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ADVISORY COUNCIL FOR AGRICULTURE AND HORTICULTURE IN ENGLAND AND WALES

WATER FOR AGRICULTURE: FUTURE NEEDS

FEBRUARY 1980

ADVISORY COUNCIL FOR AGRICULTURE AND HORTICULTURE IN ENGLAND AND WALES

The Advisory Council was originally set up in February 1973 as successor to the Agricultural and Horticultural Advisory Councils. In 1976 it was re-appointed for a further term of three years. The Council's terms of reference are:-

> "To consider and report on agricultural and horticultural matters within the field of responsibility of the Ministry of Agriculture, Fisheries and Food which may be referred to the Council by the Minister or Ministry. For the purpose of an enquiry the Council may appoint panels of members and the Council or any such panel may, with the agreement of the Ministry, co-opt persons from outside the Council's membership to assist the work on any particular subject referred to it."

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FOREWORD

"Even in an average year there are limitations on output .... due to inadequate water supplies". Thus declared the Economic Development Committee for Agriculture in their report, *Agriculture into the 1980's.* After our own careful inquiry leading to this report the Advisory Council endorses this with assurance, but not because of panic induced by the 1976 drought. The farming economy has changed a great deal in the last twenty years, and we can no longer afford the penalty of a bad year, if for no other reason than that fixed costs are too high for that and likely to remain so. To meet these, farmers have to have more reliable yields, and indeed higher yields than were dreamt of a short time ago are now possible.

The demands on water in this context are far more exacting than they were, and this must lead to the serious consideration of irrigation as an investment priority. Costs can be saved by other forms of capital investment, but nothing can yield greater reward than making the best use of soil, which in turn will not respond to its full potential without the right supply of water. The Water Authorities can fairly ask us how much we need, so that they can plan properly. The Council has not shunned the task of making projections of future demand and concludes there will be a dramatic increase in the years to come. We hope we have provided authoritative guidance for those who have to plan supply.

If we have concentrated on the water requirements of soil in order to produce crops, this does not mean we have neglected other uses of water in our industry. Ministers required us to report on all aspects of agriculture and water. But soil will always dominate in all studies of farming, and so crop irrigation has inevitably consumed most of our attention. The illusion should not be harboured that we are happily blessed with a more or less adequate rainfall in most parts of the country. This is by no means the case, and we are glad to have been asked to study a matter whose enormous importance has greatly struck us. We trust we have done justice to our task.

Nigel Strutt
Chairman
Advisory Council for Agriculture and Horticulture

January 1980

ADVISORY COUNCIL FOR AGRICULTURE AND HORTICULTURE IN ENGLAND AND WALES

WATER FOR AGRICULTURE: FUTURE NEEDS

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WATER FOR AGRICULTURE: FUTURE NEEDS

SECTION ONE

INTRODUCTION

1 There has been no recent systematic appraisal of the future water demands of agriculture and horticulture. An attempt was made by MAFF in the early 1960s on the basis of surveys carried out by the then river authorities and the Ministry's Land Drainage Service but these were rather limited in scope. Although a number of surveys were completed, the main exercise was discontinued when the water industry was re-organised during 1973/74.

2 More recently, the National Water Council has taken on the responsibility for preparing, on behalf of the water industry, a national strategy for all water services. Information on future agricultural water need will be required for this purpose. Water Authorities themselves, as required by the Water Act 1973, are currently undertaking surveys of the water in their area; the management of that water; its use; and its quality in relation to its existing and likely future uses. The Authorities will be looking to MAFF to provide estimates of probable agricultural needs.

3 Against this general background, the Advisory Council was asked by the Minister, in March 1978, to undertake its inquiry, with the following terms of reference:

> "In the light of the Government's intention to produce an overall strategy and policy for water, to consider and advise on the future needs of the agricultural and horticultural industries for water, and the measures necessary to promote its efficient use".

4 The Council appointed a Panel from among its members to conduct the inquiry, as follows:

Sir Nigel Strutt (Chairman)
Mr H R Fell (Vice Chairman)
Sir Emrys Jones
Professor D K Britton
Mr I A M Lucas
Mr D H Phillips

Sir Francis Pemberton, representing the National Water Council, was also a member of the Panel.

5 Mr J Lingard BSc, MA (Econ), Lecturer in Agricultural Economics at the University of Newcastle upon Tyne, assisted the Panel in its examination of the economic aspects of the remit.

