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ECONOMIC ASPECTS OF FARM IRRIGATION

by

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A survey carried out on groups of East Midland farms in 1961 and 1962

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CHAPTER I

INTRODUCTION

1. Objectives.

This publication has the twofold purpose of reporting the results of a survey of farm irrigation carried out in 1962 and of co-ordinating these same results with those obtained from a similar survey carried out in 1961. The results of the 1961 survey have been reported more fully in an earlier publication (1).

The objectives of the 1962 survey were to obtain further information needed to answer four basic questions, viz.: -

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

With two years survey results available, more definite answers to these questions can now be given. Nevertheless, it must be recognised that the practice of irrigation is always subject to unpredictable influences. These are of two kinds. Firstly, there is the weather which broadly determines what and how much irrigation is needed in a particular year. Secondly, there are the prices the farmer receives for his crops. Although generally somewhat more predictable than the weather, future prices are always subject to considerable uncertainty due to unexpected changes in the market and in government policy.

Thus the conclusions regarding the costs and economic benefits of irrigation given in this report should not be regarded as being anything more than a guide which some farmers may find useful in planning for the future.

2. The Plants.

A total of 44 farmers co-operated in the enquiry in 1962. Of these, 27 also participated in the survey carried out in 1961 and the remaining 17 were new co-operators. New contacts in 1962

(1) INGERSENT, K.A., Costs of Farm Irrigation, University of Nottingham, Department of Agricultural Economics. F.R. No. 148, May, 1962.

were made in the same way as the original contacts, i.e. through the good offices of the N.A.A.S.

Nineteen of the farms from which information was obtained are in Nottinghamshire and the remaining 25 in the Lindsey and Kesteven divisions of Lincolnshire. Eleven of the Nottinghamshire farms are on the bunter sandstone and four on alluvial gravel near to the River Trent. Eight of the Lincolnshire farms are on limestone and most of the remainder on sand or other light-textured soils.

3. Survey Method.

The methods used to obtain information were described in the report on the 1961 survey. Standard charges are again detailed in the Appendices

CHAPTER II

COSTS

1. Capital Requirements.

The total capital cost amongst all 44 farms, net of government grants, averaged £ 2,839 per farm. This compares with an average net capital cost of £ 1,917 amongst the smaller number of farms included in the 1961 survey. The range in capital costs per farm was also wider in 1962, from a low of £ 450 to two farms where the investment in irrigation equipment substantially exceeds £ 10,000. Excluding these, the average net capital cost per farm was £ 2,014, or about £ 100 per farm more than in 1961. Eight of the 27 farmers who were in both surveys acquired new capital equipment and so increased their total investment between the two years.

On average, the plants in the 1962 sample had sufficient sprinklers or rainguns to cover just under $2\frac{1}{2}$ acres at one setting, together with about 650 yards of portable mains piping. Eight plants are additionally equipped with underground mains, averaging rather more than two miles in total length and adding approximately £ 5,000 to total net capital costs.

Expressed in terms of a one acre setting, total net capital costs amongst farms in the 1962 sample averaged £ 986 (£ 857 in 1961). On individual farms, however, the net investment ranged from less than £ 400 to over £ 4,000 per acre setting. The latter figure was reached on a farm where, in addition to the installation of underground mains, a number of artificial reservoirs have been built to conserve winter rainfall (1).

2. Annual Costs of Ownership and Operation.

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 in any particular year. Amongst all farms included in the 1962 survey, total annual fixed costs averaged £ 111 per acre setting. On individual farms, however, the range was from less than £ 50 up to nearly £ 400 per acre setting.

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(1) This is a new plant with more reservoir storage than can be fully utilised with the existing number of sprinklers. It is the owner's intention to add more sprinklers in the future. Thus the present very high capital cost per acre setting on this farm should not be regarded as being typical even for reservoir-type plants.

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.

Although freely available to the owners of all but seven of the surveyed plants, water is sometimes an additional variable cost. Two of the plants surveyed in 1962 used mains water from a public supply at an average cost (for the two farms) of approximately £ 2. 10s. per acre-inch. On five other farms canal water was used at an average cost of only 1s. 8d. per acre-inch.

Average cost structure - comparison between 1962 and 1961.

The average cost structure in 1962, based on records from all 44 plants, is shown in Table 1. The average cost structure of the 31 farms included in the 1961 survey is also shown for comparison.

Broadly similar results were obtained in the two seasons. On average, total costs per acre-inch were approximately the same in both years, although fixed costs per acre-inch were a little lower and variable costs per acre-inch a little higher in 1962. These differences were mainly due firstly, to total fixed costs being spread over a larger average total application of water in 1962, secondly, to a slightly higher average labour input per acre-inch and, thirdly, to the inclusion of a higher proportion (though still a small minority) of farmers who had to pay for their water.

In 1962, average fixed and average variable costs were virtually identical in amount. However, this was certainly not true of many individual farms, for fixed and variable costs per acre-inch again showed very marked farm-to-farm variation. Fixed costs differed by up to £ 3. 10s. per acre-inch and variable costs by up to nearly £ 6 per acre-inch (£ 3. 8s. with one of the two farms using mains water excluded).

Plant utilisation and fixed costs per acre-inch.

The relative levels of fixed cost per acre-inch on different farms are not closely related to absolute levels of capital investment or to levels of annual fixed cost per acre setting.

Relatively high levels of investment and relatively high fixed costs per acre setting are sometimes associated with a relatively low level of fixed costs per acre-inch and vice versa. The decisive factor affecting the level of fixed cost per acre-inch on any farm is the degree to which the maximum capacity of the irrigation plant is actually utilised.

In 1962, the maximum capacity of each surveyed irrigation plant was again estimated on a standard basis. The irrigation season

AVERAGE COST STRUCTURE IN 1961 (31 FARMS) AND 1962 (44 FARMS)

TABLE 1

Per acre-inch

Item	1961				1962			
	Range From	Range To	Average	Per cent	Range From	Range To	Average	Per cent
FIXED COSTS:	s. d.	£. s. d.	£. s. d.		s. d.	£. s. d.	£. s. d.	
Depreciation and interest on capital.								
Pump (incl. ancillaries)	1. 1.	1. 13. 11.	8. 1.	14.6	1. 2.	19. 8.	6. 6.	12.1
Portable mains and laterals	6. 4.	5. 17. 4.	1. 2. 8.	40.9	5. 7.	3. 0. 2.	17. 0.	31.6
Underground mains, reservoirs and other permanent works	nil	18. 9.	2. 3.	4.0	nil	2. 3. 0.	3. 6.	6.5
TOTAL FIXED COSTS	10. 8.	7. 11. 3.	1. 13. 0.	59.5	8. 10.	3. 19. 10.	1. 7. 0.	50.2
VARIABLE COSTS:								
Man labour								
Moving laterals and attention to pump	1. 3.	1. 15. 0.	7. 8.	13.9	1. 0.	1. 10. 11.	8. 11.	16.6
Shifting from field to field	5.	8. 10.	3. 6.	6.3	5.	16. 11.	4. 0.	7.4
(Total man labour)	(2. 5.	2. 1. 0.)	(11. 2.)	(20.2)	(2. 0.	2. 6. 7.)	(12. 11.)	(24.0)
Transport	1.	2. 1.	8.	1.2	nil	3. 5.	8.	1.2
Power and Repairs								
Diesel, t.v.o. or electricity	1. 10.	10. 9.	4. 7.	8.2	1. 11.	16. 8.	5. 4.	9.9
Lubricating oil	nil	3. 1.	7.	1.0	nil	2. 0.	5.	0.8
Repairs	nil	1. 5. 0.	2. 8.	4.8	nil	1. 1. 5.	2. 5.	4.5
Tractor depreciation	nil	5. 1.	2. 0.	3.6	nil	7. 1.	2. 4.	4.3
Other costs								
Water	nil	17. 8.	9.	1.5	nil	3. 16. 2.	2. 9.	5.1
TOTAL VARIABLE COSTS	6. 7.	3. 0. 0.	1. 2. 5.	40.5	5. 2.	6. 1. 1.	1. 6. 10.	49.8
TOTAL COSTS	18. 10.	8. 5. 7.	2. 15. 5.	100.0.	15. 6.	7. 13. 0.	2. 13. 10.	100.0
Total irrigation applied (acre-inches)	20 to 746.		187	-	30 to 1,360		258	-

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 x 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.

On average, the actual utilisation of the 44 irrigation plants surveyed amounted to only 44 per cent of their theoretical maximum capacity in 1962 (compared with an average of 38 per cent utilisation amongst 31 plants in 1961). The full range of utilisation went from 6 to 98 per cent of the theoretical maximum capacity (Appendix 1).

As expected, relatively low fixed costs per acre-inch were associated with a relatively high degree of plant utilisation and vice versa. In fact, amongst plants where less than 30 per cent of their maximum capacity was actually utilised in 1962, the average level of fixed costs per acre-inch was twice as great as it was amongst plants actually utilised to 50 per cent or more of their maximum capacity (Table 2).

AMOUNT OF WATER APPLIED AND FIXED COSTS PER ACRE-INCH ACCORDING TO PERCENTAGE UTILISATION OF THE PLANT IN 1962

TABLE 2

Percentage utilisation of plant	No. of plants	Use of plant		Av. fixed costs per acre-inch
		Est. max. capacity	Water applied	
		acre-inches		
				£. s. d.
50 and over	16	623	413	19. 3.
30 to 49	14	621	253	1. 3. 6.
Less than 30	14	507	85	1. 19. 4.
All plants	44	583	258	1. 7. 0.

Reasons for differing degrees of plant utilisation.

Since in both years of the survey, the degree of plant utilisation was also the dominant factor explaining farm-to-farm differences in total costs per acre-inch, it is worth probing deeper to explain why the irrigation plant was more fully utilised on some farms than on others.

