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ECONOMIES OF SCALE IN FARM MECHANISATION

A STUDY OF COSTS ON LARGE AND SMALL FARMS

by
F.G. STURROCK
J. CATHIE
T.A. PAYNE

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FOREWORD TO AGRICULTURAL ENTERPRISE STUDIES SERIES

University departments of Agricultural Economics in England and Wales have for many years undertaken economic studies of crop and livestock enterprises. In this work the departments receive financial and technical support from the Ministry of Agriculture, Fisheries and Food.

During the past decade departments in different regions of the country have conducted joint studies into those enterprises in which they have a particular interest. This community of interest is recognised by issuing enterprise reports in a common series entitled "Agricultural Enterprise Studies in England and Wales", although the publications continue to be prepared and published by individual departments.

Titles of recent publications in this series and the addresses of the University departments are given at the end of this report.

PREFACE

As farmers are well aware, implements and tractors are becoming steadily more expensive. To some extent this is due to inflation but it is also due to the fact that machines are becoming larger and more elaborate. There can be little doubt that they can carry out cultivations rapidly and efficiently and they enable a man to increase his work output quite substantially. One can also add that on a farm large enough to employ them adequately, they can reduce costs.

There is, however, another side to the story. The small farmer obviously cannot afford to buy such equipment new, but this now also applies to what one would have called a middle sized farm a generation ago.

This question seemed worth investigating to attempt to answer two questions:

1. Does large scale equipment give an advantage in costs to the large farmer? In other words, are there genuine economies of scale in farming? and

2. How can the smaller farmer keep his costs down to a reasonable level?

The investigation was triggered off by a request from MAFF for up to date information on machinery costs for use in estimating production costs of crops and other commodities. Data of this kind is also required by agricultural valuers in estimating compensation when farms change hands. The data collected seemed, however, to provide an ideal opportunity to explore the questions posed above.

The authors wish to thank the many farmers who provided very detailed estimates of the cost of upkeep of individual machines. We hope that they will find the results of interest.

We must thank Mr J. B. Finney of ADAS together with Messrs Evans, Rutherford and their colleagues at the N.I.A.E., Silsoe, for helpful comments.

We are also indebted to Mrs Ruth Westhorp for collecting data from small farmers, Miss Rebecca Powell for computations and Miss Peggotty Wallace for patience in typing the drafts. Mr Payne, who did the first survey, is now in New Guinea.

Cambridge September 1977

F. G. Sturrock
Director, Agricultural Economics Unit

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SUMMARY

The following is a summary of some of the salient points in the report.

Chapter I Depreciation and Repairs

Depreciation

Depreciation is defined as the cost of replacement at current prices, spread over the useful life of equipment. The effects of inflation are examined and the use of historic costs are shown to be misleading as a basis for estimating machine upkeep.

Repairs

A survey was carried out on the cost of repairing individual machines on a sample of 94 farms in three groups – about 800 ha (2000 acres), 200 ha (500 acres) and 80 ha (200 acres). The results are given in detail in the appendix. During a period of inflation, unfortunately, any estimate of costs quickly goes out of date. On the assumption that repairs and the costs of new machines increase at the same rate, the ratio between the two should remain constant. Repairs can therefore be expressed as a percentage of the new price and this ratio can be used to estimate repair costs at any time. Culpin's estimates of this factor in 1959 agree quite closely with the data presented here.

Chapter II Size and Shape of Fields

Size of Field

Estimates were made of the time required to cultivate fields of different sizes after allowing for turning, headlands, changing fields and other contingencies. To be realistic, it is assumed here and later that fields are slightly irregular in shape. With a 3 m cultivator travelling at 6 km per hour, the proportion of time spent on effective work increases from 37% in a 2 ha field to 71% in a 40 ha field. As might be expected, the show separately the effect of wider implements and faster speeds of cultivation. As might be expected, the benefit from enlarging fields is very much greater with wider implements and higher speed.

Previous estimates have suggested that 20 ha (50 acres) is the optimum field size. With wider implements, however, appreciable savings are available by increasing to 40 ha (100 acres) and even to 80 ha (200 acres).

For example:

	Increase in Work Rate		
	10 to 20 ha	20 to 40 ha	40 to 80 ha
Implement 3 m wide	+11%	+9%	+6%
" 5 m "	+15%	+11%	+8%
" 10 m "	+28%	+18%	+12%

A farmer enlarging fields can make full use of this fact by buying wider implements and more powerful tractors. The combined effect can be illustrated as follows:

3 m wide cultivator @ 4 Km/hour in 10 ha field; 4 ha/day
5 m wide cultivator @ 6 Km/hour in 20 ha field; 13 ha/day
8 m wide cultivator @ 10 Km/hour in 40 ha field; 34 ha/day

Field Shape

An awkward shape can add appreciably to the time taken to cultivate a field. Some examples are given – square, rectangular, sides not parallel, re-entrants, building plots round the edge and obstruction, such as pylons or landing lights.

Chapter III The Farm Models

Having dealt with single fields, it now remains to apply the results to the whole farm. The farm sizes were chosen to demonstrate a wide variety of conditions:

Small Farm (80 ha or 200 acres) With rising costs, such farms can barely afford to buy large equipment new.

Medium sized Farm (200 ha or 500 acres) Can utilise and afford a wide range of equipment.

Large Farm (800 ha or 2000 acres) Can utilise almost all the largest equipment available. It is assumed that this is a large integrated unit. In practice, many farms of this size are awkward in shape and are a loose collection of semi-independent units. If so, their costs will be more akin to the medium sized farm.

The cropping system was uniform – 30% wheat, 30% barley, 12% sugar beet, 8% potatoes and 20% leys cut for hay and silage. The cropping was chosen to include a fair diversity of equipment appropriate to field and farm size.

As can be seen in Table 3.1, the small farm has the highest costs per hectare, followed in turn by the medium and then by the large farm. Farms with large fields have lower costs than those with small fields. The chief disadvantage of small farms was the high cost of machinery. If all the equipment were bought new at present day prices, the capital cost would be £500 per hectare on the small farm and £240 on the large one. The main reason for high costs on the small farm is that the equipment inevitably is much less efficiently utilised. Another difference is that large farms require less labour per hectare, mainly because they have larger machinery and larger fields.

It is often assumed that a greater degree of mechanisation means lower labour costs at the expense of higher machine costs. This may be true of a single farm but if we compare large and small farms, the large farms have lower labour costs and also lower machine costs because their size facilitates more efficient use of equipment.

Estimates were also made to show (for interest) separately the effect on costs of field size and greater mechanisation.

Chapter IV Small Farms and the Second-hand Market

Second-hand Equipment

In practice small farms avoid the very high cost of equipping their farms with new equipment by buying second-hand. There is in fact a regular trade in machinery moving from large to small farms. Large farmers who wish to avoid breakdowns at critical times do so by trading in part of their equipment after a few years. This is bought by smaller farmers.

Estimates were made of the effect on costs of selling quipment from large to small farms. It was assumed that the large farmer trades in one third of his equipment after three years and the small farmer buys half his equipment second-hand. The effect on the large farmer is a modest increase in depreciation which he probably regards as a modest premium for retaining a stock of reliable equipment, and some saving in repair costs. The effect on small farms is an increase in repair costs but a substantial reduction in depreciation. On balance, machinery costs on the small farm are brought down to nearly the same level as the medium sized farm. The machinery is less reliable but the capital outlay is reduced by nearly a half.

Survey of Smaller Farms

A special survey was made of 30 small arable farms averaging 50 ha (124 acres) to find what equipment they had and how they had acquired it. These small farms display a sturdy indepdnence and so far as they can, carry a full complement of equipment, a large proportion of which is purchased second-hand. Many of the cultivating implements are well over 10 years of age, but are still serviceable. Where they can afford it, small farmers buy their tractors new in spite of high prices. It would seem logical for small farmers to share expensive equipment with a neighbour but this occurs in only a minority of cases.

Chapter V Conclusions

Having examined the second-hand market, a new set of cost estimates can be constructed on the assumption that large farmers trade in some equipment after a few years and small farmers buy it second-hand. On this basis, machinery costs on the small farm can be brought down to the level of the medium sized farm.

The real disadvantage of the small farmer is not that his costs are high but that he has too few hectares to make a reasonable income.

On the assumption that his farm is organised as an integrated unit with fields of a equate size, the large farmer has a distinct advantage in costs. It is not surprising therefore that between 1968 and 1975 the number of small arable farms in England and Wales declined by 25% and the number of large arable farms increased by 16%.

The 40 ha field is large and its creation might entail the removal of some hedges. This could however be compensated by planting a few belts of trees at wider intervals, which would provide a better landscape than the hedges displaced and might encourage a few pheasants. An 80 ha field is a very large unit. It would produce some further saving in costs but in many cases its creation would damage the landscape to an extent not easily disguised. If so, this might well be the point at which further reduction in costs could be forgone in the interests of good public relations. The authors intend to deal with this aspect in more detail in a subsequent report.

CHAPTER I DEPRECIATION AND REPAIRS

Depreciation

Even when implements and machinery are repaired and maintained they eventually wear out and are replaced by new equipment. A farmer may buy a new machine for £1000 and sell it for scrap for £100 after ten years. If he then buys a new one for £1000, the replacement has cost £900. This loss is incurred in a lump sum at the end of ten years, but it is generally considered prudent to anticipate the cost by writing off a proportion each year. This is known as a wear and tear allowance or depreciation. Depreciation, in this case £900 over 10 years, can be written off in ten equal instalments of £90:

Original price	£1000
Depreciation, 1st year	90
Value at beginning of 2nd year	910
Depreciation, 2nd year	90
	820 etc.

This method spreads depreciation equally over the life of the machine. End of year valuations produced in this way do not however match market prices of second-hand machinery. As is well known, machinery drops steeply in value in the first year, but depreciation slows down in succeeding years as the equipment becomes older. This fact can be matched by using the Diminishing Value basis, which means deducting a proportion of the opening value each year as follows:

Original price	£1000
Depreciation, 1st year, 20% of £1000	200
Value at beginning of 2nd year	800
Depreciation, 2nd year, 20% of £800	160
Value at beginning of 3rd year	640
Depreciation, 3rd year, 20% of £640	128
Value at beginning of 4th year	512

The rate of depreciation in the second example is 20%. As can be seen, depreciation declines year by year from £200 in the first year to £160 in the second and so continues. As a point of interest, the value falls to approximately half after three years and to approximately 10% after ten years. Over ten years, therefore, the total depreciation in both methods is nearly identical, at 90%.

At one time farmers were expected to adhere to a list of wear and tear allowances prescribed by the Inland Revenue. These did in fact represent fairly accurately the fall in value in the second-hand market. Since then, the Government has recognised that a farmer, or indeed any businessmen investing in expensive new equipment, has to find the money to pay for it and a wear and tear allowance spread over many years comes much too late to finance the purchase. To encourage investment in modern equipment the Inland Revenue authorities have increased these allowances over the years and now permit the farmer, if he wishes, to charge the whole cost of new equipment against profit in the year it is purchased. This certainly helps to solve the cash flow problem of a farmer short of reserves. One consequence however is that income tax allowances are no longer a guide to annual rates of depreciation. It is therefore necessary for the purpose of this study to devise a system based on first principles.

Farmers do not of course always retain equipment until it is worn out. After a profitable year, a farmer may be tempted to invest any surplus available in modernising his equipment. Indeed, many large farmers make a regular practice of trading in equipment after only two or three years. The equipment traded in is then purchased second-hand by men with smaller farms. When the cost of depreciation is under discussion the issue is often confused by efforts to allow for the fact that machines often change hands during their lifetime. When advising a farmer on the date when he should change equipment, the tax allowances and the trading in prices are obviously important. But so far as the industry is concerned, the trading in price is unimportant because, apart from the dealers' commission, the receipts of the farmer selling equipment are cancelled out by the payments of the farmer buying it. So far as taxation is concerned, the allowances should in the long run equal the cost of upkeep. In this study therefore we start by calculating the cost of upkeep over the whole life of the machine. At a later point, consideration will be given to the second-hand market.

So far as depreciation was concerned, the most reasonable method appeared to be to take the price of a new machine and assume that at the end of its life it is sold for scrap for 10% of the new price. In the example given at the beginning of this chapter the machine costing £1000 was sold as scrap after ten years for £100. In fact, the implement might not be scrapped. It has very little value and the farmer might prefer to keep it on the farm as a spare to be used in an emergency. He might give an old tractor to the stockmen to cart fodder, or attach an implement such as a fore loader and not trouble to dismantle it. Old implements of this kind can however be ignored – their value and any further depreciation is negligible.

For the purpose of this study therefore depreciation per year is 90% of new price ÷ life of the machine. The "life" of an implement is defined as the period of active and reasonably full time use, ignoring retention for occasional use as a spare. In most cases, it is convenient to express the life as a given number of years. If so, depreciation becomes a fixed annual cost irrespective of the amount of use that the machine receives.

Intensity of utilisation can however be taken into account by expressing the life of a machine as a number of hours or hectares worked during its working lifetime. If a tractor used for 1000 hours a year is worn out after ten years, its life could be expressed either as ten years or as 10,000 hours. Suppose, however, that Farmer A used such a tractor for 2000 hours a year. If the tractor is worn out after 10,000 hours it will last only five years. In such a case, total depreciation should be spread over five instead of ten years.

On the other hand, a machine may be given far less than normal use. If Farmer B uses a similar tractor for only 500 hours a year, one might expect it to last 20 years. Should depreciation be spread over 20 years? The answer is no because in spite of under-use it may not last for twenty years. Even if it is well maintained, it will deteriorate. Of even more importance, it will probably be obsolete long before that time and the farmer will therefore replace it before it is worn out.

There are thus two consideration that determine the life of a machine – wear and tear and obsolescence. An attempt was made to collect farmers' opinions about the life of implements and machinery. On the whole, they tended to overestimate it and often suggested a life of 15 or 20 years. It was obvious that they were thinking of implements wearing out and found it difficult to visualise obsolescence. A very long life is of course possible. A simple implement, such as a harrow, can be made to last almost indefinitely if the tines are renewed. It is also true that on small farms one occasionally finds even complicated equipment, such as combine harvesters, still in use after 20 years.