6 The Panel received written evidence from a wide range of interested organisations – these are listed at Appendix II. A number of them, including representatives of the National Water Council, Water Authorities, and the main agricultural interests, were invited to give oral evidence. The Panel also paid visits to Rothamsted Experimental Station and to the National College of Agricultural Engineering in order to discuss the latest developments at first hand.

7 Freshwater fish farming has been excluded from the inquiry. There are complex problems associated with this relatively new industry which seem to require separate consideration. We felt we should not undertake this in the context of our terms of reference.

8 The Council's remit is confined to England and Wales. We hope nevertheless that many of our conclusions and recommendations will also be of interest and value in other parts of the UK.

9 On 1 April 1978 various statutory functions were transferred from the Minister of Agriculture, Fisheries and Food to the Secretary of State for Wales. In relation to Wales, therefore, references in this report to the Minister and the Ministry should be read, wherever appropriate, as references to the Secretary of State for Wales and the Welsh Office.

SECTION TWO

PRESENT DEMAND

10 This Section considers the purposes for which the agricultural and horticultural industries require water; the quantities in which it is taken and when; and its present pattern of use. We seek later, in Section Five, to assess likely future demand.

Sources of Data

11 The lack of reliable information about the actual take-up of water by the industry has been an obstacle to our study. The Water Authorities acknowledge that many of the figures of direct abstractions by farmers presented to us should be regarded with some scepticism. Similarly, information on the use of mains water on farms is not, as a rule, at present processed in a way that readily provides data on consumption for agricultural and horticultural purposes.

12 The figures for agricultural usage compiled by the Water Data Unit are in practice the ones largely used for reference purposes. They are nevertheless deficient in a number of ways. Although, for example, they purport to include returns of abstractions exempted from licensing by the Water Resources Act, 1963 (particularly those by farmers from adjacent streams for purposes other than irrigation) these returns are subject to a large margin of error. The problem is compounded by the unknown factor represented by abstractions generally which are not disclosed to Water Authorities.

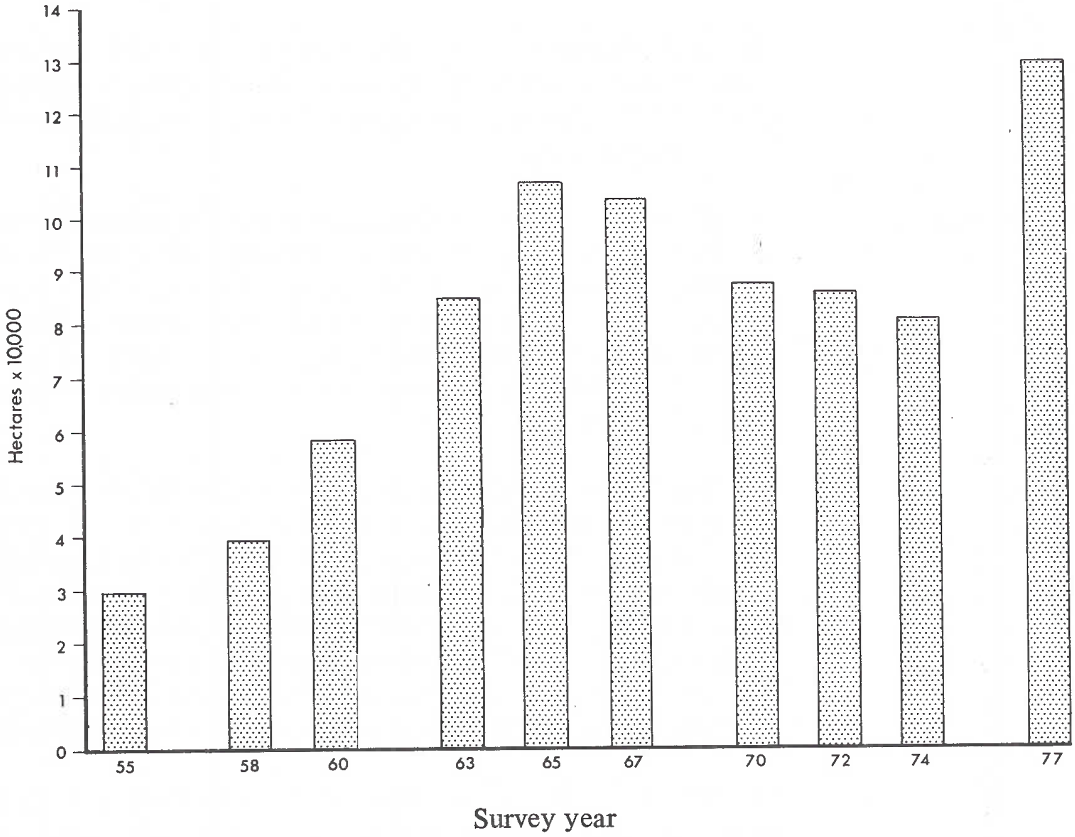
13 The WDU figures are also very broadly drawn, dividing agricultural usage into only two categories – water taken for spray irrigation, and "other". However, statistics are available for certain areas of usage which could be drawn together for the information of the industry. Certain Water Authorities record meter-readings in detail as an aid to their long-term planning but others are reluctant to insist that farmers should meter their abstractions. Little is known, for example, about the quantity of mains water used for horticultural irrigation although it is clearly significant. We think that Water Authorities could make greater efforts to record the quantities of water supplied to the industry. In our view, the cost of producing such records would be more than repaid through better long-term planning.