THE PATTERN OF IRRIGATION APPLIED TO DIFFERENT CROPS ACCORDING TO THE DEGREE TO WHICH THE CAPACITY OF THE PLANT WAS UTILISED 1962 RESULTS

TABLE 3

Per farm

Utilisation of plant capacity	Number of plants	Average size of plant (acres)		Potatoes		Sugar beet	Peas	Grass	Cereals	Other	Total acres covered
				Earlies	Second earlies and maincrop						
Below 40 per cent	22	1.8	Acres irrigated	15.4	18.7	14.3	-	9.1	1.9	6.1	65.5
			No. of inches/acre	1.90	1.35	1.28	-	1.58	0.89	1.08	1.46
			Total acre-inches	29.3	25.3	18.3	-	14.4	1.7	6.6	95.6
40 per cent and above	22	3.0	Acres irrigated	15.5	25.8	50.2	7.1	45.6	7.3	5.8	157.4
			No. of inches/acre	5.34	3.30	2.04	1.08	2.64	1.48	1.76	2.67
			Total acre-inches	82.8	85.2	102.6	7.7	120.3	10.8	10.2	419.6

(i) Pattern of usage.

Dividing the farms into two 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 3.

It will be noted that the two groups differ with respect to the average size of plant. Whereas the plants in the lower utilisation group (below 40 per cent) average only 1.8 acres in size, those in the higher group (40 per cent utilisation and above) are two thirds larger averaging a size of 3.0 acres. But, by comparison, the total acreage covered by the plants in the higher utilisation group was, on average, 140 per cent greater in 1962. Moreover, the rate of application per acre was, on average, 80 per cent greater. The total quantity of water applied (in acre-inches) is the product of "acres irrigated" times "inches per acre". After allowing for the difference in average size of plant in 1962, this was more than $2\frac{1}{2}$ times greater in the higher than in the lower utilisation group.

These results confirm the conclusions which emerged from a similar analysis of data from the 1961 survey. Farmers in the higher utilisation group again irrigated larger acreages of all the major crops. The most striking differences in this respect concerned the irrigation of sugar beet and grass.

The difference between the two groups in the average rate of water application per acre was most marked in the case of potatoes. The difference was particularly noticeable in relation to early varieties to which growers in the higher utilisation group applied nearly three times as much water as was applied by growers in the lower group. (In 1961, the difference in the rate of application was most marked in relation to sugar beet).

The general conclusion which emerges from both years' surveys regarding the pattern of usage associated with the relatively full utilisation of irrigation equipment is that,

(a) a wider range of crops is irrigated and specialist crops such as vining peas are present,
(b) a larger acreage of each kind of crop is irrigated, the difference tending to be greatest with sugar beet and grass, and
(c) water is applied more liberally to each acre but with changes of emphasis on a particular crop or crops according to the season.

(ii) Other reasons.

Farmers who took part in the 1961 survey were not specifically asked about the degree of plant utilisation. However, whilst the survey was in progress, obstacles to further utilisation on some

farms became very clear. One of the most commonly occurring of these obstacles appeared to be a shortage of water.

At the end of the second year's survey co-operating farmers were shown a list of possible obstacles to the greater use of irrigation equipment and were invited either to select one of these as the main factor preventing greater use of their plant in 1962, or to name another obstacle taking precedence over any of those shown in the list. The results are shown in Table 4.

MAIN REASON PREVENTING GREATER USE OF EQUIPMENT IN 1962

TABLE 4

Reason	Number of farms
Lack of crops needing more water	22
"Not enough hours in the day"	9
Shortage of water	7
Shortage of labour	3
Other reasons	3
TOTAL	44

Half the farmers interviewed considered that a lack of crops needing more water was the main factor preventing greater usage. About one farmer in five, by agreeing that there were "not enough hours in the day", implied that whenever crops were likely to respond to irrigation, their equipment was used to its full capacity. Somewhat surprisingly, perhaps, only about one farmer in six named shortage of water as the main obstacle to greater utilisation, and only about one in fifteen regarded shortage of labour as being the main impediment to fuller usage. Three farmers gave other reasons, which in two cases were concerned with new equipment not being ready for use at the beginning of the irrigation season.

It appears that in this area at present, on farms already equipped with the facilities for irrigation, only a minority of operators are seriously hampered by water or labour shortage. Yet, objectively assessed, a large majority of the farms visited had considerable unused capacity in 1962, and, in many cases, the same situation was observed in the previous year, 1961. This points to the conclusion that the carrying of surplus capacity is being deliberately undertaken, either as an insurance against exceptional drought conditions such as occurred in 1959, or in anticipation of a possible increase in the acreage of irrigated crops sometime in the future.

Variable costs per acre-inch and labour requirements.

The two factors appearing to have a decisive influence on the variable costs of irrigation are the terms upon which water can be obtained and labour usage.

At present, the majority of operators enjoy a free water supply. The high cost sometimes paid by the minority who are not in this happy position has already been referred to. (1)

Whether or not free water is available for irrigation is a matter largely outside the farmer's control. By contrast, the second major factor affecting variable costs - the organisation and usage of labour - is not.

3. Factors affecting labour requirements.

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-feulling 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 most farms operating and maintaining the pump accounted for only a very small proportion of the total man-hours expended on irrigation.

In presenting the final results, therefore, the only distinction made is between the labour required for operating in a particular field (including attention to the pump) and labour required for shifting from one field to the next.

On average, over two thirds of the total man-hours for irrigation were accounted for by operations within the field. The remaining labour - rather less than a third of the total, on average - was absorbed by major shifts between fields. The proportions remained remarkably consistent in both years of the survey though, in an absolute sense, the average number of man-hours per 100 acre-inches was slightly higher on the farms surveyed in 1962 than amongst those surveyed in 1961 (Table 5).

The extremely wide range in labour usage between individual farms, already remarked on in the report on the 1961 survey, was no less pronounced in 1962.

In the report on the 1961 survey it was suggested that labour

(1) See page 4.

DISTRIBUTION OF IRRIGATION LABOUR BETWEEN DIFFERENT CLASSES OF OPERATION

TABLE 5

Class of operation	Man-hours per 100 acre-inches					
	1961 (1)			1962 (2)		
	Range	Av.	Per cent	Range	Av.	Per cent
Attention to pump etc. and moving laterals	34 to 720	154	69	20 to 619	178	69
Shifting from field to field	8 to 176	70	31	9 to 339	80	31
All operations	67 to 820	224	100	39 to 931	258	100

(1) 31 plants. (2) 44 plants.

usage might tend to be higher on farms where irrigation is treated as being a full-time job for one or more men. In 1962, co-operators were asked a number of questions specifically designed to elucidate this point.

Rather more than half the plants had at least one man in full-time attendance whenever irrigation was in progress and, not unexpectedly, these plants tended to be larger (in terms of the number of sprinklers and rainguns) than the remaining plants which were operated without full-time attention. Of greater interest is the fact that, on average, the number of man-hours per 100 acre-inches was twice as large on farms where labour was always in attendance than on farms where the plant was left unattended between settings (Table 6).

SIZE OF PLANT AND LABOUR USAGE IN 1962 RELATED TO THE METHOD OF LABOUR ORGANISATION

TABLE 6

No. of full-time operators	No. of plants	Av. size of plant (acs.)	Av. no. of hours per 100 ac. ins.
At least one	28	2.73	318
None	16	1.91	154
All plants	44	2.43	258

This, then, is clearly one of the reasons for the very wide range in labour requirements between different farms. Nevertheless, there was considerable overlapping between the groups: in some cases where irrigation was treated as being a full-time job labour usage was lower than on some of the farms where full-time attention was not given.

Of those who stated that irrigation was treated as being a full-time job for at least one man, just over half considered that allowing for legitimate rest periods, that man really was fully employed moving laterals or doing other work. On the remaining farms (about a quarter of the total number surveyed) it was admitted that the man (or men) in attendance was not actively employed during the whole of the nominal working period. Two main reasons were given for not directing the man to other work during these idle periods: firstly that it was too far to go other work (or, that it would have taken too long to get there): secondly, that someone must always remain close at hand so that the pump could be stopped immediately in an emergency.

The pros and cons of this practice were discussed in general terms in the report on the 1961 survey. The decision as to whether irrigation is to be treated as a full-time job or not will clearly depend, in the last analysis, on the circumstances of the individual farm or farmer. Nevertheless, two points with a bearing on the problem are now clear. Firstly, some irrigators appear to manage quite well without giving the plant full-time attention. Secondly, the giving of full-time attention can definitely be quite costly in terms of the extra man-hours needed to apply a given quantity of water, particularly if the plant is relatively small (say, 2 acres of sprinklers or less). On the other hand, to the extent that the work is performed by regular employees during periods when work elsewhere on the farm is relatively slack, the scope for reducing costs by greater economy in the use of irrigation labour may be rather limited.

