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COSTS OF FARM IRRIGATION

by

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A survey carried out on a group of East

Midland farms in 1961.

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CHAPTER I.

INTRODUCTION

1. Objectives of the survey.

The broad objectives of this survey were twofold. Firstly, to answer questions which might be asked by farmers - particularly those in the East Midlands - who have not yet adopted irrigation, but are considering doing so. Secondly, to enable the farmer who is already irrigating and who co-operated in the survey by supplying information, to compare his irrigation costs with those of other farmers.

Farmers in the first group will require answers to three basic questions:

(i) How much capital is needed for an irrigation plant?
(ii) What are the annual costs of owning and operating the plant?
(iii) Are the benefits of irrigation worth more than the additional costs incurred?

Farmers in the second group will have already formed some opinions on these questions - based on their own experience - but they may nevertheless be interested in comparing their own experience with that of others. So it is hoped that experienced users may also be interested in the answer to a further question :-

(iv) To what extent do irrigation costs vary from farm to farm and why are some farmers able to irrigate more cheaply than others?

It is the purpose of this report to give interim answers to these questions. Because they are based on the results of only a single season's survey, many of the answers given are necessarily tentative and it is intended that the survey should be repeated for at least one more season in order that more definite answers can be given to the questions asked about the economics of irrigation.

2. Description of the Surveyed Plants.

A total of 31 farms co-operated in the enquiry. Approximately one-third of these were already known to the Department from the Farm Management Survey or other previous enquiries; the names of the remaining two-thirds were obtained from N. A. A. S. officers. No attempt could be made to obtain a random sample of farms where irrigation was being practised because no practicable method could be devised of obtaining a complete list of all farmers in the area with irrigation equipment.

Primary interest focussed on the irrigation of potatoes and sugar-beet and, for this reason, the enquiry was restricted to Nottinghamshire and Lincolnshire, where these two crops are widely grown.

Sixteen of the farms from which information was obtained are situated in Nottinghamshire and the remaining 15 in the Lindsey and Kesteven Divisions of Lincolnshire. Not unexpectedly, farms on light-textured soils predominated. Of the Nottinghamshire farms, 9 are on bunter sandstone and 3 on alluvial gravel near to the River Trent. Amongst the Lincolnshire farms, 5 are on limestone, and most of the remainder on light fen or other light-textured soils.

3. Survey Method.

Descriptive information about each irrigation plant, including quantities of all the main items of equipment and their capital cost (net of government grants, where these had been obtained) was obtained by interview with the owner.

The basic information required to estimate operating expenses - e.g. pumping hours, labour hours, fuel consumption and repair costs - was recorded by the farmer in a diary especially designed for the purpose.

Labour and certain other items were charged at a standard rate per hour, and these rates, together with details of the method used in calculating depreciation and interest charges on invested capital will be found in Appendix 2.

CHAPTER II.

COSTS

1. Capital Requirements.

On a substantial majority of the surveyed farms, the irrigation equipment was less than three years old at the time of the survey, and, with only very minor exceptions, the information obtained about capital costs related to equipment purchased, or building work done, since 1955. Enquiries made of one of the two principal manufacturers of irrigation equipment in this country led to the conclusion that equipment prices had not changed significantly during this period and that adjustment of actual capital costs, to bring them into line with current replacement costs, was unnecessary.

Amongst the surveyed farms, the total net capital cost of irrigation equipment averaged £ 1,917 per farm. On individual farms, however, investment was as low as £475 and as high as £5,400. Of course, the main reason for this wide range in capital costs per farm was that the irrigation plants were of different sizes. Two aspects of size are important:

(i) The maximum area that can be irrigated at one "setting" of all the available sprinklers or rainguns (assuming the normal working pressure is maintained at each sprinkler or raingun nozzle).

(ii) The maximum distance between the water source (where the pump is normally situated) and the lateral lines carrying the sprinklers or rainguns. This distance may be termed the "maximum reach".

The maximum area that can be irrigated at one setting is, of course, a function of the number of sprinklers or rainguns possessed by the farmer. According to their type, sprinklers and rainguns vary somewhat in their performance. However, for the purposes of this study it has been assumed, with minor exceptions, that 20 sprinklers or two rainguns are the equivalent of a "one acre setting".

Expressed in terms of a one acre setting, total net capital costs of irrigation equipment averaged £857, though on individual farms facilities comparable in this restricted sense were obtained for as little as £450 or cost as much as £1,800. In order to restrict the range of capital costs still further, it is necessary to consider the influence of the second measure of size, that of the maximum reach of the plant.

Maximum reach is, of course, dependent on the maximum length of portable main owned by the farmer. On average there were approximately 1,000 feet of portable main for each acre setting of sprinklers or rainguns. On individual farms, however, the length of portable main ranged from less than 300 feet to 3,000 feet per acre setting, and approximately half the farmers had less than 800 feet. The average total net capital costs of irrigation equipment in the latter group and on the remaining farms with more than 800 feet of main are shown in Table 1.

TOTAL NET CAPITAL COSTS PER ACRE SETTING ACCORDING TO THE MAXIMUM REACH OF THE PLANT

TABLE I.

Maximum reach of plant (feet per acre setting)		No. of farms	Net capital costs (£'s per acre setting)	
Group	Average		Average	Range
Below 800	480	16	587	418 to 1,164
800 or over	1,490	15	1,145	662 to 1,871

This table shows that the length of mains piping acquired, in relation to the number of sprinklers or rainguns, is also an important factor affecting the capital costs of irrigation equipment. Another factor tending to add to the expense of plants with a longer reach is that since friction losses are proportional to the length of pipes used, comparatively long lengths of main may entail the acquisition of bigger and more expensive pumps.

Generally speaking, however, the cost of the pump accounts for only a small proportion of the total capital outlay - less than a quarter with three out of four of the irrigation plants surveyed. On the majority of the surveyed farms pumps driven by the tractor p.t.o. and costing up to £200, or just over, were used. On the remaining farms, where pumps with their own motors (diesel or electric) were used, costs (including the motor) were generally higher, ranging from as little as £160 for a second-hand diesel driven pump, up to nearly £1,000 for a much larger pump, also diesel driven but purchased new.

The outlay on pipes accounted for three-quarters or more of the total capital expenditure on a majority of the surveyed farms. Excluding three farms with underground mains, investment in pipes, couplings, take-off valves, and sprinklers or rainguns ranged from about £350 to over £1,200 per acre setting. Including the farms with underground mains the expenditure ranged up to £1,500 per acre setting.

Underground mains, and other non-portable pieces of irrigation equipment such as pumps and motors permanently installed in a pumphouse, and the construction of dams and river intake works, are generally eligible for a 40 per cent government grant. Four of the schemes surveyed were grant-aided. Nevertheless, in spite of the grants, these schemes were amongst the most costly in terms of the owner's capital outlay. This suggests that whatever disadvantages they may have in other respects, fully portable plants have the advantage of a lower capital requirement.

The construction of reservoirs and the sinking of wells or boreholes are also eligible for grant, but were not encountered on the farms visited during the course of this survey.

No significant difference in capital cost was found to exist between plants equipped with sprinklers and those with rainguns. This conclusion was confirmed by comparative quotations for hypothetical sprinkler and raingun schemes, of the same operating capacity, from a leading manufacturer of irrigation equipment. Both quotations were in the region of £1,000, the raingun scheme actually being the cheaper, but only by a margin of about £60. Since the difference in capital cost is apparently negligible, the choice between sprinklers and rainguns needs to be based on performance or other grounds.

A general guide to the likely capital costs of new equipment for a completely portable irrigation plant (i.e. one without underground mains or other fixtures eligible for grant-aid) is given below. The figures are based partly on the results of the survey and partly on the current price lists of leading manufacturers of irrigation equipment.

Item		Approximate Capital Cost.
Pump	(a) tractor p.t.o. driven	£150 to £230 according to specification.
	(b) with own engine	£200 to £1,000 according to size, type, etc.
4" mains piping (with couplings, take-off valves, etc).		£1 per yard run according to the "maximum reach" required
3" lateral piping with sprinklers or rainguns.		£220 per acre setting

2. Annual Costs of Ownership and Operation.

The annual costs of an irrigation plant fall into two main categories - fixed costs and variable costs.

Annual fixed costs consist of capital depreciation and interest charges and remain the same in total however much or little the irrigation equipment is actually used during the year. On the other hand, annual fixed costs per acre-inch of water applied are inversely related to the total acreage covered during the season and the rate of application per acre.

Variable costs consist mainly of the charges for labour, fuel or power, oil and repairs to pumps, engines (including tractors when these are used to drive irrigation pumps) and other items of irrigation equipment. Water was generally freely available to the users of the surveyed plants, but in the few cases where it was not, this was also a variable cost.

The average cost structure, based on the records obtained from the surveyed farms, is shown in Table 2. All the costs shown in this table are expressed in terms of the application of one acre-inch of water.

