EXPENDITURES AND RETURNS

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Contents

Summary

There are three parts to the direct expenditure on a machine: the cost of machine ownership, repairs and maintenance, and fuel. Associated with these are labor and cropping, which determine the overall level of expenditure on machinery.

The profitability of a farm enterprise is determined on an annual basis as the difference between the returns from crops less the cost of producing the crop. A true annual cost of machine ownership is the annual income that exactly balances all the costs over its life, that is, the capital cost of buying the machine, the interest paid and the resale value. Repair costs are very variable.

Two alternative formulae for estimating repair costs assume that it is a function of cumulative use and that it is a function of annual use, not age. Fuel use carrying out actual tasks is also very variable but broad estimates can be made. Fuel use for draft operations is a function of soil type and not a function of tractor size. Thus, typically on

heavy land the energy required for plowing is 149 kWh ha^{-1}.

To decide how many machines are needed and hence the total farm expenditure, there are two aspects: how many hours are needed in each period of the year and how many hours work can be supplied in each period of the year. Work-planning data is available from many sources or can be calculated systematically from first principles from a consideration of the power required or the area to be covered. Workable hours can also be calculated systematically depending on soil type and rainfall. Workable hours must also be adjusted for the type of operation.

A strategic farm-planning model then determines the resources that maximize farm profit: the difference between returns and expenditure. The aim of the strategic plan is to maximize the expected profit, allowing for good and bad, or difficult, years. A whole-farm model determines the optimum labor, machinery, and cropping and the associated work plan showing the optimum times to carry out operations.

With the power of the modern desktop computers now found in many farm offices, such complex programs are no longer restricted to research laboratories. These methods of analysis are within the grasp of modern farmers and their advisers.

1. Introduction

Overall, the expenditure on power and machinery represents ~20% of the input costs to agricultural enterprises. Table 1 shows the breakdown of cost at the national level for the UK. This, however, tends to mask large differences among cropping systems. Table 2 shows the ratio between labor and machinery costs for some typical cropping systems.

Inputs	**1997 costs**	**1985 costs**
Livestock inputs	23	30
Crop inputs	12	11
Labor	21	18
Power and machinery	19	18
Buildings	8	7
Rent	1	1
Interest	4	5
Miscellaneous	12	10
Total input	100	100

Table 1. Breakdown of farm input costs (UK inputs)

Cost category	**UK Mainly dairy**	**UK (7.8 t ha^{-1}) Mainly cereal**	**Kansas (2.5 t ha^{-1}) Wheat**	**Kansas (5.4 t ha^{-1}) Corn**	**S. Carolina (4.2 t ha^{-1}) Peanuts**

Labor ($\$ ha^{-1}$)	646 (566)	207(414)	47	80	120
Machinery ($\$ ha^{-1}$)	546(371)	308(305)	130	172	376
Ratio	1.2 (1.5)	0.7 (1.4)	0.4	0.5	0.3

Note: UK figures are taken from farm cost surveys. US figures are from crop budgets.

Table 2. Labor and machinery cost in 1998 for some cropping systems (figures in brackets are 1974 data adjusted for inflation)

It is interesting to compare 1998 data with the corresponding data in 1974. On dairy farms, the labor input has remained almost constant but the machinery costs have fallen, whereas on the cereal farm, machinery costs have remained constant but labor use has been halved. The current UK costs per metric ton of wheat are the same as the Kansas costs per metric ton, although the costs per hectare are greater because the yield is much higher.

The ratio of labor to machinery has fallen dramatically. The size of machinery is continually increasing in the search for the most economic system. For field machines this means the capacity of a machine in terms of hectares covered is increasing in order to reduce the cost of labor per hectare, which is perceived to be very high.

Comparison with the US ratios and costs per metric ton, suggests that the level may now have been reached at which costs no longer decrease but are simply transferred from labor to machinery. Less developed countries have cheaper labor costs (and often higher machinery costs because they are imported) and thus a much higher input of labor and smaller machinery. As the above shows, it does not necessarily imply a higher cost per metric ton of production.

Increased machine size results in the search for ever larger areas to work and thus leads to the rise in both contracting and farm sizes. Reducing capital costs per hectare of work is equated with increasing annual utilization to the maximum. For some very expensive machinery and timely operations such as harvesting fresh peas, this has led to 24-h working with shifts of operators and planned stoppages for maintenance as one would find in a factory. A few large contracting organizations also follow the maturity of some crops northwards across a country in order to further maximize the annual use of the machines.