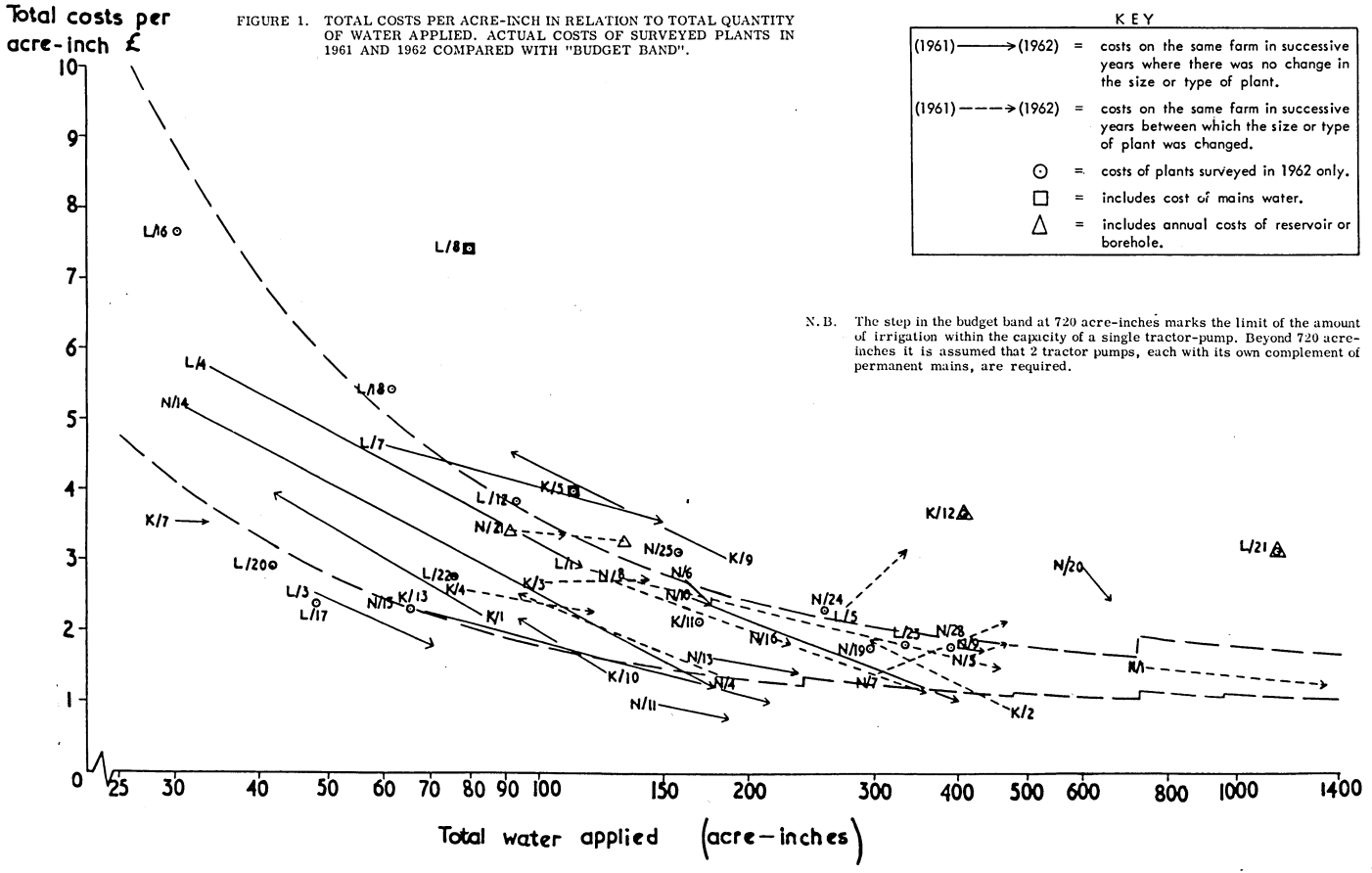
4. Analysis of main factors influencing costs.

The total irrigation costs per acre-inch actually incurred by the owners of the plants surveyed in 1962 are shown in Appendix 1. In Figure 1 costs per acre-inch are plotted against the total quantity of water applied on each farm.

The figure also shows the costs incurred by each owner in relation to the "budget band" which indicates, for any level of total application, the range within which total costs per acre-inch might be expected to fall given the normal capital outlay for a standard portable irrigation plant of the required size working under average conditions. (1)

(1) For further details of this concept see, Ingersent, K.A. Costs of Farm Irrigation. pp. 16-21.

FIGURE 1. TOTAL COSTS PER ACRE-INCH IN RELATION TO TOTAL QUANTITY OF WATER APPLIED. ACTUAL COSTS OF SURVEYED PLANTS IN 1961 AND 1962 COMPARED WITH "BUDGET BAND".



KEY

(1961)——→(1962)	=	costs on the same farm in successive years where there was no change in the size or type of plant.
(1961)- - -→(1962)	=	costs on the same farm in successive years between which the size or type of plant was changed.
⊙	=	costs of plants surveyed in 1962 only.
□	=	includes cost of mains water.
△	=	includes annual costs of reservoir or borehole.

N.B. The step in the budget band at 720 acre-inches marks the limit of the amount of irrigation within the capacity of a single tractor-pump. Beyond 720 acre-inches it is assumed that 2 tractor pumps, each with its own complement of permanent mains, are required.

In 1962, the costs of 21, or rather less than half the plants surveyed, lay within the budget band. Of the remaining 23 plants, the costs of 15 were above and eight were below the budget band.

The exceptionally high costs incurred by the owners of five of the 15 plants lying above "the band" can be explained by abnormal circumstances. Two of them were users of mains water, and the remaining three had each been obliged to meet the extra capital costs of either reservoirs or boreholes.

Excluding these exceptional plants, a majority again lay within the budget band (as in 1961) and of the minority remaining outside, approximately equal numbers were above and below the band. This reinforces the conclusion - already reached tentatively in 1961 - that provided sound basic assumptions are employed, irrigation costs covering the range of conditions found on a majority of farms can be estimated by means of budgets.

These can be usefully employed either by the farmer considering whether to adopt irrigation for the first time or by anyone (farmer or adviser) requiring an economic yardstick against which actual irrigation costs on a particular farm can be measured (as in this study).

Two year comparison of identical farms.

With respect to the 27 plants for which two years' information was obtained, the costs incurred in 1961 are also shown in Figure 1. (1962 is linked with 1961 by a "trend line" in each case).

On two thirds of these farms, total costs per acre-inch were lower in 1962 than in 1961: this downward trend in cost was generally associated with an increase in the degree of plant utilisation (Table 7). On average, the degree of utilisation went up from approximately 40 per cent of estimated maximum capacity in 1961 to 51 per cent in 1962 and fixed costs per acre-inch declined from £ 1. 10s. 0d. to £ 1. 3s. 5d. Overall average variable costs remained virtually unchanged at approximately £ 1. 1s. 0d. per acre-inch.

In some cases, the irrigation plants themselves were not truly identical in both years since new capital equipment was added in 1962. Such plants are denoted in Figure 1. by a broken "trend line". It will be noted that in one or two such cases irrigation costs per acre-inch went up in 1962 despite the fact that more water was applied. This occurred where the extra fixed costs of new capital equipment more than offset the reduction effected by spreading the fixed costs of the original plant over a larger total application of water.

Of plants which were included in the survey in both years, eight showed abnormally high or low costs per acre-inch in 1961 (three

INDIVIDUAL FARM RESULTS

1962 compared with 1961

TABLE 7

Farm Code No.	Per centage utilisation		Costs per acre-inch						Ranking	
			1961			1962				
	1961	1962	Fixed	Variable	Total	Fixed	Variable	Total	1961	1962
			£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.		
N/1	78	73	12. 0.	18. 0.	1.10. 0.	10. 1.	15. 1.	1. 5. 2.	6	6
N/4	77	26	12. 7.	14.11.	1. 7. 6.	1.12.10.	17.10.	2.10. 8.	3	19
N/5	70	66	1. 3. 3.	10. 2.	1.13. 5.	1. 1. 0.	15. 7.	1.16. 7.	8	12
N/6	23	25	1. 6. 8.	1. 8. 4.	2.15. 0.	1. 4. 3.	1. 3. 4.	2. 7. 7.	18	17
N/7	58	88	16. 7.	11. 3.	1. 7.10.	1. 3. 3.	19. 7.	2. 2.10.	4	14
N/8	22	57	1.15. 4.	18. 7.	2.13.11.	13. 9.	9. 2.	1. 2.11.	17	4
N/9	61	68	18. 2.	17. 7.	1.15. 9.	16. 5.	17.10.	1.14. 3.	9	9
N/10	34	84	1. 1. 6.	1. 8. 4.	2. 9.10.	8.10.	11. 4.	1. 0. 2.	13	2
N/11	49	62	13. 0.	6. 7.	19. 7.	10. 4.	5. 2.	15. 6.	2	1
N/13	99	98	15. 9.	17. 0.	1.12. 9.	12. 0.	16. 4.	1. 8. 4.	7	7
N/14	7	39	4. 8. 4.	14.10.	5. 3. 2.	15. 0.	9. 1.	1. 4. 1.	26	5
N/15	15	50	1.14. 7.	12. 5.	2. 7. 0.	10. 3.	10. 2.	1. 0. 5.	12	3
N/16	51	53	1. 5.10.	12. 1.	1.17.11.	1. 4. 7.	11.11.	1.16. 6.	10	11
N/20	65	71	1.16. 8.	1. 2. 2.	2.18.10.	1.14. 6.	14.11.	2. 9. 5.	21	18
N/21	26	36	2.10. 1.	18. 2.	3. 8. 3.	1.15. 2.	1.10. 7.	3. 5. 9.	23	23
K/1	17	9	1.10.11.	12.11.	2. 3.10.	3. 1. 1.	17.10.	3.18.11.	11	26
K/2	97	62	10. 8.	8. 2.	18.10.	18. 0.	19. 3.	1.17. 3.	1	13
K/3	16	22	1.16. 7.	17. 2.	2.13. 9.	1. 9.11.	1. 4. 7.	2.14. 6.	16	20
K/4	33	50	1. 6. 1.	1. 5. 0.	2.11. 1.	1. 3. 5.	1. 1.11.	2. 5. 4.	15	16
K/7	8	34	2.15. 5.	15. 7.	3.11. 0.	2. 8.11.	1. 1. 9.	3.10. 8.	24	25
K/9	26	13	1. 0. 0.	2. 0. 6.	3. 0. 6.	2. 0. 8.	2. 9.10.	4.10. 6.	22	27
K/10	53	39	13. 7.	14. 5.	1. 8. 0.	19. 4.	1. 4. 6.	2. 3.10.	5	15
L/1	16	63	1.11.11.	1. 6. 8.	2.18. 7.	10. 0.	19.10.	1. 9.10.	20	8
L/3	20	29	1. 4. 7.	1. 6. 1.	2.10. 8.	16.11.	18. 0.	1.14.11.	14	10
L/4	9	32	3. 6. 2.	2. 8. 2.	5.14. 4.	19. 9.	1.18. 4.	2.18. 1.	27	21
L/5	38	40	1.10. 8.	1. 6. 3.	2.16.11.	1.17. 6.	1. 5. 5.	3. 2.11.	19	22
L/7	14	35	1.12. 6.	3. 0. 0.	4.12. 6.	13. 6.	2.17. 0.	3.10. 6.	25	24

plants above and five below the budget band). The costs of five of these eight plants were again abnormal in 1962 (three above and two below the budget band) whereas those of the remaining three were within the normal range, i.e. inside the budget band. However, a further seven plants, whose costs were within the normal range in 1961, had abnormally high or low costs in 1962 (three plants above and four below the budget band).