On average, fixed costs accounted for about three-fifths of the total annual costs per acre-inch, and variable costs for the remaining two-fifths of the total. Depreciation and interest charges on portable pipes and ancillary equipment accounted for a major proportion of fixed costs and labour for about half the variable costs per acre-inch.

Almost all cost items were subject to considerable farm-to-farm variation. The cost ranges shown in Table 2 provide evidence of this. Variable costs differed between farms by as much as £2. 10s. per acre-inch, but differences in fixed costs were even greater, reaching as high as £7 per acre-inch.

AVERAGE COST STRUCTURE BASED ON RECORDS FROM 31 FARMS.

TABLE 2.

Item	Cost per acre - inch		
	Range	Average	Per Cent.
	s. d. £. s. d.	£. s. d.	
FIXED COSTS			
Depreciation and interest on capital.			
Pump (including ancillaries)	1. 1 to 1. 13. 11	8. 1	14.6
Portable mains and laterals	6. 4 to 5. 17. 4	1. 2. 8	40.9
Underground mains	nil to 18. 9	1. 9	3.1
Other	nil to 5. 5	6	0.9
Total Fixed Costs	10. 8 to 7. 11. 3	1. 13. 0	59.5
VARIABLE COSTS			
Man Labour			
Moving laterals	1. 3 to 1. 15. 0	6. 10	12.4
Shifting from field to field	5 to 8. 10	3. 6	6.3
Other	nil to 2. 11	10	1.5
(Total man labour)	(2. 5 to 2. 1. 0)	(11. 2)	(20.2)
Transport	1 to 2. 1	8	1.2
Power and Repairs			
Diesel, t.v.o. or electricity	1. 10 to 10. 9	4. 7	8.2
Lubricating oil	nil to 3. 1	7	1.0
Repairs	nil to 1. 5. 0	2. 8	4.8
Tractor depreciation	nil to 5. 1	2. 0	3.6
Other Costs			
Water	nil to 17. 8	9	1.5
Total Variable Costs	6. 7 to 3. 0. 0	1. 2. 5	40.5
TOTAL COSTS	18. 10 to 8. 5. 7	2. 15. 5	100.0
Total Irrigation applied (acre-inches)	20 to 746	187	-

ANNUAL FIXED COSTS PER ACRE-INCH

(a) Degree of Utilisation

Annual fixed costs per acre-inch are primarily dependent upon the degree to which the maximum capacity of the irrigation plant is actually utilised in a particular year.

The maximum capacity of each of the surveyed irrigation plants was estimated on a standard basis. The irrigation season was assumed to last for 60 days and the daily capacity of a one acre set was assumed to be one inch of water on four acres, or, four acre-inches. Hence a one acre set was assumed to have a maximum capacity, for the season, of $60 \times 4 = 240$ acre-inches. The maximum capacities of plants with sprinklers or rainguns covering more or less than one acre were assumed to be in direct proportion to the foregoing, e.g. the maximum capacity of a $2\frac{1}{2}$ acre set was assumed to be $240 \times 2\frac{1}{2} = 600$ acre-inches. This method of estimating maximum capacity is admittedly rough and ready, but has the advantage of enabling different sized plants to be compared directly on a basis of relative usage.

On average, the actual utilisation of the 31 irrigation plants surveyed amounted to only 38 per cent of their theoretical maximum capacity in 1961. The full range of utilisation went from 7 to 99 per cent of the theoretical maximum capacity.

Comparison of the figures in the fifth and sixth columns of Appendix Table 1 reveals that relatively high utilisation was associated with low fixed costs per acre-inch, and vice versa.

(b) Size of Plant

Although less important than the degree to which the full capacity of the plant was actually utilised, differences in the size of irrigation plant also accounted for some of the farm-to-farm variation in annual fixed costs per acre-inch.

Clearly, if two farmers applied exactly the same quantity of water to their crops during a particular season, but had different sized plants, the one with the smaller and less expensive plant would be expected to have lower annual fixed costs per acre-inch.

It is difficult to illustrate this point with figures drawn from the results of the survey, due to the wide differences in total water applied (see column 4 of Appendix Table 1) and to the dominating influence of the degree of plant utilisation on fixed costs per acre-inch.

However, if the twelve plants used to apply between 100 and 200 acre-inches of water are arranged in ascending order of size (in terms of the maximum irrigable area at one setting) with their fixed costs per acre-inch, the result is as shown in Table 3.

ANNUAL FIXED COSTS PER ACRE–INCH INCURRED BY THE OWNERS OF DIFFERENT SIZED IRRIGATION PLANTS WHERE THE TOTAL QUANTITY OF WATER APPLIED WAS BETWEEN 100 AND 200 ACRE–INCHES

TABLE 3

Farm Code No.	Size of plant (acres)	Total water applied (acre-inches)	Annual fixed costs per acre-inch
			£. s. d.
N/13	0.75	179	15. 9
N/4	1.00	184	12. 7
K/10	1.00	127	13. 7
N/11	1.25	147	13. 0
K/6	1.50	123	19. 6
N/10	2.00	165	1. 1. 6
N/8	2.40	128	1.15. 4
K/8	2.50	111	1. 2. 5
K/3	2.75	103	1.16. 7
K/9	3.00	187	1. 0. 0
N/6	3.00	162	1. 6. 8
L/1	3.00	113	1.11.11

The fixed costs per acre-inch incurred by the owners of the six plants of two acres or less, shown in the top half of Table 3, averaged 16s. Od., whilst those of the owners of the six plants of over 2 acres, shown in the bottom half of the table, averaged £1. 8s. 10d. Thus the smaller plants had a fixed cost advantage of about 13s. Od. per acre-inch under the conditions specified. Where the total quantity of water applied was less than 100 acre-inches, it could be expected that the smaller plant would have an even greater margin of advantage; but above 200 acre-inches the advantage would become progressively less up to the limit set by the maximum capacity of the smaller sized plant.

The second aspect of size of plant - that of "maximum reach" - also affects annual fixed costs per acre-inch. However, it is not possible to demonstrate this directly from the results of the survey, due to the difficulty of separating this effect from those of utilisation and size in terms of the maximum area that can be covered at one setting with the available sprinklers or rainguns.

The effects of this factor can be better demonstrated synthetically, using budget costs in place of actual costs. This is done in a subsequent section of the report.

The Pattern of Usage

The degree of plant utilisation was the dominant factor affecting the level of fixed costs per acre-inch. It was also the dominant factor affecting the level of total irrigation costs per acre-inch, and it is therefore worthwhile examining the features which distinguished farms where the irrigation plant was relatively fully utilised from those where it was relatively little utilised.

Dividing the farms into two approximately equal-sized groups, on the basis of the degree of plant utilisation, results in the emergence of a pattern of usage which is summarised in Table 4.

It will be noted that in both groups the average size of irrigation plant was the same - two acres.

The total acreage of irrigated crops per farm was more than twice as great in the higher utilisation group (one-third capacity and above) than it was in the lower group (below one-third capacity). In addition, the rate of water application per acre was over one-half as great again in the former group than in the latter.

The total quantity of water applied (in acre-inches) is the product of "acres irrigated" times "inches per acre", and was two-and-a-half times greater in the higher than in the lower utilisation group.

On average, the farmers in the higher utilisation group irrigated larger acreages of all the crops listed in Table 4. The most striking difference, however, was in the irrigation of sugar beet. This crop accounted for only about seven per cent of the total acreage of irrigated crops in the lower utilisation group, but in the higher group it accounted for nearly 40 per cent of the total. Another notable difference was that a number of farmers in the higher utilisation group irrigated vining peas, whereas none did so in the lower group.

THE PATTERN OF IRRIGATION APPLIED TO DIFFERENT CROPS ACCORDING TO THE DEGREE TO WHICH THE CAPACITY OF THE IRRIGATION PLANT WAS UTILISED

TABLE 4.

Per farm.

Utilisation of plant capacity	No. of plants	Average size of plant (acres)		Potatoes		Sugar beet.	Peas	Grass	Other	Total acres covered
				Earlies	Second earlies and maincrop					
Below 1/3 rd capacity	16	2.0	Acres irrigated	16.7	8.6	3.8	-	15.4	12.5	56.9
			Number of inches/acre	1.90	1.95	1.15	-	1.17	1.13	1.49
			Total acre-inches	31.7	16.7	4.4	-	17.9	14.0	84.8
1/3 rd capacity and above	15	2.0	Acres irrigated	18.1	15.7	48.2	15.5	19.1	7.6	124.2
			Number of inches/acre	3.58	2.63	2.51	0.94	2.24	1.48	2.38
			Total acre-inches	64.8	41.4	120.9	14.5	42.8	11.3	295.7

The difference between the two groups in the average rate of water application per acre was also most marked in the case of sugar beet. Growers in the higher utilisation group applied an average of $2\frac{1}{2}$ inches per acre compared with less than $1\frac{1}{4}$ inches per acre in the lower group. Farmers in the higher group also applied considerably greater amounts of water to early potatoes and grass.

The general picture which emerges, then, is that compared with those in the lower utilisation group, farmers in the higher utilisation group not only irrigated a wider range of crops and a larger acreage of each, but also applied water more liberally to each acre.