14 We have been obliged to attempt our own systematic analysis of the industry's water consumption and our best estimates are described in detail in the remainder of this Section. It will be seen that we attach chief importance to irrigation since it is in this field that the greatest changes are likely to occur and where there will be the most exacting pressures on supply. We therefore consider it first in our analysis of the pattern of present demand.

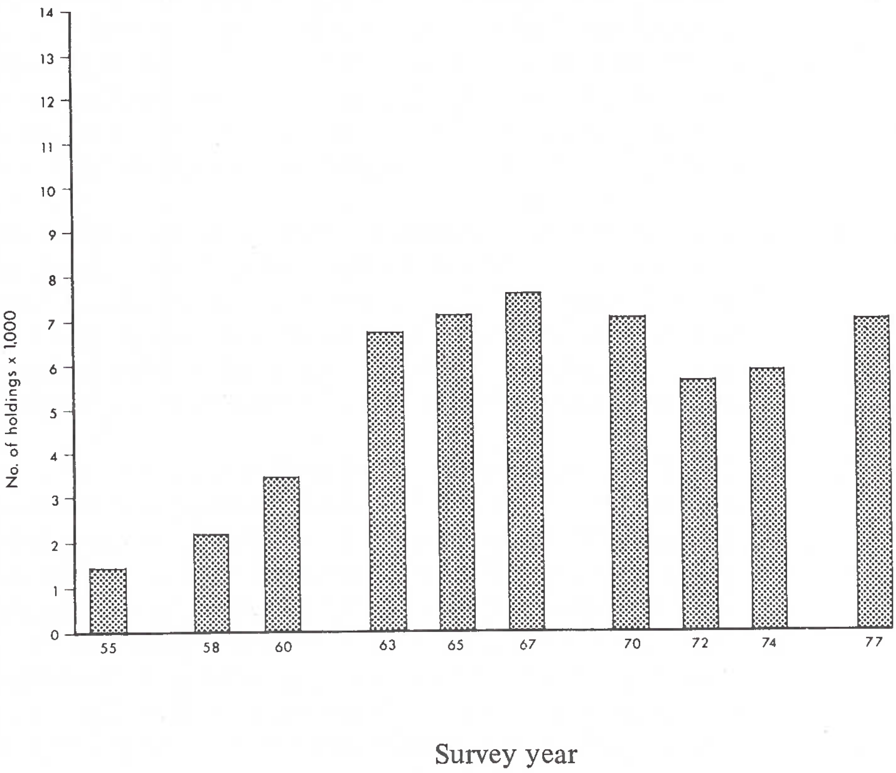
IRRIGATION

15 There was a significant expansion in the irrigated area in this country between 1955 and 1963. This was followed by a period of stabilisation lasting right up to the recent drought. Since then, as the charts below indicate, there has been some renewal of interest although it is still too soon to say with certainty whether the trend will continue. In this uncertain situation, we have tried to set out the main considerations that have led farmers to adopt irrigation in the past and which are prompting the newcomer to adopt it now. Our analysis makes two basic assumptions: first, that the necessary water is available and, second, that the economic climate will be generally favourable.