Thus, whereas in each of two individual years the costs associated with 30 to 40 per cent of the surveyed plants were abnormally high or low, the costs of less than 20 per cent were abnormal for two years running. This suggests that irrigation costs on individual farms are subject to a good deal of chance variation from year to year, due to weather and other factors. (1)

Nevertheless, irrigation costs are also affected by the deliberate managerial decisions of farmers and, exceptionally, good or bad management can result in irrigation costs being consistently below

(1) This is borne out by the comparatively low co-efficient of rank correlation ($\varrho = 0.42$) obtained from an analysis of the 1961 and 1962 rankings of the 27 plants according to total costs per acre-inch.

or above the average of farmers doing similar amounts of irrigation with similar equipment. However, it appears that, generally speaking, farm-to-farm differences in the costs of applying an acre-inch of water in a particular year are at least as much due to chance as to differences in managerial skill.

5. General conclusions concerning costs.

(i) This survey has shown marked differences in the costs of irrigation amongst a comparatively small group of farms. These differences occurred not only between farms in each year of the survey but also between years on many individual farms.

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

(iii) If annual average usage is small (say, 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) But some unused capacity in an average season is probably inevitable: otherwise the plant may be unable to cope with the total demand in years of above average irrigation need. Moreover, the ownership of extra equipment over and above normal requirements may prove beneficial in an emergency. But, as with other forms of insurance, it must be left to each individual farmer to decide how much "cover" of this kind can be justified on economic grounds.

(v) Although still considerable, farm-to-farm differences in the variable costs of irrigation are somewhat less marked than the differences in fixed costs. Extremely high variable costs are generally due to exceptional conditions such as the use of mains water. More frequently, relatively high variable costs are the results of high labour usage. It is clear that on farms where at least one man is in full-time attendance when the irrigation plant is working, the number of man-hours per acre-inch tends to be considerably higher than where the plant is left unattended between spells of pipe-shifting. Some farmers maintain that full-time attendance is essential, but this seems to be questionable except perhaps in very exceptional circumstances.

CHAPTER III

DOES IT PAY ?

1. Yield Responses in 1962.

The difficulties of obtaining reliable information on the benefits of irrigation were discussed at some length in last year's report. (1)

In 1962 also, the farmers taking part in the survey were asked about the economic benefits they thought they had obtained from irrigation in that particular season. The general picture which emerged from the replies given was strikingly similar to that obtained in the previous year.

In view of the similarity in weather between the two seasons - drought conditions early in the season followed by adequate rainfall - this result is not surprising. In both years, those who irrigated early maturing crops such as early potatoes and peas were confident that the costs of irrigation had been more than covered by the extra returns received either because of earlier maturity (and higher prices) or from higher yields. Those who had irrigated grassland early in the season were also generally of the opinion that a worth-while response had been obtained in the form of more grass, better quality grass, or both.

Maincrop potato growers were also nearly unanimous in believing that they had obtained an economic response from irrigation in both 1961 and 1962.

The crop concerning which producers were most doubtful about the value of irrigation during the two years covered by the survey was sugar beet. Although, in both seasons, a few growers thought they had obtained a worthwhile increase in yield, the majority were non-committal.

In 1962 the results of properly controlled irrigation experiments were again available from one farm (N/8) situated on the bunter sandstone of North Nottinghamshire. These results are shown below:

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(1) INGERSENT, K.A. op. cit.

Crop	Extra Yield with Irrigation (per acre)	Remarks
Early potatoes:		
Arran Pilot	2.6 tons	Lifted between 3rd and 19th July
Ulster Prince	1.7 tons	
Maincrop potatoes:		
King Edward	2.8 tons	
Majestic	1.4 tons	
Peas (threshed)	3.8 to 15.2 cwts.	Higher increase from early irrigation (at flowering): lower increase from watering late (at podding)
Wheat	4.0 cwts.	
Barley	4.75 cwts.	
Sugar beet	No response	

2. Costs of irrigating individual crops.

The averages and ranges of total per acre expenditure on irrigation for the four major irrigated crops, on farms included in the 1962 survey, are shown in Table 8. These costs rest on the assumption that, on each individual farm, irrigation costs per acre-inch were the same for all crops.

TOTAL EXPENDITURE PER ACRE ON THE IRRIGATION OF INDIVIDUAL CROPS

1962 results.

TABLE 8

Crop	No. of farms	Av. rate of application (ins. per ac.)	Av. total cost per acre-inch	Total cost per acre	
				Average	Range
			£. s. d.	£. s. d.	£. s. d. £. s. d.
Early potatoes	25	3.09	3. 2. 0.	8. 1. 3.	1.16. 6. to 17. 5. 9.
Maincrop potatoes	29	2.68	2.15. 6.	6. 5. 9.	2. 0.10. to 22. 0. 6.
Sugar beet	34	1.80	2. 7. 1.	3.16. 2.	1. 5. 6. to 7. 9.11.
Grass	24	2.01	2. 2. 5.	3.19.11.	17. 5. to 13.10. 3.

In reporting the results of the 1961 survey it was remarked that differences in average cost per acre between crops were principally due to differing average rates of application. This conclusion is only partially borne out by the results of the 1962 survey. Thus, for example, although, on average, the irrigation of an acre of early potatoes cost twice as much as the irrigation of an acre of grass, the potatoes only received $1\frac{1}{2}$ times as much water as the grass. The discrepancy is accounted for by the fact that, on average, the total cost per acre-inch was substantially higher for early potatoes than for grass. In fact, in these terms, the costs of irrigating both early and maincrop potatoes appear to have been materially greater than the costs of irrigating sugar beet and grass. In view of the oft-expressed view that moving pipes is more difficult and laborious in potatoes than in most other crops, particularly when the haulm is well developed and nearly meets between the rows, this result is in accordance with what practical experience would tend to suggest.

Break-even Yield Increases.

In calculating the break-even yield increases needed to bring in sufficient extra revenue to cover the extra costs of irrigation, for each of the four crops listed in Table 8, the following farm-gate prices have been assumed:

	Per ton
	£. s.
Early potatoes	25. 0.
Maincrop potatoes	13.15.
Sugar beet	6. 8.
Grass (as hay)	7. 0.

The approximate break-even yield increases, based on these prices and the average and the highest irrigation costs per acre as shown in Table 8, are given below. Shown in brackets beside each break-even yield increase is the corresponding figure obtained from the results of the 1961 survey (1) (already published in the first report on this enquiry).

	Extra yield (cwts per acre) needed to cover	
	Average total cost	Highest total cost
Early potatoes	6 (5)	14 (11)
Maincrop potatoes	8 (9)	18 (20)
Sugar beet	12 (13)	23 (26)
Grass (as hay)	11 (11)	39 (21)

(1) Following the results of the 1963 Farm Price Review, the assumed farm-gate price for maincrop potatoes has been increased 10s. 0d. per ton in this report: assumed prices of remaining crops remain the same as previously.

On the whole, the estimates of break-even yield increases based on two seasons' results are remarkably similar. The tentative conclusion of the first year's survey is therefore confirmed, namely that, even at the highest cost level, the yield increases required to break even with the extra costs involved are not unduly high in relation to many of the published results of irrigation experiments.

The extra yields shown above would be sufficient to cover the total costs of irrigation. However, since the fixed costs of irrigation are inescapable, the farmer who already has an irrigation plant and who has to decide whether it will pay to irrigate a "marginal" field only needs to know that he can cover the variable costs of irrigating the field.

Table 9 shows the averages and ranges of variable per acre costs of irrigation, on farms included in the 1962 survey, for the four major crops already discussed above.

VARIABLE EXPENDITURE PER ACRE ON THE IRRIGATION OF INDIVIDUAL CROPS

TABLE 9 — 1962 results.

Crop	Variable cost per acre	
	Average	Range
	£. s. d.	s. d. £. s. d.
Early potatoes	4. 1. 4.	16. 4. to 10. 2. 9.
Maincrop potatoes	2.19. 0.	15.10. to 13.16. 8.
Sugar beet	1.15. 9.	12. 9. to 4. 0. 5.
Grass	1.15. 6.	9. 0. to 3. 2. 6.

The approximate break-even yield increases calculated on the basis of the variable costs shown in Table 9, and the same prices as before, are shown below. The corresponding figures based on the results of the 1961 survey are again shown in brackets.

	Extra yield (cwts. per acre) needed to cover	
	Average variable costs	Highest variable costs
Early potatoes	$3\frac{1}{4}$ ($2\frac{1}{2}$)	8 ($5\frac{1}{2}$)
Maincrop potatoes	$3\frac{1}{4}$ (4)	10 (8)
Sugar beet	$5\frac{1}{2}$ (6)	13 (12)
Grass (as hay)	5 ($3\frac{1}{2}$)	9 (6)

Again, the calculations based on two different year's irrigation costs point to the same broad conclusions. For these crops, the break-even yield increases required to justify the greater utilisation of an existing irrigation plant are quite low, even at the highest levels of variable cost per acre encountered on farms included in this enquiry. This conclusion tends to support the view that once an irrigation plant has been acquired it can be used with advantage almost as a routine operation, whenever crops appear likely to show a positive response, rather than only occasionally under conditions of extreme drought. Considerable circumstantial evidence has been collected during this survey that a good many farmers with irrigation equipment still tend to apply too little water and too late.

Extra fertilisers.

There is some experimental evidence that grass is better able to withstand the effects of drought when the nitrogen status of the soil is high than when it is low. In other words, it would appear that supplementary nitrogen and irrigation are to some extent substitutes.