On fact is obvious – much of the most expensive machinery on the farm is used for only a few days a year. A combine harvester or a potato harvester is used on most farms for only about twenty days a year. If the farmer discards it after eight years, it will have been in use for less than 1500 hours. In all probability therefore, he is not discarding it because it is worn out but because a better machine is available; in other words, it is obsolete. It may be kept as a spare or sold to a small farmer who repairs it and continues to use it on a limited acreage.

Tractors which are used all the year round are in a different category. They can be used heavily and are sometimes worn out in five or six years. More typically however they are worked hard for the first three or four years, then downgraded to lighter duties and are finally kept as spares or discarded.

The rule adopted for this survey was to divide equipment into two categories with an estimated life of ten years for standard equipment and tractors, and eight years for machines with many moving parts that are more likely to become obsolescent. See Table 1.1. We then wrote off 90% of the new price over the appropriate number of years. This implies depreciation (on a diminishing value basis) of 25% and 20% respectively. The remaining 10% can cover use as spare or value as scrap.

Table 1.1 Depreciation & Life of Field Equipment

20% Depreciation (10 year life)	**25% Depreciation** (8 year life)
Tractors	Combine harvesters
Corn drills	Sugar beet harvesters
Balers	Potato harvesters
Ploughs	Precision drills
Cultivators	Potato planters
Harrows	Sprayers
Rolls	FYM spreaders
Mowers	Fertiliser distributors
Tedders	Forage harvesters
Trailers	Hedge cutters
Fork lifts	

Life (years) is time taken for value to fall to 10% of the cost of replacement by a new machine.

It is sometimes argued that inflation reduces the cost of depreciation. Suppose that a farmer buys an implement for £1000. After two or three years, he sells it for £900. At first sight, the depreciation appears to be only £100. But with inflation a new implement costs £1400. The cost of replacement is thus £500 (£1400 less £900), and this and not the £100 is the true cost of maintaining the farmer's equipment. This point is set out in more detail in Table 1.2.

Table 1.2 Comparison of Depreciation based on Historic Costs and on Replacement Cost

	1	2	3	4	5	6
	Written down value (@ 20%)	Sale Price S/H (inflation @ 15%)	Historic* Depreciation (£10,000 less Col. 2)	Cost of New Equipment (inflation 15%)	Replacement Cost (Col. 4 - Col. 2)	Ratio Historic to Replacement Col. 3 as % of Col. 5
	£	£	£	£	£	£
Year 0	10000	-	-	10000	-	-
1	8000	9200	800	11500	2300	35%
2	6400	8448	1552	13200	4752	33
3	5120	7782	2218	15200	7418	30
4	4096	7168	2832	17500	10332	27
5	3277	6587	3413	20100	13513	25
6	2621	6054	3946	23100	17046	23
7	2097	5578	4422	26600	21022	21
8	1678	5135	4865	30600	25464	19
9	1342	4724	5276	35200	30476	17
10	1074	4350	5650	40480	36130	16

* If sold in the year concerned for price in column 2.

Suppose that a farmer bought a tractor for £10,000. In five years' time, he has written the value in his accounts down to £3277. Due to inflation, however, prices are rising by 15% a year, and he sells the tractor second-hand for £6587. On a historic basis, depreciation over the five years is only £3413 (£10,000 less £6587). This is much less than the depreciation of £6723 (£10,000 less £3277) shown in his books by writing down the original purchase price.

The price of a new tractor after five years has however now risen to £20,100 (15% inflation). The actual cost of replacing the tractor after five years is thus £13,513 (£20,100 less sale of old tractor for £6587). This is the true cost of maintaining the farmer's stock of equipment and the depreciation of £3413 on the historic basis, (the orthodox accounting procedure) is entirely misleading. If this were the allowance the farmer received for tax purposes it would in this case cover only 25% of the cost of replacement. The remaining 75% would have come from taxed profits or the injection of fresh capital from another source. As can be seen from the last column, the historic cost depreciation drops steadily further and further behind the real cost of replacement. In the fifth year, historic depreciation covers only 25% of replacement and in the tenth year only 16%.

The fact that depreciation allowances based on historic costs no longer cover the cost of replacement is now being recognised and applies not only to agriculture but to all industry. The Sandilands Committee made recommendations on a new system of inflation accounting but the accounting profession has not yet agreed on a procedure. In the meantime, the position has been eased by the Inland Revenue provision allowing farmers to write off the whole of the cost of equipment (purchased after March 1972) in the year of purchase.

As a point of interest, it is worth calculating whether the real cost of replacement has been changed by inflation. Suppose that in the example just given, there had been no inflation and that machinery could be sold for the written down value. If so, the cost of replacement in any particular year would be £10,000 less the written down value. This is shown in column 2 of Table 1.3. If this figure is adjusted by the index to allow for 15% inflation it coincides with the replacement cost in Table 1.2. Thus the cost of replacement is unaltered in real terms by inflation. In other words, if all costs and returns increase, a higher nominal charge for depreciation can be met from a larger supply of shrinking pounds.

This may seem an elementary point, but is worth emphasis because discussion on machinery costs has been confused by attempts to allow for inflation. As we have shown that the cost of replacement is not directly affected in real terms by inflation, it seems reasonable to ignore it in the remaining chapters of this report.

Table 1.3. Replacement Cost With and Without Inflation

	Written down value (@ 20%) £	Replacement Cost		
		No Inflation £	Index of Inflation £	With 15% Inflation £
Year 0	10000	-	100	-
1	8000	2000	115	2300
2	6400	3600	132	4752
3	5120	4880	152	7418
4	4096	5904	175	10332
5	3277	6723	201	13513
6	2621	7379	231	17046
7	2097	7903	266	21022
8	1678	8322	306	25464
9	1342	8658	352	30476
10	1074	8926	405	36150

Repairs

As already mentioned, a survey was conducted into the cost of machine repairs. Repairs are recorded in farm income surveys conducted by the universities, but only as a total for the farm. Some data is collected on specialised machines for use in commodity studies, but no comprehensive survey has been carried out in recent years.

The decision was therefore made to conduct a special survey. As the problems of maintaining equipment differ widely between large and small farms, three size groups were chosen:

Large farms around 800 hectares (2000 acres)	18 farms
Medium sized farms areound 200 hectares (500 acres)	39 "
Small farms around 80 hectares (200 acres)	37 "

It was necessary to estimate the annual use and cost of repair on each machine and implement on these farms. This was a time consuming task because repair bills are apt to include a wide variety of items – not all of them related to implement repairs.

Appendix 1 summarises the use of implements on large, medium sized and small farms. As might be expected, implements are much more heavily used on large farms. The average plough, for example, is used on 157 ha on large farms and only 36 ha on small farms. The number of furrows is merely the arithmetical average of all the ploughs on the farms concerned. The same is true of the "average" width of other implements. These averages do however give a general indication as to whether the machines in one group are larger than in another. As might be expected, larger implements are found on larger farms but the difference in size of implements between large and small farms is perhaps less than might be expected. One reason (discussed in Chapter IV) is that implements on small farms have often been purchased second-hand from large farms. Many of them are therefore of a size that one would expect on large farms. It is also evident that machines are worked harder on large farms. Cultivating implements cover a greater area at a higher speed and this may be due to the fact that they are pulled by more powerful tractors. Machines are also working nearer to capacity on large farms. Combine harvesters, for example, work 19.1 days in the year on large farms and 20 days is an accepted estimate of the number of days suitable for harvesting cereals in an average season. On small farms, they averaged only 10.6 days.

Appendix 2 gives details of the cost of repair, classified by size or type of implement. The data was collected towards the end of 1975. During a period of inflation, repair costs increase continuously. Any list of repair costs is thus liable to go out of date as soon as it is collected. There is fortunately an alternative method of estimating repair costs – as a percentage of the cost of new machines. This simplifies the calculation because the price of new machines can easily be ascertained from catalogues. The formula depends, however, on the assumption that as prices rise the cost of repairs and spare parts keeps in step with the cost of new machines. A well known list of hourly repair costs as a percentage of new prices is given in Farm Mechanisation Management by C. Culpin, 1959. The list is based on the author's wide experience as senior machinery officer in the NAAS with some help from the American estimates contained in the Agricultural Engineers Handbook. The American data gives estimates of "wear out life" and "total repairs in wear out life" as per cent of list price and from this an hourly costs can be estimated. Tractors, for example, are given a life of 12,000 hours and total repairs during this time of 120% of the list price. Per hour, this amounts to 0.01% of the list price and this is also the figure that Culpin recommends.

The Culpin estimates were however published eighteen years ago and there has been a dramatic increase in prices since then. There have also been substantial changes in the design of machines. It therefore seemed worthwhile to test whether the ratio between repair costs and the price of new equipment had remained unchanged.

Having collected repair costs, these were compared with the cost of new equipment at the same date. These are shown in Table 1.4 alongside Culpin's estimates in 1959. On the whole, Culpin's estimates of cultivating implements and ploughs still seem to apply. The ratio seems to have declined to some extent, however, for some of the large machines such as combine, potato and sugar beet harvesters (0.02, 0.03 and 0.04 compared to 0.04, 0.07 and 0.05 respectively). It may be of interest to add that present American estimates are 0.03 for all three harvesters which is closer to the present survey results than the Culpin estimates. A fall in these ratios is in fact understandable. Machines of this kind have been greatly improved and they include a number of devices to improve efficiency of harvesting that were unknown eighteen years ago. They have therefore become relatively more expensive. At the same time they are more reliable and suffer fewer breakdowns. If this is true, a fall in the ratio is to be expected. In other words, the cost of buying these large machines has increased rather more than the cost of repairing them.

Table 1.4 Cost of Repairs & Spares per hour as a Percentage of New Price of Machine

	This Survey	Culpin's Estimates
Ploughs	0.07	0.07
Cultivators	0.11	0.07
Dutch harrows	0.07	0.07
Disc harrows	0.05	0.05
Rolls	0.03	0.01
Sprayers	0.04	0.05
Fertiliser distributors	0.04	0.05
Combine drills	0.03	0.05
Seed drills	0.04	0.03
Combine harvesters	0.02	0.04
Balers	0.03	0.04
Sugar beet harvesters	0.04	0.05
Potato planters	0.03	0.04
Potato harvesters	0.03	0.07

CHAPTER II SIZE AND SHAPE OF FIELD

Size of Field

The traditional landscape of farming land in this country is a chequerboard of small fields surrounded by hedges or, in some parts, by stone dykes. Many of these were no more than two or three hectares (5 or 7½ acres). When cultivations were done by horses, these were convenient sizes and even a two hectare field could keep a ploughman employed for a week. But with a tractor, he could do this in a morning and would then have to spend an hour or more moving to another field and setting it out before he could start again. It is not surprising therefore that arable farmers find small fields a nuisance and remove hedges to enlarge them.

Farmers who have done so often claim that they have reduced field labour by a quarter, or half or even more. These reductions in labour may well be true but they are not necessarily due entirely to improvements in field lay-out, because farmers that have not changed their field boundaries have also been reducing labour staffs.

There have in the past been one or two attempts to assess the effect of field size on the amount of labour required to carry out cultivations. One of the first was by Carslaw* in 1930. He showed that the number of turns at the end of the field fell from 176 per acre on a one acre field to 28 in a 27 acre field. He also noted that in a 9 acre field fewer turns were required if it was long and narrow and more if it was square, triangular or round. Carslaw was of course writing at a time when horses did most of the cultivations and 27 acres was a large field. In 1968, Edwards** estimated that with a turning time of 0.6 min. and a speed of 3 MPH, the amount of time lost was 35% in a 100 yard row falling to 6.5% in a 750 yard row. He also showed that with lower speeds and a quicker turn, the loss could fall to 2% or less. From this, he concluded that there was little point in having a row longer than 750 yards, which implied (in a square field) a field of 20 hectares (50 acres).

These were useful pioneering studies, but factors such as the time spent in cultivating headlands and changing fields are not mentioned. As a result they somewhat understate the advantages of larger fields. Of more importance, new developments such as larger implements and powerful tractors capable of higher speeds certainly reopen the question of the optimum field size and farm lay-out.

Before dealing with the details of field shape and size it is worth describing the savings that result from amalgamating fields. These are as follows:

1. The number of turns at the end of the field is reduced. This is a fairly obvious point but is illustrated in Figure 1. In (a) the tractor and implement turn forty times in cultivating the two small fields. If the boundary is removed, the number of turns falls to twenty. This represents an appreciable saving in time.

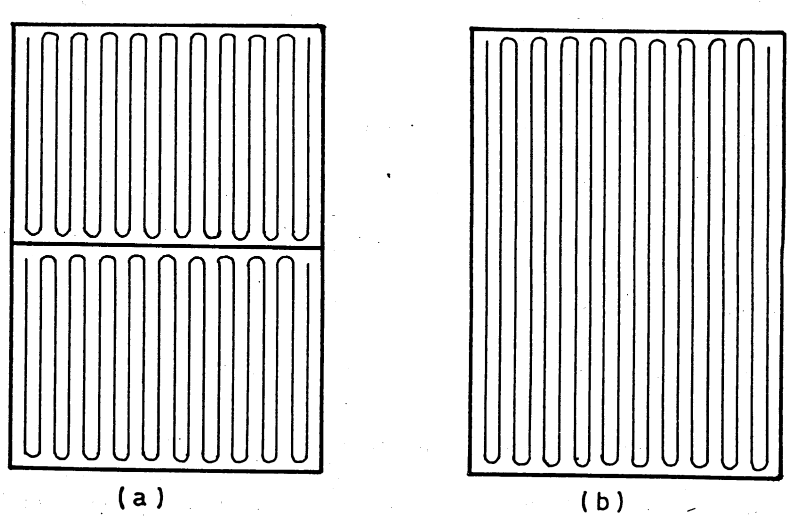

Fig.1. Effect of removing a hedge on the number of turns in cultivating a field. (a) before: 40 turns (b) afrer: 20 turns.

* R.McG. Carslaw. The Effect of Size and Shape of Field on Costs and Profits. Journal of Yorkshire Agricultural Society, 1930.

** A.J. Edwards. Field Size and Machine Efficiency, Monks Wood Symposium No. 4, 1968.

2. Some headlands are eliminated. When carrying out field operations, the tractor can be driven up to the fence or hedge but the implement behind stops about 10 m short of the end of the field. Thus, although the tractor has covered the whole of the field from end to end, the implement has not. This leaves an uncultivated headland at each end of the field that must be dealt with afterwards. The presence of a headland thus produces a duplication of effort that would be avoided if the boundary were removed and the field enlarged.