It does not necessarily follow, of course, that all the additional irrigation carried out on farms in the higher utilisation group was profitable. This would be true only if the additional financial returns exceeded the additional costs of labour, power and repairs. All that can be said with certainty is that to the extent that a lowering of fixed costs per acre-inch of water applied is a worthwhile goal in itself, the owners of the plants in the higher utilisation group were the more successful.

The relationship between irrigation costs and the resulting economic benefits is referred to again later in the report.

Variable Costs per acre-inch.

Although total variable costs per acre-inch ranged somewhat less widely than total fixed costs per acre-inch, there were nevertheless considerable differences in the variable costs of irrigation between one farm and another (See Table 2 and Appendix Table 1.). The reasons for these differences are not easy to identify. In fact, it is easier to point to factors which do not appear to have any influence on variable costs than to factors that do have such an influence. For example, neither the size of irrigation plant, nor the total quantity of water applied during the season, had any apparent effect on variable costs per acre-inch. Moreover, the variable costs of operating sprinkler-type plants did not differ significantly from those of raingun-type plants.

The one factor which did appear to have a decisive influence on variable costs was labour usage. On average, the total irrigation labour input was approximately $2\frac{1}{4}$ man-hours per acre-inch of water applied. However, the average was pulled upwards by a very small number of farms where labour usage was extremely high and, in fact, on approximately half the surveyed farms labour use amounted to less than $1\frac{3}{4}$ man-hours per acre-inch. The average cost of labour and the average total variable costs per acre-inch on these farms, and on those where the irrigation labour input exceeded $1\frac{3}{4}$ man-hours per acre-inch, are shown in Table 5.

COST OF LABOUR AND TOTAL VARIABLE COSTS PER ACRE-INCH IN RELATION TO THE AMOUNT OF LABOUR USED.

TABLE 5.

Amount of Labour used (Man-hours per acre-inch)		No. of Farms	Cost of Labour per acre-inch	Total Variable Costs per acre-inch
Group	Average			
Below 1.75	1.2	17	6s. 2d.	16s. 1d.
1.75 and above	3.4	14	17s. 3d.	£1. 13s. 0d.

The extra expenditure on labour of approximately 11s. 0d. per acre-inch accounted for a high proportion of the extra 16s. 11d. per acre-inch in total variable costs incurred by the high labour group.

Low labour usage is clearly one of the keys to low overall operating costs for irrigation. It is, therefore, worthwhile analysing the use of irrigation labour on the surveyed farms in rather more detail, in order to bring out some of the reasons for the wide variation in labour costs.

3. Factors affecting labour requirements.

The labour requirements for farm irrigation are affected by such factors as the time of application in relation to the growth habits of different crops, soil type and topography, and the different shapes of irrigated fields. All these factors are largely outside the farmer's control and their relative importance varies greatly from one farm to another. But there are also other factors affecting labour requirements, such as the distance between irrigated fields, the type of irrigation equipment used and differences in method, such as the frequency with which sprinklers or rainguns are shifted and the distance they are shifted at each move, which are largely within the control of the farmer.

Co-operating farmers were asked to keep separate records of the labour used for three types of operation:

(i) Labour used in starting and stopping the pump and in routine attention such as re-fuelling and lubrication.

(ii) Labour employed in moving sprinklers or rainguns from setting to setting within a single field.

(iii) Labour used for shifting the whole of the portable equipment (including the pump and mains piping) from one field to another.

Analysis of the records showed that, on average, nearly two-thirds of the total man hours for irrigation operations were accounted for by the movement of laterals within the field. Major shifts of the equipment from one field to another absorbed, on average, rather less than a third of the total labour, and the expenditure of labour on routine attention to the pump, and similar operations was of quite minor importance.

The actual figures are presented in Table 6.

DISTRIBUTION OF IRRIGATION LABOUR BETWEEN DIFFERENT CLASSES OF OPERATION

TABLE 6.

Class of Operation	Man-hours per 100 acre-inches		
	Range	Average	Per cent
Attention to pump, etc.	3 to 58	17	7
Moving laterals	26 to 700	137	62
Shifting from field to field	8 to 176	70	31
All Operations	67 to 820	224	100

Operation of the plant.

In spite of the uncontrollable factors mentioned above, it might be thought that the majority of farms in a district would have broadly comparable labour requirements for routine attention to the pump and engine and for the movement of sprinkler lines or rainguns. The almost staggeringly wide range in the actual usage of labour for these operations - as revealed by Table 6 - may therefore come as a surprise to many readers.

On many of the surveyed farms the periodic movement of laterals was regarded as being virtually a full-time job for one or more men who remained with the plant whenever it was working. But on other farms such constant attention was deemed to be unnecessary, and the sprinklers or rainguns were left unattended for long periods between shifts.

It may therefore be suspected that on at least some of the farms where irrigation was regarded as a full-time job there was a not inconsiderable amount of concealed underemployment. It may be argued, however, that the alternative method - that of sending men to the field only when the equipment needs shifting - requires a larger gang, has a more disrupting effect on work elsewhere on the farm, and calls for greater managerial control and supervision. In effect, these are arguments in favour of treating irrigation as if it were a full-time job (as indeed it may be, on occasion) and they may well carry considerable weight with many irrigation users. Nevertheless, those who adopt this method of organising their irrigation labour should be aware of the possible economic disadvantages. The most important of these is that unnecessarily high labour costs may be incurred. This will be most serious where the diversion of too much labour to irrigation results in too little being left for urgent tasks elsewhere on the farm. For example, on a farm where the irrigation of early potatoes coincided with sugar-beet singling, or hay-making, a man might be better employed in the beet or the hayfield, in between shifting the irrigation lines, than staying in the potato field to remedy minor defects such as pipe joint leakages and blocked jets. But if there is no other useful work to be done, a man may be better employed watching for trouble in the irrigation field than anywhere else.

Experienced users may say that the advantages of making one or more full-time men really <u>responsible</u> for the efficient operation of the irrigation plant outweigh any marginal saving in labour that might result from a different method of labour organisation. For the large and unusually busy farmer, who has insufficient time to supervise irrigation himself, this argument may well prove decisive. But for others - perhaps a majority - the losses which may result from being over-liberal in the provision of labour for irrigation, especially with all labour becoming increasingly scarce and expensive, are a strong counter-argument.

An additional reason for high operating labour requirements was that, on a small minority of the farms, the laterals were moved less than the recommended distance (normally 60 feet with sprinklers) between successive settings.

The reason given for doing this was that, in the opinion of the farmers concerned, the recommended spacing of the laterals did not give full coverage of the ground or an even distribution of water. Whilst there may have been some substance in this contention, it is perhaps questionable whether these farmers were getting sufficient extra benefits, from following this unorthodox practice, to cover the extra costs of labour needed for more frequent movement of the pipes.

Shifting from field to field.

By contrast with the variation in labour requirements for actually operating the irrigation plant, the large farm-to-farm variations in labour used in shifting equipment from field to field were scarcely surprising. The labour requirements for this class of operations are primarily determined by the almost accidental factors of farm topography and farm layout, by the choice of crops and the rotation followed, and by the number of fields which are accessible with the available equipment and existing sources of water.

As Table 6 shows, on average, nearly one-third of the total man hours devoted to irrigation were accounted for by these shifting operations. On individual farms, however, as little as one-tenth or as much as one half the total irrigation labour was absorbed in this way.

Hence, although the survey average of 70 man hours per 100 acre-inches of water applied is as good an estimate of the labour required for shifting equipment from field to field as can be obtained for general use, this figure is of very limited usefulness for predicting the amount of labour likely to be required for this purpose on any particular farm.

4. Analysis of Main Factors Influencing Costs.

The total irrigation costs per acre-inch actually incurred by the owners of the surveyed plants are shown in Appendix 1. Alternatively, total irrigation costs can be estimated from budgets, making appropriate assumptions regarding type and size of plant, the total amount of water applied during the season, and the amount of labour required.

This "synthetic" method of estimating costs has the advantage that the relative importance of the various factors affecting the level of total costs per acre-inch can be seen more clearly than in the analysis of actual costs in which the really important relationships are bound to be obscured, to some extent, by unimportant details.

Furthermore, the synthetic costs can be compared with the actual costs and, if there is close agreement between them, this not only increases confidence in the reliability of the results obtained by both methods, but also enables inferences to be made from the budgets about the probable reasons for the considerable variation in actual costs which, as has been clearly shown, occurred between plants taking part in the survey.

Budgetary analysis has therefore been used to check and add to the conclusions already reached from an analysis of actual costs.

Construction of Budgets.

(a) Capital Outlays and Annual Fixed Costs.

Consideration has been limited to sprinkler schemes and budgets have been drawn up for plants capable of irrigating 1, 2 and 3 acres at a setting. Additionally, "maximum reach" has been considered at two different levels - "(a) plants" having 1,000 feet, and " (b) plants" having 3,000 feet of 4" portable mains piping.

