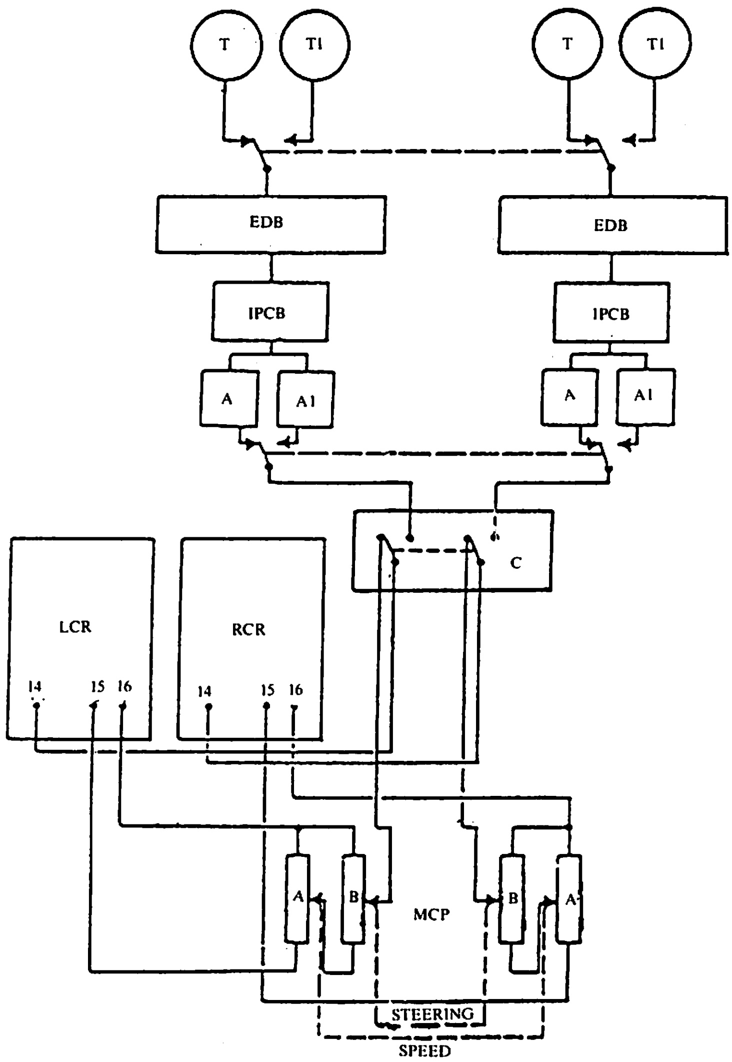
A gantry configuration was chosen for the tractor, the width being such that multiples of it would be equal to the boom width so that the boom tracks would provide some of the tractor's tracks. Two sections of a more-or-less full height boom were made; it was fitted with weatherproof shrouded electricity conducting equipment (AKAPP) which had a roller-mounted collector trolley. A scaled-down gantry 'tractor', 3.4 m wide, was made and this was fitted with two 3 hp inverter-fed geared electric motors, the initial intention being to study control aspects of the tractor/boom assembly with the tractor running unloaded. It was, in effect, a platform designed to carry only its own control equipment together with an operator during its early stages of development.

When operating a commercial centre pivot irrigation unit the boom moves very slowly, being kept approximately in line by switches mounted on the articulation points. It will normally work in one direction only but can be modified to cover less than a complete circle and then run in the reverse direction. The boom made for the current work was designed to run at considerably higher speeds (5 km/h at 17.3 m radius) and was fitted with variable speed drives so that the frequency of stopping and restarting the motors was minimised; it was also programmed to make one revolution, then pause for a controlled time before running in reverse for a second complete revolution. The pause was included to allow time for the 'tractor' to move from one pass to an adjacent one by running one of the wheel drive motors in a particular direction for an appropriate time while the other motor remained stationary. This manoeuvre resulted in the tractor turning through 180 degrees and moving sideways by one width.

It was considered that a non-contact system of keeping the tractor and the reference points on the boom within close range of one another was required. Equipment capable of measuring distance by a non-contact method was just being introduced for automatically controlling the height and level of sprayer booms: manufactured by Polaroid; it consisted of two ultrasonic emission and detection transducers together with circuit boards, the latter being interfaced with an actuator. It was decided to use two such transducers, pointing at target plates carried on the boom, to control the speed of the gantry tractor's two wheel drive motors. This, it was thought, would keep the tractor more — or — less within a fixed distance from the boom and parallel to it.

The tractor was equipped with the first two transducers and put through a series of trials in the laboratory with the drive wheels jacked clear of the ground. Some difficulty was experienced in balancing the outputs from the two control systems, however this problem was eventually overcome by using balancing amplifiers. Changes in the range of output motor speed were achieved by adjusting the gain of the amplifiers. A simplified version of the control system is shown in fig 1.

While this work was in progress it was realised, with some relief, that a third transducer might not be required to correct for sideways movement. An extremely simple, but nevertheless effective solution was found that eliminated the problem of compensating for sideways drift: the key element that made this possible was replacing the original flat target plates by stepped ones (as shown in the top part of fig 2). The effect of this modification was, for example, that when the tractor drifted to the right when it was following the boom, the



A, A1 Amplifiers
EDB Polaroid's circuit board
C Auto/Man changeover switch
IPCB Interfacing circuit board
LCR LH motor's inverter
RCR RH motor's inverter
MCP Man/control speed and steering potentiometers

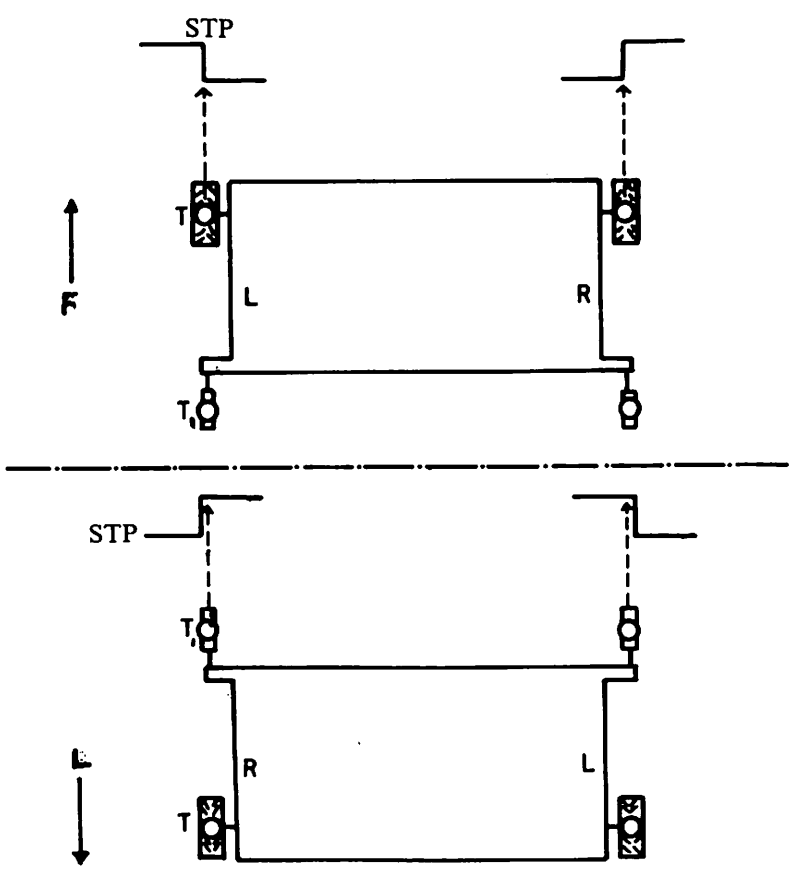
Fig 1 Block diagram of the tractor's control system

right hand transducer would begin to focus on a more distant part of the plate; this would result in the right-hand wheel accelerating, thus making the tractor swing to the left and so get back on line. Similar changes in signal and motor speed also applied when the tractor led the boom, as it did on alternate passes after it had been equipped with two further transducers (the lower part of fig 2).

4 Testing

After a series of simulated runs in the laboratory the equipment was tested using a trailing cable supply, following targets carried on a trolley that was pulled by hand along a chalk line on a large area of tarmac. Its performance when following both straight and curved lines was assessed at a range of speeds, as also was its ability to compensate for starting 'off centre'. It was only then connected to the centre pivot boom.

For the final set of tests, the centre pivot circle was divided into five degree sectors; seventy two marked plates were then accurately positioned (one on each radius) so that the centre line of the plate was exactly below where the centreline of the tractor should be as it passed. Drops of coloured fluid were deposited on the plate as the tractor passed and from their positions the efficiency of the automatic steering system could be assessed. At 2, 3 and 4 km/h on a 28 m diameter circle the mean errors of the tractor path from a truly circular one were 7.3, 5.2 and 7.5 cm respectively, the maximum errors being 16.0, 12.3 and 17.3 cm.



T Front transducers (2 off)
T1 Rear transducers (2 off)
STP Stepped target plates

Fig 2 Positions of the stepped target plates mounted on the boom, and of the ultrasonic transducers with the 'tractor' following (F) or leading (L) the boom

5 Future development

The next stage in the programme is to automate the manoeuvre that has to be performed after each revolution of the boom, then to impose such loads on the tractor that will make it develop wheelslip so that the limits of its control system can be established.

Whether or not a larger tractor will then be made — one that is capable of doing useful work — is not yet known. It is understood that Alcock, working in South Dakota, has started to use his tractor on a limited scale to sow and treat crops, but this sort of work is not envisaged at Nottingham with the present equipment.

In any further work on larger equipment in which the aim is towards automatic control, attention will also have to be given to factors such as the detection of blockages and mechanical failure, to systems capable of dealing with component malfunction and possibly to the monitoring of soil and crop conditions before and after any operation.

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Developing a cultivation system for tea planting

J Attyang

1 Introduction

METHODS of crop production vary greatly throughout the world depending on climatic and environmental conditions. Therefore, farm machinery applications and mechanisation technique must be flexible and achieve maximum return on investment made in farming operations. Development of tea as a crop is no exception to this.