AREAS WHICH FARMERS SAID THEY WOULD IRRIGATE IN A DRY SEASON: 1955–1977*



NUMBERS OF HOLDINGS PRACTISING IRRIGATION: 1955–1977*



* Source: MAFF Statistical Surveys

16 To date, the principal source of information on irrigation demand for water has been the Ministry of Agriculture Census which asks farmers "the typical area of each crop which they would irrigate in a dry season and for which water would probably be available". Although the Census is an annual one, the irrigation return is intermittent and enables estimates to be made of the number of holdings with irrigation equipment and of the areas of various crops potentially capable of irrigation. The returns also provide information on a number of other matters such as sources of water supply, storage systems and capacities, and the type of equipment used. Furthermore, even though they give only an approximate guide, the returns can be used to assess the quantities of water likely to be taken up for irrigation.

17 Apart from the information derived from MAFF, we have profited from the recent survey by the Anglian Water Authority of the demand by farmers in its area for irrigation water*. We have also had the benefit of data supplied by others who gave evidence to us, in particular the Meat and Livestock Commission, Milk Marketing Board, Potato Marketing Board and the British Sugar Corporation.

Benefits of irrigation

18 There are very few years in which crops grown in most lowland areas in England and Wales would not gain from additional water at some time during the growing season. The judicious use of irrigation can make valuable contributions to farm productivity and profitability by helping to:

a. raise crop yields through the avoidance of the periodic checks to growth from lack of soil moisture;

b. ensure, for perennial crops, the continuance of such increased yield levels into subsequent years;

c. improve timeliness of harvest;

d. enhance crop quality generally;

e. protect the overall investment in the crop and in the enterprise as a whole by improving the consistency of yield and reducing the chance of partial or complete crop failure; and

f. assure the reliability and continuity of supplies to the market.

19 The extent and impact of these benefits will vary according to individual farming circumstances. Local limitations of soil and climate, the type of crops that can be grown, water availability and cost, are all factors determining the degree to which irrigation can be used. The individual farmer's standards of husbandry and management can also significantly modify the benefits in practice.

20 Consistency of crop yield and security of supply are beneficial, not only to the individual farmer, but also to the nation. The greater certainty afforded by irrigation enables a more stable and consistent economic development within the industry, and provides an effective insurance against the climatic uncertainties which beset the individual farmer and agriculture as a whole.

*Survey of Demand for Irrigation Water. Anglian Water Authority 1978

Present irrigation practice

21 Most crops grown in this country have been irrigated at some time or other – either commercially or under experimental conditions – and information on the results is constantly being fed back into the industry. An analysis is made below of the irrigation pattern that has developed. The principal crops concerned and the main factors relevant to each are identified, and particular attention is paid to location, seasonal growth characteristics, water needs, and fertiliser requirements.

Potatoes

22 Potatoes are currently the most important of the irrigated crops. Comparatively shallow-rooted, they are increasingly being grown on light soils with small moisture reserves and accordingly sensitive to soil moisture deficits. All crops – whether earlies, second earlies, or maincrop – respond well to irrigation, giving significant increases in yield. Irrigation can also be used to control tuber size, providing a greater proportion of ware-sized potatoes relatively free from secondary growth and cracking, and with better storage qualities. Common Scab can also be reduced.

23 Growers of early potatoes have for many years shown interest in irrigation. Maincrop growers, on the other hand, have been less quick to exploit the potential advantages, for although the capital costs are identical, the financial returns are less. Significantly – as the Table below shows – the use of irrigation has been greater in the less traditional maincrop potato-growing districts where the crop is grown on soils with lower moisture reserves. However, the MAFF Census demonstrates a renewal of interest amongst growers in both the early and maincrop sectors since 1976: the irrigable area for earlies has increased from 30 per cent in 1971 to 48 per cent today, while that for maincrop has more than doubled from 7 to 15 per cent.

24 *Early Potatoes.* Since this crop is usually grown on light soils with limited moisture reserves, irrigation is recommended when the soil moisture deficit (SMD*) attains 20–25 mm. This does not apply for crops lifted during the first 7–10 days of the local harvest period in the very early areas, when tuber size is usually of more importance than overall yield: here a single water application about 7–10 days before the potential harvest date will give the best returns. Generally speaking, the later the date of harvest, the greater the need to irrigate. In later districts, irrigation is required throughout the life of the crop, producing larger increases in yield.