Thus the budgets cover a total of six different levels of capital investment.

Prices of equipment were taken from the current catalogues of the leading manufacturers. Assumptions regarding the number of sprinklers needed to cover an acre, the maximum capacity of a given sized plant (in acre-inches per year) and depreciation and interest rates on capital equipment are the same as those employed elsewhere in the report (see Appendix).

Estimated capital costs and annual fixed costs pertaining to each of the six plants are shown in Table 7.

ESTIMATED CAPITAL COSTS AND ANNUAL FIXED COSTS FOR SIX HYPOTHETICAL IRRIGATION PLANTS

TABLE 7.

Item	Size of plant					
	1 acre		2 acres		3 acres	
	(a)	(b)	(a)	(b)	(a)	(b)
	£	£	£	£	£	£
	CAPITAL COSTS					
Pump	200	200	200	200	200	200
4" Mainline	359	1,017	359	1,017	359	1,017
3" Sprinkler line	218	218	436	436	654	654
Miscellaneous equipment	20	20	40	40	60	60
TOTAL	797	1,455	1,035	1,693	1,273	1,931
	ANNUAL FIXED COSTS					
Pump	29	29	29	29	29	29
Mains, laterals and other equipment	68	142	95	169	122	196
TOTAL	97	171	124	198	151	225
Maximum capacity (acre-inches)	240	240	480	480	720	720

(b) Costs per acre-inch.

Fixed costs per acre-inch corresponding with differing total amounts of water applied by each of the plants are shown in Table 8. If the extent of the cost ranges contained in the columns of this table are compared with those contained in the rows, it can be seen that differences in plant size and the amount of water applied can both affect fixed costs per acre-inch to a marked degree. But potentially, at least, variation in cost caused by differences in the amount of water applied are (relatively) the larger.

FIXED COSTS PER ACRE-INCH FOR SIX HYPOTHETICAL IRRIGATION PLANTS

TABLE 8.

Plant	TOTAL WATER APPLIED (acre-inches)					
	60	120	240	360	480	720
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
1 (a)	1. 12. 4.	16. 2.	8. 1.	-	-	-
1 (b)	2. 17. 0.	1. 8. 6.	14. 3.	-	-	-
2 (a)	2. 1. 4.	1. 0. 8.	10. 4.	6. 11.	5. 2.	-
2 (b)	3. 6. 0.	1. 13. 0.	16. 6.	11. 0.	8. 3.	-
3 (a)	2. 10. 4.	1. 5. 2.	12. 7.	8. 5.	6. 4.	4. 2.
3 (b)	3. 15. 0.	1. 17. 6.	18. 9.	12. 6.	9. 5.	6. 3.

Variable costs per acre-inch were assumed to be affected only by differences in labour efficiency. Two alternative assumptions were made regarding irrigation labour requirements - a "low" level of $1\frac{1}{4}$ man-hours per acre-inch and a "high" level of $3\frac{1}{4}$ man-hours per acre-inch. The variable costs of all remaining inputs (transport of equipment, power for pumping, repairs and tractor depreciation) were put at 10s. 6d. per acre-inch. Hence, with labour charged at the standard rate, total variable costs were assumed to be either 16s. 9d. per acre-inch ("low" labour requirements) or, £1. 6s. 9d. per acre-inch ("high" labour requirements).

Total costs per acre-inch, corresponding with differing total amounts of water applied by each of the six plants, and with the two different levels of irrigation labour requirements, are shown in Table 9. The figures in this table support the following conclusions regarding the relative importance of factors affecting total costs per acre-inch:

(i) The most certain way of ensuring low costs is to use the irrigation plant as nearly as possible to its maximum capacity.

(ii) Where the total application of water is low - say, 60 acre-inches per annum or less - the choice of a suitable sized plant is more critical than the efficient organisation of labour.

(iii) Where the total application of water is high - say, 360 acre-inches per annum or more - the choice of a suitable sized plant is less critical than efficient organisation of labour.

(iv) In the middle of the range of annual application rates - say, between 60 and 360 acre-inches per annum - where the majority of plants in the survey were found to be operating, the choice of a suitable sized plant and efficient organisation of labour are of approximately equal importance.

TOTAL COSTS PER ACRE-INCH FOR SIX HYPOTHETICAL IRRIGATION PLANTS.

TABLE 9.

Plant	Labour Requirements	Total Water Applied (acre-inches)					
		60	120	240	360	480	720
		£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
1 (a)	Low	2. 9. 1.	1. 12. 11.	1. 4. 10.	-	-	-
	High	2. 19. 1.	2. 2. 11.	1. 14. 10.	-	-	-
1 (b)	Low	3. 13. 9.	2. 5. 3.	1. 11. 0.	-	-	-
	High	4. 3. 9.	2. 15. 3.	2. 1. 0.	-	-	-
2 (a)	Low	2. 18. 1.	1. 17. 5.	1. 7. 1.	1. 3. 8.	1. 1. 11.	-
	High	3. 8. 1.	2. 7. 5.	1. 17. 1.	1. 13. 8.	1. 11. 11.	-
2 (b)	Low	4. 2. 9.	2. 9. 9.	1. 13. 3.	1. 7. 9.	1. 5. 0.	-
	High	4. 12. 9.	2. 19. 9.	2. 3. 3.	1. 17. 9.	1. 15. 0.	-
3 (a)	Low	3. 7. 1.	2. 1. 11.	1. 9. 4.	1. 5. 2.	1. 3. 1.	1. 0. 11.
	High	3. 17. 1.	2. 11. 11.	1. 19. 4.	1. 15. 2.	1. 13. 1.	1. 10. 11.
3 (b)	Low	4. 11. 9.	2. 14. 3.	1. 15. 6.	1. 9. 3.	1. 6. 2.	1. 3. 0.
	High	5. 1. 9.	3. 4. 3.	2. 5. 6.	1. 19. 3.	1. 16. 2.	1. 13. 0.

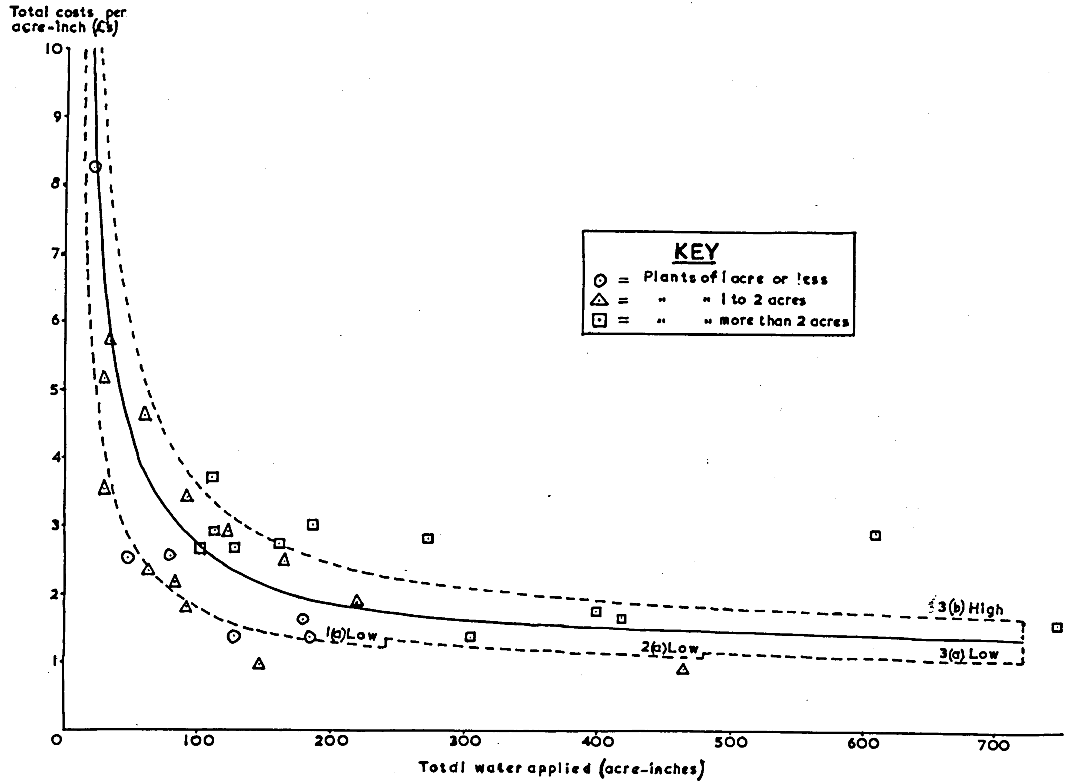

FIGURE 1. TOTAL COSTS PER ACRE-INCH IN RELATION TO TOTAL QUANTITY OF WATER APPLIED AND OTHER FACTORS. ACTUAL COSTS OF SURVEYED PLANTS COMPARED WITH SYNTHETIC COST CURVES.

In Figure 1. the synthetic irrigation costs derived from the budgets described above are compared with the actual costs worked out for each of the surveyed plants. Synthetic costs are shown by the curves (each curve representing a different set of budget assumptions) and actual costs by one or other of the three symbols representing plants in different size groups.