Following good tea prices in 1983/84, Brooke Bond Kenya Limited decided to convert land formerly under cinchona plantation to tea production (cinchona is a bush from whose bark quinine is extracted) and this gave rise to the need to develop a mechanical cultivation system suitable for the conditions prevailing at their Kericho Estates which would be capable of coping with the annual development programme as established (150 ha). On an old and well established tea plantation like Kericho with little or no new development, it is not often possible to compare on site, various methods of stump and root removal under controlled conditions.

2 Objectives

To devise a system of land cultivation that would meet the following conditions:—

- (i) lift old cinchona stumps with most of its rooting system to the surface without reburial;
- (ii) provide suitable planting medium for tea both in surface tilth and cultivated depth without undue soil disturbance;
- (iii) be simple and versatile to cope with the land development programme as already set by the management;

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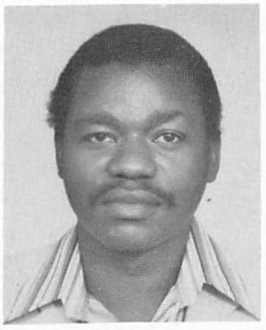

J Attyang

- (iv) achieve the above objectives at acceptable cost levels to make tea developments economical considering the prevailing tea prices.

The removal of cinchona roots was necessary to prevent possible underground transmission of a "feared" root disease, *Armillaria mellea*, from cinchona to new tea plants. The two plants have a similar rooting pattern.

3 Sites

Kericho tea plantations are situated on the Mau Escarpments, highlands west of the great Rift Valley averaging between 2000 to 2400 m above sea level. The topography is rugged and undulating, interspersed with regular streams. The annual rainfall, 1500–1600 mm is bimodal with a definite dry period in January to March. Temperatures vary between 35°C maximum (day) and 4°C minimum (night). Soils are sandy loams, friable, deep, very absorbent and rather prone to rapid drying in areas with sparse vegetative cover. Top soils are shallow in steep areas and easily eroded by water if not protected, weathering also plays an important role in producing cultivation tilth. Under these conditions and in the absence of termites, root growth is very good but once plants are dead, roots take long to decompose.

Two similar sites, each of 10 ha previously under cinchona, were chosen on two estates for trials of two cultivation systems. The sites were overgrown with bushes and covered with a lush mat of rhizometous Kikuyu and couch grass.

4 Systems of land preparation

The two following systems of land preparation were compared:—

- (i) conventional system, consisting of manual removal of surface trash using simple hand tools followed by manual digging out of stumps/roots up to 300 mm deep, covering and compacting the stump holes and tillage by conventional primary and secondary methods.
- (ii) mechanical system consisting of manual removal of surface trash/vegetation followed by mechanical stump/root removal and finally by secondary cultivation.

Before any operations were started, the extent of the cinchona rooting system had to be established to give an idea of rooting type, depth and spread. Several root profile pits were dug in test areas to varying depths and scaled photographs taken of exposed roots (fig 2).

It became clear as a result, that cinchona roots reach depths of up to 1500 mm and it had to be decided whether it was necessary or even economically feasible to remove roots below a certain depth. This had to be related to the risk and level of *Armillaria* infection as it is known that even a cinchona root hair can transmit *Armillaria* from one plant to another.

Another limitation imposed was the equipment available. Due to the need to keep down development costs, only equipment already at the plantation was to be used and any modifications required had to be simple and inexpensive. Very little

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Subject Index & Author Index

1988

The Agricultural Engineer

Subject Index 1988

Title of paper	*Author*	*Yr of publ*	*Vol no*	*Pt no*	*Page*
Pest and weed control					
Spraying systems and legislation	Landers A J	1988	43	2	51–52
Selection of equipment					
Selection of a combine	Yule T, Copland T A and O'Callaghan J R	1988	43	1	25–27
Selecting the right field machines	Baldwin D	1988	43	2	47–49
Tractors					
Tractor efficiency and fuel conservation — A New Zealand approach to advisory work	Sims R E H, Young R and Martin G A	1988	43	1	12–17
Power potential from performance monitors	Parish S	1988	43	1	28–29
Institution matters					
Times and technologies of the Institution's first and next 50 years	Matthews J	1988	43	1	2–4
The Jubilee History of the Institution 1938–88	Gibb J A C	1988	43	1	31–32
Challenge and change in agricultural engineering	Witney B D	1988	43	3	66–69

The Agricultural Engineer

Author Index 1988

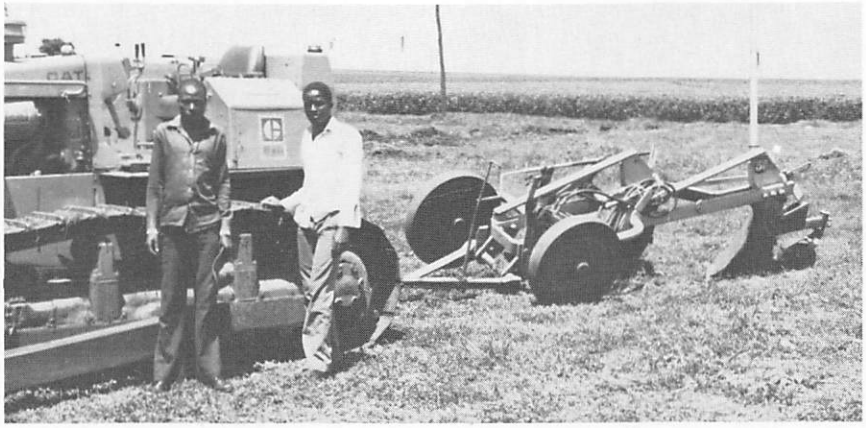
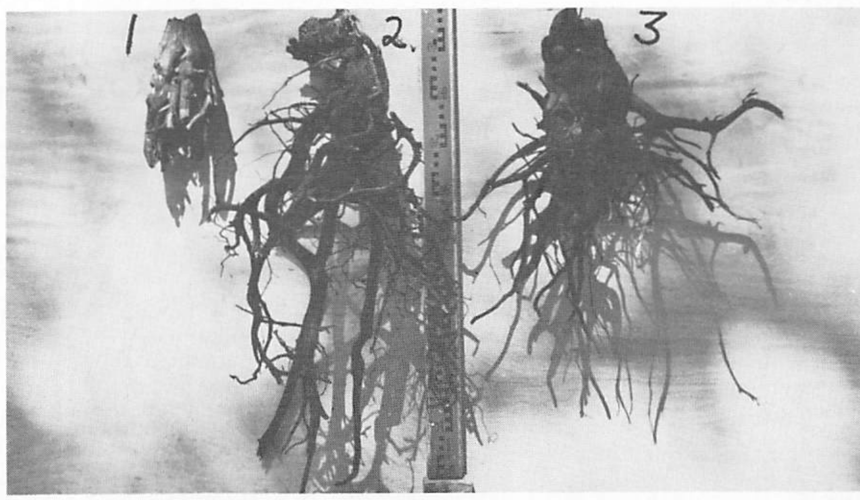


Fig 1 (Left) Caterpillar D6 track layer with Nardi plough.

Fig 2 (Below) Extent of root removal by: 1 = hand labour, 2 = Nardi plough, 3 = root plough. (Note: "hand labour" represents quantity of root dug out manually before ploughing and the rule is one metre in length)



work had been done by technical representatives of machinery manufacturers in Kenya on this type of work, hence, little assistance could be obtained from such sources. This is a typical situation that agricultural engineers often find in developing countries.

Surface removal of vegetation by a rotary slasher was also tried and costings compared with manual slashings. Similarly, work rate, performance assessments and costs of the two systems described below, were monitored.

4.1 System 1 — Conventional system

The conventional system was employed to avoid using heavy equipment and sophisticated technology and to rely on labour as much as possible for all operations prior to ploughing. The sequence of operations followed is given below:—

- Manual slashing of all surface vegetation using common hand tools.
- Manual digging of cinchona stumps using jembes and mattocks. Some hand tools such as pincers were made to enhance the number of stumps lifted per man day but the stumps were too deep rooted to be eased out whole using such tools. The mattock method involved chopping of the stump roots while digging them out, this was more acceptable to the workers and tasks were set between 45 and 50 stumps per man day.
- Manual collection from the field to the periphery.
- Manual covering of stump holes to facilitate even ploughing.
- Ploughing and harrowing using a wheeled tractor.

Table 1 Comparative actual costs Ksh*/ha of various operations in each system

Operation	Mechanical system		
	Mouldboard plough (600 mm)	Root plough	Conventional system
Site preparation	1950	6200	1566
Manual stump digging	—	—	4470
Mechanical stump digging	7900	11140	—
Covering holes	—	—	—
Stump removal	985	8240	6.0
Ploughing	—	—	12.0
Harrowing	165	200	6.0
Total cost	11000	20000	6000

Table 2 Comparison of machine costs and quality operation

Parameter assessed	Mouldboard plough (600 mm)	Root plough	Conventional system
**Actual machine costs, Ksh/ha*	11000	20000	6000
Elapsed time, days/ha	13	3	6
Estimated root removal, %	95	70	85
Approx depth of cultivation, mm	460 — 510	250 — 480	360 — 410

**One pound sterling is approximately equivalent to Ksh 30.00*

For ploughing, the following equipment was operated by a MF 290 4 wheel drive tractor.

(i) Nardi two furrow 400 mm reversible short body mouldboard plough (fig 1),

(ii) Ransomes two furrow one-way 550 mm disc plough,

(iii) MF two furrow one-way 500 mm disc plough and

(iv) Kvenerland three furrow 350 mm one-way long bodied mouldboard plough.

4.2 System 2 — Mechanical system
The objective of this system was to mechanise all the labour intensive operations as much as possible while maintaining the simplicity and cost-effectiveness of the operations. The sequence followed was:—

— mechanical slashing of all surface vegetation where practical,

— ploughing out all cinchona stumps by tractor plough,

— manual collection of ploughed out stumps to field periphery and

— harrowing using a wheeled tractor.