3. There are inevitable stoppages during work to make minor adjustments and for personal needs.

4. When one field is finished there are delays before the tractorman can begin work elsewhere. If he has been cultivating one field and his next task is to cultivate the next field and there is a gap in the hedge, the delay may be only a few minutes. More often however he will have a different job to do in another part of the farm. He must therefore pack up the cultivator (if it is wider than the gate or the lane outside), drive back to the farmyard, pick up another implement, say a plough, and take it to another field. He will then spend minutes deciding how the ploughing is to be carried out. All of this implies a loss of time which is greatly reduced if the farmer has fewer and larger fields.

5. There are delays in travelling to the field in the morning and returning at night.

The rate of work in hectares per hour, when the implement is in operation, the *Spot Working Rate,* can of course be estimated quite easily from the width of the implement and its forward speed. The actual amount accomplished after allowing for turns and headlands etc. is the *Field Rate.* This amount, including travel between fields etc. in a day or a week is still less for the reasons given above. If we assume for example a 10 ha (25 acre) field cultivated with an implement 3 m (10 ft.) wide moving a 6 Km/hour (4 MPH) that takes 20 seconds to turn at the headlands and 40 minutes to change fields, the effective time is shown in Table 2.1. The field has two sides not quite parallel (see No. 4, Figure 5).

Table 2.1. Proportion of Time Spent on Effective Work

(Implement 3 m wide moving at 6 Km/hour or 4 MPH)

Field Size (ha)	2	4	8	10	20	40	80
Effective work	37	47	57	59	65	71	74
Turns	20	19	15	14	12	8	7
Headlands	4	3	3	3	2	2	1
Changing fields	22	14	8	7	4	2	1
Contingencies	17	17	17	17	17	17	17
	100	100	100	100	100	100	100
ha per day	4.64	5.96	7.11	7.42	8.27	8.94	9.39
ha/day (2 ha = 100)	100	128	153	160	178	193	202

It will be seen that in a small 2 hectare (5 acre) field only 37% of the time is spent cultivating; 42% is spent turning and changing fields. Even at 8 ha (20 acres) only 57% is effective. At 40 ha (100 acres) 71% of the time is effective and at 80 ha (200 acres) 74%. The amount of work accomplished also increases proportionately. If the 2 ha field is 100, the area cultivated per day is increased by 60% in a 20 ha (50 acre) field and is doubled in a 80 ha (200 acre) field. It is thus hardly surprising that arable farmers find large fields convenient.

The area covered in a day does not depend solely on size of field - it also depends on the width of the implement (see Table 2.2). Both factors are inter-related because large fields give scope to wide implements. In a small field, a Wide implement is a nuisance in turning and when the field is finished time can be wasted in manoeuvring it through gates and narrow lanes.

Table 2.2. Effect of Width of Implement and Size of Field

Ha per day (6 Km/hour)

Field Size (hectares)	2	4	8	10	20	40	80
Width of Implements							
1 m	1.80	2.17	2.47	2.55	2.79	2.98	3.12
3 m	4.64	5.96	7.11	7.42	8.27	8.94	9.39
5 m	6.36	8.64	10.81	11.41	13.13	14.39	15.32
8 m	8.43	12.09	15.91	17.07	20.59	22.70	24.32
10 m	9.21	13.73	18.67	19.00	24.31	27.67	29.98
12 m	9.86	15.00	20.90	22.73	28.23	32.33	35.44
20 m	11.48	18.92	28.00	31.34	40.94	49.41	55.85

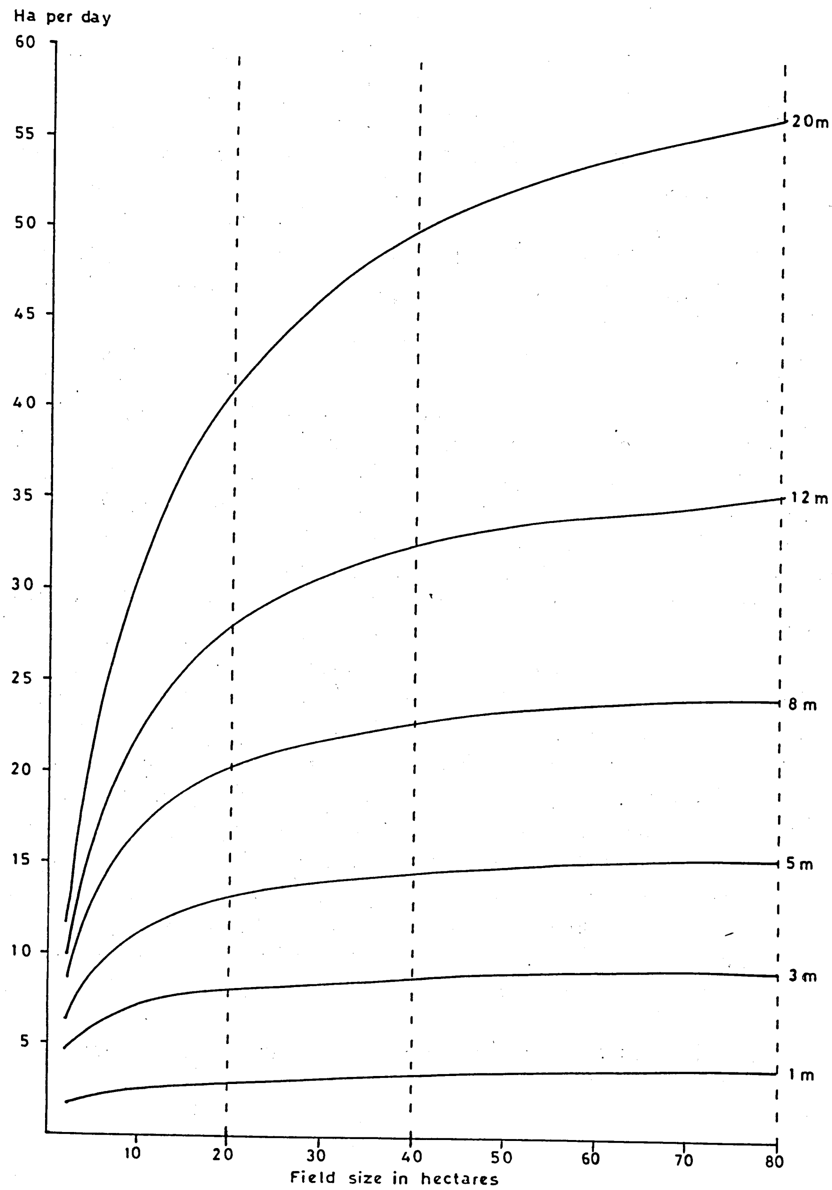

Fig.2. Increase in work rate due to larger fields and wider implements The effect of enlarging fields is obviously much greater with wide implements. The vertical lines help to indicate the increase in work rate due to changing from 10 to 20, 20 to 40 and 40 to 80 ha (25 to 50, 50 to 100 and 100 to 200 acres).

Figure 2 shows the rate of work with six implements varying from 1 m (3 ft.) to 20 m (66 ft.) wide. The effect of enlarging fields is shown more clearly in Table 2.3. Most arable farmers would agree that fields of at least 10 ha (25 acres) are desirable. Taking the 10 ha field as standard, it is obvious that the rate of work in a 4 ha field is substantially less - with an implement 5 m wide the rate falls by a quarter and with 20 m it falls by 40%.

Table 2.3. Increase in Work Rate due to Larger Fields and Wider Implements

Implement Width	Index of Work Rate					Increase in Work Rate		
Field ha Size (acres)	4 (10)	10 (25)	20 (50)	40 (100)	80 (200)	10 to 20 (25 to 50)	20 to 40 (50 to 100)	40 to 80 (100 to 200)
1 m	85	100	109	117	122	+9%	+8%	+5%
3 m	80	100	111	120	126	+11%	+9%	+6%
5 m	76	100	115	126	134	+15%	+11%	+8%
8 m	74	100	121	133	142	+21%	+12%	+9%
10 m	72	100	128	146	158	+28%	+18%	+12%
20 m	60	100	131	158	178	+31%	+27%	+20%

A point of more general interest is the benefit to be obtained by increasing a 10 ha field to 20, 40 or 80 ha (50, 100 or 200 acreas). As might be expected, the wider the implement, the greater the benefit of larger fields. An increase from 10 to 20 ha gives quite a large increase ranging from 9% to 31%. A width of 1 m could stand for a 3 furrow plough and 20 m could stand fro a wide sprayer. Apart from these two, most cultivating and harvesting equipment varies from 3 m to 10 m for them the increase of 11% to 28% in work rates is obviously worthwhile.

In passing, it may be mentioned that the use of "tram lines" in cereals may lead to some standardisation of size for seed drills, fertiliser distributors and sprayers. Tram lines are of course rows left unsown to allow a tractor to traverse a crop without treading down the cereals. If the tram lines are 12 metres apart, a 4 m seed drill could cover this in three bouts and a 6 m drill in two bouts. Some of the new fertiliser distributors have a boom 12 m wide and could also be used to apply granular herbicides.

Most farmers would agree that 20 ha (50 acre) fields are an advantage for arable land. Further enlargement is more controversial. The Table shows however that a move from 20 ha to 40 ha (50 to 100 acres) gives increases of 9% to 18% in work rates for most cultivating and harvesting equipment. This is well worth obtaining. Fields of 40 ha are of course only really feasible on farms of 200 ha (500 acres) or more in size.

A further increase from 40 to 80 ha (100 to 200 acres) is even more controversial and implies farms of 800 hectares (2000 acres) or more, all within one ring fence and farmed as an integrated unit. On such a farm, the bulk of the implements would be 5 m to 10 m in width. For these widths, the increase in work rate is a further 8% to 12%. This is less than for the previous step but is nevertheless appreciable.

There is a further factor influencing the rate of work - the forward speed of the tractor (see Table 2.4 and figure 3). ADAS survey work indicates that tractors are often driven well below their potential capacity. There is often a wide variation from one farm to another for the same operation that cannot be explained in terms of technical factors. In many operations all that is required to take up the power available in the tractor engine is an increase in forward speed. In other cases a wider implement may be required. Allowance must of course be made for adverse weather and soil conditions in slowing up operations, but in reasonable conditions most cultivations could be carried out at a working speed of 6 –

Table 2.4. Effect of Forward Speed on Hectares Cultivated per Day

Field Size (ha)	2	4	8	10	20	40	80
Speed Km/hour							
4	5.22	6.75	8.07	8.39	9.37	10.07	10.55
6	6.36	8.64	10.81	11.41	13.13	14.39	15.32
10	7.71	11.15	14.81	15.98	19.23	21.96	24.01

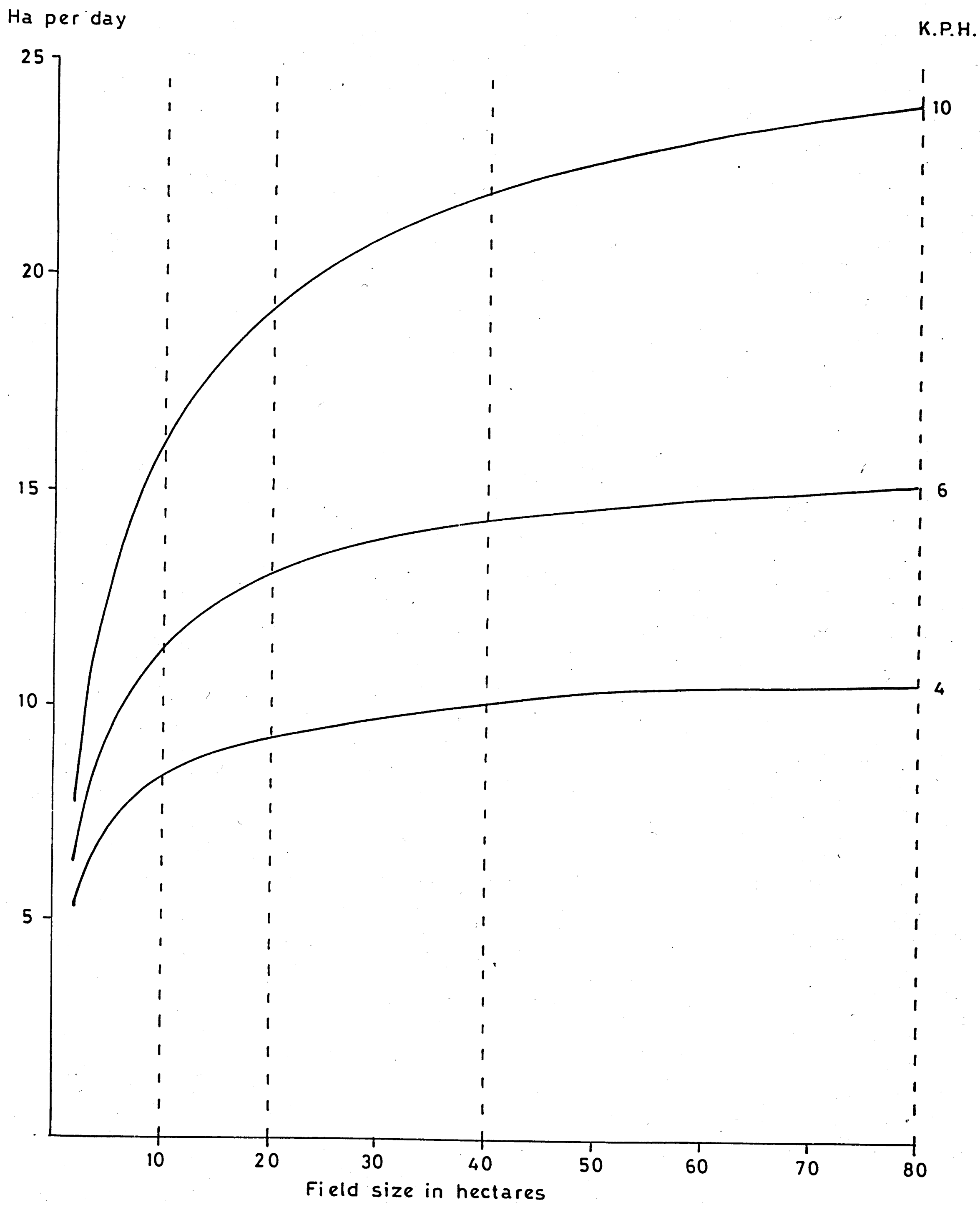

Fig.3. Increase in work rate due to increase in forward speed (Km/hour). The effect of enlarging fields is greater with higher speeds. The vertical lines help to indicate the increase in work rate in changing from 10 to 20, 20 to 40 and 40 to 80 ha (25 to 50, 50 to 100, 100 to 200 acres).