Nevertheless, a good many farmers appear to find that when they irrigate grass extra nitrogen is beneficial also. Just over half the farmers surveyed in 1962, who had irrigated grass, stated that they had applied extra nitrogenous fertiliser as a direct consequence of irrigation (A similar proportion of farmers in the smaller 1961 sample gave a similar answer to this question). Some farmers stated specifically that the extra fertiliser was applied immediately before irrigation and between "harvests", i.e. cuts or grazings, and this was implied in nearly all the answers. The amount most commonly quoted was an additional 2 cwts. per acre of nitro-chalk or sulphate of ammonia before each extra cut or grazing.

The position appears to be, therefore, that on many farms where irrigation of grassland is practised, although the amount of top dressing per "harvest" is unchanged, the total quantity of nitrogenous fertiliser applied is similarly increased because a higher total number of harvests is aimed at during the season.

CHAPTER IV

IRRIGATION NEED IN 1962

1. Method of Estimation.

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 1962. Rainfall records from a total of 12 stations were used.

In two cases rainfall records actually collected on the farm itself were used and a further 15 farms are within five miles of a recording station. The maximum distance between a surveyed farm and a rainfall recording station was approximately 14 miles.

Although, in each of the two years covered by the survey, the same basic method of estimating the irrigation need on each farm was used - the "water balance sheet" method [1] - in 1962 an attempt was made to allow for the varying needs of different crops during different periods of the season. Details of the optimum soil moisture conditions assumed to be required by each of the main crops or groups of crops are as follows: -

Grass, Vining Peas and Other Row Crops.

Field capacity minus a cumulative planned deficit of half an inch per month over the whole of the six month period from April to September.

First Early Potatoes.

As for grass over the three month period from April to June only.

Second Early Potatoes, Maincrop Potatoes and Sugar Beet.

Half the estimated requirement for early potatoes during the April - June period plus the full requirement, as estimated for grass, during July and August.

Cereals.

As for grass and early potatoes, but without a planned deficit, during April and May only.

(1) For a detailed description of this method see, INGERSENT, K.A., op. cit., p. 29.

The estimated total irrigation needed in 1962 by crops grown in the vicinity of each of the 12 rainfall recording stations is shown in Appendix 2.

The overall average irrigation need of the crops irrigated on each farm was then calculated as shown in the example below:

Crop	Acres	Theor. need (ins.)	Theor. no. of ac. ins.	Actual no. of ac. ins.
Sugar beet	102	2.39	243.8	252.0
Grass	36	3.94	141.8	54.0
Peas	42	3.94	165.5	47.0
Barley	58½	0.99	57.9	88.0
	238½		609.0	441.0

The total irrigation actually applied on this farm was

$$\frac{441 \times 100}{609} = 73 \text{ per cent of the total theoretical need.}$$

To facilitate comparisons between farms, both theoretical irrigation need and actual application were divided by the total acreage irrigated. Thus in the above example the theoretical need was

$$\frac{609 \text{ ac. ins.}}{238.5 \text{ acres}} = 2.55 \text{ ins. per acre, and the actual average}$$

rate of application

$$\frac{441 \text{ ac. ins.}}{238.5 \text{ acres}} = 1.85 \text{ ins. per acre.}$$

Theoretical irrigation needs and the actual rates of application on each farm, expressed in these terms, are shown in Table 10.

2. Difference between Estimated Need and Actual Application.

Between different farms, the actual application of water ranged from a high of 175 per cent to a low of only 22 per cent of the theoretical need. However, the amount of water actually applied exceeded the theoretical requirement on only eight of the 44 farms surveyed in 1962, and, on average, within the group as a whole, crops received rather less than three quarters of the irrigation requirement. Nearly an inch more 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 the basis described above. On some individual farms the shortfall exceeded two inches. (1)

(1) These results are in broad agreement with those obtained in 1961 using the more conservative of two alternative methods of estimating total irrigation need on each farm. See, INGERSENT, K.A. op. cit., p. 31 and Table 12.

"IRRIGATION NEED" on individual farms.

April to September, 1962.

TABLE 10

Farm Code No.	"Irrigation need"	Actual rate of application	Difference between actual rate and irrigation need	Actual rate as % of theor. need
	inches of water			
N/1	3.08	4.32	+ 1.24	140
N/4	1.66	1.45	- 0.21	87
N/5	3.29	3.11	- 0.18	95
N/6	2.86	2.02	- 0.84	71
N/7	2.51	2.07	- 0.44	82
N/8	3.68	2.47	- 1.21	67
N/9	2.55	1.85	- 0.70	73
N/10	2.66	4.66	+ 2.00	175
N/11	3.56	2.50	- 1.06	70
N/13	3.81	2.62	- 1.19	69
N/14	4.50	2.78	- 1.72	62
N/15	3.60	1.84	- 1.76	51
N/16	3.33	2.35	- 0.98	71
N/19	2.95	1.98	- 0.97	67
N/20	3.45	2.07	- 1.38	60
N/21	2.06	2.15	+ 0.09	104
N/24	3.09	3.88	+ 0.79	126
N/25	2.94	3.48	+ 0.54	118
N/28	2.39	3.00	+ 0.61	126
L/1	3.75	2.99	- 0.76	80
L/3	2.28	1.90	- 0.38	83
L/4	2.94	1.74	- 1.20	59
L/5	3.32	2.43	- 0.89	73
L/7	2.69	1.03	- 1.66	38
L/8	2.79	1.29	- 1.50	46
L/12	2.84	1.86	- 0.98	65
L/16	2.31	0.65	- 1.66	28
L/17	4.79	2.00	- 2.79	42
L/18	2.52	0.55	- 1.97	22
L/20	3.02	1.62	- 1.40	54
L/21	3.28	3.50	+ 0.22	107
L/22	2.78	2.00	- 0.78	72
L/23	3.13	2.52	- 0.61	81
K/1	2.70	1.50	- 1.20	56
K/2	3.71	1.43	- 2.28	39
K/3	2.49	1.06	- 1.43	43
K/4	2.70	3.00	+ 0.30	111
K/5	3.01	2.47	- 0.54	82
K/7	2.84	0.68	- 2.16	24
K/9	3.81	1.59	- 2.22	42
K/10	3.39	1.46	- 1.93	43
K/11	3.16	1.15	- 2.01	36
K/12	3.12	1.81	- 1.31	58
K/13	2.80	2.44	- 0.36	87
Av.	3.05	2.17	- 0.88	72

In the report on the 1961 irrigation survey the following were put forward as possible reasons explaining the discrepancy between theoretical irrigation requirements and the amounts of irrigation actually applied by farmers:

(i) Differences in rainfall between the farms and the rainfall recording 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.

The importance of the first reason was discounted due to the fact that at least 80 per cent of the farmers in the survey applied less than the theoretical requirements of water (if this reason was of prime importance one would expect to find that about half the farmers applied more and the remaining half less than the theoretical requirement). The results of the 1962 survey fully confirm this conclusion.

The second reason was certainly of importance on a number of farms, but on the evidence provided by Table 4 (p. 9) these did not constitute a majority of those surveyed. Half the farmers interviewed stated categorically that the main reason preventing greater use of their irrigation equipment in 1962 was the lack of crops needing more water.

Thus, by a process of elimination, one is forced to the conclusion that the third reason is probably of major importance. The results obtained in both years of the present survey strongly suggest either that estimates of irrigation need based on present methods of calculation are too high or that many farmers consistently underestimate the quantities of water required by their crops. (1) There is clearly a need for work to be done to find out whether irrigating fully up to the level indicated by the water balance sheet method of calculating irrigation need really is consistent with attainment of the highest possible level of profits under commercial conditions. In other words, does an optimum calculated on the basis of purely technical considerations (i.e. the relationship between natural rainfall and potential transpiration) serve as an entirely satisfactory guide to farmers whose goal is the economically optimum amount of irrigation, that is, the amount of irrigation giving the greatest possible margin between additional returns and the additional costs involved ?

(1) The results of at least one other survey point to a similar conclusion. See DADD, C.V., Survey of Irrigation Practice, 1961. N.A.A.S. Qu. Rev., Vol. XIV, No. 57, Autumn 1962.

If the application of objective methods of estimating irrigation need really is superior to the farmer's intuitive judgement then this needs to be demonstrated in practice. In future, users may then enjoy the benefits of using irrigation with greater precision and with greater certainty of worthwhile results than at present.

3. 1962 and the "Normal Irrigation Year" compared.

It is estimated that, over the whole of the six month period from April to September 1962 the average irrigation need amongst seven rainfall recording stations in the survey area exceeded the long-term average by nearly 40 per cent.

The average irrigation need amongst these seven stations was, in total, almost the same both in 1962 and in the previous year 1961 (Table 11). Moreover, the two seasons were similar in that the need for irrigation was confined to the months of May, June, and July (though in 1962 the need during May was negligible over most of the survey area).

MONTHLY SOIL MOISTURE DEFICITS

1961 and 1962 compared with the 1916 - 50 average.

TABLE 11

Month	Monthly soil moisture deficit (inches)				
	Average 1916-50	1961	Difference from average	1962	Difference from average
April	-	-	-	-	-
May	0.65	1.11	+ 0.46	0.16	- 0.49
June	1.44	2.44	+ 1.00	2.78	+ 1.34
July	0.58	0.45	- 0.13	0.92	+ 0.34
August	0.16	-	- 0.16	-	- 0.16
September	-	-	-	-	-
Total - 6 months	2.83	4.00	+ 1.17	3.86	+ 1.03

The conclusion, then, is that although, in both these years, the period of irrigation need was comparatively short, nevertheless both were years in which the total extra water required amounted to considerably more than the long-term average requirement. (1)

The size of the irrigation plant required on a farm partially depends upon the period of time within which the irrigation needs to be performed as well as upon the total acreage covered and the

(1) Based on actual rainfall over the period from 1916 - 1950.

amount of water applied. Moreover, as shown above, irrigation need was markedly concentrated in the early summer months both in 1961 and 1962. Nevertheless, the fact that in two years of above average irrigation need the actual utilisation of the surveyed plants averaged well under half their estimated maximum capacity strongly suggests that many of the farmers concerned are over-equipped in relation to their existing acreage of irrigated crops.