For this system, the following equipment was tried:—

— vertical rotation flail mower which was preferred to a horizontal rotation gyro-mower,

— Nardi 600 mm two furrow trailed mouldboard plough with hydraulic depth wheel behind a Caterpillar D6D crawler tractor,

— a "home-made" root plough of 2100 mm working width drawn behind a GM Terex 82–40 tractor,

— a Ndume trailed offset disc harrow (20 × 600 mm diameter) with a working width of 4.5 m drawn behind a 4 wheel drive Lamborghini 955 tractor, this equipment was also used in system 1 to level off "bumpy" areas.

5 Results of trials

Costs of the two basic systems were compared with a view to determining the level of labour or machinery substitution in each and these are given in table 1 and comparisons of machinery costs and work quality are given in table 2 and in fig 2.

The following can be inferred from these results:—

5.1 In all the three systems, stump uprooting, whether by labour or machinery formed the major cost and this operation was identified as having potential for cost reduction.

5.2 Site preparation before uprooting stumps can be costly depending on the subsequent operations; however, the conventional system required better preparation.

5.3 Where manual stump uprooting is adopted considerable cost saving can be achieved by setting higher task rates (number of stumps per man day).

5.4 Quality assessment was based on depth of cultivation achieved and the number of subsequent operations required. In all the three systems, the quality achieved was acceptable. The 600 mm mouldboard plough achieved higher root removal but required further secondary operations to develop a suitable tilth. However, it was not possible to remove all the cinchona roots by any of the systems (see table 2).

5.5 Hand lifting of stumps was sometimes unpopular especially compared with other estate jobs such as leaf plucking. The labour turnover rose as the task for stump lifting increased. Simple hand tools to enhance labour productivity and a simple labour incentive system could reduce labour preference for other jobs.

5.6 The desirable characteristics required in the cultivation system are cost effectiveness, good root removal, reasonable speed of work and acceptable depth of cultivation. The root plough, although having the highest workrate, did not meet the main requirement as it buried the very stumps it was supposed to expose!

6 Conclusions and recommendations

6.1 Before any cultivation system is selected, the crop requirements for depth of tilth must be known as this influences the type of implement required. This should include both short and long term crop growth needs.

6.2 The cost limits of the cultivation must be known in order to eliminate methods of tillage that are too expensive.

6.3 Field obstacles such as stumps, matted grass and thick bush can have considerable influence on the cost of cultivation. Wheel tractors are more vulnerable to sharp stumps than small crawler tractors, the root plough is less vulnerable to blockage by grass and other trash than a mouldboard plough, however, it does not lift cinchona root stumps effectively.

6.4 A combination of both conventional and mechanical systems is recommended to suit prevailing machinery and labour both in terms of costs and availability.

Economic realities of energy conservation in UK farm dairies

J L Carpenter

Summary

CONSIDERATION is given to the amount of energy potentially available for conservation as shown by the evidence of an audit carried out in 13 dairy parlours in South Devon, UK. The practicalities of the site management options are examined with particular emphasis on scale of operation and possible complication of milking procedures.

The alternative methods of reducing energy bills are reviewed and assessed with the conclusions drawn that savings may be made by careful appraisal of existing techniques but investment in new 'retro-fit' equipment is not easily justified on economic grounds.

Additionally, few energy conservation methods produce a heat regeneration pattern which satisfactorily fits that of demand.

1 Introduction

Since 1973 UK dairy farmers have been concerned about the cost of the energy required to abstract and store milk prior to collection for processing. Although energy costs have not escalated recently at their former rapid rate it is still at a level to cause producers to review their expenditures. In addition to this rise in price, technology changes such as increased automation, more rapid milk cooling and higher applied standards of hygiene have all increased the power demands made on rural (mostly electrical) supplies at a time when expanded access is not encouraged by the general economic climate. The net result of these influences has been an increase in the use of energy conservation equipment.

As this growth did not always appear to have a rational basis, a research team at Seale-Hayne College, together with other interested parties, set out to create a greater understanding of the working parameters of energy saving methods by investigating in detail the use of energy in 13 herringbone milking parlours on farms in the South West of the UK (Carpenter *et al*, 1983).

The results of the initial audit carried out indicated that any attempt to make real savings at an economic price would require a specific site appraisal of the energy load characteristics imposed by the milking routines. This in turn entailed knowing the approaches taken by both management and operatives to the tasks and equipment essential to the milk extraction process. However, some common patterns of use emerged from the data gathered which might form a basis for future advice and ultimately design of equipment.

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2 Audit results

Table 1 shows the mean proportions of the energy used in the five major activities requiring electrical power in dairies. Approximately one third (or one-half, in the case of plant cleaned by acidified boiling water,

Table 1 Proportion (%) of total dairy electrical energy used in five tasks

Method of plant cleaning	*Circulation cleaning (CC), %*	*Acidified boiling water (ABW), %*
Cooling & storing milk	44	38
Vacuum pumping	19	12
Lighting	2	2
Udder washing	9	4
Plant cleaning	26	44
Mean total cost £ cow $^{-1}$ yr $^{-1}$ (at 5p/kWh)	**11**	**14**

A.B.W.) is needed to heat water to various temperature levels (30–40°C for udder washing and 75–85°C for plant cleaning — 95°C for A.B.W.). With lighting being almost discountable at two percent, the rest of the energy is supplied to electro-mechanical powering systems for refrigeration or vacuum producing purposes. The energy (and financial) cost per cow shown is significantly greater in the cases where higher temperature plant cleaning methods are employed. But at much lower temperatures — 'cold water washing' — the cost of chemicals needed for plant hygiene more than offsets savings to be made (Kneeshaw, 1986).

The periodicity of the demand was demonstrated to be predictable, but variously different for most installations. An example of the daily heat and power requirement pattern for one farm is given in figure 1. The seasonal variations established were also predictable, affected by external factors such as temperature in addition to 'internal' influences like the herd calving periods and their consequent effects on milk production. Figure 2 indicates how the requirement for bulk tank refrigeration (affected by both the above factors) may impose its influence on the total demand over a year.

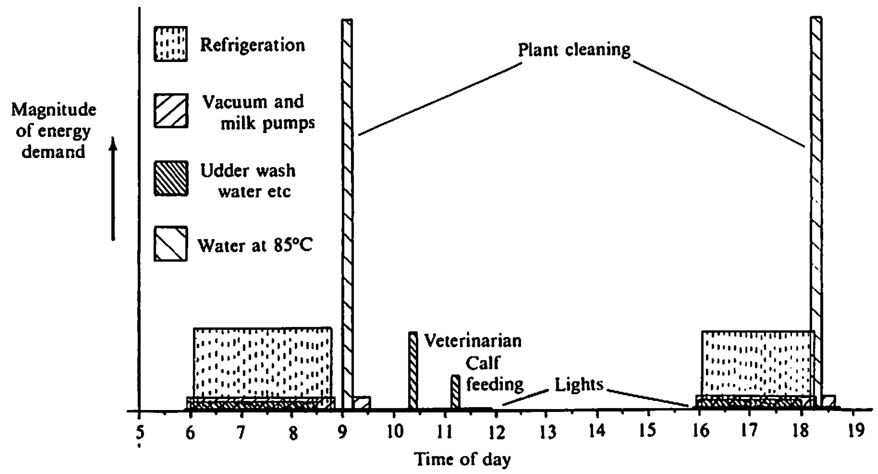


Fig 1 Diagram of typical energy demand in milking parlours

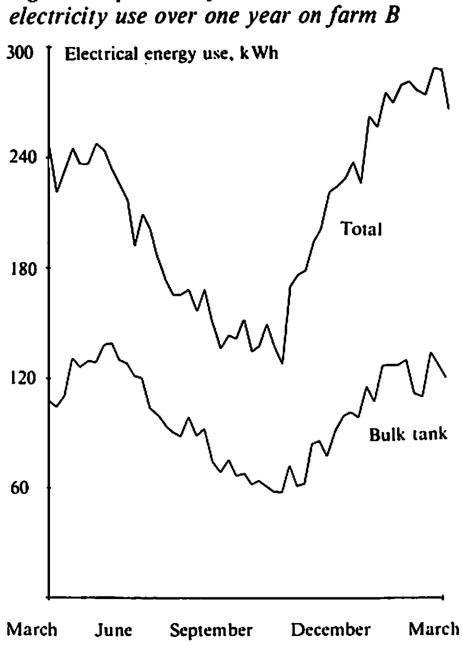
Table 2 demonstrates the consistency with which energy is used on particular sites. Farms A, D, F and G maintained reasonably constant herd sizes whilst farm K increased (by approximately 50%) and farm M decreased down to one third) during the same three year period.

3 Alternative conservation strategies

If a pattern of use, daily, weekly, annually, can be established or predicted for a site then it will be possible to:

1. make comparisons with good management situations and hence pinpoint opportunities for saving and
2. fit the output patterns of alternative energy sources to the demands expressed by the existing dairy system.

Fig 2 Comparison of bulk tank and total electricity use over one year on farm B



It is obvious (to outside observers — but not necessarily to those most concerned — the operators) that the first approach to economy should be via greater efficiency of use. This may be brought about in various ways, as presented in Table 3, which aim to utilise existing techniques or equipment better (or as the devisers originally intended!) by the correct interpretations of timeliness, by achievement of target temperature and by minimising thermal losses. In practice this means setting time-switches, thermostats and vacuum levels more precisely, in addition to the routine replacement of worn piping, insulating jackets, tap-washers etc. Regular cleaning of items like refrigerator cooling coils will also save energy, as will the routine employment of a service engineer to attend to the more sophisticated pieces of equipment such as the compressor.