10 Km (4 – 7 MPH). In practice the speed is often only 4 Km/hour (2½ DPH). There are of course operations where a slow speed is necessary. Rolling for example must be deliberate if the soil is to be consolidated and so also must inter-row cultivations if damage to plants is to be avoided. To some extent, low sppeds are a matter of habit and the degree of urgency that a particular season demands. Irregular field surfaces, poor seat design and failure to control sound levels in tractor cabs have led tractormen to reduce forward speeds in order to make their work more tolerable. Modern designs of tractors might overcome some of these problems. Comfort is certainly the factor most commonly quoted by drivers as limiting overall output in the more power-demanding field operations.

It is evident that field size, implement size and speed of operation all have an effect on the effective rate of work. It is also evident that these three factors interact and reinforce each other, and the effect of any one of them is very much less than all three together. This is demonstrated in Figure 4 which shows a

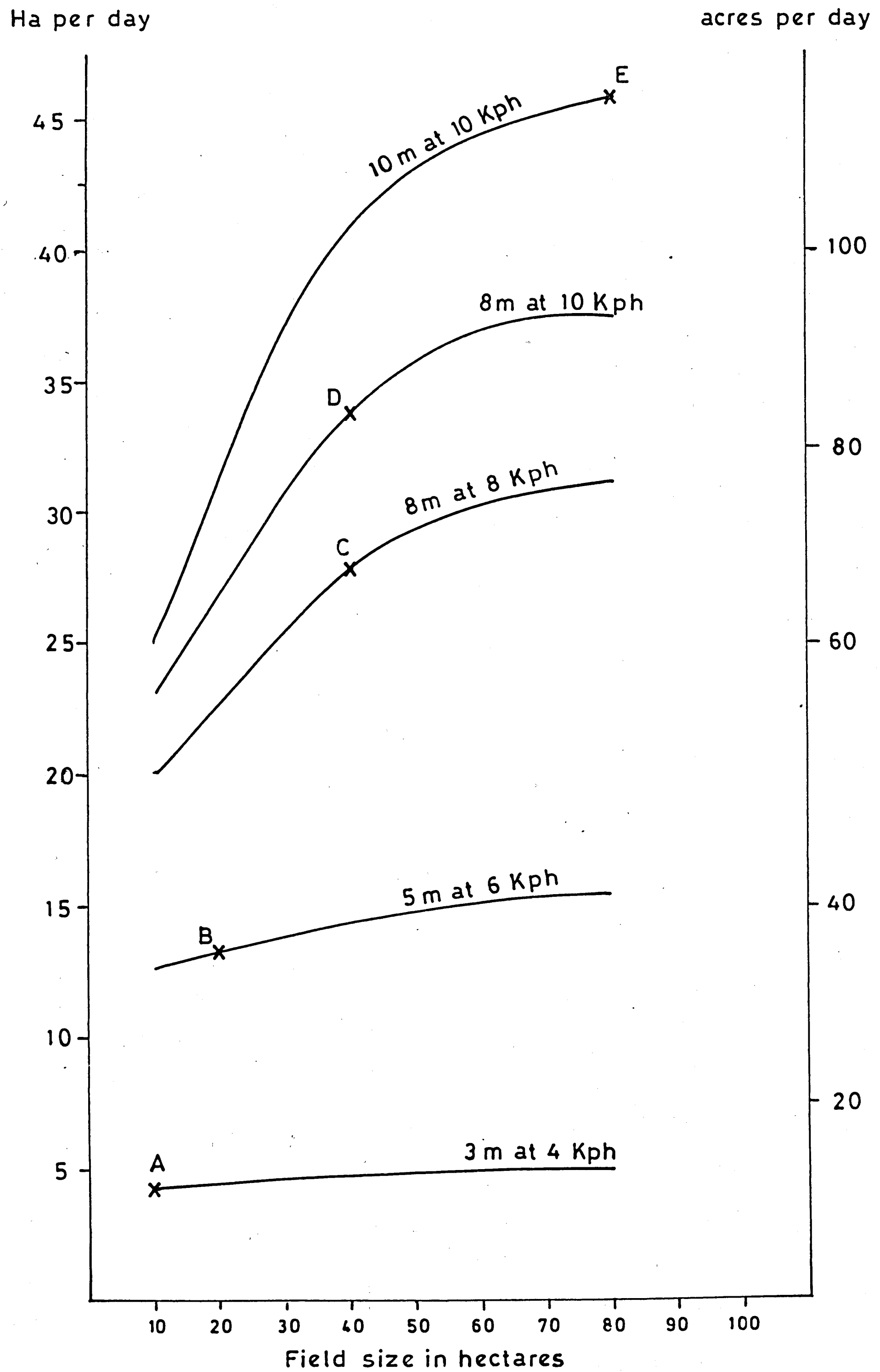

Fig.4. Combined effect of larger fields, wider implements and higher speeds.

A. 3 m wide cultivator @ 4 Km/hour in 10 ha field. 4 ha per day.
B. 5 m wide cultivator @ 6 Km/hour in 20 ha field. 13 ha per day.
C. 8 m wide cultivator @ 8 Km/hour in 40 ha field. 28 ha per day.
D. 8 m wide cultivator @ 10 Km/hour in 40 ha field. 34 ha per day.
E. 10 m wide cultivator @ 10 Km/hour in 80 ha field. 46 ha per day.

variety of implement widths moving at different speeds. It is obvious that the wider the implement and the higher the speed the greater the effect of field size. A farmer enlarging fields will therefore tend to buy wider implements and larger tractors and increase the speed to make full use of the change he has made. His results can therefore move from one curve to another. Take heavy cultivators as an example. The farmer with 10 ha (25 acre) fields might start with a 3 m implement, pulled by a 60 HP tractor (point A). The output is 4 ha (10 acres) in a 7 hour day. With 20 ha (50 acre) fields he might change to a 5 m (16 ft.) cultivator and a 90 HP tractor. The output would then rise to 13 ha (33 acres) per day (point B). With 40 ha (100 acre) fields he might have an 8 m (25 ft.) implement pulled by a 150 HP tractor. This would increase the output to 28 ha (70 acres) at point C. If he also increased the speed to 10 Km/hour (6 MPH), the output would rise to 34 ha (85 acres) per day (point D). This is more than eight times the original rate.

Finally, to take the extreme limit on very large farms with 80 ha (200 acre) fields, a 10 m (33 ft.) cultivator and a 215 HP tractor, could cultivate 46 ha (115 acres) per day (point E). This is for a 7 hour day. With two hours: overtime, the area cultivated could increase to 59 ha (148 acres). It will thus be obvious that it is the combination of larger fields with wider implements and higher speed that provides a worthwhile devidend.

It appears evident that previous estimates showing no advantage in enlarging fields beyond 20 ha (50 acres) were based on narrow implements and small tractors.

Shape of Field

As farmers are well aware, an awkward shape can add appreciably to the time taken to cultivate a field. A few examples are given in Figure 5. All the fields are 10 ha (25 acres) in size and estimates are given

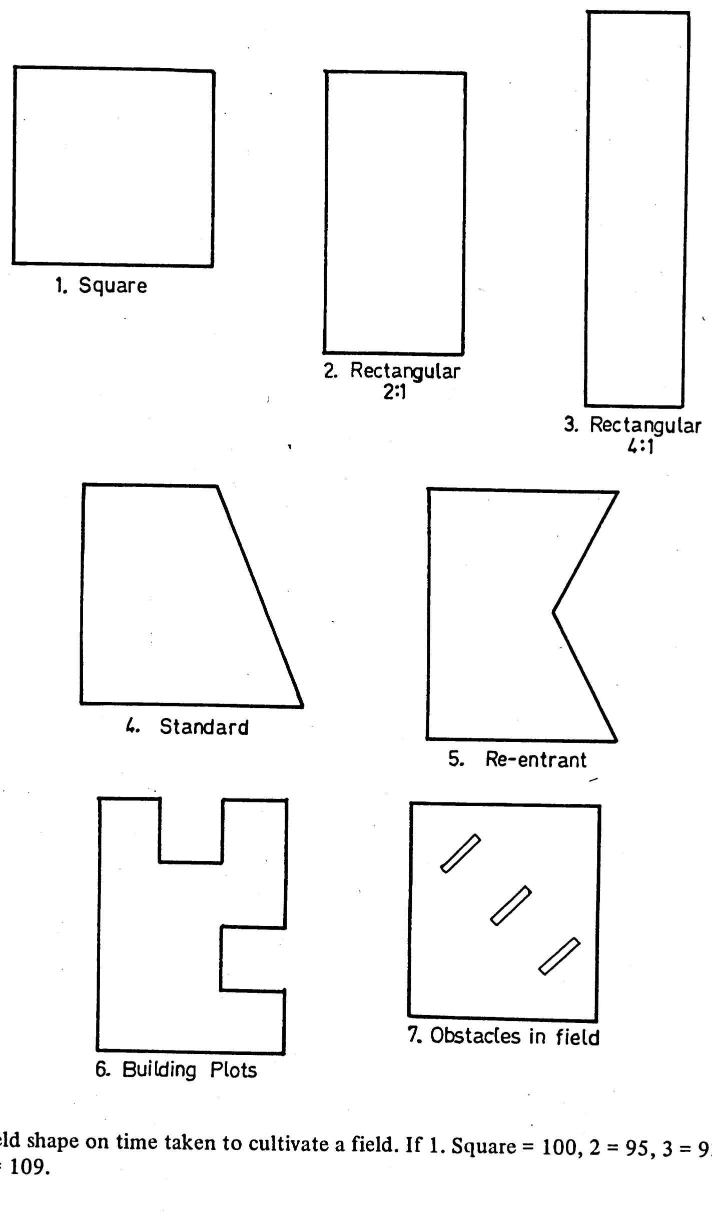

Fig.5. Effect of field shape on time taken to cultivate a field. If 1. Square = 100, 2 = 95, 3 = 93, 4 = 105, 5 = 104, 6 = 107, 7 = 109.

of the time required to cultivate (including turning, headlands and changing the field) with a 3 m (10 ft.) machine and a forward speed of 6 Km/hour. The square field requires 63.3 minutes per hectare. Taking the square shape as 100, a long narrow field requires rather less time - 95% if the length is twice the width and 93% if it is four times the width. This assumes that cultivations are done lengthwise. If cultivated across, the long thin field would be at a disadvantage.

Very few English fields, however, are rectangular. Field 4 has two sides not parallel. If cultivations are started parallel to one of them, a triangle is left on the opposite side. When cultivating a triangle, the bouts become shorter and shorter until the corner is reached. This increases the number of turns and in comparison with the square field increases the time taken by 5%. Although the triangle could be avoided by cultivating across (because the two other sides are parallel), the number of turns in this particular case would however still be the same.

Field 5 has one side curving inwards. This leaves two triangles to be cultivated. This is compensated to some extent by the greater length of the field and on balance the time taken is only 4% more than for the square. If the field were shorter, it would pay to cultivate across and avoid the triangles. Field 6 has a main road on two sides and two building plots have been sold. This leaves an awkward shape and a number of tiny headlands. The time taken is 7% over par. Field 7 typifies obstacles such as pylons, isolated trees or (as in this case) landing lights near an airfield. Such obstacles are a nuisance quite out of proportion to their size. In this case, the obstacles occupy 2% of the area but add 9% to the time taken to cultivate the field.

Table 2.5. Effect of Field Shape on Time to Cultivate 10 ha (25 acres)

Fields Shape	Minutes per ha	Index
1. Square	56.6	100
2. Rectangle (2:1)	54.0	95
3. Rectangle (4:1)	52.4	93
4. Standard shape*	59.5	105
5. Re-entrant side	59.1	104
6. Building Plots	60.5	107
7. Obstacles in field	62.0	109

* Two sides not parallel: adopted as standard in farm models

Shape of field is thus a matter of some importance. In the example quoted, the total range from awkward to most convenient was 16% in man and machine time.

As very few fields in England are regular in shape, it was decided to use Field No. 4 (with two sides not parallel) as a standard in the farm models.

The results quoted relate to a 10 ha (25 acre) field. On smaller fields the loss of time caused by an awkward shape would be greater. On larger fields, the shape would be of less significance.

CHAPTER III THE FARM MODELS

The Choice of Farm Types

In Chapter II it has been shown that the rate of field work is strongly influenced by factors such as field size, implement width and forward speed. So far, we have dealt with single operations. Crop production, however, includes a wide variety of cultivating and harvesting operations and it now remains to be seen whether the same factors apply to the whole farm. In particular, we wish to study whether there are economies of scale.

As tractors and machinery become larger and the capital investment increases, it seems probable that larger farms and larger fields will be necessary to carry these costs and to provide adequate employment for such developments. It was therefore decided to construct farm models representing three farm sizes - 80, 200 and 800 hectares. These three sizes (which coincide with those surveyed) have been chosen deliberately to illustrate three quite distinct situations, as follows:

1. 80 hectares (200 acres), the "small" farm. With the increasing size and cost of field equipment, 80 hectares is becoming the lower limit on which expensive new equipment can be economically employed.

2. 200 hectares (500 acres), the "medium sized" farm. This size should provide reasonably adequate employment for a wide range of medium to medium-large field equipment on offer to the farmer.

3. 800 hectares (2000 acres), the "large" farm. This size should provide full time employment for the largest equipment available.

Size is a relative term and 80 ha (200 acres) would be regarded in Germany as quite a large farm. Even in this country, 200 ha (500 acres) might be considered as a large farm. In arable farming however, the size tends to increase and as a matter of convenience these farms will be referred to as "small", "medium" and "large".