CHAPTER V

ESTIMATING THE EFFECT OF IRRIGATION ON FARM PROFITS

In conclusion, it is proposed to show how the results of this survey and information obtained from other sources can be used to estimate the extra profits potentially obtainable from the use of irrigation on a farm.

1. Information Required.

To enable the correct decision to be made, four main kinds of information are required when the installation of an irrigation plant is under consideration.

Firstly, there is the question of capital requirements. Secondly, information is needed to form the basis of estimates of the annual costs of plant ownership and operation. Thirdly, a reliable basis is needed upon which to estimate the additional crop yields and financial returns that are likely to be obtained. Fourthly, since, with the adoption of irrigation, it may become profitable to make fundamental changes in the cropping and stocking of the farm, a wide range of information is needed to enable the profitability of alternative re-organisation plants to be tested.

Capital requirements.

These were discussed at length in the first section of Chapter II. The most important factors determining the size of the capital outlay are, firstly, the size and type of plant and, secondly, the nature of the water source.

The required size and type of irrigation plant is in turn dependent upon such considerations as:

(a) kinds of crops to be irrigated and the total acreage of each,

(b) irrigation need of each crop both with respect to the amount and the season of application, and

(c) farm size and layout, and the location of irrigated fields in relation to the water source.

Where water is available from a surface source, such as a river, stream, lake or pond, the capital needed for source works is normally nil, or quite insignificant in amount. In contrast, where it is necessary to sink a borehole or to build an artificial reservoir to obtain a supply of water the extra capital required for this purpose may be very substantial.

Annual costs of plant ownership and operation.

Annual fixed costs are determined, firstly, by the amount of

capital invested and, secondly, by the rate of plant depreciation due to usage and obsolesence, together with interest on the capital invested.

Annual variable costs are determined mainly by the amounts of labour and fuel used for irrigation and by the expenditure on repairs to equipment. Although water from a public supply is not commonly used for irrigation, due to its high cost, where it is used it constitutes an important variable cost. The total amount of each of these variable costs in any particular year depends on the usage of the plant which, in turn, depends on irrigation need.

In thinking about farm management problems it is sometimes necessary to recognise resources which, although variable in relation to the performance of a particular operation, may nevertheless be fixed in relation to the farm as a whole. For instance, regular farm labour intermittently performing irrigation work during the summer varies in amount (and therefore cost) from year to year according to the quantity of irrigation needed. At the same time the size of the regular labour force may well remain fixed from year to year from the point of view of the farm as a whole. It follows that although, in a sense, the cost of all irrigation labour is variable, the extent to which regular workers can be diverted to irrigation from other tasks, without adversely affecting the economy and profitability of the farm as a whole, will generally be subject to a definite upper limit. Therefore, although in this survey all irrigation labour was charged at a standard rate per hour, in practice account should be taken of the real cost of employing regular workers on irrigation in terms of the opportunities given up for the profitable use of labour elsewhere on the farm.

It should also be borne in mind when planning that although water is generally free it may nevertheless be limited in quantity particularly in seasons, or at times during any particular season, when the potential benefits of irrigation are at maximum.

In summary, then, in planning the use of irrigation on any farm it must be recognised that the use of the plant may sometimes be restricted due to the limited availability of key resources such as water and labour.

Additional returns.

With cash crops the additional returns depend upon the kinds of crops irrigated, the extra yields obtained and the improvement, if any, in the market prices received for crops sold. Of these factors the most important, and probably the most difficult to estimate, are the yield responses. In particular, there is a need for reliable information on the relationship between yield per acre and the application of a standard quantity (say, one inch) of irrigation, allowing for differences in soil type and the geographical

location of farms. Such information is vitally needed to enable yield responses to be estimated in relation to different total rates of application (inches per acre).

With the irrigation of grassland, estimation of additional returns is complicated by the problem of utilisation. Most important, it is essential to know what increase in the stocking rate is needed to ensure the efficient utilisation of the extra herbage produced by irrigation.

Managerial Adjustments.

In order to determine the extent to which the availability of irrigation makes it profitable to introduce new enterprises onto the farm (and/or to drop old ones), information is required concerning input/output relationships, the costs of variable inputs, capital requirements and product prices for all such enterprises.

Moreover, quite apart from changes in the kinds of crops grown and the types of livestock kept, the adoption of irrigation often leads to the intensification of existing enterprises and this, in turn, may entail increases or decreases in expenditure on variable inputs such as feeding stuffs and fertilisers and to additional capital outlays for livestock and even buildings. Information on the likel magnitude of such changes is therefore needed for planning pur poses.

Moreover, it must not be overlooked that the introduction of nev enterprises, or even expansion of existing ones, may entail an increase in the size of the regular labour force due to the augmentation of labour requirements during certain critical periods.

2. Sources of Information.

Capital requirements.

As a first step, the farmer must decide what crops he wishes to irrigate and the acreage of each. Different crops require irrigation at different periods of the season but the irrigation need during the peak period determines the maximum plant capacity for which provision needs to be made. The present author has described elsewhere a method which may be employed to estimate irrigation need in the driest years of a ten year cycle. (1)

Once the maximum amount of irrigation likely to be required during any one season has been decided, the required capital outlay can be estimated by either of two methods.

(1) INGERSENT, K.A. Seasonal Variation in the Costs of Grassland Irrigation. Farm Management Notes, No. 29.

One alternative is to obtain a quotation for a specific scheme from the manufacturers of irrigation equipment or from a firm of irrigation engineers. This method is virtually the only reliable one for schemes involving the construction of permanent installations such as underground mains, boreholes and reservoirs. A second alternative, feasible in the cases where a relatively simple portable scheme is envisaged, is to make a rough estimate of capital costs from manufacturers' catalogues and price lists, or from figures given either in the first report on this survey, (1) or in similar publications. (2)

Annual costs of plant ownership and operation.

Suggestions regarding the average lengths of economic life which different kinds of irrigation equipment may be expected to have are given in Appendix 3. These are largely based upon equipment manufacturers' experience.

Information on variable costs per acre-inch, under average conditions, can be obtained from this and other similar reports. (3)

A method of estimating irrigation need, and hence total variable costs over a ten year period has been described elsewhere by the present author. (4) Total variable costs based on the annual average irrigation need over ten years are most useful for planning purposes.

Additional Returns.

This is where sufficient reliable information is most conspicuously lacking. This is true both with respect to information about yield responses and about the effect of irrigation on crop quality and prices.

Regarding yields of irrigated crops, the best source of information is undoubtedly the results of controlled experiments carried out under soil and climatic conditions closely resembling those of

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(1) INGERSENT, K.A., Costs of Farm Irrigation, F.R. No. 148 May, 1962, Chapter II.

(2) NIX J.S. and PRICKETT, C.N., Farm Crop Irrigation: the Economic Aspects, University of Cambridge, School of Agriculture, Farm Economics Branch Report No. 55.
NATURAL RESOURCES (TECHNICAL) COMMITTEE, Irrigation in Great Britain, H.M.S.O. 1962.

(3) e.g. NIX and PRICKETT. op. cit. or,
NATURAL RESOURCES (TECHNICAL) COMMITTEE. op. cit.

(4) INGERSENT, K.A., Seasonal Variation in the Costs of Grassland Irrigation, Farm Management Notes No. 29. University of Nottingham, Department of Agricultural Economics, Spring 1963.

the farm in question. Some such results, relating to experiments carried out in various parts of the country, are reported in an official governmental report, [1] and in a report issued from the University of Cambridge [2]. Of particular interest in the East Midlands is the information on the results of irrigation experiments with potatoes and sugar beet published in the Annual Reports of Gleadthorpe Experimental Husbandry Farm between 1955 and 1960.

However, due to the general dearth of information about the yields of irrigated crops based on controlled experiments, a good deal of reliance has to be placed on the remaining and second-best source of information - the experience of neighbouring farmers and others already using irrigation on the same crops. Quite apart from the difficulties of accurately recording yields under ordinary farm conditions, the fact is that farmers who irrigate rarely leave any part of a crop unirrigated. Consequently they can only guess at the response to irrigation. Guesswork is an unsatisfactory quide to planning and should only be resorted to when nothing more reliable is available.

Planning should be based on average yield increases, including years in which there is no response or irrigation is unnecessary.

With regard to the effect of irrigation on the quality and market prices of crops, systematic information is virtually non-existent. With a crop like early potatoes, where irrigation may result in earlier maturity and harvesting, it may be possible to make a rough estimate of the price premium due to earlier marketing from the pattern of seasonal prices shown by the weekly market reports of Ministry of Agriculture which are published in the trade press.

With irrigation becoming ever more widely practised, it is probably now unwise to budget for scarcity prices in very dry seasons.

Managerial Adjustments.

Potentially profitable changes in cropping and stocking, consequent on the introduction of irrigation, may either involve the expansion of some existing enterprises (and the reduction or elimination of others) or the introduction of entirely new enterprises. Valuable information for use in planning adjustments of both these kinds is obtainable from "The Farm as a Business", published by the Ministry of Agriculture or from the regional farm management handbooks issued by some Centres of the Provincial Agricultural Economics Service. [3]

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(1) NATURAL RESOURCES (TECHNICAL) COMMITTEE, op. cit.

(2) NIX and PRICKETT, op. cit.

(3) e.g. THEOPHILUS, T.W.D. Farm Planning Handbook. University of Nottingham, Department of Agricultural Economics, March, 1962.

There is no readily available source of information concerning the effect of irrigation on the optimum use of fertilisers, pesticides, and other variable resources, or on the amount of extra labour needed for harvesting and the extra costs of marketing a larger crop. Obviously, much variation can be expected according to the differing circumstances of farms and farmers.

Additional experimental work is needed to throw light on some of these problems, e.g. optimum levels of fertiliser application for use in conjunction with irrigation.