Figure 3 demonstrates the potential effect which operator skill (or varying practices) may have on the energy bill in the dairy. This

Table 2 Annual electricity use (kW) in 6 South Devon milking parlours over 3 years

Farm Code	*First Year*	*Second Year*	*Third Year*
	(Mean number of cows in herd shown in parentheses)		
A	13857 (53)	13003 (56)	13840 (58)
D	18630 (60)	18902 (62)	17740 (59)
F	23446 (96)	22963 (88)	22967 (90)
G (kWh equivalent of oil fired heater)	37678 (105)	37682 (108)	37112 (104)
K (New parlour installed in 2nd year)	30836 (121)	46774 (144)	45642 (156)
M	46559 (164)	27971 (78)	22339 (74)

Table 3 Summary of energy saving methods for UK farm dairies

Style of conservation	*Saving method*	*Potential % saving of total energy expended in dairy*
Load reduction	Chemicals substituted for heat	15 - 40
	Increased insulation	10 - 15
	Service efficiency	5 - 15
	Accurate control settings	3 - 15
	Milk cooling by transfer to water prior to refrigerating	15 - 25
Load recycling Heat recovery from:	milk	10 - 20
	vacuum	1 - 2
	wastewater	2 - 5
Load substitution 1) Heat only	Solar gain	3 - 6
	Wind generation	30 - 40
	Biomass furnace	30 - 40
	Biogas	30 - 40
	Flash (instantaneous) heaters	10 - 15
	Heat pumps	15 - 20
2) Motivepower (% heat by electrical generation)	Wind generation	50 - 75
	Biogas	80 - 100
	Total energy modules (eg Totem) via biogas	90 - 100
Cost resheduling	Off peak tariffs	40 - 50

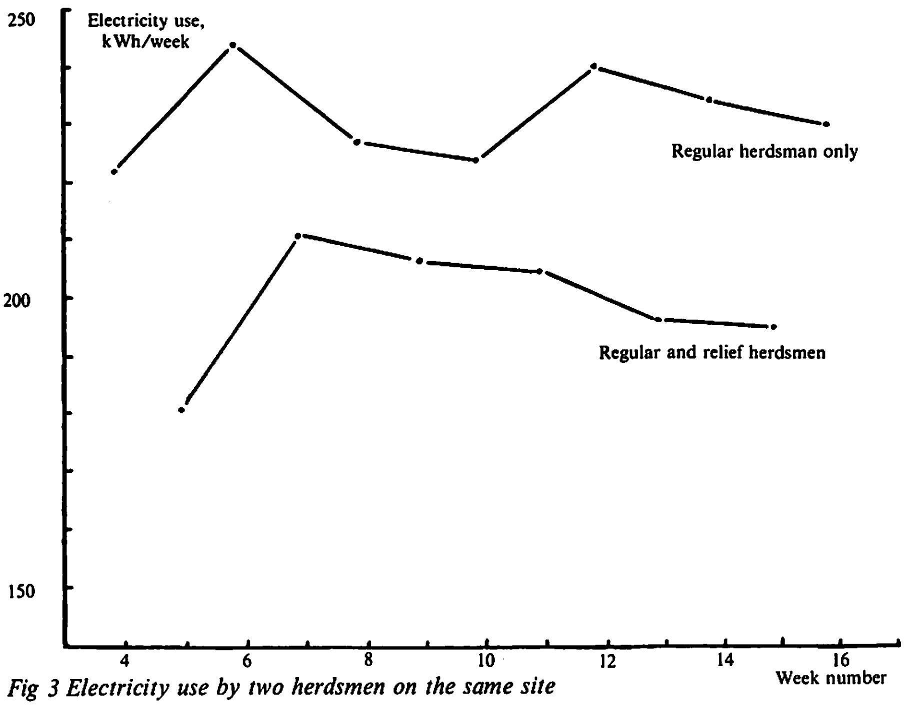


Fig 3 Electricity use by two herdsmen on the same site

highlights the need for staff to be informed of the energy implications of their work routines and the desirability of conservation training.

Less easy to circumvent is the problem of equipment mismatch, a common difficulty where machines are deliberately oversized to cope with peak loads or where manufacturers, for their own reasons, only offer a limited range of power options. This latter possibility ensures that a proportion of installations are supplied with overcapacity for their lifetimes and thus are continually wasteful from their inception.

It was the experience of the audit team that careful attention to all these above details would produce important savings, perhaps in extreme cases of halving the energy bill. Table 4 represents the results of work on two typical sites and demonstrates the level of energy conservation possible without major investment.

Once the 'waste' energy has been minimised the remaining demand can be examined for potential substitution and/or matching to alternative supplies. There are many possible sources (Table 3) but most require significant investment and almost always produce management complications which require the modification of existing practices. However, most of these systems can be made to generate usable energy when incorporated correctly but the real dilemma always lies in establishing the level at which investment can reasonably be sustained by the return on capital i.e. their 'cost-effectiveness'. (A further 'National' dilemma can be seen in the contrast between Governmental need — always to economise — and the requirement of the individual, farmer or other, whose interests may not be best served by conservation, this problem will be ignored for the purposes of this paper.)

4 Scale of operation and choice of an 'alternative' energy source

4.1 The options

Although it is clear from the foregoing that specific site requirements will ultimately decide the most appropriate methods to be used, the choice may initially be resolved by a simple consideration of the scale of operation required to make them technically efficient. Bio-gas digesters, at £150 - £300/cow (1987 prices) and heat pumps at £100 - £150/cow, both require a minimum size 100 cow unit to be realistic and may produce an embarrassing surplus of heat in summer! Bio-mass furnaces, which are more energy efficient in sizes over 50kW and cannot be controlled easily at low output, may cost £30 - £60/cow to install, again making them suitable only for the largest dairy units. Additionally the two latter systems in providing heat rather than power would be less useful anyway (as heat normally represents less than 50% of the total expenditure). Even the first option requires a 'converter' to translate the bio-gas to mechanical/electrical power and this may cost £20 - £50/cow in itself, or more than that if a sophisticated system such as a total energy module (Totem) is used to achieve maximum benefit.

Less capital intensive (or more easily scaled down) equipment such as solar power (Carpenter *et al*, 1986) at £20 - £60/cow, or wind power at £30 - £80/cow generators have problems related to their respective energy sources which lead to a need for storage, buffering and 'back-up' methods. Also their control is often awkward.

Most, if not all, of the above installations are much too expensive to be contemplated in the present climate of dairy economics. However, despite the current industrial depression two heat transfer and recycling systems have become 'front-runners' in dairy energy conservation in the UK over the last ten years through 'common-sense' selection (and in some instances by aggressive salesmanship!). These cheaper options, the heat recovery unit (HRU) and the 'plate-cooler' (£600–£2000/unit) are both relatively simple, small scale devices which probably represent the greatest degree of complication in installation and use which might reasonably be incorporated into current dairy practice.

4.2 The practicalities of heat recovery and plate cooling

The HRU takes heat rejected from the bulk tank refrigerator and stores it in water at up to 65°C ready for

Table 4 Potential for improvement by 'Good Housekeeping'

Energy expenditure	*kWh/m³*		*kWh/cow*	
	First year	*Second year*	*First year*	*Second year*
Farm I (55 cows, ABW)	60	50	357	267
Actual saving over 9 months = £197 (£250 est. in full year)				
Farm II (80 cows, CC)	56	44	322	264
Actual saving over 1 year = £319.				
NB: Energy cost = 5p per kWh				

plant cleaning. The plate cooler lowers the milk temperature from 35° to 15–20°C before passing it to the bulk tank storage, so reducing the load on the refrigerator compressor (and also limiting the heat which may be conserved by an HRU).

The popularity of these methods stems from the significant and obvious reductions they make in parlour energy bills, because of which their economic value has never seriously been questioned.

The Seale-Hayne audit evidence (Carpenter *et al* 1982, 1983, 1986) suggests that their performance should be carefully considered before investment is undertaken for the following reasons. Firstly, the survey, which included several HRUs, indicated that the installation standards are likely to be less than optimal, leading to poor returns or even hindered refrigeration. Secondly, retro-fitting the equipment was often complicated (and expensive) due to the nature of the dairy siting. Thirdly, management routines which are governed by rigid hygiene requirements were often not flexible enough to benefit fully from the available recovered (or saved) heat. For example, the low grade heat, at 10–15°C from plate coolers was often poured to waste down a drain, it not being thought worth recovering. Finally, and perhaps most importantly, the opportunity for saving or transfer were shown to be limited to comparatively small quantities (table 1). As it is unlikely that an HRU will achieve more than two-thirds of the required rise in temperature (50°C c.f. 75°C) or that a plate cooler will lower the milk temperature by more than half (35°C to 18°C) there are limitations to the savings to be made even if the equipment is installed and maintained correctly.

Two further factors make the situation still more difficult for energy conservation devices. The total load of dairy electricity only accounts for about two percent of the cost of producing milk, giving it a low priority on the management scale; in addition, very advantageous electricity supply tariffs encouraging 'off-peak' (night-time) use may reduce the cost of heating and refrigerating loads down to one-third of their previous level. The latter approach has been so successful that certain, off-peak tariffs are said to have achieved a 62% overall market penetration rising to 98% in some areas of the UK, allowing the majority of milk producers to choose between electric power at 2p per unit (kWh) and 5.5p per unit for minimal expenditure on time switches.

Table 5 Scenario assessments of the potential for savings with HRUs

Assumptions:— 100 cow herd. Good awareness of energy saving measures.
Energy cost per year — £11 per cow.
Water heated from 10° to 85°C.

	Good scenario		*Poor scenario*
Energy used in water heating	30% of total		25% of total
Cost of water heating energy	£330		£275
Assume HRU lifts water to	60°C		50°C
Therefore HRU gain in temp	50°C		40°C
Proportion of heat contributed	50/75%		40/75%
Proportion of cost contributed	£220		£147
Assume HRU costs (inc. inst.)	£600		£800
Assume interest at 15%, total/yr	£90	at 18%,	total/yr £144
Nominal payback time for capital	4½yrs		266 yrs
(Reducing balance basis, minimum likely	3½yrs)		

Note 1. No allowance is made for operating factors such as the 'topping-up' energy source being combined in the same enclosure as the HRU coils, losses sustained from storage or the complex nature of the relationship between the compressor operating time, the ice bank and the refrigerant flows. These and lesser factors such as remote installation may account for one-third to one-half of the theoretical gain shown above.

Note 2. The estimations take no account of the possibilities of off-peak tariffs in either water heating or refrigeration which can dramatically reduce the financial advantage shown here.

Table 5 demonstrates two possible contrasting financial relationships for scenarios drawn for one HRU installation site. They take no account of factors such as cheap rate electricity supplies, which must make any conservation device less competitive. It must be concluded from these that the average situation, lying somewhere between the examples given, is not encouraging.