These types of considerations lead to interesting questions about the useful life of an agricultural machine. Many UK farmers use a tractor for certainly no more than 1000 h y^{-1} but expect to replace it after about five years. Similarly, a combine harvester would generally not be kept on a farm for more than 10 years even if it worked for only 200 h y^{-1}. Many farmers do have older tractors, but they are kept for minor tasks around the farm.

Contractors vary between those who replace their machinery every year with the aim of ensuring maximum reliability to those who keep their machines for much longer working hours than farmers (though shorter in terms of number of years). In contrast, small farmers in Italy and Greece would expect to have 15-year-old tractors, generally purchased secondhand.

The total expenditure associated with machinery is clearly made up in many different ways in different situations. In all these cases, however, there are three parts to the direct expenditure on a machine: capital repayment over the life of the machine, repairs and maintenance, and fuel. Associated with these are labor and cropping, and less tangible factors such as reliability, which determine the level of expenditure on overall machinery. Each of these is considered in more detail in the following sections.

2. Direct Machine Expenditure

2.1. Capital Repayment

The profitability of a farm enterprise is usually determined on an annual basis as the difference between the returns from crops less the cost of producing the crop. To enable one to consider machinery costs on an annual basis, the notion of depreciation was introduced. There is confusion between depreciation for tax purposes, depreciation that is the reduction in resale value of a machine, and depreciation that is the purchase price averaged over the life of the machine.

None give an accurate picture of the annual cost of a machine or take into account inflation, so it is best to avoid the term depreciation. A reasonable definition of the annual cost of a machine is the annual income that exactly balances the machine cost so that over the machine's life the change in the farm bank balance would be the same with the machine as without it. When considering inflation, the annual income is that which has equal purchasing power each year.

The following example illustrates this concept of an annual cost, with no inflation. It is estimated that if a farm business followed a particular plan, the bank overdraft over 10 years would be reduced from £100 000 to £50 000. Suppose in an alternative plan, the farmer purchases a machine for £60 000, but otherwise continues with the same plan.

If the extra annual income needed to reduce the overdraft, now £160 000 to the same £50 000 in ten years is £15 000, including interest costs and selling the 10-year old machine, then £15 000 is the annual cost of owning the machine.

The calculation of the annual cost of machine ownership involves three types of cash flow:

(a) the capital cost of buying the machine
(b) the interest paid on borrowed capital
(c) the income from selling the machine

The effect of tax on the annual cost cannot be considered in a general method. There are so many different combinations of tax rates and associated notional depreciation rates that it is not possible to write down a general formula. If, however, the amount of tax is known or can be easily estimated, it can be included in the calculations.

The annual cost of machine ownership has been shown to be:

$$A = \frac{\left(C - S_N w^N\right)\left(w - 1\right)}{w\left(w^N - 1\right)} \qquad (1)$$

Where

$$w = \frac{1+g}{1+r}$$

C is the initial capital cost
S_N is the current resale value of an N-year-old machine
N is the number of years the machine is owned
g is the inflation rate
r is the interest rate

This is also the annual cost of owning and replacing the machine every N years. This annual cost allows one to measure the true annual profitability of a farm. Note that the annual cost is constant for a constant value of w. Thus, inflation of 2% with an interest rate of 5% is the same as inflation of 10% and an interest of 13.2%, inflation of 20% and interest of 23.5%, etc.

The annual cost should not be confused with the cash flow necessary to purchase a replacement machine. When the machine is to be replaced, the cash needed is the difference between the new cost and the resale value.

This can be very large, especially with inflation. Earning this sum can be thought of as investing at rate r an annual amount F (which increases each year to allow for inflation) into a sinking fund so that at the end of the machine's life there is sufficient money $(C – S_N)(1 + g)^N$ to replace it. (A reducing overdraft is the equivalent to an increasing sinking fund.) The uninflated annual cash flow required is:

$$F = \frac{\left(C - S_N\right) w^{N-1}\left(w - 1\right)}{\left(w^N - 1\right)} \qquad (2)$$

The effect of inflation on a £10 000 machine with an interest rate of 15% is shown in Table 3. The annual cost reduces as inflation increases. Correspondingly, however, the cash that has to be generated to replace the machine after 10 years increases. They are equal when the inflation and interest rates are equal.

Inflation rate (%)	**Annual cost (£)**	**Annual input to sinking fund (£)**

0	1993	493
10	1267	812
20	785	1202
30	480	1633

Table 3. Comparison of annual cost and annual income needed to replace a machine

2.2. Resale Values

The capital cost of a machine is known when the investment decision is being considered. The unknown future factors in the above annual cost formula are the resale value and the replacement interval.