3. Construction of Budgets.

A hypothetical sandland farm of 300 acres will be used to exemplify the application of the budgeting technique to the problem of estimating the effect of introducing irrigation upon overall farm profit. The initial cropping and stocking of the farm is assumed to be as follows.

A five-course rotation is followed, consisting of one year each of wheat, roots and Italian ryegrass, and two years of barley. Thus, each year, the cropping consists of 120 acres barley, 60 acres wheat, 60 acres one year ley, and 30 acres each of sugar beet and maincrop potatoes.

On the livestock side, it will be assumed that there is a flock of 120 breeding ewes, the progeny being fattened on the grass.

The farm labour force is assumed to consist of four regular men (excluding the farmer himself) plus casual labour for the sugar beet and potatoes.

The gross margins from the various crop enterprises and the sheep, the fixed costs of the farm, and hence the net farm income, are assumed to be as follows: -

Enterprise Gross Margins.			£
Wheat	-	60 acres at £ 26	1,560
Barley	-	120 acres at £ 25	3,000
Sugar beet	-	30 acres at £ 47	1,410
Potatoes	-	30 acres at £ 50	1,500
Sheep	-	120 ewes at £ 5	600
			8,070

Fixed Costs.			£	
Labour	-	4 regular men at £ 600	2,400	
Rent Machinery depreciation Miscellaneous	}	300 acres at £ 10	3,000	
				5,400
		NET FARM INCOME		£ 2,670

The initial net farm income, then, amounts to just under £ 9 per acre.

For the sake of simplicity in explaining the procedure, only two alternative plans for the use of irrigation on the farm will be considered. In actual practice it might well be advisable to consider more than two such plans.

Plan 1.

With this plan, the top priority would be given to the irrigation of 60 acres roots (30 acres potatoes + 30 acres sugar beet) during July and August and the size of plant would be planned on this basis, i.e. sufficient sprinklers to cover 60 acres in a ten day cycle.

Since the root crops would not require irrigation during the early part of the summer except, perhaps, in very exceptional circumstances, the plant should be available for use on the 60 acres of grassland during May and June. It is assumed that irrigation would enable the grassland to carry one extra ewe to the acre, i.e. increasing the original flock of 120 ewes by 60 to a total of 180 head. The policy would then be to get as many lambs as possible sold off irrigated grass by mid-July.

Plan 2.

This provides for a number of fundamental changes in the cropping and stocking programme of the farm.

Firstly, the sheep enterprise would be dropped and grass eliminated from the rotation. The 60 acres of land so released for other cropping would be put into an entirely new cash crop - vining peas. (1)

Secondly, 15 of the original 30 acres of maincrop potatoes would be replaced by first early potatoes.

In making these changes, it is implicitly assumed that neither vining peas nor early potatoes could be grown economically without irrigation on the type of land in question in a low rainfall area.

Thus, under Plan 2, there would be no livestock on the farm and the completed cropping programme would be as follows: -

> 180 acres cereals, 30 acres sugar beet, 15 acres maincrop potatoes, 15 acres early potatoes, and 60 acres vining peas.

Priorities for receiving irrigation would be allocated as follows: -

(1) A processor's contract is, of course, needed for this crop: it is assumed that this can be obtained.

May and June	15 acres early potatoes and 45 acres vining peas.
July and August	15 acres maincrop potatoes, 30 acres sugar beet, and 15 acres vining peas.

As with Plan 1 the required size of plant would be sufficient sprinklers to cover 60 acres in a ten day cycle.

Capital Budget.

It is assumed that an adequate supply of suitable water is freely available from a river, stream or lake and the farmer decides in favour of a completely portable irrigation plant with a tractor-driven pump. The estimated capital requirements, and the annual fixed costs of plant ownership, (1) are set out below: -

	Capital Costs	Annual Fixed Cost
	£	£
1 tractor pump	200	29
60 sprinklers	660	
¼ mile mainline	1,320	231
Miscellaneous equipment	60	
TOTAL	£ 2,240	£ 260

The length of mains piping required has been arbitrarily determined. Obviously, this will vary greatly in practice according to the size and shape of the farm and the nature and position of the source of water.

Irrigation Need.

Before proceeding with the estimation of the variable costs of irrigation on the example farm a necessary first step is to estimate the irrigation need of the various crops in the "average season" including seasons when, for one or more of the crops, no irrigation is needed. For this purpose, although the example farm is purely hypothetical, it is nevertheless necessary to place it in a defined geographical area. It will, therefore, be assumed that the farm is in North Nottinghamshire, near to Worksop.

Estimates of the total irrigation need in an average season, and also in the driest season during a ten year period, are set out

(1) Based on the same assumptions regarding depreciation and interest rates as elsewhere in the study: for details, see Appendix 3.

below for each of the two plans. (1)

Crop	Irrigation needed (inches per acre)		Acreage	Total acre-inches required	
	Average season	Driest season		Average season	Driest season
			PLAN 1		
Maincrop potatoes	2.5	5.0	30	75	150
Sugar beet	2.5	5.0	30	75	150
Grass	2.0	4.5	60	120	270
				270	570
			PLAN 2		
Early potatoes	2.0	4.5	15	30	67½
Maincrop potatoes	2.5	5.0	15	37½	75
Sugar beet	2.5	5.0	30	75	150
Vining peas	2.0	4.5	60	120	270
				262½	562½

Although the estimates of total irrigation need for both plans are virtually identical, this is purely co-incidental.

Total variable costs.

The assumed variable costs per acre-inch, based on the results of the present survey, are as follows: -

	s. d.	
Labour	7. 6.	(i.e. 1¼ man-hours at 6s. 0d.) (2)
Fuel and oil	6. 6.	(including transport of pipes)
Repairs and tractor depreciation	5. 0.	
TOTAL	19. 0.	

(1) The method of estimation used is described in "Irrigation", Ministry of Agriculture, Fisheries and Food. Bulletin No. 138. H.M.S.O. Londen, 1962. The recommendations given in the bulletin as to when different crops require irrigation were followed except that here no provision has been made for the irrigation of grass after the end of June. The bulletin makes no specific recommendations regarding the irrigation of sugar beet or vining peas. For the present purpose, the sugar beet crop was regarded as requiring irrigation during the same period as maincrop potatoes, and vining peas, during the same period as grass.

(2) Total irrigation labour requirements are assumed to be 2½ man-hours per acre-inch. However, it is further assumed that half this requirement is supplied by the farm's regular labour force during normal working hours and that the remaining half is overtime which has been charged at the statutory overtime wage rate for adult male workers.

The total variable costs of irrigation associated with each of the two plans are, therefore as follows: -

Plan 1.

		£
Average season	- 270 acre-inches at 19s. 0d.	257
Driest season	- 570 acre-inches at 19s. 0d.	542

Plan 2.

Average season	- 262½ acre-inches at 19s. 0d.	249
Driest season	- 562 acre-inches at 19s. 0d.	534

Total Costs of Plant Ownership and Operation.

These are merely the sum of the fixed and variable costs already worked out. Details are as follows: -

Plan 1.		Average season	Driest season
		£	£
Fixed costs		260	260
Variable costs		257	542
	TOTAL	517	802
Plan 2.			
Fixed costs		260	260
Variable costs		249	534
	TOTAL	509	794

Other Additional Costs.

In addition to the actual costs of irrigation, the implementation of both plans would entail additional costs of other kinds.

Details of the estimated cost of these additional items are as follows: -

Plan 1.

	£
N. fertiliser for grassland - 60 acres at 30s. 0d.	90
Concentrates for 60 ewes at 25s. 0d.	75
Other incidentals for 60 ewes at 15s. 0d.	45
15 gimmers (replacements) at £ 10	150
Annual cost of replacing one extra ram	9

It is assumed that the larger ewe flock which is a feature of Plan 1 could be managed by the existing regular labour force.

Plan 2.

For vining peas: -

		£
Seed	60 acres at £ 11.	660
Fertilisers	" " " £ 3. 5s.	195
Repairs and fuel	" " " £ 3. 10s.	210
Spraying	" " " £ 4.	240
Transport to viner	" " " £ 5.	300
Annual depreciation and interest charges on specialised equipment (cutter-rower and green crop loader)		80

For early potatoes: -

Extra cost of seed (compared with maincrop)	15 acres at £ 10	150

The cutter-rower and green crop loader required for the vining peas would cost £ 350 to £ 400 and giving each a life of five years the annual fixed cost would be about £ 80, as shown.

It is not considered that, apart from a lorry driver - included in the estimated cost of transport to the viner - any extra labour would be required for the vining peas. This is because the only really labour-consuming operations - cutting and loading the peas - would be done during the relatively slack time between root hoeing and corn harvest. Although there might be some clash with the lifting of early potatoes, this should not result in any serious labour difficulties so long as the casual labour previously employed for lifting maincrop potatoes in October was available for lifting the earlies in late June and July.

Returns Foregone.

Plan 1. would not involve any loss of revenue compared with the present.

Plan 2. Detailed estimates of the revenue lost by giving up the sheep enterprise are as follows: -

		£
160 lambs	at £ 6. 10s.	1,040
24 cull ewes	at £ 3.	72
120 fleeces	at £ 1. 10s.	180
		1,292

Costs Saved.

Plan 1. would not involve any saving of costs compared with the present.

Plan 2. Detailed estimates of the savings associated with the implementation of this plan are as follows: -

	£
From the one year ley: -	
Seed, fertiliser, fuel and repairs - 60 acres at £ 5	300
From the ewe flock: -	
Concentrates for 120 ewes at 25s. 0d.	150
Other incidentals for 120 ewes at 15s. 0d.	90
30 gimmers (replacements) at £ 10	300
Annual cost of replacing 3 rams	27
From maincrop potatoes: -	
Difference in acreage levy between early and maincrop potatoes - 15 acres at £ 2	30

Extra Returns.