Plate coolers potentially have an advantage over HRU's in commercial terms because they assist the refrigerator to cool the milk (a contractual necessity) down to 4.4°C within half an hour of the last morning milk being delivered to the bulk tank. (This may be an important factor where "off peak" electrical supplies cause difficulties with potential shortages of 'ice-bank' and thus of cooling capacity in periods of high ambient temperatures and peak load such as spring-time.) Their main disadvant-ages are a need for a large volume of water and complicated fitting arrangements to ensure correct (ie acceptable to the Milk Marketing Board) and efficient milk flow patterns. They can also be appreciably cheaper than HRUs for similar potential conservation levels.

5 Discussion

Most 'alternative' methods of providing energy for farm dairies have important drawbacks. The crucial nature of the energy use, with its commercial and legal implications, make it difficult for any system to substitute for the readily available, easily controlled and varied, single or three phase electrical supply. When substitution is possible, the consumer is still faced with a need to provide electricity for control and emergency 'back-up' in case of operating difficulties or source failure.

Two major factors have a greater effect than others. These are, firstly, the poor 'fit' which many of the alternatives give to the periodic demand pattern in the parlour and, secondly, the usual lack of intensity of the energy produced, as for instance where low grade heat is produced when high grade is required. Thus any system presently available must be 'managed' if it is to be of maximum value and give an optimised return on the capital expended. As operation of the dairy itself requires considerable management expertise any diversion of skill and attention into channels which are relatively minor, at two percent of the cost of milk production, runs the risk of being counter-productive.

The conservation of energy is not, therefore, a high priority for most farm managers, but it would be accepted if it could be incorporated, at a moderate price, as a natural course of events, into parlour design and did not lead to new work patterns. The economic level of investment can be readily calculated, in simple fashion (ignoring tax incentives) to demonstrate that if hot water only (at £4 cow year) is to be provided the point at which the return on capital becomes just acceptable is about £15 per cow (assuming notional interest, depreciation and maintenance charges of 15%, ten and two percent respectively). This figure becomes £44.50 if all the parlour energy is to be replaced from a new source. Thus for a 100 cow herd the capital invested must not exceed £1500 and £4500 in each case. These estimates assume that the equipment will substitute all the energy demanded of the system.

It is clear also, that for practical reasons, 'add-ons' or 'retro-fits' are not likely to provide total satisfaction. Thus, designers of original equipment such as water-heaters and refrigerators should be considering variants which include higher efficiency heat exchange, shorter term storage and more sensitive (and accurate) self-adjusting control systems, all of which will lead to reduced losses without much greater expense.

Conclusions

1. The amount of energy to be saved or substituted is small relative to other inputs to agriculture, at approximately two to three percent of the total and is generally supplied as electricity.
2. There is considerable scope for savings and economy with existing equipment, perhaps up to one-third of the present expenditure.
3. The periodic but consistent all year round demand raises doubts about the suitability of many of the alternative source possibilities.
4. The level of investment in energy conservation devices should be associated with their potential for saving, which is usually limited to £2 – 5/cow and may be even less than that if thorough economy measures are taken first.
5. The two common energy conservation options installed in milking parlours, HRUs and plate-coolers, save significant amounts of energy but are only marginally worthwhile investments; the former less useful than the latter in this respect.
6. Greater consideration should be given to energy saving concepts in the design of milking plant and initial installation procedures.
7. Operators should have a greater awareness of the factors involved in saving energy and be encouraged to develop an interest in its conservation.

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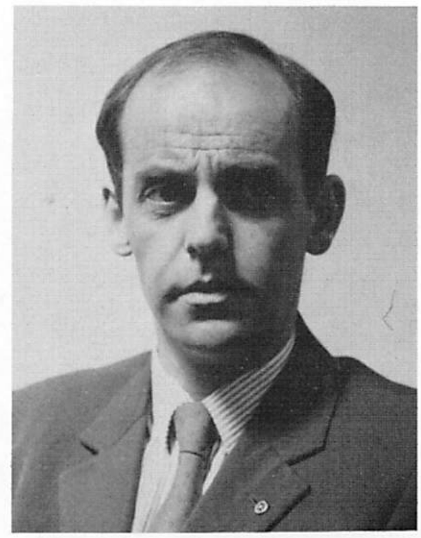
Information technology for machinery management teaching at the Royal Agricultural College

A J Landers



Summary
INFORMATION technology has many definitions. This paper reviews five main areas of application to machinery management teaching at the Royal Agricultural College; Computer programs, video, viewdata systems, on-line literature searches and database. The development of information technology and the benefits it can bring to lecturers and students are outlined.

1 Introduction
The machinery department staff at the Royal Agricultural College is responsible for teaching Farm Machinery and Machinery Management to students on certificate, diploma and degree courses.

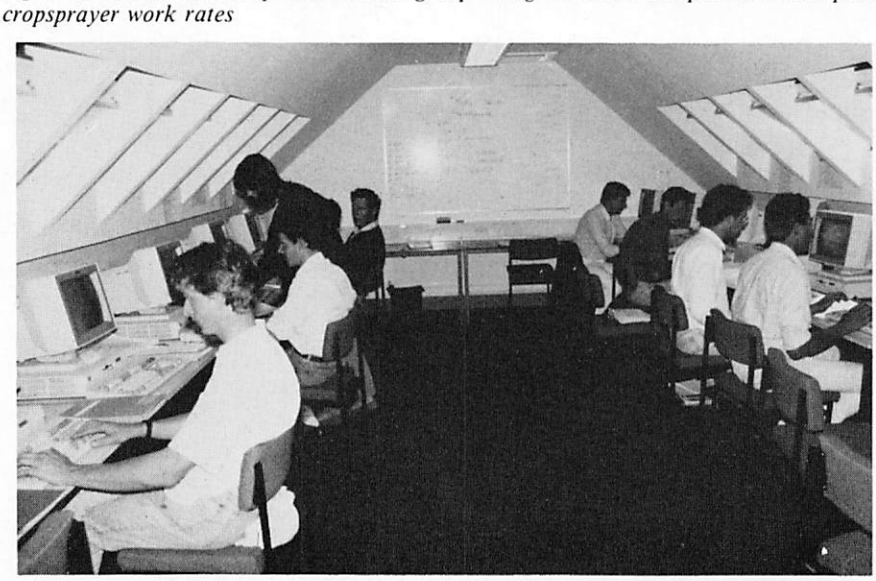
Recent developments in communications have resulted in novel techniques being used as an aid to teaching machinery management. Traditional methods of teaching are still used, the developing technology being an additional aid to teaching and learning, providing different ways of communicating, manipulating and handling information.

2 Computer programs
Computer programs have been developed to help give students a better understanding of mechanisation by using the College's Apple computers. A number of programs demonstrate the basics of farm machinery whereas others detail some complex costing exercises.

A dearth of programs for farm machinery led to the development of specialist ones by the author and Peter Clarke, a student on the Diploma in Rural Estate Management Course. The collection of programs is being constantly updated by the generosity of contacts at other universities, colleges or research institutes and by new developments at the Royal Agricultural College. The programs can be used in tutorials, in special studies groups or by the individual student.

2.1 Tutorials
The tutorial system at the College enables staff to engage small groups in critical discussion and to review the results of set work. Small groups of 6 to 12 students can meet tutors in the computer laboratory where programs can be demonstrated as a follow up to the current lectures. For example the students will study agricultural crop sprayers in lectures and demonstrations, then the tutorial group will see the Sprayer selection/Sprayer calculation programs (figure 1). These two programs will calculate the effect on work rate of a crop sprayer by using 8 main variables and 26 other parameters. The user can use this 'what-if' program to look at changes

Fig 1 A mechanisation special studies group using the IBM computers to compare cropsprayer work rates



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in application rate, boom width, tank size etc. It will demonstrate, for example, the impact a water bowser will have on the efficiency of the spraying operation.

One of the benefits of this program is that it allows the student the opportunity to consider the effects of various changes in a spraying system before the expense of implementing them. Discussion can then follow regarding points made in the lecture, the students' own experiences, and the effect on sprayer output as demonstrated in the programs.

2.2 Special studies

Students wishing to study a particular subject in greater detail can join a special studies group for one afternoon per week for one term's duration.

An example of a mechanisation special studies group is on grain drying and storage. A small group of students can visit a number of grain driers on farms, accompanied by the farmer, the machinery dealer or store designer and study various methods of grain drying and storage. An afternoon can be spent looking at the program developed by Smith (1984) at the erstwhile Scottish Institute of Agricultural Engineering.

This program calculates the energy used by the fan heater to dry the grain; it also decides whether the grain will go mouldy and calculates germination damage. An interesting feature is that it calculates the minimum energy required to dry the grain safely and an operator can try to achieve this value using the various control methods. It also allows the user to consider the effects on drying grain by changes in grain depth, drying hours and heat.

2.3 Individual use

All students at the College have the opportunity for computer studies as part of their course — the basic programs studied being farm management and finance. All the mechanisation programs can be used by the students in their own time, each disc being accompanied by a small card, outlining the operating instructions. The computer programs can be used by students for their management case studies, an example being one on combine harvester selection written by Clarke and Landers. It is based on published information that included two surveys on combine performance carried out over a number of seasons in England and Scotland. These surveys were conducted by the Agricultural Development and Advisory Service and the Scottish Agricultural Colleges respectively. The key points noted are drum width, straw walker area and management as opposed to traditional selection criteria of speed and width. The use of the program allows the effect of changes in combine size (straw walker area), standard of management and operator performance to be seen.

A further program exists that will develop the break even calculation that compares company ownership with the use of a contractor's machine.

2.4 Dissertations

Computer programs have provided an interesting topic for dissertations by students on the Diploma in Advanced Farm Management course. Fox (1986) validated the program on sprayer selection, comparing actual sprayer work rates with computer predicted ones. Voss (1986) validated the program on the cost of harvesting potatoes, comparing the costs of different machines and labour and their effect on harvester output.

These two dissertations resulted in some of the survey farmers subsequently contacting the College regarding changes in their harvesting/spraying systems.

Maynard (1987) studied the perennial question of machinery replacement intervals. During his studies Maynard developed a program that helps in making a decision on the replacement of a tractor or combine. The use of this type of program was not considered of great value until recently when:

(i) changes in capital allowances were introduced,

(ii) a fall in cereal prices became a possibility, and

(iii) trends towards a decline in farm profit and a fall in land values appeared.