25 Yield responses from irrigation can be expected in at least 8 years out of 10 in the main producing areas, with about an extra 2 tonnes per hectare for each 25 mm of water correctly applied. But for early potatoes yield per hectare is not necessarily the best measure of profitability: selling on a higher priced market, even at a lower yield, can prove more advantageous in their case.

*The total water extracted by evaporation and transpiration, less gains by rainfall or irrigation, is termed the *soil moisture deficit* or SMD. It represents the amount of rain or irrigation that would restore the soil to field capacity, with no surplus for drainage.

TABLE 1: EARLY POTATOES – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	6,650	36	7,096	42	5,963	71
South Eastern	3,436	38	3,456	38	3,297	63
East Midland	3,686	27	3,448	19	5,023	24
West Midland	3,255	32	3,294	29	4,113	50
Others	6,776	21	6,138	19	7,626	39
Total	23,803	30	23,432	30	26,022	48 (12 000 ha)

26 *Maincrop Potatoes* (including second earlies). Here, irrigation is recommended to keep the SMD below 25 mm on light textured, and 35 mm on heavier textured, soils. Yield response can again be expected in at least 8 years in 10, giving an increase of the order of 2 tonnes per hectare per 25 mm of water correctly applied. In contrast to early potatoes, higher yields are the main objective in irrigating this crop; tuber size can also be controlled and quality improved.

TABLE 2: MAINCROP POTATOES – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	55,710	9	49,687	9	38,589	25
South Eastern	11,106	12	10,232	11	11,157	40
East Midland	32,062	9	24,967	7	32,334	11
West Midland	17,210	10	16,381	8	19,612	18
Others	45,290	2	45,607	2	49,142	6
Total	161,378	6	146,874	7	150,834	15 (22 500 ha)

Sugar Beet

27 Sugar beet is a deep rooting plant which in suitable conditions can make use of soil water from a depth as low as 1.5 metres. It has consequently been considered to be comparatively unresponsive to irrigation. The 1977 MAFF Survey gives support to this belief, indicating that at present no

more than 9 per cent of the national area is likely to be irrigated in a dry year. However, the ability of the crop to utilise water at a considerable depth does not make it immune from drought stress. Recent research work at Brooms Barn Experimental Station has shown that applications of irrigation water earlier than previously recommended can lead to significant yield increases and this new thinking alters the whole approach to sugar beet irrigation. Furthermore, the current trend to move sugar beet off the heavier land onto lighter – and more drought-prone – soils will emphasise even more the advantages of extra water application.

28 There has been a significant improvement in the sugar beet cost/return relationship since the UK joined the EEC. Elimination of yield fluctuations from year to year will be of great importance in the areas under sugar beet if it is to be used to its greatest potential and if factory capacity is to be fully exploited. Irrigation thus becomes an increasingly important factor in securing greater stability of supply for both growers and processors.

TABLE 3: SUGAR BEET – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	120,550	5	123,523	5	110,631	10
South Eastern	347	5	237	6	252	10
East Midland	37,620	5	33,907	4	46,467	7
West Midland	15,508	9	16,476	7	18,217	16
Others	15,573	1	21,061	2	26,827	5
Total	189,598	5	195,204	5	202,394	9

Soft Fruit

29 Most soft fruits are comparatively shallow rooted and are accordingly particularly susceptible to dry conditions. Yields can also be reduced in a subsequent year because of the restrictive effects of water shortage upon the development of new wood and/or crown growth. The main crops of commercial importance are *strawberries* and *blackcurrants* and, to a lesser extent, *raspberries* and *gooseberries.* All show a response to irrigation though requiring different application techniques.

TABLE 4: SOFT FRUIT – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	4,963	17	4,454	20	3,683	35
South Eastern	3,395	15	3,304	19	3,125	33
East Midland	508	23	333	27	634	28
West Midland	2,635	21	2,885	21	2,769	28
Others	1,378	25	1,515	22	1,606	31
Total	12,879	18	12,491	20	11,817	32

Top Fruit

30 In contrast to soft fruit, tree fruits are deep rooting, and on many soils are not therefore so susceptible to water deficiency. The proportion of the commercial orchard fruit area likely to be irrigated is currently only 12 per cent, significantly less than for soft fruit. *Culinary apples,* which account for one-third of the total commercial orchard area, are not normally irrigated nor do they need to be. *Pears* and *plums* are seldom irrigated.