The continuous curve shows the relationship obtained from the budgets between total costs per acre-inch and the total quantity of water applied with the effects of size of plant and labour efficiency eliminated. In effect, the cost figures shown in each column of Table 9 have been added together and averaged. Each average has then been plotted against the total number of acre-inches of water applied corresponding to it, and the points have been connected by drawing a smooth curve through them.

The dotted curves show the extent to which this relationship may be modified by the effects of size of plant and labour efficiency, subject to the limitations of the assumptions made in drawing up the budgets. The uppermost of these curves shows the relationship between the total application of water and costs per acre-inch under the least favourable conditions allowed for in the budgets, i.e. the ownership of sufficient sprinklers to cover three acres at a setting and 1,000 yards of portable main, coupled with labour requirements of $3\frac{1}{4}$ man-hours per acre-inch.

The lowermost "curve" really comprises one complete synthetic cost curve and parts of two others. Up to a total application of 240 acre-inches of water it corresponds with the costs shown in the topmost row of Table 9. Between 240 and 480 acre-inches it corresponds with the costs shown in the fifth line down of the third, fourth and fifth columns of the table. The "step" at 240 acre-inches denotes the difference in operating cost between a 1(a) type plant, worked to its maximum capacity and a 2(a) type plant worked at only 50 per cent of maximum capacity. Similarly, the step at 480 acre-inches denotes the difference in cost between a 2 (a) type plant working at maximum capacity and a 3(a) type plant working at 67 per cent of maximum capacity. Thus, the lowermost curve shows the relationship between the total application of water and costs per acre-inch under the most favourable conditions allowed for in the budgets.

The cost curves shown in Figure 1. do not cover all sets of assumptions used in drawing up the budgets. For example, two additional curves could have been drawn showing the costs of operating a 1(b) type plant, the difference between them being due to the assumed difference in labour requirements. Had they been shown, all the remaining curves would have had one feature in common: every point on any one of them would have lain somewhere between the two existing dotted curves.

With approximately two-thirds of the irrigation plants surveyed, the actual costs per acre-inch of water applied lay within the "budget band" shown in Figure 1. This fact supports the conclusion that the assumptions made in drawing up the budgets were realistic and adequately covered the range of working conditions found on a majority of the farms.

There is a marked concentration of plants in the broadest part of the band - between total applications of, say, 50 and 200 acre-inches. So, in 1961 at least, many of the surveyed irrigation plants were operated within the range of total output where reasonably low irrigation costs are dependent upon the choice of a suitable sized plant - both in terms of the maximum area that can be covered at a setting, and also of the maximum range of the equipment.

In this connection, it may be necessary to consider whether 1961 was a below average year from the point of view of irrigation need. If so, then it was only to be expected that a large measure of excess capacity would be encountered. This question will be considered in the next chapter.

As regards the irrigation costs of the minority of plants lying above or below the budget band, there were doubtless peculiarities on each of these farms contributing to their abnormality in this respect, and, in all probability, their results were due to a combination of good or bad luck, and good or bad management.

5. General Conclusions about the Costs of Irrigation.

(i) This survey has shown very marked differences in the costs of irrigation amongst a comparatively small group of farms.

(ii) Differences in the annual fixed costs of irrigation account for a major proportion of the total cost variation and the amount of usage a plant gets during the season is paramount in determining the total costs per acre-inch.

(iii) If average annual usage is small (say, a total of 100 acre-inches or less), a plant capable of irrigating two or three acres at a setting, and with upwards of half a mile of portable mains, can be an expensive luxury costing several pounds per acre-inch more in use than a smaller plant with less excess capacity.

(iv) Nevertheless, the ownership of extra equipment over and above normal requirements may sometimes prove beneficial in an emergency. For example, extra sprinklers or a spare raingun may occasionally be useful to save a crop which is in danger of complete destruction, such as freshly brairded sugar beet on light land just before a severe gale. Moreover, extra mains piping may enable such a crop to be reached even though it is not in the normal irrigation cycle.

In circumstances such as these, the costs of owning extra equipment constitute an additional "insurance premium". As with other forms of insurance, it must be left to each individual farmer to decide just how much cover is economically justified in his particular circumstances.

By comparison with the differences in fixed costs, farm-to-farm differences in the variable costs of irrigation are comparatively small. Nevertheless, good organisation of irrigation labour can save up to 10s. 0d. per acre-inch of water applied. Efficient labour organisation is especially advantageous to farmers irrigating on a large scale.

CHAPTER III

DOES IT PAY?

1. Economic Benefits and their Assessment.

In theory, the profitability of irrigation depends on the "cost/ benefit ratio". The greater the ratio of economic benefit to the cost, the greater the profitability of the practice.

The economic benefits of irrigation can take a number of forms. Although higher crop yields may be the most tangible form of benefit, other advantages, which are less easy to identify and measure precisely may nevertheless be of considerable importance. For example, where irrigation brings a crop to maturity earlier, or enhances its quality, this may mean that it can be sold for a higher price.

The economic benefits of irrigating grassland are especially difficult to measure. The problem is not merely that of finding how much extra grass has been grown but also how much of the extra production has actually been utilised by livestock. Nevertheless, many livestock farmers are now coming to regard the costs of owning irrigation equipment as insurance against the loss of grazing and grassland products during a drought.

It is much more difficult to get reliable information on the benefits of irrigation than on the costs and, indeed, it is greatly to be doubted whether a survey of this kind can be expected to add much to our knowledge in this respect. One difficulty is that environmental and other factors, which affect crop yields quite apart from irrigation, vary so much between farms. But the most formidable difficulty, perhaps, is that since farmers nearly always irrigate the <u>whole</u> of any crop they consider likely to benefit from the treatment there is usually no unirrigated "control" with which the irrigated yield can be compared.

Hence the best sources of information about the yield increases likely to be obtained from irrigation are the experimental stations which have carried out properly controlled experiments. The results of irrigation experiments carried out in this country have been adequately reported elsewhere and need not be repeated here (1)

In the present survey, two farms were exceptional in that irrigated and unirrigated yields of otherwise similarly managed

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1- An excellent summary of these results will be found in the report entitled "Farm Crop Irrigation in The Economic Aspects" by J.S. Nix and C.N. Prickett. This report can be obtained from the University of Cambridge, School of Agriculture, Farm Economics Branch, Price 4s. 0d. post free.

crops were available. Both these farms are situated on the bunter sandstone of North Nottinghamshire, and their results are given below.

Farm Code No.	Crop	Extra Yield with Irrigation (per acre)
N/5	Early potatoes (lifted 30th June)	$2\frac{1}{4}$ tons
	Maincrop potatoes (K. E. and Majestic)	$1\frac{1}{2}$ tons
	Beans	16 cwts
	Peas (threshed)	12 cwts
	Grass	3. 8 cwts (dry matter)
N/9	Vining peas	12 cwts (shelled peas)

The other farmers taking part in the survey were asked for their opinions about the economic benefits they had obtained from irrigation in 1961. Their replies were, of course, largely guesswork, though a few (perhaps commendably) refused to guess and simply said they did not know. From the replies given, the following picture emerged.

(i) There was general agreement that early potatoes and grass showed a worthwhile response to irrigation in 1961. The estimated increase in the yield of early potatoes was put somewhere between one and five tons per acre (obviously the gain depended, to some extent, on the date of lifting). Some early potato growers claimed earlier maturity (and hence a higher price) as well as higher yields, but they were not unanimous on this point. There was fairly general agreement that irrigated crops recovered more quickly than others from the severe frosts which occurred at the end of May, and also that irrigation improved tuber quality by lessening the effects of potato scab.

For the reasons stated above, farmers were unable to be at all precise about the response obtained from the irrigation of grass, but the majority thought they had obtained at least one extra grazing or an extra cut of hay or silage early in the season. Other points were that irrigation helped to produce a fortnight's earlier bite in the spring, and that newly sown leys were saved from the effects of the drought in late May and June.

(ii) Most, but not all, growers of maincrop potatoes thought that irrigation had increased yield: estimates of this increase ranged from one to six tons per acre. The opinion was also expressed by some growers that irrigation helped to improve quality by reducing the number of cracked tubers and, with some varieties, that a higher proportion of potatoes of the size required for pre-packing was produced.

(iii) Although sugar-beet was irrigated on more than half the surveyed farms, only a small minority of users were prepared to hazard a guess that this crop had shown a positive yield response to irrigation in 1961.

This picture largely conforms with the pattern of irrigation response which might have been expected from the weather during the summer of 1961. Rainfall was considerably below average in May and June, about average in July and above average in August. It scarcely seems surprising that early maturing crops such as early potatoes or grass for mid-summer use should suffer more from an early drought, and therefore show a relatively greater response to irrigation, than a late-maturing crop such as sugar beet.

The Costs of Irrigating Individual Crops.