The two factors of importance in this context and critical in reducing the farmer's fixed inputs, are the on-going repair costs for farm machinery and the high annual depreciation of new farm machines. Data needed for repair costs is found in the records the farmer has kept, thus placing a demand on historic information. A second source of data is by access to the records of dealers guide for secondhand prices. By using such figures it is possible to calculate a true market figure of tractor or combine value.

For this decision-making operation, the farmer has his own information required for the program as his own historic records constitute the farm's database.

Such basic information may read as follows:

Past records show that a major overhaul is imminent for a three year old tractor. The farmer may therefore obtain an estimate from the dealer to carry out repairs. The farmer needs to know if he should sell his tractor now or have it repaired. After entering the repair charge into the computer he can see the effect on the minimum holding cost displayed on the VDU.

3 Video

Video tape is used as a teaching aid in the library, machinery demonstration hall, lecture rooms and tutorials. The videos are either purchased or borrowed from the distributor.

3.1 Videos in the library

A large collection of videos is kept in the library. Students have free access to them and a video player during library opening hours. Videos may be borrowed overnight. An increasing number of students have their own video players. During lectures reference is made to a particular video (as it would be made to a particular book or paper) and students are then able to use the video collection in the library. Video tapes are used by students for revision purposes prior to exams. They provide an overall view of a particular topic and are a change from normal book revision.

3.2 Videos in the machinery demonstration hall

The machinery demonstration hall is used to show students different examples of farm equipment. Manufacturers and local machinery dealers kindly provide the College with new and secondhand equipment. The students can see the various designs, construction and crop flow, etc. A video can be used to help demonstrate the equipment, eg: during the summer, students compare various designs of round baler. The use of net wrapping big bales has increased the output of these balers and a video from New Holland or Claas shows the wrapping operation. The video can be used to show the finer points of a machine in operation (figure 2). A number of combines are displayed to the students in the demonstration hall. A second video can be used to show various changes in design, as for instance in a range of hillside combines, New Holland TF combines, Powerflow tables and Claas 3-D sieves.

A video can also be used to provide an overall view of field operations to students who are not familiar with a particular crop, eg: a potato harvesting video is used prior to the students seeing harvesters in the machinery hall. The same video can be used later to demonstrate the finer points, eg: damage to potatoes as they travel through the machine. Although students are taken on field trips to potato growers and see harvesters in action, the teaching timetable may not coincide with the date of the visit.

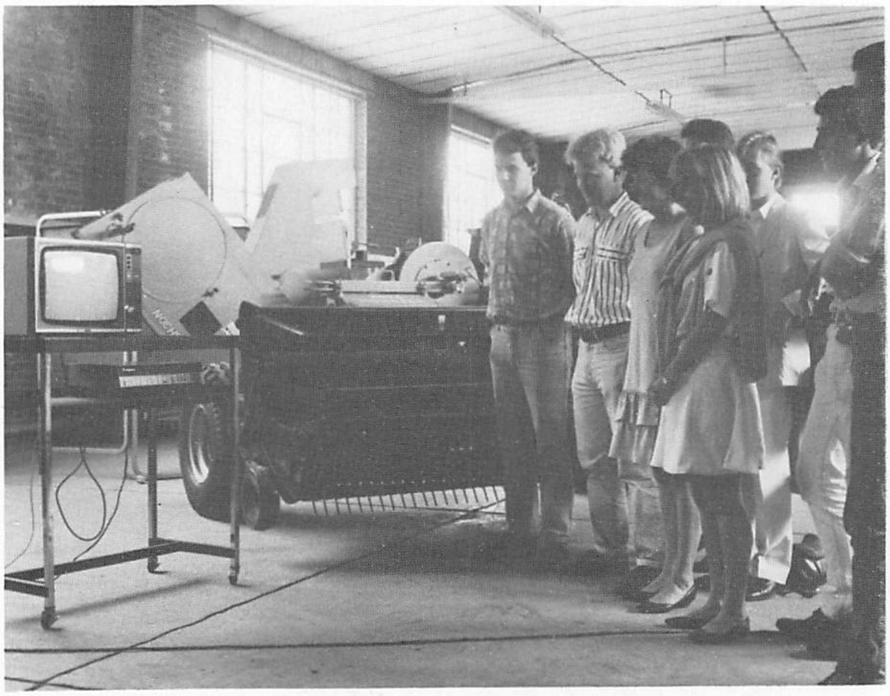

Fig 2 A video being used to show the finer points of a machine in operation

3.3 Videos in the lecture room

Videos are very rarely used in the lecture room, as the machinery department has an excellent collection of slides. However, occasionally a video is used to demonstrate a particular subject. For instance, a three minute video published by AFRC Engineering on electrostatic spraying is used during lectures on spray application techniques. A very short video can demonstrate a complex machine and provide a change of voice and aspect for the students.

3.4 Videos in tutorials

The College system of tutorials allows staff to meet students in small groups for discussion. A video may be used for a particular theme, as an audio and visual introduction to a topic such as traction and the subsequent discussion will expand many aspects on tractors, tyres, soils, compaction, cropping and weather, etc, based upon previous lectures, farm visits and the students' own experiences.

Videos on machinery are available from manufacturers and are obviously commercially biased. Areas of interest can be noted prior to presentation and a record kept of the appropriate number on the video player trip meter.

A number of videos on general agriculture contain some very good views of equipment in work and have the advantage of showing the equipment in conjunction with the overall aspects of crop husbandry.

4 Viewdata systems

The library has a BBC micro computer and Modem connected to the telephone line, which allows access to ICI Agviser and Prestel Farmlink systems. The lecturer can use Agviser viewdata to assist with machinery management in two different ways — by using the information providers and the mechanisation computer programs.

4.1 ADAS provides the following information

(a) Tyres and traction. This information is based upon research carried out at The Agricultural and Food Research Council (AFRC) Engineering Institute at Silsoe, and helps the farmer choose the correct tyres and ballast for his tractor and thus obtain optimum traction.

(b) Crop protection. This information gives the farmer guidelines for the safe and correct application of agricultural chemicals. The user can select the correct nozzle size for a given droplet requirement. The important points of calibration procedure are outlined, thus enabling the farmer to obtain the best from his sprayer. The effect of weather (eg: drift) is covered, along with the important aspects of safety.

(c) Irrigation. This program helps the farmer to optimise crop performance and the return on investment in machinery by determining when and how much water needs to be applied. The farmer inputs information on rainfall, crop, pipe sizes and receives information on soil moisture deficit, infiltration rate and application rates and dates.

(d) Harvesting and storage. This program presents the farmer with the guidelines to ensure that potatoes are harvested correctly. Details such as the timing of harvesting, to ensure that the skins have set, along with other ways of minimising damage, are given. Information regarding the correct storage of potatoes is also provided.

(e) Grain drying and storage. Guidelines are provided for the correct storage of grain. Information, such as the correct depth of storage for ambient air drying, ventilation rates, relative humidity/ moisture content equilibrium and grain store characteristics are detailed.

4.2 The Health and Safety Executive provide a farm hazard file
This gives guidance on the safe use and operation of farm machinery. The user can call up a specific farm machine and find the relevant safety points to follow and a brief resume of the current safety legislation applicable to that machine. Descriptions of the published safety leaflets are also given.

4.3 Information from AFRC Engineering Institute
There are three computer programs specifically written for machinery management by the Operation Research Group at AFRC Engineering Institute, Silsoe which have been available on Agviser since Spring 1986. The programs cover both the financial and the efficiency appraisal of farm machines and operating systems and are listed below:

(a) Spraying logistics. This will calculate the effect on work rate of a crop sprayer by using eight main variables and 26 other parameters. The user can use this 'what-if' programme to look at changes in application rate, boom width, tank size, etc. It will demonstrate, for example, the impact a water bowser will have on the efficiency of the spraying operation.

(b) Tractor and work rates. The user inputs information such as tractive conditions (soil type/condition), power available, tyres and ballast and the program will calculate the work rate when pulling a plough, a subsoiler or a chisel plough. The results are given for the work rate of a tractor and implement at a known wheelslip. The user can see the effect of changing plough size, width and depth along with changes in soil type.

(c) Cost. This calculates the annual cost of a machine and allows repairs, interest rates and resale value to be included in the calculations. The user can change various parameters and examine their effect on the cost of ownership eg: interest rate, annual use, replacement period and inflation rate. The program is based upon the annual cost of machinery calculated using actual cashflows (Audsley and Wheeler, 1978).

4.4 Prestel Farmlink on Viewdata
The agricultural information service provided by British Telecom provides farmers with a similar service to that of the Agviser system. The mechanisation information is limited to details of equipment that is for sale through agricultural machinery dealers or merchants. The services provided by the dealers are also covered and include a contact name and a telephone number in case of emergency. The ADAS information service provided on ICI Agviser is also available on Prestel Farmlink. Farmlink has, however, only a limited coverage in scope and detail in the area of mechanisation management.

4.5 Viewdata availability
Landers and Robson (1987) observed that Viewdata allows lecturers immediate access to a range of unbiased information and independent advice through one source. The user can keep up to date with recent articles of interest without having to search through many publications.

Viewdata services are, at present, only available to lecturers and a few students at the College. When the new computer laboratory is finished, Viewdata may be available for supervised student use. The programs on Viewdata are used in a similar way to the teaching methods described under Computer programs.

5 On-line literature searches
The College library has access to a large number of computer databases via the telephone line. The Librarian can supply a list of references from a wide range of sources, often from the periphery of a subject. The speed of retrieval is most impressive. Agdex and Commonwealth Agricultural Bureau (CAB) abstracts are mainly used.

5.1 Agdex
Agdex provides the user with a bibliographical index service from the Scottish Agricultural Colleges (SAC), based at the Edinburgh School of Agriculture. It gives abstracts of recent articles taken from such applied agricultural sources as the weekly and monthly farming press, publications from the Ministry of Agriculture, Fisheries and Food (MAFF), SAC, AFRC reports and semi-scientific literature and trade and business literature. There are 31 subject areas covered, thus saving the user time and allowing him to be better informed on topical farm management issues.