Machine	**Resale value group**	**Repair type††**	**Useful life**	
			Class	**Hours**
Stationary power unit	1	2	1	12 000
Tractor, two-wheel-drive	1 or 5†	2	1	12 000
Tractor, four-wheel-drive	1 or 5†	1	1	12 000
Tractor crawler	1	1	1	12 000
Combine, power take-off	2	5	4	2000
Combine, self-propelled	2 or 6†	3	4	2000
Swather, self-propelled	2	5	3	2500
Forage wagon and box	2	5	2	5000
Fertilizer equipment, dry or liquid	3	6	5	1200
Floats and scrapers	3	3	3	2500
Harvester flail	3	4	4	2000
Harvester, potato or sugar beet	3	4	3	2500
Hay conditioner	3	5	3	2500
Loader, ensilage	3	5	4	2000
Loader, front end	3	3	3	2500
Manure spreader	3	3	3	2500
Mower	3	7	4	2000
Rake, side delivery	3	5	3	2500
Seeding equipment	3	5	5	1200
Sprayer, mounted	3	5	5	1200

Machine	**Resale value group**	**Repair type††**	**Useful life**	
			Class	**Hours**
Tillage equipment, plows, planters, cultivators, harrows, etc	3	7	3	2500
Truck, feed	3	3	3	2500
Truck, farm	3	4	4	2000
Truck, pick up	3	3	4	2000
Wagon, feed	3	5	3	2500
Baler with engine	4	3	3	2500
Baler, power take-off	4 or 7†	4	3	2500
Blower, ensilage	4	4	4	2000
Forage harvester, towed	4	4	4	2000
Forage harvester, self-propelled	4	3	4	2000
Sprayer, self-propelled	4	4	4	2000

†These resale values have been calculated with UK data
†† Cumulative repair costs = a $(X)^b$ where X is the accumulated hours of use as a percentage of the wear-out life. (a,b)= (0.100,1.5), (0.120,1.5), (0.096,1.4), (0.127,1.4), (0.159,1.4), (0.191,1.4), (0.301,1.3) for types 1 to 7 respectively.

Table 4. List of machine types with their resale value, repair type, and useful life

The American Society of Agricultural Engineers (ASAE) has classified agricultural machinery into four groups for estimating the resale value. The same form of curve has been fitted to UK data for balers, combine harvesters, and tractors. Table 4 lists the resale groups for a number of machines. The resale value of an *n*-year-old machine as a percentage of the new list price is

Group 1 machines: $68{\cdot}(0.920)^n$
Group 2 machines: $64{\cdot}(0.885)^n$
Group 3 machines: $60{\cdot}(0.885)^n$
Group 4 machines: $56{\cdot}(0.885)^n$
Group 5 machines (tractor): $78.2{\cdot}(0.825)^n$
Group 6 machines (combine): $97.0{\cdot}(0.796)^n$
Group 7 machines (baler): $79.9{\cdot}(0.821)^n$

The results suggest that UK tractors lose value very much quicker than the American figures suggest, but balers and combines are worth more for the first five years. The reasons for this are not clear. The American figures may be out of date or American conditions may be different from British—either a different secondhand market or different wear on the machinery.

Specific makes of machine will differ from these standard curves. This can be because the make is more or less reliable than average, the size is (not) wanted by the type of farmer buying second-hand machines, or because spare parts are difficult or expensive to obtain. In some countries, this can lead to a zero resale price for broken-down machinery.

There are also difficulties over interpreting resale value/trade-in value and list price/purchase price. There are few people, if any, who purchase machinery at the list price.

The discount is used by the machinery salesman to persuade the farmer to trade, both by increasing the resale value and thus giving an attractive trade-in value and/or reducing the list price. Such factors need to be taken into account in determining annual costs.

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Biographical Sketch

Eric Audsley is Head of the Mathematics and Decision Systems Group at UK's Silsoe Research Institute. He has over 20 years experience of applying mathematical, operational research, and systems modeling techniques to the analysis and optimization of decisions concerning agricultural systems. One of the main areas he has developed is the application of linear programming to whole-farm modeling in ways that allow complete flexibility of choice of cropping and machinery, constrained only by agronomic and physical factors, in determining long-term optimal profit. Models have been developed for arable, horticultural, and grass farm systems. He has also developed a number of models to examine decision making with uncertainty using probabilistic optimization models such as dynamic programming. Recently, the models have also been developed to calculate environmental emissions such as nitrate and pesticide emissions as a function of the type and timing of operations, and carry out multi-objective optimization of whole-farm systems.