The total per acre cost of irrigating a particular crop depends partly on the amount of water applied. Table 10 shows the averages and ranges of total per acre expenditure on irrigation for the four major irrigated crops on the farms in the survey. These costs rest on the assumption that, on each individual farm, irrigation costs per acre-inch were the same for every crop.

So, the differences in average cost per acre between crops, as shown in the table, were principally due to the differing average rates of application. Thus, on average, early potatoes received about one and two-thirds as much water per acre as grass, and the costs of irrigating early potatoes were approximately two-thirds greater per acre than the costs of irrigating grass.

TOTAL PER ACRE EXPENDITURE ON THE IRRIGATION OF INDIVIDUAL CROPS

TABLE 10.

Crop	No. of farms.	Average rate of application (inches per acre)	Average total cost per acre-inch	Total cost per acre	
				Average	Range
			£. s.	£. s.	£. s. £. s.
Early potatoes	17	2.78	2. 14	6. 14	2. 7 to 13. 11.
Maincrop potatoes	20	2.42	2. 16	6. 0	2. 7 to 13. 13.
Sugar beet	17	1.96	2. 9	4. 6	1. 4 to 8. 17.
Grass	16	1.66	2. 12	3. 16	1. 8 to 7. 7.

On the other hand, the differences between farms in the per-acre cost of irrigating any one crop were as much due to farm-to-farm differences in irrigation costs per acre-inch as to differences in the rate of application.

On average, only slightly more was spent on the irrigation of early potatoes than on the irrigation of maincrops. This seems a little surprising because most of the dry weather in 1961 occurred during the period when early potatoes were bulking up. Moreover, potatoes lifted and sold during the early season usually command a higher price per ton than maincrops. For both these reasons it might have been expected that more would have been spent on irrigating early potatoes than on maincrop potatoes in 1961.

It will also be noted that, on average, less was spent on the irrigation of sugar beet than on potatoes. This is much as would be expected from the season's weather and the fact that the per acre value of sugar beet is generally lower than that of potatoes.

The amount spent on the irrigation of grass was, on average, less than the amounts spent on the irrigation of arable crops. This suggests that the needs of grassland, and the livestock enterprises dependent on it, may have been subordinated to the needs of arable crops on a majority of the surveyed farms. Although insufficient information was obtained about the overall organisation of the farms to confirm or refute this hypothesis, general observation of the farms themselves, and of the districts in which they are situated, lend some support to it.

2. Break-Even Yield Increases.

As previously explained, on a majority of the surveyed farms, estimates of the extra crop yields obtained from irrigation were usually based on nothing more than guesswork. In such circumstances, it is often better to calculate the increase in yield which would be needed to bring in enough extra revenue to cover the extra costs of irrigation.

This has been done for the four crops listed in Table 10, assuming the following farm-gate prices:

Early potatoes	£25. 0s. per ton
Maincrop potatoes	£13. 5s. per ton
Sugar beet	£6. 8s. per ton
Grass (as hay)	£7. 0s. per ton

With these prices, and the average and highest per acre irrigation costs shown in Table 10, the approximate break-even yield increases are:

	Extra yield (cwts. per acre) needed to cover:	
	Average total cost	Highest total cost
Early potatoes	5	11
Maincrop potatoes	9	20
Sugar beet	13	26
Grass (as hay)	11	21

Even at the highest cost level, these break-even yield increases are not unduly high in relation to many of the yield increases shown by the published results of irrigation experiments.

The extra yields postulated above would have been sufficient to cover the total costs of irrigation - fixed as well as variable costs. However, the farmer who already has an irrigation plant and who has to decide whether it will pay to irrigate a "marginal" field (this may or may not be a field which has already received some irrigation) only needs to know that he can cover the variable costs of irrigating the extra field. This is because the fixed costs of irrigation are inescapable and must therefore be met however much or little the plant is used.

Table 11 shows the averages and ranges of variable per acre costs of irrigation for the four major crops already discussed above.

VARIABLE PER ACRE EXPENDITURE ON THE IRRIGATION OF INDIVIDUAL CROPS

TABLE 11.

CROP	VARIABLE COST PER ACRE	
	Average	Range
	£. s.	£. s. £. s.
Early potatoes	3. 5	- 16 to 6. 19
Maincrop potatoes	2. 12	- 16 to 5. 4
Sugar beet	1. 17	- 12 to 3. 18
Grass	1. 6	- 13 to 2. 1

The approximate break-even yield increases calculated on the basis of the variable costs shown in Table 11, and the same prices as before, are as follows:

	Extra yield (cwts. per acre) needed to cover: Average variable cost	Highest variable cost
Early potatoes	2½	5½
Maincrop potatoes	4	8
Sugar beet	6	12
Grass (as hay)	3½	6

It is apparent that provided the variable costs of irrigation do not rise above the highest levels encountered in the survey, and crop prices do not fall drastically, the break-even yield increases required to justify the greater utilisation of an existing irrigation plant are quite low.

It seems probable that the real limit to the profitable utilisation of irrigation equipment is often set by the available supply of labour or water on a farm rather than by the farmer's inability to find a crop likely to respond to more irrigation.

Are extra fertilisers required?

It is sometimes held that in order to use irrigation to the greatest economic advantage it may be necessary to apply more fertilisers. Co-operating farmers were therefore asked whether they had applied more fertiliser to their irrigated crops than they would have applied if those crops had not been irrigated but had otherwise been grown under identical conditions. It was not always possible to give an answer to this question since, in some cases, a farmer had never grown the particular crop without irrigation. But, of the substantial number of replies received, the majority indicated that there would have been no difference in fertiliser treatment. Nevertheless, a sizeable minority indicated that they applied additional nitrogen to irrigated grass - usually 2-3 cwts. of nitro chalk, or an equivalent quantity of a substitute fertiliser, at an extra cost of between £1. 10s. and £2. 0s. per acre.

In such cases, the full extra costs of irrigating grass might have been as much as £2 per acre higher than the amounts shown in Table 10. This extra cost of £2 per acre also adds approximately 6 cwts. per acre to the break-even yield of hay required to cover all the extra costs associated with the irrigation of grass.

At present, the economics of the relationship between irrigation and fertiliser usage can only be dealt with in the light of what we find most farmers are actually doing. The problem of what it might pay them best to do must remain unanswered until the results of experiments designed to show the complementary effects of irrigation and fertilisers on the yields of various crops become available.

CHAPTER IV

"IRRIGATION NEED" IN 1961.

1. Method of Estimation.

Following the work of H. L. Penman at Rothamsted, "irrigation need" has been defined as the difference between the amount of rainfall received during any specified period and the loss of moisture from the soil due to potential transpiration during the same period. If the whole of this difference was made up by irrigation, then the soil moisture content would be restored to "field capacity". In practice, it is recommended that the soil moisture content should not be kept at field capacity, but that a "planned deficit" should be allowed to occur, in order to conserve irrigation water and to encourage deeper root development of crops. Where this recommendation is followed in calculating irrigation need, the planned deficit is deducted from the difference between rainfall and potential transpiration.

Use was made of local rainfall records, and of potential transpiration rates obtained from the Meteorological Office, to estimate the theoretical irrigation need on each of the farms surveyed during the summer of 1961. Rainfall records from a total of 12 stations were used.

Three of the farms are equipped with a rain gauge and a further eleven are within five miles of a recording station. Ten more of the farms are between five and ten miles, and the remaining farms more than ten miles from a station. The maximum distance between a survey farm and a recording station was approximately 24 miles.

The "water balance sheet" method of estimating irrigation need was used, allowing a planned deficit of half-an-inch at the end of April increasing steadily, at the rate of half-an-inch per month, to a total of three inches at the end of September (1). A balance sheet was kept for each of the twelve recording stations and the irrigation need of each farm was taken to be the same as that worked out for the nearest recording station. The balance sheets were drawn up at the end of each month to show the irrigation needed to restore the soil moisture to the level of the planned deficit after taking into account potential transpiration and rainfall received since the end of the previous month.

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(1) For a full description of this method, see : M.A.F.F. Technical Bulletin No.4, "The Calculation of Irrigation Need", H.M.S.O. 1954.

"IRRIGATION NEED"

TABLE 12.