5.2 CAB abstracts
This database has a global coverage of literature. Experience has shown that the use of the correct keywords are essential to obtain appropriate references. Incorrect keywords result in vast lists of irrelevant references, incurring extra cost and frustration.

5.3 Update
Update is the literature database of the Welsh Agricultural College and is available in hard copy only at the Royal Agricultural College library.

5.4 Costs
The high cost of on-line searches, £6–7 for the average search of 10 minutes including a print-out, has resulted in searches being carried out only for important topics. Less important ones are researched traditionally.

6 Machines database
An area of continuing interest is the Machines Database operated by ADAS. The operation centre is at Silsoe and the data is stored on MAFF's computer at Guildford. The objective of this system is to give an information service to the Ministry's advisory personnel. The database is managed from the ADAS Liaison Unit at the AFRC Engineering Institute. It is staffed by the Director of the Network and two part-time computer operators who are responsible for the physical input of data into the system. The database gives the ADAS mechanisation advisers information on the specification of farm equipment and its availability to farmers. This information is derived from the machinery trade. The system is designed to provide the latest information on farm equipment.

At present this service is only linked directly by telephone to the micro computers of ADAS officers, but there is a possibility that agricultural colleges will be allowed to use hard copy produced from this database. The cost of this service has yet to be decided. At present there are 8500 items of machinery on the database, the intention is to increase this to 20,000 articles.

It operates by machinery manufacturers supplying specifications of equipment to the office at Silsoe where it is then stored. The information is updated every six months.

The limitation in the usefulness of the database during the early period of operation was due to the small number of farm machines for which information was available. The main advantage obtained by its use is in providing the adviser with information which is beneficial in making investment decisions on capital expenditure for machinery, where a wide range of choice of machines is on offer. The main problem is in the low number of users, (access is limited to use by the ADAS advisers). Advisers, while sceptical of its value, have indicated that they find its greatest use in providing names and addresses of manufacturers, and for providing information on obscure equipment seldom seen.

Robson and Landers (1985) observed that the system is carrying an increasingly large volume of data on machine specifications. The structuring of this data and the way in which regular updating takes place are important factors that influence the efficiency of the system. It provides an up-to-date table of machines, specifications and prices. Thus it would be very useful, prior to each term, to obtain the tables of equipment relevant to the subjects to be taught.

7 Conclusions

Information technology, as described in this paper, is just one of the many aids used to enable students to gain a better understanding of farm machinery and machinery management.

Information technology has great potential to increase the effectiveness of teachers. New learning methods are always on the horizon and professional educators should be prepared to consider the relevance of these methods to their subject area and adapt the curriculum accordingly.

People, their motives and the acceptance of change, have a direct influence on the operation and development of information technology. New technology must be viewed alongside traditional methods of teaching and must be kept in perspective, particularly its cost and educational effectiveness.

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Review of recent British Standard Specifications

M D P Matthews

BS AU 218: 1987 Automotive synchronous belt drives, (24 pages)

THIS specifies requirements for synchronous pulleys and endless synchronous belts for use in automotive applications. Section 1 defines the terms used in the specification of both belts and pulleys. Section 2 provides specifications for belts in terms of dimensions and tolerances and their performance under specific operating conditions. Section 3 provides the specifications for pulleys regarding their dimensions and tolerances and the material finish. The Standard for balancing is as specified in BS 5265 but a formula is provided to calculate the limiting speed in rev/min below and above which static and dynamic balancing is required respectively. Appendices provide test procedures for flex fatigue, resistance to ozone and high and low temperatures, methods to measure the belt pitch length, tensile strength and groove profiles, and axial and radial runout on pulleys. The final appendix provides design and installation recommendations.

BS 3731: 1987 Vee blocks, (7 pages)

SPECIFICATIONS for hollow or solid, single or double vee blocks made from cast iron, steel or granite (solid only) are laid down in this Standard. Two specifications are provided with regard to heat treatment (surface hardness), grade of finish and geometric accuracy. A specification is also provided for matched pairs and a system of making vee blocks is explained. Appendices cover the recommendations on general dimensions and methods of testing vee blocks as singles and matched pairs.

Mike Matthews is a Technical Executive of the Agricultural Machinery Partnership Scheme located at AFRC Institute of Engineering Research, Silsoe, Bedford.

BS 5540: Part 5: 1987 Evaluating particulate contamination of hydraulic fluids, Part 5, Method of reporting contamination analysis data, (7 pages)

THIS Standard covers the reporting of contamination analysis techniques; viz:

- microscopic particle counting,
- automatic particle counter,
- gravimetric

It is intended to establish the minimum information required to allow valid analysis of contamination level data. Reference is made to ISO Standards relating to hydraulic fluid power but goes on to show data recording sheet layouts for the three analysis techniques and graphic methods of reporting the results.

BS 6703:1988 Manually operated torque wrenches and drivers, (7 pages)

DIMENSIONS, design characteristics and operating comfort are specified for manually operated torque wrenches and drivers in the 6.3 mm to 25 mm square drive range and two classifications are used, ie indicating types and setting types. It also specifies the requirements for endurance, torque value ranges and accuracy. The classification, finish and dimensions are all referred to other British Standards. The maximum torque value is stated for each of the five sizes in the square drive range and a maximum effort at full torque value is recommended. Guidance on safety instructions for users is recommended along with the markings that the manufacturer is required to show. Two appendices cover the measurement of accuracy and evaluation of endurance.

BS 7007:1988 Abrasive products

THIS Standard is in three parts.

Part 1. Specification for dimensions and designation of truncated cone abrasive sleeves (2 pages).

A table of dimensions is given in terms of height, large diameter and small diameter.

Part 2. Specification for designation and dimensions of coated abrasive flap wheels with shafts (2 pages).

A table of dimensions is given in terms of the diameter of the flap wheel, width of the flap, shaft diameter and free length of the shaft.

Part 3. Specification for dimensional tolerances on non-standard coated abrasive products (3 pages).

Reference is made to ISO Standards on abrasive belts, sheets and discs and the conditions under which the dimensions are measured. Recommendations are made on the tolerances of outside diameters of discs, width and length of belts, and on other cross-sections.

BS 1660: 1988, Machine tapers

THIS Standard is in ten parts.

Part 1 (ISO 296-1974). Specification for shanks and sockets for self-holding tapers (morse and metric 5%) (5 pages)

Recommendations for the dimensions of tapers for tool shanks are given in three categories, viz:

- for general use Nos. 1—6 morse tapers,
- sizes below No. 1 morse (either 4 and 6 metric and 0 morse or 1-3 Brown and Sharp taper),
- above No 6 morse (No 80-200 metric).

Part 2 (ISO 238-1974). Specification for reduction sleeves and extension sockets for tools with morse taper shanks (5 pages).

Dimensions in mm and in are given for each item of equipment.

Part 3. Specification for turret sockets and reduction sleeves with capped ends for tools with morse taper shanks (4 pages).

Tables of dimensions are given for morse taper shanks sizes 1-6 and turret sockets 1-5.

Part 4 (ISO 297-1982). Specification for spindle noses and tool shanks with self-release 7-24 tapers (5 pages).

Tables of dimensions in mm and thread specifications are given.

Part 5. Specification for adaptors with 7-24 internal and external tapers (3 pages).

A table of dimensions in mm is given.

Part 6 (ISO 4202-1978). Specification for adaptors with external 7-24 tapers for tools with morse taper shanks (3 pages).

A table of dimensions in mm is given.

Part 7. Specification for extension adaptors with external 7-24 tapers for tools with morse taper shanks (2 pages).

A table of dimensions in mm is given.

Part 8 (ISO 2583-1972). Specification for collar dimensions for 7-24 taper tool shanks and equipment (2 pages).

Tables of dimensions in mm and in are given.

Part 9 (ISO 1080-1975). Specification for cotter slots (4 pages).

Methods of dimensioning slots on tapers and reduction sleeves and the orientation of slots on tapers are given with tables of dimensions in mm and in.

Part 10 (ISO 239-1974). Specification for drill chuck tapers (Jacob and Short morse) (3 pages).

Tables of dimensions in mm and in are given.

BS 4639: 1987, Brakes and braking systems for towed agricultural vehicles, (5 pages)

THE requirements for brakes and braking systems when towed agricultural vehicles are used in combination with agricultural towing vehicles are specified in this Standard. In addition to the towed agricultural vehicle, four other definitions are given of equipment to which this Standard applies, viz

- agricultural trailed appliance conveyor
- agricultural trailed appliance,
- balanced vehicle and
- unbalanced vehicle

The terms used in the specification of braking systems are also defined. Four categories of braking systems are specified according to the maximum mass of the towed vehicle. The specification of braking systems in relation to the number of axles and the maximum weight of the vehicle and the maximum pressures for hydraulic and pneumatic systems are given including low pressure fail-safe systems. Similar requirements are listed for the agricultural towing vehicles. Characteristics and the performance of complete braking systems are listed primarily for service brakes but also for parking brakes. Appendices detail the methods of testing the braking force of service and parking brakes along with a list of 12 standard test conditions. A specimen test report is also provided.

BS 6735:1987, Reach volumes for the location of controls on agricultural tractors and machinery, (59 pages)

THIS Standard specifies the positions available for hand and foot controls which can be conveniently reached by the seated operator from the normal working position during the normal working of a tractor or machine. Definitions are provided for the main aspects of the Standard. ISO 3411 is quoted as providing the standard dimensions of operators with large and small operators being 5% of the population above and below the Standard respectively. The primary principal and secondary controls are explained as is the corresponding primary and principal space for convenient siting of those controls without leaning, twisting, etc. Operator reach is defined for the operation of controls by fingers, thumb and finger, hand grasp, toe, heel, ball of foot. The seat index point and its relation to the hip point is explained along with the pedal reference point and the three reference axes originating at the hip point of a small operator. Volumetric hand-reach and foot-reach spaces are defined for small operators with the seat in its lowest and furthest forward position in the siting of primary, principal and secondary controls. Special allowance is made for agricultural tractors where the primary controls may involve twisting of the operator when monitoring equipment attached at the rear. The minimum independent horizontal and vertical adjustment of the seat is specified to accommodate a large operator.