A study of these farm sizes provides an opportunity to assess the economies of scale that exist now or could be developed in the future. In this respect, there is a contrast between farms of 200 ha and 800 ha (500 and 2000 acres). A large proportion of the 200 hectare farms have been in existence for many years and there has been ample opportunity to rationalise them into economic units. Although often far from ideal, the field lay-out is usually reasonably convenient with a network of roads leading to a single set of farm buildings from which work on the land can be directed without undue difficulty. The 800 hectare farms are often very different. The majority have come into existence within the last forty years and they have often been built up during the lifetime of one man with the ability to manage a large undertaking and to accumulate enough capital to take over neighbouring farms as they fall vacant. Such farms have often not been rationalised and remain a loose amalgamation of farm units. The farmhouses may now accommodate foremen with a fair degree of local autonomy, who keep in touch by telephone with the proprietor. The different units may share a few large items such as combine harvesters but, apart from that, they operate almost as separate entities with their own complements of labour and machinery.

There are a number of reasons why most large arable farms have not yet been integrated into single units:

1. A farmer, wishing to enlarge his operations, would like to acquire farms on his boundary that would fit conveniently into his existing land. In practice, he can buy or rent only the farms that come on to the market and these may not be ideally situated. As a result, his territory may be irregular in shape and some of his outlying holdings may not even be contiguous. In these circumstances rationalisation may be difficult if not impossible.

2. With heavy death duties, the large farm unit may not survive the death of its creator. The heir may therefore have to sell part of the estate to pay these taxes. If so, it might be easier to sell an outlying holding that is still recognisable as an individual farm than a slice of land cut off from a large integrated unit.

3. Until 1960, land was (by present standards) comparatively cheap. A farmer with capital to invest was therefore wise to spend it on acquiring land rather than on enlarging fields or reconstructing farm buildings.

So long as the large farm remains a collection of individual farms, the costs of an 800 hectare (2000 acre) farm closely resemble those of a 200 hectare (500 acre) farm. There are, however, a few large farms which are fully integrated as single units and their numbers are growing. It is to explore the possibilities of such units that the model has been constructed.

Designing the Farm Models

In seeking to explore economies of scale in arable farming, it is necessary to consider first of all where these economies are likely to reside. The finances of an arable farm contain two elements:

1. Gross Margins of individual crops. These in turn consist of the output of these crops minus the variable costs for seed, fertiliser, herbicides, pesticides and casual labour.

2. Fixed or Common Costs consisting of:

Machinery costs (including depreciation and fuel)
Labour costs
Rent (if the farmer is a tenant)
Other overheads

So far as Gross Margins are concerned, there is no reason why the small farmer should not use the same seed, fertiliser and other materials as the big farmer and obtain the same yields. The large farmer can of course buy requisites such as seed and fertiliser on a large scale and secure extra discounts. He may also be able to drive a harder bargain when he sells his produce. But apart from this consideration, gross margins need not be less than on a large farm. So far as fixed costs are concerned, overheads for office and other expenditure are usually greater on a large farm. The level of rents on farms of different sizes brings in other factors such as quality of land, but fundamentally the small farm need not be at a disadvantage.

We are thus left with the use of labour and machinery as the major factors susceptible to economies of scale. In designing the model, the following conventions were adopted:

1. The same cropping pattern is assumed throughout:

30% wheat	8% potatoes
30% barley	20% rotational leys
12% sugar beet	

The purpose of the models is to ascertain the labour and machinery necessary to produce these crops. Hay and (on the large farms) silage are produced and straw is baled for cattle kept on the farm. The cattle and stockmen are not included in the model which is solely concerned with crop production. Foremen and office staff that might be expected on the larger farms are also omitted.

2. Lists of tractors and machinery were chosen appropriate to the size of farm and field. With 800 ha the farmer might prefer to grow more cereals and less rotational leys. On smaller holdings, the farmer might concentrate either on potatoes or sugar beet but not both to avoid the expense of two sets of specialist machinery.*

Two considerations however seemed paramount:

1. To provide a reasonable diversity of crops with each large enough to justify specialist equipment.

2. To assume a uniform system of cropping throughout - otherwise economies of scale in comparing farms of different sizes would not be clearly recognisable.

3. A standard list of cultivations was prepared following the normal practice on the 90 farms surveyed.

4. A list was made of the dates within which critical field operations (e.g. sowing seed, harvesting etc.) must be performed. A standard list was employed of working days available in each month after allowing for adverse weather**.

5. The rate of work for cultivations was calculated from the width of the implement and the appropriate forward speed. For harvesting, the criterion was throughput. Allowance was made for turning, headlands, changing fields and transporting materials to the fields. To this a contingency allowance of 20% was added for adjustments and the personal needs of the driver. A working day of 8 hours was assumed, of which 7 hours was operational. No allowance was made for overtime, which was regarded as a reserve for unusually adverse weather and other conditions.

6. Labour profiles were constructed to ascertain the number of men and machines required. If it was found, for example, that one machine could not accomplish its task in the days available, two machines (or a larger model) were included.

* The authors are particularly indebted to Mr. J. B. Finney, Machinery Officer, ADAS, for help in this matter.

** Farm Planning Data 1975, Agricultural Economics Unit, Cambridge.

Table 3.1. Labour and Machinery Costs on the Farm Models

Farm Size	Small 80 ha (200 acres)	Medium Sized 200 ha (500 acres)				Large 800 ha (2000 acres)			
Field Size	8 ha (20 acres)	10 ha (25 acres)	20 ha (50 acres)	40 ha (100 acres)	40 ha (100 acres) with 145 HP tractor	10 ha (25 acres)	40 ha (100 acres)	80 ha (200 acres)	80 ha (200 acres) with 215 HP tractor
Cost of Machinery-total	£40,656	£72,323	£68,141	£70,594	£76,783	£196,376	£192,550	£192,550	£210,287
per ha	502.30	357.43	337.75	348.41	379.30	242.63	237.91	237.91	259.18
per acre	203.28	144.65	136.28	141.19	153.57	68.19	96.28	96.28	105.14
Workers required	3	5	4	4	4	9	7	7	7
Cost per ha									
Repairs	£13.05	£16.28	£15.20	£13.89	£14.04	£17.77	£14.95	£13.89	£14.76
Fuel	18.90	17.17	16.23	14.38	14.83	14.68	13.07	12.43	13.59
Depreciation	50.95	35.85	34.00	35.08	37.88	24.64	24.46	24.46	26.44
Total – machinery	82.9	69.30	65.43	63.35	66.75	57.09	52.48	50.78	54.79
Labour	113.05	75.37	60.29	60.29	60.29	33.85	26.19	26.19	26.19
Total	£195,95	£144.67	£125.72	£123.64	£127.04	£90.94	£78.67	£76.97	£80.98
Costs per acre									
Repairs	£5.28	£6.59	£6.15	£5.62	£5.68	£7.19	£6.05	£5.62	£6.38
Fuel	7.65	6.95	6.57	5.82	6.00	5.94	5.29	5.03	5.50
Depreciation	20.62	14.51	13.76	14.20	15.33	9.97	9.90	9.90	10.70
Total – machinery	33.55	28.05	26.48	25.64	27.01	23.10	21.24	20.55	22.58
Labour	45.75	30.50	24.40	24.40	24.40	13.70	10.60	10.60	10.60
Total – labour & machinery	£79.3	£58.55	£50.88	£50.04	£51.41	£36.80	£31.84	£31.15	£33.18

7. The repair costs of each machine were calculated from its purchase price and hours of use multiplied by the standard factor (see Chapter I). Depreciation was calculated by the methods described in the same Chapter.

First Results

The results are shown in Table 3.1. The 200 ha medium sized farm is shown with three field sizes - 10 ha (25 acres) which would be typical of many farms of this size, 20 ha (50 acres) a size to which many fields have been enlarged, and 40 ha (100 acres) which is found occasionally. The large farm was shown with fields of 10 ha (25 acres) typical of the recently formed large farm where not many of the fields have yet been amalgamated, 40 ha (100 acres) and 80 ha (200 acres). The last, 80 ha, is rare in this country but frequently occurs in countries such as the U.S.A. and Australia.

The capital cost shown is the price of buying equipment new at 1977 prices. As can be seen, this increases from just over £40,000 on 80 hectares up to about £200,000 on 800 hectares (2000 acres). Per hectare, however, the cost falls from just over £500 on 80 hectares to around £350 on 200 hectares and to £240 on 800 hectares. The higher capital cost per hectare on small farms is due to the fact that even if one chooses the smallest models available, a large proportion of the machines are not fully used on 80 hectares. This is particularly true of large items such as combine harvesters.

Utilisation of Machinery

There is another point. Machines are a "lumpy" input. They come one at a time and their capacity does not necessarily match the amount of work to be done on any particular farm. If the machine is under-used, this can increase the cost of equipment per hectare. Suppose, for example, a machine has the capacity to harvest 100 hectares in the time available. If the farmer has 50 hectares, he will need one machine although it will be used at only half capacity. If he has 150 hectares, one machine is not enough and he will need two with a total capacity of 200 hectares. The machine will therefore be used at only 75% capacity. The effect of this on the cost of equipping a farm is shown theoretically in Table 3.2. It is assumed for simplicity that the farmer has three operations to do on all his crops and that they require three different machines. Their cost and capacity is:

Machine A	Capacity 100 hectares	Cost £5000
Machine B	Capacity 140 hectares	Cost £7000
Machine C	Capacity 180 hectares	Cost £9000

Table 3.2. Effect of Farm Size on Utilisation of Machinery

Size of Farm	Number of Machines Required			Capital Cost		Utilisation
	A	B	C	Total	Per hectare	
40 hectares (100 acres)	1	1	1	£ 21000	525	29%
80 hectares (200 acres)	1	1	1	21000	263	57%
160 hectares (400 acres)	2	2	1	33000	206	73%
240 hectares (600 acres)	3	2	2	47000	196	77%
400 hectares (1000 acres)	4	3	3	68000	170	88%
600 hectares (1500 acres)	6	5	4	101000	168	89%
800 hectares (2000 acres)	8	6	5	127000	159	94%

With 40 hectares, the farmer needs one of each of the machines. The total cost is £21000 or £525 per hectare. The machines are however working well below capacity - only 29%. With 80 hectares, three machines are again required costing £21000 or £263 per hectare. They are however used to 57% of capacity. As the acreage increases more machines are required, but as the numbers increase they can be made to fit the acreage more accurately and the utilisation of capacity gradually rises to 94% at 800 hectares. As the utilisation improves, the cost per hectare falls from £525 to £159. The example is of course an oversimplification. Machines come in different sizes and with a larger area, a farmer might prefer one large to two or three small ones. Nonetheless, the example does illustrate the fact that on small farms, implements are frequently under-used and this does tend to increase the capital cost and upkeep of equipment per hectare. As shown in Chapter IV however, the small farmer can avoid high capital investment per hectare by buying second-hand equipment.

A second factor that might influence costs is the relative costs of large and small machines. In other words, does a machine with twice the capacity cost twice as much to buy? If it does cost less, this would constitute an economy of scale. Examples drawn from four different manufacturers are given in Table 3.3. There is some evidence that when the type stays constant, the cost per metre of width, per horse power or per tonne capacity tends to fall with increasing size. As machines increase in size, however, their specification tends to change and this is indicated by a bar.

Table 3.3. Purchase Price of Machines of Different Sizes

Tractors

	Make A	Cost per HP
47 HP	£ 4100	£ 87
60 HP	4620	77
66 HP	4845	73
88 HP	10016	114
105 HP	10789	103
180 HP	17726	98

Tractors

	Make B	Cost per HP
53 HP	£ 4254	£ 80
68 HP	6054	89
89 HP	8064	91
145 HP	12263	85
118 HP	13215	112
145 HP	14288	99

Combine Harvesters

Tonnes/hour		Cost/Tonne/hour
3.75	£12500	£3333
4.50	14240	3164
5.25	15935	3035
6.75	18150	2689
8.25	22635	2744
10.50	31700	3019

Spring Time Harrows

		Cost/ft wide
36 tine	£ 540	£46
45 tine	668	45
54 tine	840	48
63 tine	1204	58
72 tine	1327	56
81 tine	1454	55

Larger harrows, for example, are made to fold so that they can easily be moved from field to field. Tractors beyond a certain size change from two to four wheel drive. When pulling heavy implements a four wheel drive reduces wheel slip and enables the tractorman to carry out operations more quickly. Larger implements are pulled by more powerful tractors and again, the speed of work may be increased. These changes in specification can therefore be regarded as modifications necessitated by the increasing size of the implement. They add to the cost but in so far as they increase productivity, they probably do not increase costs per unit of output.

There is a further point. In comparing machines in catalogues, the price does not necessarily increase uniformly with size. Some sizes are more popular than others and with keen competition, their prices tend to be lower. Unusually large or small models with limited market or machines specially imported tend to be more expensive. Apart from these special considerations, therefore, there is a tendency for the cost of machine upkeep per unit of output to fall slightly with increasing size.

Returning to the annual costs per hectare in Table 3.1, it can be seen that depreciation per hectare falls quite sharply with increase in farm size from about £51 on the small farm to £35 on the medium sized farms and £25 on the large farms. This follows the same pattern as the capital cost of new equipment for these farms. The cost of repairs per hectare is broadly similar on all the farms. The cost of fuel per hectare is also fairly uniform with a slight tendency to increase on small farms and small fields where cultivations take more time.

Utilisation of Labour

The main item where there is scope for economies of scale is in the use of labour. As can be seen, the cost per hectare declines from £113 on the small farm to £60 to £75 on medium sized farms, and to £26 to £33 on the large farms. The cost also declines with size of field.

The general picture that emerges is that increased mechanisation made possible by larger farms and larger fields results in lower labour costs. As mechanisation is generally regarded as a substitute for labour, one might expect a fall in labour costs to be accompanied by an increase in machine costs. In fact, machine costs per hectare are generally less on larger farms and fields.

There is, however, one exception to the last statement. It is possible to over mechanise and to increase costs without sufficient recompense in reduced labour costs or increased output. Two examples are given below.

One novelty in recent years has been the introduction of very large tractors. Although they have received a fair amount of publicity, an analysis of the Cambridge Farm Management Survey reveals very few tractors over 100 HP even on farms of 800 hectares. This may be because most of the fields are no more than 10 to 20 hectares and this would limit their scope. To explore the possibilities, alternative versions are included with large tractors - 145 HP on the medium sized and 215 HP on the large farms.