Farm Code No.	"Irrigation need"		Actual rate of application in	Difference between actual rate of application and "irrigation need" in		Actual rate of application as a percentage of "irrigation need" in	
	Apr. -Sept.	June-Sept.	Apr. -Sept.	May-Aug.	June-Aug.	May-Aug.	June-Aug.
			inches of water				
N/1	3.49	2.76	3.47	- 0.02	+ 0.71	99	126
N/3	3.93	2.86	0.89	- 3.04	- 1.97	23	31
N/4	3.56	2.89	2.99	- 0.57	+ 0.10	84	103
N/5	3.49	2.76	3.12	- 0.37	+ 0.36	89	113
N/6	3.49	2.76	2.00	- 1.49	- 0.76	57	72
N/7	3.49	2.76	2.71	- 0.78	- 0.05	78	98
N/8	3.49	2.76	1.72	- 1.77	- 1.04	49	62
N/9	3.49	2.76	1.61	- 1.88	- 1.15	54	58
N/10	3.49	2.76	1.45	- 2.04	- 1.31	58	53
N/11	3.49	2.76	2.92	- 0.57	+ 0.16	84	106
N/13	4.41	3.05	2.08	- 2.33	- 0.97	47	68
N/14	4.57	3.29	1.09	- 3.48	- 2.20	24	33
N/15	4.57	3.29	1.15	- 3.42	- 2.14	25	35
N/16	5.35	4.04	2.43	- 2.92	- 1.61	45	60
N/20	3.49	2.76	2.20	- 1.29	- 0.56	63	80
N/21	5.35	4.04	2.63	- 2.72	- 1.41	49	65
K/1	5.35	4.04	2.08	- 3.27	- 1.96	39	51
K/2	4.83	3.18	2.70	- 2.13	- 0.48	56	85
K/3	4.83	3.18	2.36	- 2.47	- 0.82	49	74
K/4	4.83	3.18	2.00	- 2.83	- 1.18	41	63
K/6	4.41	3.05	1.79	- 2.62	- 1.26	41	59
K/7	4.41	3.05	1.00	- 3.41	- 2.05	23	33
K/8	4.83	3.18	1.40	- 3.43	- 1.78	29	44
K/9	4.83	3.18	1.61	- 3.22	- 1.57	33	51
K/10	4.83	3.18	1.56	- 3.27	- 1.62	32	49
L/1	2.97	1.81	0.99	- 1.98	- 0.82	33	55
L/3	3.58	2.21	4.29	+ 0,71	+ 2.08	120	194
L/4	2.97	1.81	1.48	- 1.49	- 0.33	50	82
L/5	2.97	1.81	2.38	- 0.59	+ 0.57	80	131
L/6	3.58	2.21	1.14	- 2.44	- 1.07	32	52
L/7	4.02	2.88	0.79	- 3.23	- 2.09	20	27
Av.	4.08	2.91	2.00	- 2.08	- 0.91	51.8	71.4

2. Difference between Estimated Need & Actual Application.

In Table 12, the theoretical irrigation need of crops on each of the surveyed farms during 1961 is shown against the average number of inches of water actually applied to each irrigated acre. Between different farms, the actual application of water ranged from a high of 120 per cent to a low of only 20 per cent of the theoretical need. However, only one farmer applied more than the theoretical estimate of need and, on average, this group of users put on only about half the theoretical requirement of water. Approximately 2 inches of additional water would have been required to bring the total quantity applied to the average irrigated acre up to the level indicated by the calculation of irrigation need.

It may be objected that even when a theoretical irrigation need exists, not all crops benefit from the application of water. For example, it is the policy of many growers of sugar beet not to irrigate the crop until late June or early July. Sin Similarly with maincrop potatoes, some growers consider that it is beneficial to defer irrigation until after the tubers are formed (1). Sugar beet and maincrop potatoes accounted for just over 40 per cent of the total acreage of irrigated crops on the survey farms and such policies doubtless had some effect on farmers' own estimates of irrigation need early in the season. However, even when the requirements of crops such as grass, early potatoes and peas early in the season were entirely ignored, by excluding the months of April and May from the calculation of irrigation need, it was found that the amount of water actually applied exceeded the theoretical requirement on only 6 of the 31 farms surveyed. On average, the irrigation water actually applied during the whole season amounted to only about 70 per cent of the theoretical need occurring after the end of May.. Nearly an inch of extra water would have been needed on the average irrigated acre to bring the total quantity of water applied up to the level of irrigation need calculated on this second more conservative basis. On some farms the shortfall was a great deal more than one inch.

This state of affairs may have resulted from any or all of the following :-

- (i) Differences in rainfall between the farms and the measuring stations.
- (ii) Farmers' inability to apply as much water as they themselves thought was needed.
- (iii) Differences between farmers' judgements of irrigation need and estimates of need based on theoretical principles and calculations.

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(1) See, J.J. North : Irrigation of Farm Crops, J.R. Agric. Soc., 1960, 121, 8.

Since at least eighty per cent of the farmers applied less than the theoretical requirement of water, the whole of the discrepancy certainly cannot be ascribed to the first-mentioned of the above reasons.

The second reason was certainly of importance on a number of farms. In a few cases, water shortage seriously curtailed irrigation operations at certain periods of the season. Mechanical breakdowns also interrupted irrigation for lengthy periods on some farms. Labour difficulties prevented some farmers from applying as much water as they might otherwise have done. In 1961, the greatest need for irrigation occurred in the second half of May and during June. This is the time of year when, on most farms, operations such as hay making and beet singling make strong competitive demands on the available labour force. The operation of an irrigation plant makes further demands upon a limited labour supply which a farmer may sometimes decide it is impossible to meet, and so the demand for irrigation gives way to other demands on the time of the farm labour force.

On one of the surveyed farms irrigation is carried out according to the results of calculations performed to determine irrigation need : on this farm also, records are taken of rainfall and other weather observations are made. On the remaining farms decisions concerning when to irrigate and how much water to apply are based solely on the intuitive judgement of the farmer. Intuitive judgement is bound to vary a good deal between individuals and it is therefore hardly surprising either that rates of application varied widely between farms or that comparatively few of them corresponded closely with the theoretical need. What does seem somewhat surprising is that a substantial majority of the surveyed farmers put on less water than the theoretical optimum. This strongly suggests either that estimates of irrigation need based on present methods of calculation are too high or that farmers consistently underestimate the quantities of water required by their crops. Unfortunately, it is at present impossible to decide which of these two interpretations of the facts is the more correct. Information is required on the relative yield increases obtained by farmers irrigating "according to the book" and by those relying on their own judgement to tell them how much water to apply, under conditions where the total amount applied is not restricted by water or labour shortage or by major mechanical breakdowns.

3. 1961 and the "Normal Irrigation Year" Compared.

Seven of the twelve stations from which records of 1961 rainfall were obtained also had long-term records showing the average monthly rainfall over the period from 1916 to 1950 (1). Monthly

(1) Meteorological Office : Monthly Weather Report. Various issues.

averages of potential transpiration are also available for counties or half counties. Thus it was possible to calculate the long-term average irrigation need at each of these seven stations and to compare this with the figures obtained in 1961.

The results of this comparison are summarised in Table 13 where the figures are averages based on all seven of the stations with long-term records. The conclusion is that in 1961 irrigation need in the survey area was considerably above average in May and June and slightly below average in July and August. The planned deficit was not exceeded in April or September, either in 1961 or during 1916-50; hence there are no data relating to these two months.

Considering the season as a whole, an irrigation need of four inches of water in the survey area during 1961 exceeded the long-term average by about 50 per cent. This conclusion gives added significance to the fact that a large measure of unused irrigation capacity was found on the surveyed farms in 1961. It is difficult to escape the further conclusion that in a year of average irrigation need the amount of unused capacity would be even greater and fixed costs per acre-inch higher on many of these farms.

"IRRIGATION NEED"

1961 compared with the 1916–50 average

TABLE 13.

Month	"IRRIGATION NEED"		
	In 1961 (inches)	Average 1916-50 (inches)	Difference (inches)
April	-	-	-
May	1.11	0.52	+ 0.59
June	2.44	1.44	+ 1.00
July	0.45	0.58	- 0.13
August	-	0.16	- 0.16
September	-	-	-
Total 6 months	4.00	2.70	+ 1.30

CHAPTER V

SUMMARY AND CONCLUSIONS

The results of this enquiry, and the conclusions reached, can be summarised under the three main headings given in the statement of objectives:-

(i) The amount of capital needed for an irrigation plant.
(ii) The annual costs of ownership and operation.
(iii) The benefits of irrigation in relation to the costs.

Capital Requirements.

The average net capital cost of the irrigation plants surveyed, after allowing for any government grants obtained, was just under £2,000 per farm. But there were wide farm-to-farm variations due to differences in the size of plant.

The average net capital cost per acre setting was approximately £850. But amongst farms where the "maximum reach" of the plant (determined by the total length of mains piping) was below average, the net capital cost was less than £600 and, on farms where this second measure of plant size was above average, it reached nearly £1,150 per acre setting.

The outlay on pipes accounted for a major proportion of the total capital expenditure.

Other things being equal, fully portable plants appear to have the advantage of a lower capital requirement in spite of the grants available towards the costs of installing underground mains and other permanent parts of an irrigation system. But, due to the very small number of farms in the survey with permanent irrigation installations, this can only be regarded as a very tentative conclusion.

There appeared to be no significant difference in capital cost between plants equipped with sprinklers and those with rainguns.

Annual Costs of Ownership and Operation.

On average, annual fixed costs per acre-inch of water applied accounted for about three-fifths of the total costs of ownership and operation, and variable costs for the remaining two-fifths. Depreciation and interest charges on portable pipes and their ancillary equipment were usually the principal element of fixed costs, and labour commonly accounted for about half the variable costs per acre-inch.