31 It is accordingly *dessert apples* that respond best to irrigation, both in terms of yield and of quality. As with soft fruit, irrigation can also help to improve wood growth and the permanent framework of the tree, with beneficial effects upon future yields. Although precise figures are not available, many commercial growers are already making considerable use of irrigation, especially in the new intensive and close-spaced orchards. Yield response can be expected in at least 8 years out of 10; *Cox's Orange Pippins,* for example, giving a response of 0.27 tonnes per hectare per 25 mm of water applied.

TABLE 5: TOP FRUIT – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	11,805	15	10,691	18	9,857	23
South Eastern	26,528	4	25,421	5	23,285	8
East Midland	224	18	202	25	319	20
West Midland	8,966	7	8,737	4	7,756	8
Others	4,608	4	4,217	3	3,546	4
Total	52,131	7	49,268	7	44,763	11

Vegetables

32 The yields of most vegetables can be improved by judicious irrigation. However, a number of them – notably *parsnips, asparagus, cabbage (spring greens),* and early-picking *peas* – show virtually no response and are seldom

irrigated in commercial practice. The benefits of irrigation to a second group of crops, whilst important, are related essentially to the establishment or "prior to harvest" stages – as for example with *brussels sprouts, cabbage (spring-hearted),* and *radishes.* As a result, the primary use of irrigation is for *cauliflowers, lettuce, celery, turnips, onions* and *beans.*

33 In the case of *carrots* the large proportion of the crop grown on land under annual tenancy has tended to inhibit the use of irrigation. Research findings show that *peas,* for whatever purpose they are grown, are the only crop showing a response at the flowering stage irrespective of the level of water deficit (ie even when the level is zero) but in spite of this obvious advantage, the growers of *harvest peas* do not normally invest in irrigation. As regards *vining peas,* the buyers' contract conditions may preclude it.

TABLE 6: VEGETABLES – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	85,766	8	93,357	7	86,166	13
South Eastern	17,285	24	17,068	25	18,936	34
East Midland	29,889	3	27,861	4	54,346	4
West Midland	8,547	17	7,588	20	8,863	30
Others	29,838	4	39,043	3	43,603	5
Total	171,325	8	184,917	14	211,914	12

Protected Crops

34 Protected crops are all irrigated, generally under the closest controlled conditions. Almost half of the area is under *tomatoes,* with *other vegetables* occupying a similar area. *Ornamentals* and *nursery stock* make up the remainder.

TABLE 7: PROTECTED CROPS – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	596	100	611	100	517	100
South Eastern	467	100	509	100	523	100
East Midland	64	100	65	100	166	100
West Midland	136	100	145	100	169	100
Others	548	100	640	100	698	100
Total	1,811	100	1,970	100	2,073	100

Cereals

35 Only a minute proportion of the total crop area of cereals, something like 5,000 hectares, is indicated by the MAFF Survey as likely to be irrigated in a dry season. The practice is essentially confined to the lighter soils, usually on *spring barley* and mainly in East Anglia, where the equipment is already available for irrigating other crops. It is to be noted that a number of farmers are also resorting to irrigation to help establish *winter wheat* when sown under exceptionally dry conditions. There can thus be special conditions where farmers with irrigation equipment will use it for cereals with profitable results but normally only as a secondary use.

TABLE 8: CEREALS – AREA OF CROP AND ESTIMATED IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

REGION	1972		1974		1977	
	Total Grown	% Irrigated	Total Grown	% Irrigated	Total Grown	% Irrigated
Eastern	889,495	0.2	870,793	0.3	821,300	0.5
South Eastern	481,023	-	471,257	-	459,232	-
East Midland	562,099	-	504,906	-	542,725	-
West Midland	305,993	-	305,525	-	294,520	-
Others	1,032,448	-	1,073,886	-	1,047,443	-
Total	3,271,058	0.1	3,226,367	0.1	3,165,220	0.2

Grass

36 Grass responds well to irrigation but despite the work of a number of pioneers some years ago, irrigation of grassland has not taken on extensively in this country. Grass is solely of value when utilised by animals, and irrigation is really only considered to be economic when the grass is consumed by dairy cows. Grass yield responses are obtainable even in wetter areas as experiments in County Wexford in the Republic of Ireland have shown.