There can be little doubt that these large tractors can pull large ploughs and cultivators at quite a high speed and cultivations can be completed very quickly. Apart from these tasks, however, it is not too easy to find adequate employment for them. Most of the other equipment on sale in this country can be pulled equally well by a 90 HP tractor and to use a larger one is wasteful. For this reason, the 145 HP tractor was under-employed on the medium sized farm. On the large farm, the 145 HP tractor could be usefully employed but the 215 HP tractor was under-used. For this reason, the 145 HP tractor on 200 hectares and the 215 HP tractor on 800 hectares increase costs without any countervailing advantage. They certainly save time in cultivations but not by enough to reduce the labout force by one man. The labour costs per acre thus remain unchanged.

A few of these very large tractors have recently been imported from the U.S.A. So far, they have been used almost entirely for ploughing and heavy cultivations. In the hands of a contractor, they could be fully employed on such work but on a farm there is usually not enough heavy cultivation unless the farm is very large or a large amount of subsoiling is required. There are, however, special conditions that could justify a large tractor. If the farmer wished to grow more wheat, sugar beet or winter rape instead of barley, a tractor capable of carrying out cultivations repidly in the autumn could deal with the labour peak and generate enough extra income from the new crops to justify the cost.

Seasonal labour profiles were prepared for the farm models. In each case, the horizontal axis is marked out with the number of days available each month, after making allowance for unfavourable weather. There is a rectangle for each task - the length represents the number of days required for the operation and the height the number of men employed. Having fitted all the operations into the appropriate season, labour peaks emerge - particularly March and April to sow the spring crops, August to harvest cereals and October and November to sow the winter wheat and harvest sugar beet and potatoes (for example, see Figure 6).

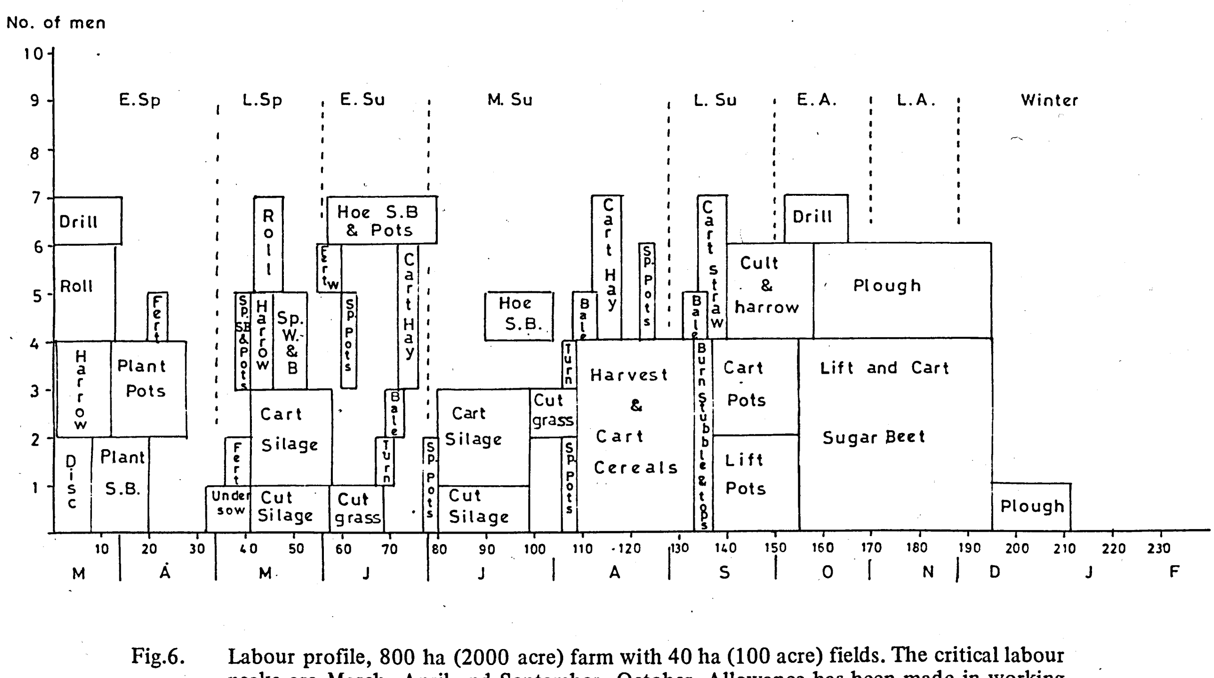

Fig.6. Labour profile, 800 ha (2000 acre) farm with 40 ha (100 acre) fields. The critical labour peaks are March–April and September–October. Allowance has been made in working days for unfavourable weather. For simplicity, operations are shown in single blocks although in practice some would be interspersed.

The permanent labour force must be able to deal with the peak labour demands, and it is this that determines the permanent labour force. Having ascertained the number of men required, their cost has been included in Table 3.1.

The number of workers on the small farm is three. On the medium sized farm it is five with 10 hectare fields and four on those with larger fields. On the large farms, 9 men are required with 10 ha (25 acre) fields. With larger fields, the labour force falls to seven. The number of men given in each case is a reasonably generous allowance but the same standard is used throughout. If the farmer is prepared to do some manual work at peak periods, the number of employees could be reduced by one. It will also be recalled that with 20 per cent of cash roots, the cropping is reasonably intensive.

Effect of Larger Fields and Implements

The saving in labour due to a combination of larger farms, larger fields and larger implements can be illustrated by stating the number of workers required to farm 800 hectares (2000 acres).

10 farms of 80 hectares (200 acres) require	30 men
4 farms of 200 hectares (500 acres) require	16 men (40 ha fields)
1 farm of 800 hectares (2000 acres) requires	7 men (40 ha fields)

Total costs per hectare for labour and machinery are:

Farm Size	**Small 80 ha (200 ac)**	**Medium 200 ha (500 ac)**	**Large 800 ha (2000 ac)**
Field Size:			
8 ha (20 acres)	£195.95	-	-
10 ha (25 acres)	-	£144.67	£90.94
20 ha (50 acres)	-	£125.72	-
40 ha (100 acres)	-	£123.64	£78.67
80 ha (200 acres)	-	-	£76.97

There thus appear to be substantial economies of scale. Costs per hectare fall from £195.95 on the small farm down to £123.64 to £144.67 on the medium farms and to £90.94 to £76.97 on the large farms.

The figure of £195.95 for the 80 ha farm is extremely high and illustrates the disadvantage that the smaller farmers would suffer if they bought new machinery. In practice, they offset this cost to a large extent by purchasing second-hand machinery - a matter to be dealt with in Chapter IV.

Turning now to the medium and large farms, it can be seen that larger fields produce a substantial reduction in costs. On the medium sized farms, costs fall by 15% in moving from 10 ha (25 acre) to 40 ha (100 acre) fields, and on the large farms, costs fall by 15% moving from 10 ha to 80 ha (200 acre) fields. These represent the savings one could expect in practice. As a point of interest, however, it is possible to show separately how much of the reduction in costs and labour required is due to field size and how much to increased mechanisation.

The effect of increased mechanisation on its own can be demonstrated by comparing the medium and large farms with the same field size. This is a fair comparison because they differ only in the size of tractors and implements.

Farm Size	**Medium 200 ha**	**Large 800 ha**	**Reductions in cost**
10 ha fields	£144.67	£90.94	37%
40 ha fields	£123.64	£78.67	36%

In both cases, the use of larger mechines causes a fall in costs of about 36%. Of this, three quarters is due to labour and the rest to better utilisation of larger machinery.

The effect of field size on its own can be demonstrated by holding the farm size and equipment constant and varying the field size. The results for the medium sized farm are given in Table 3.4.

Table 3.4. Comparison of Costs on Small, Medium & Large Fields
(all on a 200 ha farm)

Field Size	10 ha (25 acre)	20 ha (50 acre)	40 ha (100 acre)
Repairs	£ 16.16	£ 14.97	£ 13.89
Fuel	16.73	15.52	14.38
Depreciation	35.09	35.09	35.09
Labour	60.29	60.29	60.29
	128.27	125.87	123.65
No. of men	4	4	4
Man hours	3585	3369	3171
Index, man hours	100	94	88

To do this, it was necessary to assume that the farm with 10 ha fields had the larger machinery recommended for farms with 20 ha or 40 ha fields. When this was done, only 4 men were required. As all the farms now had the same equipment and labour, depreciation and labour costs are the same. The larger fields do however produce an appreciable saving in fuel and repair costs.

So far we have used the number of men required. Men however are a "lumpy" commodity. They come one at a time and are not a very sensitive indicator of labour requirements. A better measure is the number of man hours of productive field labour. As can be seen, this declined by 6% in moving up to 20 hectare fields and by 12% to 40 ha fields. These reductions are not however quite sufficient to affect the number of men - 4 in each case.

The same procedure has been followed for the large farms (Table 3.5). Again equipment on the farm with 10 ha fields has been brought in line with that of the farms with larger fields. As can be seen, the enlargement of fields from 10 ha (25 acres) to 40 ha (100 acres) produces a substantial reduction in costs from £91.87 to £78.67 per ha. Half of this is due to labour and the remainder to repairs and fuel. The number of workers required falls from 9 to 7 or in man hours by 16%.

Table 3.5. Comparison of Costs on Small, Large & Very Large Fields
(all on 800 ha farms)

Field Size	10 ha (25 acre)	40 ha (50 acre)	80 ha (100 acre)
Repairs	£ 18.19	£ 14.95	£ 13.89
Fuel	15.37	13.07	12.43
Depreciation	24.46	24.46	24.46
Labour	33.85	26.19	26.19
	91.87	78.67	76.97
No. of men	9	7	7
Man hours	9679	8116	7533
Index, man hours	100	84	78

A further increase from 40 ha (100 acre) to 80 ha (200 acre) fields produces a further reduction of £1.70 per ha in costs or 7% in man hours.

It is thus evident that increase in field size and further mechanisation each separately provide an appreciable increase in productivity. In practice, however, a farmer improving the lay-out of his farm will also change his tractors and equipment to take full advantage of his farm rationalisation. The reductions in cost from these together are thus likely to be more akin to those shown in Figure 4 & Table 3.1 earlier in this chapter.

CHAPTER IV SMALL FARMS AND THE SECOND-HAND MARKET

The Second-hand Market in Farm Equipment

It has been shown that per hectare the cost of buying a full complement of new equipment for a small farm is substantially greater than for a large one. In the three models the figures were:

Per hectare	Purchased New at 1977 prices	Depreciation
80 ha (200 acres)	£502	£51
200 ha (500 acres)	£337 to £379	£34 to £38
800 ha (2000 acres)	£237 to £259	£24 to £26

If this occurred in practice, the small farm would be at a disadvantage with depreciation costs 70 per cent above those of medium sized farms and more than twice those of large farms. Evidence drawn from the Farm Management Survey tends to show that in practice costs for machinery upkeep per hectare are very little more on small than on large farms.

The question therefore arises as to how small farmers manage to keep machinery costs to such a modest level. The main reason is that they buy second-hand equipment of which there is a plentiful supply. Large farmers normally buy new equipment. Some of them keep equipment for its full life; others have a policy of trading in machines after three or four years in part exchange for new equipment. The dealers who take this second-hand equipment usually sell it to small farmers.

The sale of equipment from large to small farmers is advantageous to both parties. The large farmer has enough land to employ equipment to capacity but, with a tight schedule, he cannot afford breakdowns at critical times such as harvest. He therefore prefers to have a stock of fairly new machinery on which he can rely. To encourage the farmer to buy a new machine, the machinery salesman will point out the improvements that have been incorporated into their newest models and will draw attention to the fact that the cost of a new machine can be charged against profits to reduce income tax. The last argument is likely to appeal to the farmer if he was just had a profitable year. The salesman keen to make a sale will offer a generous allowance for the old machine in part exchange. Indeed, in a period of inflation, he may offer the farmer as much as he paid for the machine new two or three years before. This may seem a bargain until the farmer realises that the price of a new machine has increased substantially and the cost of replacement is keeping pace with inflation. The salesman may then point out that if the farmer delays, the price will soon be higher still.

The economic effect of this system of selling equipment from large to small farms can be assessed by modifying two of the farm models. So far it has been assumed that farmers buy equipment new and sell it at the end of its useful life. We shall now assume that on the 200 hectare farm, equipment is brought new and sold after three years in part exchange for new machines. The trading-in price assumed is 51.2% or 42.4% of the new price, corresponding to depreciation rates of 20% or 25% and to a life of 10 or 8 years (see Chapter I). The amount the salesman offers in part exchange depends of course on the condition of the equipment and how keen he is to make a sale. Enquiries from merchants and published lists of second-hand values seem however to confirm the estimates given above as a reasonable average.

Table 4.1. Depreciation Costs of Equipment Replaced after 3 years

Medium Sized (200 ha) Farm	Equipment with 10 Year Life (20% depreciation)		Equipment with 8 Year Life (25% depreciation)
New value of equipment	£37395		£33199
Sell after 3 years @ 51.2% of new price	19146	@ 42.2% new price	14010
Depreciation over 3 years	18249		19189
			18249
		Total depreciation	37438
		Per hectare per year	£62.40

Table 4.1 (contd.)

Costs per hectare	Kept for 8 or 10 years		Renewed after 3 years
Depreciation	£35.08		£62.40
Repairs	13.89	60% of average	8.33
	£48.97		£70.73

Cost of repairs and depreciation if -

Half the equipment is renewed after 3 years	£59.85
One third of the equipment is renewed after 3 years	£56.17
All equipment is kept for 8 or 10 years	£48.97

If equipment is renewed after three years, there will be a saving in repair costs. These should be very small in the first year while the equipment is under guarantee and below average in the second year. If we assume a long term average of 100, repairs in the first three years can be taken as 20, 60 and 100 or an average of 60% of normal. On this basis, repairs and depreciation together amount to £70.73 per hectare for equipment renewed after three years. In practice, the farmer will renew only part of his equipment. If he renews half, the cost will be £59.85, and one third, £56.17. This can be compared to £48.97 if all the equipment is kept for its full life. The extra £7.20 or £10.88 per hectare would probably be regarded as quite a modest price for ensuring that the most important items of equipment were new and reliable.