There were substantial differences between farms in the total costs of irrigation per acre-inch. But the differences in fixed costs were greater than the differences in variable costs. This was partially due to similar sized plants getting differing amounts of usage on different farms, and partially to different owners having different sized plants. The former appeared to be the more important of these two factors in explaining inter-farm differences in fixed cost per acre-inch.

Of the factors affecting the level of variable costs per acre-inch, labour usage appeared to be the most decisive and the truly economic use of labour is clearly one of the keys to low overall operating costs for irrigation. The results of the survey showed that, on average, nearly two-thirds of the total man-hours going into irrigation operations were required for the movement of sprinkler lines (or laterals with rainguns) between one setting and the next in the same field. Major shifts of the equipment from one field to another were relatively much less important. Low labour requirements therefore largely depend on the efficient organisation of pipe-shifting operations within each field. Whether such efficiency depends upon <u>not</u> treating pipe-shifting as a full time job for one or several men is a problem requiring further examination.

The most certain way of ensuring low costs per acre-inch is to use an irrigation plant of any given size as near as possible to its maximum capacity. Most of the plants surveyed were utilised a long way below their estimated maximum capacity in 1961.

The choice of a suitable sized plant is also important, especially where the total quantity of water applied during a season is likely to be relatively small; otherwise, the burden of depreciation and interest charges on unused equipment may seriously erode any profits resulting from the use of irrigation.

<u>Are the Benefits worth more than the Costs?</u>

Reliable information on the benefits of irrigation is much harder to come by than information on costs, and, in any case, it is to be expected that the benefits will vary considerably from crop to crop and from year to year.

Practically all the farmers in the survey who irrigated early potatoes thought that, in 1961, they had obtained an economic increase in yield. A similar opinion was held regarding a high proportion of the fields of maincrop potatoes which received irrigation.

By contrast, only a minority of those who irrigated sugar beet were confident that in 1961 they had obtained a paying response.

The benefits of irrigating grassland are even more difficult to assess than those of arable crops. However, most farmers who irrigated grass thought that they had obtained a worthwhile response, particularly during the dry early part of the season. But how effective a use they were able to make of any additional grass produced remains an open question, which it was not feasible to examine as part of the survey.

The results of this survey suggest that, provided the irrigation plant is not seriously under-utilised in relation to its capacity - due to shortage of water or for any other reason - the increases in the yields of early and maincrop potatoes, sugar beet and hay required to break even with irrigation costs could easily be obtained by farmers in the East Midlands over a run of seasons.

Apart from grass on a few farms, the crops embraced by this survey did not receive extra fertilisers. Nevertheless, it at least seems possible that important complementary relationships exist between irrigation and the application of fertilisers, and there would seem to be a strong case for more husbandry experiments designed to measure the effects of any such relationships.

A large majority of the farmers in this survey applied less water to each irrigated acre than the estimate of "irrigation need" based on local records of rainfall and potential transpiration. Shortage of water at least partially explained this discrepancy on a few farms, but the general problem remains of whether intuitive judgement is a better method of estimating irrigation need than calculations based on climatological records.

Calculations based on the objective method of estimation suggest that, in the survey area, irrigation need in 1961 was substantially above the long-term average. This would seem to reinforce the conclusion that, on a good many of the farms surveyed, the irrigation plant might be bigger than strictly economic considerations could justify. Some owners appear to be paying a rather high "insurance premium" to cover themselves against losses which might occur in another exceptionally dry year like 1959 (assuming sufficient water was available).

However, capital already sunk in an over-large irrigation plant for present needs may be difficult or impossible to recover. Another possibility is that (the supply of water permitting) the use of the under-utilised plants might be extended - either by covering a larger acreage or by the application of more water to part or all of the existing irrigated acreage. It is worth remembering that, due to the inescapable nature of fixed costs, once the plant has been acquired the marginal costs of additional irrigation will almost always be considerably lower than the average total costs per acre-inch revealed by this enquiry. In other words, to the farmer who already has an irrigation plant, the prospect of a break-even yield increase which will cover only variable costs per acre-inch is sufficient to justify applying more water to a crop, or extending the use of the plant to an extra field.

APPENDIX I

Individual Farm Results

APPENDIX TABLE I.

Farm Code No.	Size of irrigation plant (1) (acres)	Use of plant: Estimated maximum capacity of plant (2) (acre-inches)	Use of plant: Water actually applied (acre-inches)	Use of plant: Percentage utilisation	Costs per acre-inch: Fixed £. s. d.	Costs per acre-inch: Variable £. s. d.	Costs per acre-inch: Total £. s. d.
K/2	2.00	480	465	97	10. 8	8. 2	18. 10
N/11	1.25	300	147	49	13. 0	6. 7	19. 7
N/4	1.00	240	184	77	12. 7	14. 11	1. 7. 6
N/7	2.20	528	304	58	16. 7	11. 3	1. 7. 10
K/10	1.00	240	127	53	13. 7	14. 5	1. 8. 0
N/1	4.00	960	746	78	12. 0	19. 8	1. 11. 8
N/13	0.75	180	179	99	15. 9	17. 0	1. 12. 9
N/5	2.50	600	418	70	1. 3. 3	10. 2	1. 13. 5
N/9	2.70	648	399	61	18. 2	17. 7	1. 15. 9
L/6	1.60	384	93	24	1. 0. 11	15. 2	1. 16. 1
N/16	1.80	432	219	51	1. 5. 10	12. 1	1. 17. 11
K/1	2.00	480	83	17	1. 10. 11	12. 11	2. 3. 10
N/15	1.80	432	63	15	1. 14. 7	12. 5	2. 7. 0
N/10	2.00	480	165	34	1. 1. 6	1. 8. 4	2. 9. 10
L/3	1.00	240	48	20	1. 4. 7	1. 6. 1	2. 10. 8
K/4	1.00	240	80	33	1. 6. 1	1. 5. 0	2. 11. 1
K/3	2.75	660	103	16	1. 16. 7	17. 2	2. 13. 9
N/8	2.40	576	128	22	1. 15. 4	18. 7	2. 13. 11
N/6	3.00	720	162	23	1. 6. 8	1. 8. 4	2. 15. 0
L/5	3.00	720	273	38	1. 10. 8	1. 6. 3	2. 16. 11
L/1	3.00	720	113	16	1. 11. 11	1. 6. 8	2. 18. 7
N/20	3.90	936	609	65	1. 16. 8	1. 2. 2	2. 18. 10
K/6	1.50	360	123	34	19. 6	1. 19. 4	2. 18. 10
K/9	3.00	720	187	26	1. 0. 0	2. 0. 6	3. 0. 6
N/21	1.50	360	92	26	2. 10. 1	18. 2	3. 8. 3
K/7	1.50	360	30	8	2. 15. 5	15. 7	3. 11. 0
K/8	2.50	600	111	18	1. 2. 5	2. 12. 1	3. 14. 6
L/7	1.80	432	60	14	1. 12. 6	3. 0. 0	4. 12. 6
N/14	1.90	456	31	7	4. 8. 4	14. 10	5. 3. 2
L/4	1.50	360	34	9	3. 6. 2	2. 8. 2	5. 14. 4
N/3	1.00	240	20	8	7. 11. 3	14. 4	8. 5. 7
Average all farms	2.03	487	187	38	1. 13. 0	1. 2. 5	2. 15. 5

(1) Measured in terms of the maximum area that could be covered at one setting with available sprinklers or rainguns.

(2) Based on the assumption that a one acre set reached the limit of its capacity with the application of one inch of rain to 4 acres per day for 60 days, i.e. the limit was set at 240 acre-inches.

APPENDIX 2

Standard Charges & Procedures

1. Fixed Costs

(a) In working out the annual costs of depreciation, the economic life of each of the main items of equipment was assumed to be as follows :-

Item	Life
Pumps	10 years
Portable mains and laterals	15 years
Underground mains, buildings and other fixed equipment	25 years

(b) Interest on the capital invested in irrigation equipment of all kinds was charged at 7½ per cent per annum.

(c) The combined annual costs of capital depreciation and interest are, in effect, the equivalent of a fixed-term annuity paid by the irrigation plant to its owner to enable him to recover his capital in instalments and draw interest on the unrecovered balance at a pre-determined rate. So, in converting the capital costs of irrigation equipment into their annual cost equivalent, use was made of the formula also used to work out the value of the annuity which a given capital sum will yield.

2. Variable Costs

(a) Man Labour.

All labour charged at 5s. 0d. per hour.

(b) Pumping Power and Repairs to equipment.

(i) Fuel, oil and electricity - actual or estimated consumption at cost.
(ii) Repairs - at cost
(iii) Tractor depreciation (pumping only) - 1s. 3d. per hour.

N. B. Depreciation of motors integral with pumps was included in fixed costs with pump depreciation.

(c) Tractor transport

Running costs only, charged at 3s. 0d. per hour.

(d) Water

Charged at cost on the small minority of farms where a free supply was not available.

3. Averages

All calculations give equal weight to each farm irrespective of the acreage irrigated or the total quantity of water applied.