Plan 1. Detailed estimates are as follows: -

Potatoes:

Net increase in returns, 30 acres at £ 30	900

Sugar beet:

Net increase in returns, 30 acres at £ 9	270

Sheep:

80 lambs	at £ 6. 10s.	520
12 cull ewes	at £ 3.	36
60 fleeces	at £ 1. 10s.	90

The estimated net increase in potato returns is based on an assumed yield increase due to irrigation, of 2 tons per acre on average over a period of ten years. It has also been assumed that any increase in market value due to higher quality throughout the crop would be offset by the additional costs of harvesting and marketing the extra yield of potatoes.

The estimated net increase in the returns from sugar beet is based on an assumed average yield increase, due to irrigation, of $1\frac{1}{2}$ tons per acre.

Plan 2. Detailed estimates of the extra returns are as follows: -

	£
Maincrop potatoes:	
Net increase in returns, 15 acres at £ 30	450
Early potatoes:	
Net increase in returns, 15 acres at £ 50	750

Sugar beet:
As in Plan 1. 270

Vining peas:
Net increase in returns, 60 acres at £ 70 4,200

The net increases in the returns from maincrop potatoes and sugar beet have been estimated on the same basis as in Plan 1.

The net increase in returns from early potatoes is based on the estimated difference in gross output per acre between early potatoes grown with irrigation and maincrop potatoes grown without irrigation.

The estimated returns from the vining pea crop are based on an assumed total yield of 36 cwts of shelled peas per acre and a price of 40s. 0d. per cwt.

Extra Profits.

The foregoing estimates of extra costs, and costs saved, and of extra returns and returns foregone, relating to each of the two plans are summarised below.

PLAN 1

Extra costs:	£	Extra returns:	£
Irrigation (average season)	517	Potatoes	900
		Sugar beet	270
Other variable costs:		Sheep	646
Grass	90		
Sheep	279		
Returns foregone	nil	Costs saved	nil
MARGIN	930		
	£ 1,816		£ 1,816

PLAN 2

Extra costs:	£	Extra returns:	£
Irrigation (average season)	509	Maincrop potatoes	450
		Early potatoes	750
Other variable costs:		Sugar beet	270
Vining peas	1,685	Vining peas	4,200
Early potatoes	150		
Returns foregone		Costs saved	
Sheep	1,292	Ley	300
MARGIN	2,931	Sheep	567
		Maincrop potatoes	30
	£ 6,567		£ 6,567

It is estimated that the implementation of Plan 1. would increase net farm income by approximately £ 930 to a total of about £ 3,600 per year. Originally, the farm yielded a net income of just under £ 9 per acre: with Plan 1 carried into effect it should yield £ 12 per acre.

The additional profit of £ 930 represents an annual return of just over 40 per cent on the £ 2,240 invested in irrigation equipment.

By comparison, it is estimated that the implementation of Plan 2. would increase net farm income by approximately £ 2,930 to a total of about £ 5,600 per year. This represents approximately £ 18 per acre, or double the original net income of £ 9 per acre.

Including the investment in specialised equipment for harvesting the vining pea crop, the additional of profit £ 2,930 would constitute an annual return of more than 100 per cent on a capital outlay of approximately £ 2,600.

Conclusions.

Other plans incorporating the use of irrigation could doubtless be devised for the example farm, and some of these might well show an even higher additional profit than either of the plans described above. The main purpose of Plans 1 and 2, however, is not to describe the most profitable way in which irrigation might be employed on the example farm but to ilustrate the method of estimating the potential earning capacity of irrigation on any farm. However, Plans 1 and 2 have been deliberately chosen to illustrate a further point of considerable importance.

Plan 1 leaves the cropping and stocking and the basic organisation of the farm virtually unchanged. No new enterprises are introduced and irrigation is used only for increasing the output of existing enterprises. By contrast, Plan 2 provides for the elimination of one enterprise - the ewe flock - and the introduction of two entirely new ones - vining peas and early potatoes. The much greater profitability of Plan 2, compared with Plan 1, is a direct result of these fundamental changes in basic farm organisation. However, it is obvious that the successful implementation of Plan 2 would call for a much higher order of managerial skill and ability than Plan 1, which is much more straightforward. As with most new techniques in farming, irrigation is likely to yield its maximum economic potential only in the hands of the really first-class manager.

APPENDIX 1.

INDIVIDUAL FARM RESULTS - 1962

TABLE 1

Farm Code No.	Size of irrigation plant (acres)	Use of plant			Costs per acre-inch		
		Estimated maximum capacity of plant	Water actually applied	Percentage utilisation	Fixed	Variable	Total
		acre-inches			£. s. d.	£. s. d.	£. s. d.
N/11	1.25	300	187	62	10. 4.	5. 2.	15. 6.
N/10	2.00	480	401	84	8.10.	11. 4.	1. 0. 2.
N/15	1.80	432	214	50	10. 3.	10. 2.	1. 0. 5.
N/8	2.60	624	353	57	13. 9.	9. 2.	1. 2.11.
N/14	1.90	456	180	39	15. 0.	9. 1.	1. 4. 1.
N/1	7.75	1860	1360	73	10. 1.	15. 1.	1. 5. 2.
N/13	0.75	240	236	98	12. 0.	16. 4.	1. 8. 4.
L/1	3.00	720	452	63	10. 0.	19.10	1. 9.10.
N/9	2.70	648	441	68	16. 5.	17.10.	1.14. 3.
L/3	1.00	240	70	29	16.11.	18. 0.	1.14.11.
N/19	2.50	600	302	50	13. 1.	1. 2. 3.	1.15. 4.
N/28	3.45	828	387	47	15. 6	1. 0. 4.	1.15.10.
N/16	1.80	432	230	53	1. 4. 7.	11.11.	1.16. 6.
L/23	3.00	720	343	48	18. 7.	17.11.	1.16. 6.
N/5	3.00	720	473	66	1. 1. 0.	15. 7.	1.16. 7.
K/2	2.00	480	299	62	18. 0.	19. 3.	1.17. 3.
N/7	2.20	528	463	88	1. 3. 3.	19. 7.	2. 2.10.
K/11	2.50	600	170	28	1. 7. 2.	15. 8.	2. 2.10.
K/10	1.00	240	93	39	19. 4.	1. 4. 6.	2. 3.10.
K/4	1.00	240	120	50	1. 3. 5.	1. 1.11.	2. 5. 4.
N/24	2.55	612	258	42	14. 0.	1.12. 2.	2. 6. 2.
K/13	0.80	192	66	34	1. 7. 3.	19. 4.	2. 6. 7.
N/6	3.00	720	178	25	1. 4. 3.	1. 3. 4.	2. 7. 7.
L/17	1.00	240	48	20	1.13. 9.	14. 0.	2. 7. 9.
N/20	3.90	936	665	71	1.14. 6.	14.11.	2. 9. 5.
N/4	1.50	360	94	26	1.12.10.	17.10.	2.10. 8.
K/3	2.75	660	144	22	1. 9.11.	1. 4. 7.	2.14. 6.
L/22	2.80	672	76	11	2. 7. 5.	7.11.	2.15. 4.
L/4	1.50	360	115	32	19. 9.	1.18. 4.	2.18. 1.
L/20	1.50	360	42	12	2. 0.11.	17. 7.	2.18. 6.
N/25	1.65	396	160	40	1. 3. 6.	1.18.10.	3. 2. 4.
L/5	3.50	840	340	40	1.17. 6.	1. 5. 5.	3. 2.11.
L/21	11.40	2736	1141	42	2.10. 1.	12.10.	3. 2.11.
N/21	1.50	360	131	36	1.15. 2.	1.10. 7.	3. 5. 9.
L/7	1.80	432	153	35	13. 6.	2.17. 0.	3.10. 6.
K/7	1.50	360	34	9	2. 8.11.	1. 1. 9.	3.10. 8.
K/12	3.00	720	407	57	2.18. 9.	14.10	3.13. 7.
L/12	1.20	288	93	32	12. 1.	3. 4. 7.	3.16. 8.
K/1	2.00	480	42	9	3. 1. 1.	17.10.	3.18.11.
K/5	2.50	600	111	19	1. 7. 0.	2.12. 3.	3.19. 3.
K/9	3.00	720	92	13	2. 0. 8.	2. 9.10.	4.10. 6.
L/18	2.50	300	62	10	2. 0. 2.	3. 8. 3.	5. 8. 5.
L/8	1.00	240	79	33	1. 7. 7.	6. 1. 1.	7. 8. 8.
L/16	2.00	480	30	6	3.19.10	3.13. 2.	7.13. 0.
Av. All Farms	2.43	583	258	44	1. 7. 0.	1. 6.10.	2.13.10.

APPENDIX 2.

CALCULATED IRRIGATION NEED, 1962, BY CROPS AND RAINFALL RECORDING STATIONS

Rainfall Recording Station	Crop				
	Grass (1)	Early potatoes (2)	Second early and maincrop potatoes and sugar beet (3)	Vining peas and other row crops (4)	Cereals (5)
	inches per acre				
Sutton Bonington	4.83	3.55	3.06	4.83	1.64
Mansfield	2.50	2.05	1.48	2.50	0.06
Nottingham	4.39	3.15	2.82	4.39	1.12
Warsop	3.94	3.11	2.39	3.94	0.99
Finningley	4.17	3.19	2.58	4.17	1.21
Gainsborough	4.55	3.55	2.78	4.55	0.93
Waddington	4.28	3.27	2.65	4.28	1.06
Welton-le-Marsh	3.34	2.67	2.01	3.34	0.96
Lincoln	4.79	3.41	3.09	4.79	1.25
Cranwell	4.52	3.64	2.70	4.52	1.33
Stixwould	4.13	2.84	2.71	4.13	0.89
Caldecott	4.46	3.33	2.80	4.46	1.36

(1) Whole season's need - with planned deficit.

(2) Need for April-June period only - with p.d.

(3) ½ need during April-June period plus whole need during July-August - with p.d.

(4) Whole season's need - with p.d.

(5) Need for April-May period - without allowing a p.d.

APPENDIX 3.

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 $7\frac{1}{2}$ 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. Od. 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. Od. 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.