Now we turn to the smaller farmer buying such equipment second-hand. The first point to be considered is the commission the dealer is likely to take on the sale. If the dealer is keen to make a sale, and has already given a generous price for the old machine, he may be lucky if he can recover it on re-sale. In this case, the dealer has no margin on the second-hand sale and must depend on the profit he makes on the new machine and on the spare parts and other services he hopes to provide later. The dealer may recondition a machine before selling it, and add this to the price, but he may prefer to sell it as it stands and agree with the customer on any reconditioning required.

As an alternative, the dealer may sell to a trader who exports equipment to countries such as Denmark or Turkey where there are few large farmers that can afford to buy large, expensive machines. This is a selective trade and tractors of makes that are popular abroad sell at quite a high price even when old.

Farmers buying large and complex machinery such as combine harvesters often prefer to buy from a dealer they know because he is prepared to take some responsibility for its condition. Simple equipment, such as harrows that can be judged on sight by the farmer, is often purchased at farm sales or auctions.

It now remains to examine the costs of the farmer buying second-hand equipment. The estimate shown in Table 4.2 uses the small 80 hectare farm model.

Table 4.2. Depreciation Costs of Small Farmer Buying Second-hand Equipment

Small (80 ha) Farm	Equipment with 10 Year Life		Equipment with 8 Year Life
Price if purchased new	£20006		£20650
Buy second-hand 56.3% of new price	11263	46.4% of new price	9582
Sell for scrap 10% of new price	2001		2065
Depreciation (over remaining life)	9262		7517
Depreciation per year (9 years)	1029	(7 years)	1074
			1029
		Total depreciation	2103
		Depreciation per ha	£26.29

Table 4.2 (contd.)

Comparison:	All Bought New		All Bought Second-hand
Depreciation	£50.95		£26.29
Repairs	13.05	15% above average	15.01
	£64.00		£41.30

Cost of repairs and depreciation

Half equipment bought second-hand	£52.65 per hectare
All equipment bought new	£64.00 per hectare

If the equipment with a life of 8 or 10 years on medium and large farms is sold after 3 years, the remaining life is presumably only 5 or 7 years. But on smaller farms, the equipment is used much less and such farmers are slower to discard equipment because it is obsolete. A remaining life of 7 and 9 years has therefore been taken. Ten per cent has been added to allow for dealers' or auctioneers' commission. No allowance has been made for reconditioning by the merchant. If the machine needs repair, the cost is likely to fall on the farmer in any case, either as part of the purchase price or later as part of his subsequent repair costs.

It has already been estimated that repairs are only 60% of normal in the first three years. If so, then if the long term average is 100, the average for the remaining 7 and 9 years will be 113 and 117 - or overall 15% above the long term average. This is nearly double the cost allowance for the first owner. We can now compare the costs. If all equipment were purchased new and retained for 8 or 10 years, the costs per hectare on the medium sized farm would by £48.97 and on the small farm £64.00. This difference of £15.03 would be a severe handicap to the smaller farm. Indeed on a farm of less than 80 hectares, the dis-

	Medium Sized Farm 200 hectares	**Small Farm** 80 hectares
All equipment bought new and kept for life	£48.97	£64.00
One third renewed after 3 years	£56.17	-
Half purchased second-hand 3 years old	-	£52.65

advantage would be even greater.

If. however, the medium sized farmer renews a third of his machines after 3 years to ensure that his equipment is in first class condition, his costs rise by £7.19 to £56.16 - a fairly modest premium. If the small farmer buys half his equipment second-hand, his costs fall to £52.65, no more than on the medium sized farm.

The estimates given refer to equipment changing hands after three years. A large farmer might of course sell after four or five years and when profits fall or cash is short, this is what he is likely to do. If so, depreciation will cost slightly less and repairs slightly more. The purchaser would pay less but the equipment would presumably wear out sooner and cost rather more to repair. On balance, costs are likely to be close to or fall between the alternatives already quoted.

There can be little doubt that this is the way that small farmers avoid the diseconomies of scale that might be anticipated because they do not have the area to carry the cost of new machines. Second-hand equipment is of course less reliable and lacks the most modern improvements. It does, however have the great advantage that the price is substantially less than for new equipment. To a farmer short of capital, this may be a matter of prime importance.

Survey of Equipment on Smaller Farms

It has just been shown that by purchasing second-hand machinery a small farmer can reduce the capital cost of equipping his farm to a reasonable level. The example used was a 80 ha (200 acre) farm. There are, however, many arable farms much smaller than 80 ha. How do they manage to equip their farms at a reasonable cost? To confirm our theories on the matter, it was decided to carry out a special survey of farms below 80 ha in size to find what equipment they carried and how they had acquired it.

A sample of 30 farms was chosen of which seven were below 40 ha (100 acres), 18 were 40 to 60 ha (100-150 acres) and eight were over 60 ha (150 acres). The average size was 50 ha (124 acres). All were arable farms (MAFF groups 8 and 9) depending on ordinary farm crops such as cereals, sugar beet, potatoes, beans and oil seed rape. By definition, they had only a limited amount of livestock.

The list of equipment on these farms is given in Table 4.3. A striking feature is that in spite of their small size, nearly all these farms carry a full complement of implements and machinery. The farmers obviously value their independence and, apart from hiring or borrowing a few specialist machines, they are largely self-sufficient. It will be seen that a large proportion of the equipment is more than ten years old, especially implements such as harrows, rolls, cultivators and ploughs which do not date readily. Indeed, if the farmer renews the tines and shares such cultivating implements can be made to last indefinitely. A large proportion are purchased at sales or auctions.

The really expensive items are the harvesting machines which are usually bought from dealers. Combine harvesters cost from £10,000 to £30,000 and it is not surprising that 26 out of 28 machines were purchased second-hand. Two farmers, however, had bought new combines - one fairly recently. Only three of the farmers shared combines with neighbours. Four farmers had no combine and depended on contractors.

Most of the second-hand combines are large because they come from large farms. They are thus able to harvest the cereals on a small farm in a few days. Three farms had the time to harvest crops for neighbours. Apart from this, most of the combines are not being used for a large acreage and if well maintained they should last for a long time. It is not surprising therefore that of 28 combine harvesters, 19 were more than ten years old. A few were 15 to 20 years old. A difficulty at that age is obtaining spare parts. One farmer with a very old combine had managed to buy another of the same model at a sale and was cannibalising it for spare parts.

Fourteen farmers grew sugar beet. Two of them used contractors to lift their crops. The remainder owned 18 machines of which 12 had been purchased second-hand. Only one was shared. Of the nine potato harvesters, six had been bought second-hand. They were mostly of the simple elevator type requiring a gang of pickers. Balers are another expensive item. Of 26 farmers baling hay or straw, 10 used contractors and 12 had bought second-hand machines. Only three had bought new. A large proportion of the sprayers were purchased. A second-hand machine in poor condition could be a nuisance.

Table 4.3. Inventory of Field Equipment carried by 30 Arable Farmers with less than 80 ha (200 acres)

Machine	No.	Bought New	Bought S/H	Contractor used	Age (years) 0-3	4-6	7-10	10+
Tractors	93	49	44	1	30	10	14	39
Ploughs	47	24	23	2	2	11	9	25
Cultivators	65	42	23	1	22	11	7	25
Discs	23	7	16	1	2	5	4	12
Harrows	55	34	21	-	9	5	2	39
Rolls	31	9	22	-	3	-	1	27
Inter-row Cultivators	19	10	9	1	2	1	3	13
Drills (Corn)	3	5	1	1	1	1	-	6
Drills (Combine)	26	12	14	-	4	2	6	14
Drills (Precision)	10	6	4	5	2	-	2	6
Fertiliser Distr.	29	21	8	-	9	7	10	3
Potato Planter	5	1	4	3	-	-	-	5
Harvester (Combine)	28	2	26	4	1	-	8	19
Harvester (Potato)	9	3	6	-	2	3	-	4
Harvester (Sugar Beet)	18	6	12	2	4	3	6	5
Balers	15	3	12	10	-	2	4	9
Sprayers	28	20	8	4	6	7	5	10
FYM Spreaders	9	4	5	1	1	-	4	4
Hedge Cutters	4	2	2	-	3	1	-	-

S/H = Second-hand

The other major item of cost is the provision of tractors. The total number - 93 or more than three per farm - may seem extravegant. In fact, 39 of them are more than ten years old. At that age they have little value and the farmer is tempted to keep them as spares or for odd jobs about the farm.

It will be noticed, however, that 49, or more than half, these tractors had been purchased new. Most of the farmers stated that while prepared to buy second-hand implements, they bought new tractors whenever they could afford them. A surprising fact was that in spite of rising prices these farmers had purchased 26 new tractors within the past three years, at prices varying from £2000 to £7000. More tractors were purchased in the last three years than in the previous six.

A likely explanation is the effect of inflation and joining the EEC. First cereals, then potatoes increased in price and farmers' accounts showed enhanced paper profits. As their tax liability was likely to increase, farmers promptly invested surplus cash in equipment that could be charged against profits. No doubt they considered it wise to renew equipment before prices increased once again. In doing so they gave priority to tractors which are in use all the year round.

In addition to buying equipment second-hand, there are two ways in which a farmer can offset the cost of machine upkeep:

1. He can share equipment with a neighbour. Of the 30 farmers surveyed, 14 shared some items with other farmers - of which three were relatives. The usual items were sprayers, fertiliser distributors, seed drills, balers and occasionally harvesting machines.

2. He can do work on contract for a neighbour. The usual tasks were harvesting cereals and baling hay or straw. Thirteen farmers said they did work on contract, either regularly or occasionally to help a neighbour whose work had fallen behind for some reason.

In theory the sharing of machines would appear to be beneficial, especially on small farms of less than 50 hectares. As has been shown, this occurs in only a minority of cases. Work on crops must be carried out at the right time and if the partner fails to return the implement in time, the delay could reduce crop yeilds. Farmers therefore tend to carry as complete an inventory of implements as they can afford.

Nevertheless, joint ownership of a machine can be successful if the farmers concerned have a good working relationship. Difficulties could arise, however, in deciding who has first call on the machine and who is responsible for repairing any damage to it. One solution is for ownership to remain with one farmer while the use of the machine is shared. Farmer A might agree to buy a combine harvester and share it with Farmer B. Farmer B in return might agree to buy a sugar beet harvester and share it with Farmer A. Each farmer will repair his own machine and if he has any fear about damage to his machine, he can send a man or go with it himself to operate it on the other farm. On a very small one-man farm this would provide a gang of two which would be an advantage for tasks such as harvesting.

CHAPTER V CONCLUSIONS

One of the themes running through this report has been the possibilities of economies of scale in arable farming. The farm models were constructed to show whether larger farms or larger fields on farms produced such an effect. One estimate has already been given in Chapter III (Table 3.1) but there are two respects in which this can now be improved.

1. It has already been pointed out that the cost of equipping a small farm with a full complement of tractors and implements would be excessive. Small farmers avoid this diseconomy to a large extent by purchasing second-hand equipment. The data in Table 3.1 has therefore been recalculated on the assumption that the large and medium sized farmers sell one third of their equipment after three years and that the small farmer buys half his equipment second-hand.

2. Labour costs have been based on man hours of productive work. This is a more sensitive indicator of changes induced by alterations in the level of mechanisation or field size than is obtained by charging workers as single individual units. The rate charged per hour includes an allowance for time spent on other tasks such as ditching, hedge cutting, fencing and general maintenance which are necessary to crop production.

The results are shown in Table 5.1 and Figure 7. As can be seen, the small farm is now at less of a disadvantage. Depreciation has been reduced to £38.62 per hectare, which is less than on the medium sized farms. Repairs have increased but total machinery costs at £75.02 are at about the same level as on 200 ha. For this price, the small farmer has older and less serviceable equipment but at least he succeeds in keeping his costs down to a reasonable level. His machines need more repair but he is probably an expert in "make do and mend".

Table 5.1. Labour & Machinery Costs on Large & Small Arable Farms with Large and Small Fields (Costs per hectare)

Farm Size	Small 80 ha (200 acres)	Medium 200 hectares (500 acres)			Large 800 hectares (2000 acres)		
Field Size	8 ha (20 ac) £	10 ha (25 ac) £	20 ha (50 ac) £	40 ha (100 ac) £	10 ha (25 ac) £	40 ha (100 ac) £	80 ha (200 ac) £
Repairs	17.50	14.11	13.17	12.04	15.40	12.96	12.04
Fuel	18.90	17:17	16.23	14.38	14.68	13.07	12.43
Depreciation	38.62	45.17	42.80	44.19	31.00	30.73	30.73
Sub Total	75.02	76.45	72.20	70.61	61.08	56.76	55.20
Labour	71.93	64.09	61.08	55.49	47.85	38.48	33.50
Total	146.95	140.54	133.28	126.10	108.93	95.24	88.70
Index 1	-	100	95	90	100	87	81
Index 2	105	100	95	90	77	68	63

Index 1 – To show effect of larger fields – 10 ha (25 acre) field in each group – 100

Index 2 – To show overall effect of larger farms and field – 200 ha farm farm with 10 ha fields = 100