37 For optimum results, it is accepted practice to apply heavy nitrogen dressings, using irrigation to keep the soil above a maximum deficit of 25–35 mm. At lower levels of nitrogen use, it has been shown by the Grassland Research Institute that water and nitrogen are to an extent substitutes. Where clovers form a part of the sward, irrigation becomes more important owing to their susceptibility to drought.

38 The MAFF Census gives details of the area of grassland likely to be irrigated in a dry season (about 30,000 hectares in 1977), the overwhelming proportion of which is likely to be devoted to dairy husbandry. To calculate the irrigated proportion of grass grazed by dairy cows, we have in Table 9 below made the currently accepted assumption that each dairy cow on average requires 0.2 hectares of grazing, both irrigated and non-irrigated.

TABLE 9: GRASS FOR DAIRY PRODUCTION – ESTIMATED AREA AND IRRIGATION BY MAFF REGION

1972, 1974 and 1977

(hectares)

	1972		1974		1977	
REGION	Total Area of Grass Grazed by Dairy Cows*	% Irrigated	Total Area of Grass Grazed by Dairy Cows*	% Irrigated	Total Area of Grass Grazed by Dairy Cows*	% Irrigated
Eastern	23,559	18	24,278	21	22,320	35
South Eastern	53,647	8	53,620	6	49,558	13
East Midland	36,138	7	36,011	5	34,687	8
West Midland	84,370	3	85,426	2	84,141	5
Others	296,987	2	303,568	1	298,806	3
Total	494,701	4	502,903	3	489,512	6

*Estimated (see paragraph 38).

Forage Maize

39 Forage maize makes much of its growth during the later part of the summer. Since it is cultivated at high plant population levels and tends to be grown in lighter textured soils it is a crop sensitive to drought. Irrigation is advised when the SMD exceeds 40–50 mm and the expected response for each 25 mm of water applied is of the order of 0.75 tonnes per hectare. It is used on only a limited scale at present, however, partly because of physical difficulties, although the modern types of equipment allow a more efficient application of water.

Total Irrigation Use

40 We can now proceed to estimate, from the crop area figures given above and the volume likely to be applied to each in a dry year, the total amount of water at present being used for irrigation. If irrigation were to be carried out to full capability (ie if farmers applied that optimum quantity of water in a dry year to the entire area which, on the strength of the Census returns, they say they would), we estimate that the total amount of water involved would be of the order of 170 million Mm^3. In practice, the present usage is less than 100 per cent of what is desirable, and possibly as low as 50 per cent. Limitations on the mobility of equipment, shortage of labour, and inadequate technical knowledge of plant water requirements, all combine to reduce applications below the optimum. Taking these factors into account, we think a reasonable estimate of the volume of water currently required for outdoor irrigation would be 86 Mm^3 in a dry year, with an additional 12 Mm^3 applied to protected crops.

41 A breakdown by water source is possible on the strength of further information from the MAFF Census. This shows that by area of irrigated crops (outdoor), 7 per cent of the water needed is taken from the public mains, 74 per cent from surface sources and 19 per cent from ground sources (including other sources which would be licensed as groundwater). In terms of quantity, we estimate therefore that 6 Mm^3 is taken from the mains, 66 Mm^3 from surface sources, and 17 Mm^3 from groundwater.

42 We should point out that although our estimate of abstraction from groundwater (17 Mm^3) is not unduly out of line with WDU statistics for 1976, (19 Mm^3), our estimate of surface water abstraction, (66 Mm^3) differs substantially from the 1976 WDU figure (40 Mm^3). We have already explained some of the admitted deficiencies in these data. Another partial explanation may be that the actual water uptake for irrigation by farmers in 1976 was less than it would normally have been because of the various restrictions operating during the period; according to one Water Authority the amount was only about 80 per cent of what they would have taken. Nevertheless, the difference between our estimates and the published data cannot easily be reconciled and we believe the point merits closer examination.

WATER FOR LIVESTOCK

43 A sufficient and reliable supply of good quality drinking water for his animals is essential for the livestock farmer. The total amount of water consumed by livestock is greater than that taken annually for the purpose of irrigation but the demand is fairly even over the year; and the fluctuation from year to year, while measurable, is insignificant by comparison with irrigation. For this reason the demands of livestock drinking are much less likely to place seasonal pressures on supply. Nevertheless, it is essential that these demands should be fully met.