BS 6914: Part 4: 1988 (ISO 7132-1984), Terminology (including definitions of dimensions and symbols) for earth moving machinery, Part 4, Glossary for dumpers, (13 pages)

THIS Standard establishes the terminology used in commercial specifications for self-propelled dumpers. Definitions are given with respect to the methods of dumping, the steering system, drive system, and numbers of axles. The nomenclature associated with the components of the various types is specified and the methods of stating machine dimensions and mass are included. Terminology relating to performance is stated in respect to the power, speed, tractive forces available, steering and braking capability, rated payload and payload discharge time. The final section standardises the specifications as required in commercial literature (using SI units) as related to engine, transmission, drive axles, steering, brakes, tyres, hydraulic system, suspension, rated body capacity, operating mass, system fluid capacities and dimensions.

BS 6978: Part 1: 1988 (ISO 7256/1-1984), Seed drills, Part 1, Methods of test for single seed drills, (14 pages)

THIS first part of a British Standard specifies test methods for single seed or precision drills. It enables test organisations to follow a common code to allow comparison of tests conducted in different geographic and/or climatic zones. Notes are given on the selection of the drill unit, the checking of its stated specification and with a reminder of the need to adhere to manufacturers' instructions. The seed types and sizes to be used are specified as required for single and multi-purpose drills with four types defined for the latter. Seed dimensional characteristics, purity and moisture content are stipulated as a record of the sample used.

The mandatory tests covered in the Standard deal essentially with the precision of seed planting and the efficiency of metering. These are listed as static — with a moving adhesive belt or other recording method and mobile — using one of the above techniques but with the drill on a trolley or on a bed of sand having specified characteristics. Procedure is specified with regard to the position of coulters, hopper filling, calculation of forward speed, adjustment of the metering mechanism, duration and measurement of seed spaces. A procedure for a slope test is also provided.

A method of processing the data produced is given leading to an evaluation in terms of a Quality of Feed Index, a Multiples Index and a Mass Index, and a Standard Deviation and Coefficient of Variation of Precision.

Appendices give greater detail of the mandatory tests with examples of how to record and present the results as a report. Tests on the effects of seed dressings on the feed, and the performance in cultivated land (culminating in a uniformity test after emergence) are specified as optional tests. A device for measuring the depth of sowing is described.

Increasing access to engineering in universities

RECOMMENDATIONS for improving the image of engineering among young people and for increasing the access to engineering university courses have been made by The Engineering Council and the Standing Conference on University Entrance.

In a joint report "Admissions to universities: action to increase the supply of engineers" aimed specifically at universities, the two organisations say that to eradicate the United Kingdom's balance of payments deficit it will be necessary to accelerate the country's acknowledged recovery. To accomplish this the supply of properly educated and trained people has to be sufficient.

At a time when the labour pool is set to diminish, at least equal numbers of higher technicians and graduates will be required now as in the recent past.

"The gap at the Higher National level is extremely serious and is already reflected in reported shortages," the report warns. The nation's weakness is most seriously exposed at the Incorporated Engineer level.

The Engineering Council and the Standing Conference on University Entrance (SCUE) say they and other organisations should continue to promote the widening of access to universities with particular reference to Business and Technician Education Council (BTEC), Scottish Vocational Education Council (SCOTVEC), International Baccalaureate (IB), European Baccalaureate (EB) and Access courses.

With the engineering institutions they should specifically lend support to the establishment of Access courses — designed for students who may not have traditional entry qualifications — which would prepare students for science and engineering degree courses.

SCUE and The Engineering Council in collaboration with other bodies should ask Government to review the funding arrangements for mature students on engineering Access and similar courses and to make grants available.

The Engineering Professors' Conference, the Committee for Engineering in Polytechnics and professional bodies should consider and recommend modifications to existing degree syllabuses to ensure that they are more suitable for students from a wider technical and scientific background.

It is also proposed that the image of engineering should be improved, by a co-ordinated initiative to illustrate the school syllabus in science. technology and mathematics, with practical examples drawn from industry, manufacturing, consumer products or from those providing public services. The initiative should cover primary and secondary education to the age of 18 or 19.

Employers should be invited to find ways of making careers in engineering even more attractive and appealing to young people. The Engineering Council should invite its Industrial Affiliates to help in this.

Other recommendations in the report,* which resulted from a joint working group, include:

(i) The Engineering Council should implement its strategy for its regional organisations, in partnership with other local bodies, to encourage engineers to: support schools in developing relevant curricula; support community involvement; support careers activities. This is fully described in the Council's strategy on '5–19 Liaison'.

(ii) The Engineering Institutions, the Engineering Professors' Conference (EPC) and the Committee for Engineering in Polytechnics (CEP) should be invited, as a matter of urgency, to review the entry of requirements for engineering first degree courses with a view to determining the content and level of mathematics and physics required for entry. EPC and CEP should consult as appropriate with the accrediting bodies.

Both The Engineering Council and SCUE recognise that the higher education polytechnics and colleges sector has already made considerable progress on broadening access. The primary audience for this document is therefore the university sector, but it is hoped that parts of the report might be of interest to a wider audience.

* Copies of the report "Admissions to universities: action to increase the supply of engineers" may be obtained from The Engineering Council, 10 Maltravers Street, London WC2R 3ER.

Book Review

Traditional Food Plants, Food and Nutrition, Paper 42

Publisher: FAO, Rome, 1988. 593 pages.

THE purpose of this resource book is to provide agricultural planners, educators and trainers with a compendium of knowledge about certain nutritious plant foods, both gathered and cultivated in arid, semi-arid and sub-humid lands of eastern and south-eastern Africa. The goal is to improve nutritional status among those who grow or buy the plants.

The book is divided into two major parts plus addenda. The first part describes the basic scientific principles of nutrition, and does so in an easy to read, well structured format, relating it particularly well to major nutritional problems in East Africa. It also provides information on the place of plants in the farming system and diet.

The second part is an anthology of over 100 of the selected plants. It is indexed by scientific name and includes vernacular names, general description, food value and use, storage requirements, other possible commercial uses, the plants ecology and general comments on cultivation and marketing. The main emphasis of the section is however, on the food value and uses. This section is easy to follow and provides an excellent reference work. One small 'gripe' is that the drawings provided of each plant have not, in all cases, been copied very clearly in the rather poor quality paper and type. However this does keep the cost of the work more competitive and ensure more widespread distribution.

Annex 1 provides a list of sources of germplasm and further research information of food plants which should prove invaluable to those involved in furthering this work. Annex 2 attempts to provide a table classification of the plants by food group (ie: cereals, roots and tubers, legumes, oil seeds, vegetables, fruits and others), and nine characteristics relating to cultivation of the plant (growth, habit and degree of domestication and ecology). This provides an 'at a glance' classification which may be of use to those involved but seemed to be rather confusing to the less informed.

Finally the authors have made a plea to the reader that they make any observations towards the completion and updating of material. This can only add to an excellent reference work which represents a major advance in the literature whilst very much meeting its purpose.

M Hann

Book synopses

Soil Physics

B P Ghildyal and R P Tripathi

Publisher John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, England. ISBN 0 470 20125 8. £36.95 (hardcover)

THIS is primarily a text book for advanced undergraduate and postgraduate courses in soil physics (a branch of soil science dealing with the state and transport of matter and energy in soil). It looks in detail at four main branches of the study: soil solids, soil water, soil gases and soil heat. Each of the headings is divided into chapters and subheadings for ease of use, and there are tables and diagrams throughout.

Anaerobic Digestion of Biomass

Edited by David P Chynoweth and Ron Isaacson

Publisher Elsevier Applied Science Publishers Ltd, Crown House, Linton Road, Barking, Essex IG11 8JU, England. ISBN 1 85166 069 0. £42 (hardcover)

THIS book is the result of data collected by the Gas Research Institute. It documents the status of anaerobic digestion processes for the conversion of biomass and wastes to methane at the commercial, developmental, and research levels and identifies the data gaps that exist between commercialisation and development, process limiting steps, and research needs.

Environmental Biotechnology

Edited by Christopher F Forster and D A John Wase

Publisher Ellis Horwood Ltd, Market Cross House, Cooper Street, Chichester, West Sussex PO19 1EB, England. ISBN 0 85312 8383. £65 (hardcover)

THIS book studies the application of biotechnology (a combination of biochemistry, microbiology, and chemical engineering) to the management of the environment. Chapters cover aerobic processes, anaerobic wastewater treatment, mineral leaching with bacteria, composting and straw decomposition, solid waste, agricultural alternatives to current intensive farming practices, microbial control of environmental pollution, continuous culture of bacteria, cell immobilisation, aeration of wastewater and process engineering principles. The final chapter looks to future study possibilities.

Sixth Canadian Bioenergy R&D Seminar

Edited by Zsa-Zsa Stiasny

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IN detailing the proceedings of the Sixth Canadian Bioenergy R&D Seminar, held at Richmond, British Columbia, in February 1987, this book covers new developments in the field of bioenergy since the last seminar in 1984. It also summarises all recent research and development work done in Canadian institutes on the subject. This book is directed primarily at researchers dealing with biomass production, direct combustion, chemical extraction, new liquid fuels, biological processes, material handling and pre-treatments.

N T Chamen

The Agricultural Engineer incorporating Soil and Water

THE new title of the Journal takes account of the recent incorporation within the Institution of the Soil and Water Management Association (SaWMA).

Future issues will introduce other changes – such as to offer a regular element of soil and water management content, to present some other new features and to adopt some new styling and layout.

We are pleased to announce that Geoff Baldwin – formerly of the SaWMA journal 'Soil and Water' has joined us as Production and Advertising Manager. He will take over the former role with effect from the June issue, and has been in charge of advertising since early this year.

Norman Stuckey and Linda Palmer have indicated that they would like to take this opportunity to reduce their work load. We thank them both for the hard work they have put in maintaining not only the quality, but also the timeliness and the economics of our journal over past years.

We also have pleasure in welcoming Barry Sheppard to the Editorial Panel, who will liaise between the Journal and Newsletter Editorial groups. He will also be obtaining copy on news items pertaining to machinery and techniques.

Mike Willis has resigned from the Editorial Panel, and we thank him for his services and wish him well for the future.