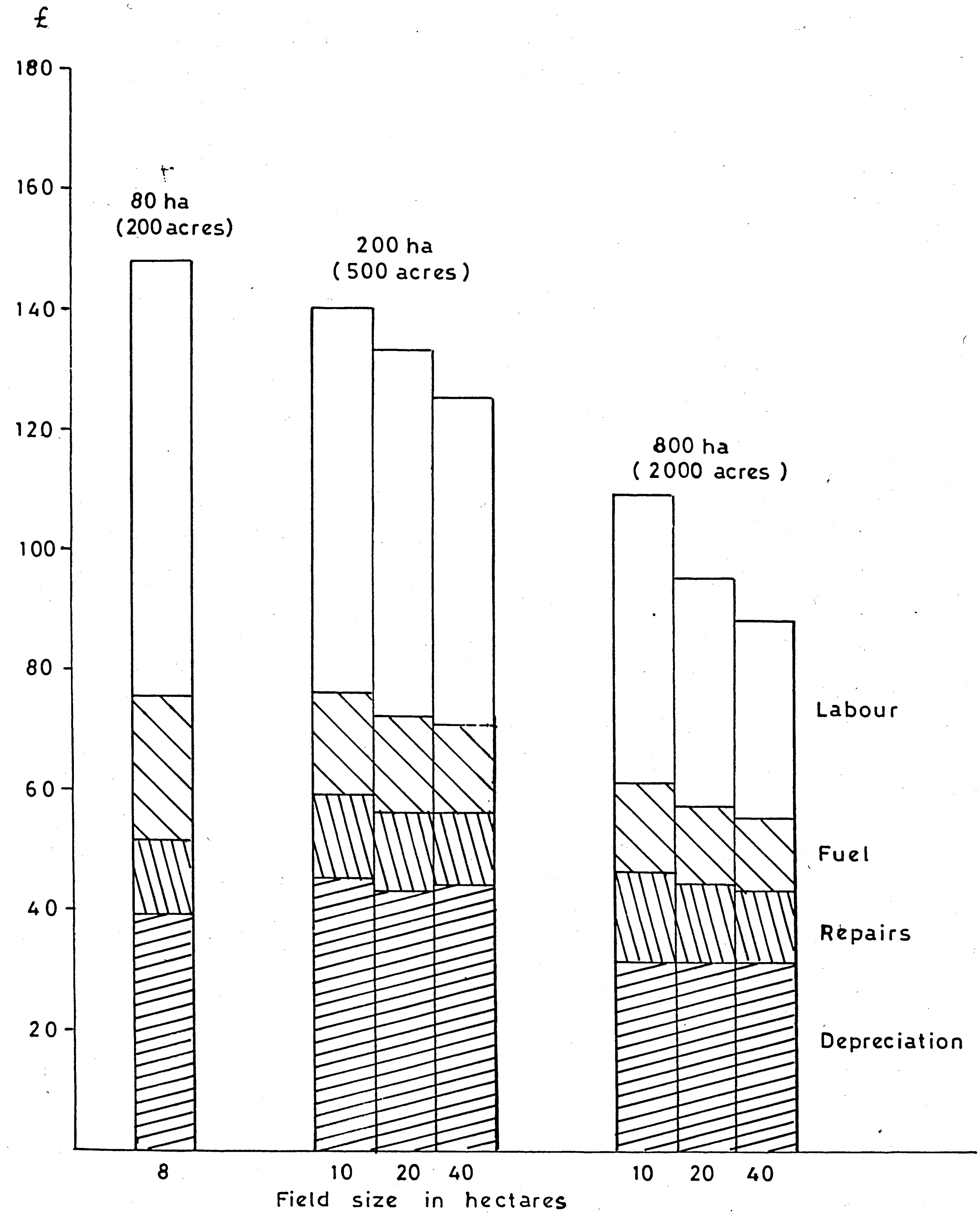

Fig.7. Cost per hectare on farms of different sizes. Depreciation on the small (80 ha) farms is reduced by assuming that half the equipment is bought second-hand. The medium and large farms renew a third of their equipment after 3 years.

By charging only "productive work" on field cultivations and harvesting, the cost of labour per hectare is very little greater on the small than on the medium sized farm. The small farm has, however, too much work for two men but not enough for three. If three are employed as suggested in Chapter III, the amount of productive work per man is less than on the medium or large farms. By implication, output and income per head will also be less.

The real disadvantage of the small arable farmer is not that his costs in cash are high but that he has insufficient land to provide a reasonable standard of living. At 80 ha (200 acres) this is less of a problem, but there are still many arable farmers with half this area whose income is less than that of a farm worker.

Such a man values his independence and is prepared if need be to tolerate a low return for his labour. But his son, when he inherits, may not be prepared to follow his example and is tempted to sell his land to a larger neighbour. It is of significance that in seven years from 1968 to 1975 the number of small arable farms has fallen by 25% (Table 5.2).

Table 5.2. Number of Arable Farms (England and Wales)

Size		No. of Farms		Change
SMD	Average (ha)	1968	1975	1968–75
275-1199	70	17317	13050	–25%
1200-4199	192	7584	6576	–13%
Over 4200	470	1000	1160	+16%

MAFF Farm classification

We now turn to a comparison of the medium and large farms. As can be seen (Table 5.1 and Figure 7) there are substantial economics of scale. Compared with a 200 ha farm with 10 ha fields, costs per hectare on the 800 ha farm are reduced by 23% with the same field size; with larger fields the reduction is 32% and 37% for 40 and 80 ha fields.

It is worth emphasis that these calculations assume a large rationalised farming unit of 800 hectares with a reasonably convenient lay-out and equipment of adequate size. As mentioned in Chapter III many large farms are no more than a loose amalgamation of smaller units, each with their own staff and complement of implements. Such farms are likely to have costs more akin to the 200 ha models.

The level of costs shown can thus be regarded as an indication of the potential of large farms. Some farmers have organised their holdings on these lines; others have not yet done so. The results indicate however that large farms have a potential cost advantage over medium sized farms. It is again of significance that while the number of medium sized arable farms declined by 13% between 1968 and 1975, the number of large farms increased by 16%.

The effect of field size alone can be dealt with in stages. An increase to 20 ha (50 acres) is obviously an advantage. On the medium sized farms, results indicate a fall in costs and man hours of 5%. A move instead to 40 ha (100 acres) produces a fall in costs of 10% and in man hours of 13%. On the large farm, the reduction in costs is 13% and in man hours 20%.

A 40 ha field is a large unit. In size it might be 400 x 1000 metres or a long narrow 250 x 1600 metres. On a farm of 200 ha, the farmer would be limited to five fields. This need not however restrict his crop rotation unduly. It should be possible to fill at least two or three of them with cereals and divide the other if need be for other crops.

The 80 ha (200 acre) field is feasible only on a very large farm. It is an extreme case and has been included to assess the scope for further cost reductions. A field of this size is a very large unit. It could for example be 800 x 1000 or 400 x 2000 metres. Compared to the 40 ha (100 acre) field, there is a further reduction of 7% in cost and 13% in man hours.

Fields of this size are rare in Great Britain but they do occur. The factors limiting enthusiasts for such fields are irremovable barriers such as the public roads provided by the County Council.

In the U.S.A. or in Australia, however, fields of this size would seem quite normal. Indeed some are very much larger. A farmer might cultivate 400 ha single-handed using a tractor of over 200 HP to ensure that the land is cultivated and the crops sown at the proper time. He has certainly no time to waste on headlands or changing fields. This is of course a less intensive form of agriculture and a farmer needs the output of a very large area to provide him with a reasonable living.

The enlargement of fields entails the removal of hedges and fears have been expressed that if English farmers follow the lead of American or Australian farmers, they will ruin the landscape. The English farmer is however attempting to operate twentieth century equipment in an eighteenth century framework and to keep costs to a reasonable level; the lay-out of field boundaries must be modified to take advantage of modern equipment. Many modifications have already been made but a new generation of larger tractors and implements is on the way and this may encourage larger fields and larger farms.

The question therefore arises as to whether a reasonable compromise can be devised which will satisfy the farmer, the naturalist and the environmentalist. The 80 ha (200 acre) field is probably too large and would certainly damage the landscape. The 40 ha (100 acre) field is less objectionable. Some hedges would be lost but many of those in arable areas have already been cut back to an extent that provides little in the way of amenity or shelter for birds or insects. The introduction of a few belts of trees at wider intervals at the end of 40 ha fields would probably provide a better landscape than the few straggly hedges they replace. This is not a matter that can be dealt with adequately on this occasion and the authors hope to deal with it in a subsequent report.

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Appendix 1 Use of Implements on Large, Medium and Small Farms

		Average Width	Annual Use Ha	Annual Use Days	Ha Per Day
Ploughs	Large	3.5f	157	35.1	4.45
	Medium	3.1f	59	19.9	2.95
	Small	2.9f	36	16.4	2.18
Cultivators	Large	3.6m	231	15.1	15.25
	Medium	2.9m	110	14.2	7.75
	Small	2.8m	52	8.9	7.00
Harrows, Spring tined	Large	4.6m	297	31.3	9.46
	Medium	3.8m	110	12.8	8.51
	Small	3.3m	56	7.8	8.42
Harrows, Dutch	Large	3.9m	159	13.2	12.78
	Medium	3.2m	59	5.5	10.75
	Small	3.2m	54	5.6	9.75
Harrows, Disc	Large	2.9m	155	18.2	8.50
	Medium	3.0m	97	10.1	9.63
	Small	2.9m	41	5.2	7.85
Harrows, Power	Large	3.0m	84	11.6	7.20
	Medium	3.4m	53	8.4	5.27
	Small	3.1m	51	10.2	5.99
Rolls	Large	4.6m	221	13.1	16.87
	Medium	4.6m	104	7.6	13.71
	Small	4.4m	86	6.1	14.15
Fertiliser Spreaders	Large	-	491	34.7	14.15
	Medium	-	202	15.3	13.15
	Small	-	72	6.5	11.13
Drill, Combine	Large	3.6m	265	23.1	11.45
	Medium	3.3m	147	15.0	9.79
	Small	3.2m	76	9.8	7.81
Drill, Seed	Large	3.7m	253	19.0	13.31
	Medium	3.4m	113	9.0	12.59
	Small	3.4m	78	7.0	11.13
Drill, Precision	Large	8.2r	84	9.8	8.58
	Medium	5.5r	36	5.9	5.99
	Small	5.0r	23	4.5	5.06
Hoes, Tractor	Large	5.6r	145	22.7	5.39
	Medium	5.4r	84	13.2	5.39
	Small	5.0r	48	10.5	4.53
Rotovators	Large	1.8m	33	12.9	2.55
	Medium	1.7m	11	4.4	2.43
	Small	1.7m	20	8.1	2.43
Sugar Beet Harvesters	Large	2.2r	70	28.6	2.47
	Medium	1.0r	33	32.1	1.01
	Small	1.0r	13	15.2	0.89
Combine Harvesters	Large	4.2m	193	19.1	10.12
	Medium	3.9m	134	15.5	8.70
	Small	3.4m	71	10.6	6.72

Potato Harvesters	Large	1.1r	23	19.4	1.17
	Medium	1.3r	24	21.6	1.13
	Small	1.0r	18	20.7	0.85

Large – around 800 hectares; Medium – around 200 hectares: Small – around 80 hectares
f = furrows
r = rows

Appendix 2 Repairs and Utilisation by Size of Implement

	Number	Annual Use		Hectares	Repairs	
		hectares	hours	per hour	annual	per hour
Reversible Ploughs						
2f	25	57	219	0.26	£105	£0.48
3f	36	87	245	0.36	181	0.74
4f	16	173	294	0.59	288	0.98
5f	6	179	307	0.58	304	0.99
Orthodox Ploughs						
2f	7	45	187	0.24	103	0.55
3f	17	83	248	0.33	154	0.62
4f	17	92	187	0.49	125	0.67
5f	7	87	133	0.65	137	1.03
6f	4	274	249	1.10	359	1.44
All Ploughs	135	99	233	0.43	172	0.74
Chisel Ploughs & Stubble Cultivators						
Under 3m	37	90	99	0.91	43	0.43
3–3.7m	25	127	115	1.10	54	0.47
3.7 and over	14	320	228	1.40	112	0.49
All Chisel Ploughs	76	145	128	1.13	59	0.46
Spring Time Cultivators						
Under 3.7m	24	83	85	0.98	33	0.38
3.7–4.9m	17	135	81	1.66	45	0.55
4.9m and over	25	279	94	2.97	78	0.83
All Spring Time Cultivators	66	171	88	1.94	53	0.60
Power Harrows						
Average width 3m	22	66	87	0.76	100	1.15
Dutch Harrows						
Under 3.7m	27	63	55	1.14	14	0.26
3.7 and over	17	148	97	1.54	19	0.19
All Dutch Harrows	44	96	71	1.35	16	0.22
Rolls						
Rib	66	157	85	1.85	13	0.16
Flat	5	103	42	2.45	4	0.10
All rolls	71	154	82	1.88	13	0.15

Disc Harrows						
Light	17	72	63	1.15	25	0.40
Heavy under 3m	16	116	117	0.99	54	0.46
Heavy over 3m	10	180	124	1.45	47	0.38
All disc harrows	43	114	98	1.16	41	0.42
Combine Drills						
Under 3m	41	117	111	1.05	42	0.37
Over 3m	18	255	170	1.50	78	0.46
All combine drills	59	159	129	1.23	53	0.41
Seed Drills						
Under 3m	15	98	85	1.15	£ 40	0.47
Over 3m	18	246	144	1.71	78	0.54
All seed drills	33	179	117	.53	61	0.52
Precision Drills						
5 rows and less	28	25	40	0.63	21	0.54
over 5 rows	20	84	88	0.95	61	0.69
All precision drills	48	49	60	0.82	38	0.63
Band Sprayers						
5 rows and less	6	38	62	0.61	14	0.23
over 5 rows	6	183	143	1.28	39	0.27
All band sprayers	12	111	103	1.07	26	0.26
Inter-row Hoes						
5 rows and less	39	64	102	0.63	23	0.22
over 5 rows	14	141	153	0.92	52	0.34
All inter-row hoes	53	85	115	0.74	30	0.26
Fertiliser Spreaders						
Bulk spreaders	14	428	195	2.19	41	0.21
Full width distributors	18	143	84	1.70	19	0.22
Spinners	36	166	94	1.77	11	0.12
All fertiliser spreaders	68	213	112	1.90	19	0.17
Crop Sprayers						
Less than 900 litres (mounted)	40	21	106	1.99	22	0.21
Over 900 litres (trailer)	10	435	148	2.94	39	0.26
All crop sprayers	50	256	114	2.24	25	0.22
Combine Harvesters (average width)						
Large (4.5m)	23	214	147	1.45	298	2.03
Medium (3.8m)	40	135	131	1.03	204	1.55
Small (3.3m)	32	83	106	0.78	183	1.74
All combines	95	136	126	1.08	220	1.75
Balers						
over 160 hectares of use	14	185	199	0.93	104	0.52
60–160 hectares of use	25	107	112	0.95	32	0.28
under 60 hectares of use	20	40	50	0.80	29	0.59

All Balers	59	103	112	0.92	48	0.43
FYM Spreaders	23	20	71	0.28	57	0.81
Sugar Beet Harvesters						
1 row trailer	28	21	186	0.12	173	0.93
1 row self-propelled	15	30	116	0.26	152	1.31
2 rows or more	12	101	264	0.38	704	2.67
All Sugar Beet Harvesters	55	41	211	0.20	319	1.51
Potato Planters	20	24	82	0.29	32	0.39
Potato Harvesters	15	24	147	0.17	215	1.46

Repairs - To raise to February 1978 levels, add 50% based estimate on MAFF index.

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