44 Because water consumption by livestock cannot be derived from figures documented by the Water Data Unit we have had to make our own estimate by taking the June 1977 Census figures of animal population and multiplying these by the average per capita consumption for each species. The latter figures are based both on observed behaviour and on measured biological needs, but they do of course cover wide variations between farming systems and husbandry practices. Our averages are in many cases lower than those used in other contexts: as an instance, the figure for dairy cow consumption at 50–60 litres per day is considerably lower than the standard provision (150 litres per day) laid down in the regulations for the construction of farm buildings. An attempt has also been made to estimate the amount of the water used for other needs, such as cleaning milking parlours and yards and pipeline feeding for pigs. As with drinking water, the figures are not exact but reflect the broadest available consensus of opinion.

Dairy Cattle

45 Dairy heifers up to their first calving have needs closely allied to those of the beef herd. About 35 litres of water a day per dairy cow for maintenance, and a further 1.5–2 litres for every litre of milk, have been assumed. The change from cowshed to parlour milking has reduced requirements for cleaning water: experiments suggest an average requirement of 5 litres per cow for circulation cleaning of parlours plus 2½ litres per cow for bulk tank cleaning. In the past, a good deal of water was used for milk cooling, but the adoption of bulk collection methods has made this no longer a significant demand.

46 Of the 52,769 dairy units in England and Wales in 1977 about which information was available, 11,748 depended upon private sources of supply. In the absence of better information, we have assumed that these figures provide a measure of the relative importance of the public mains and direct abstraction in this sector generally.

Beef Cattle

47 Here it is difficult to generalise because of the wide variety of husbandry systems. For yarded suckler cows, consumption has been estimated at around

45 litres per day; for yarded finishing cattle 28 litres per day; and for younger cattle of various ages an average of 20 litres per day. Requirements at grass will, of course, vary according to the locality and the season. In some farming circumstances most or all these requirements will be met from natural sources; but in warm periods on dry pasture the figures might well be exceeded and it is not unrealistic therefore in our view to use them as a year-round norm. Of these needs, taking into account all the various systems of husbandry, it is estimated that 70–80 per cent will be met from piped supplies.

Sheep

48 Traditionally, sheep have been kept out of doors throughout the whole year and, when fed on high moisture content crops such as roots, or on grass in wet climates, not provided with drinking water. Approximately half of the national flock is to be found in hilly areas where streams alone supply all the drinking water needed. Water requirements, from either direct abstraction or from the public mains, are difficult to estimate but except under lowland intensive conditions are not likely to be great. However, these circumstances are changing. Inwintering of the ewe flock is on the increase whilst stocking rates on lowland pastures are moving upwards in response to economic pressures. Piped water has to be available in these conditions and consumption by a housed ewe can be as high as 4 litres a day. Nevertheless, 80 per cent of needs by the national sheep flock are estimated as still likely to be met from streams and from natural sources.

Pigs

49 Water for pig production is drawn almost entirely from public supplies. For this reason, and because most pigs are housed, accurate measurement of their drinking requirments can be made much more easily than with other livestock. Records from Terrington Experimental Husbandry Farm show that sows suckling piglets consume around 18 litres per day; dry sows around 10 litres; finishing pigs averaging 65 kg live weight, using bite type drinkers, about 6 litres; and other pigs on average 3 litres per head per day. However, these figures are based to some extent on systems with very little water wastage, in contrast to many ordinary farm systems. Further allowance must be made for the considerable volume of water used in scrubbing out pens, and we have added 33 per cent to account for waste and a further 25 per cent for cleaning.

Poultry

50 The water needs of the poultry industry during the production stages are relatively modest. Apart from water for drinking, there is a requirement for the cleaning of the houses between batches of stock or, as with some cage laying houses, at regular intervals during production. Some laying units still use wet methods of manure handling and this involves additional water use. To allow for these variations, and to take account of waste, we have added 50 per cent to per capita consumption for layers, and 25 per cent for other stock. On this basis, it is estimated that poultry water needs amount to about 7 Mm^3 per annum.

51 Our conclusions concerning water consumption for livestock, based on the assumptions above, are summarised below.

TABLE 10: ESTIMATED LIVESTOCK WATER USAGE 1977 – Mm³

Livestock		Annual Total	Total taken by direct abstraction: surface and ground sources
Dairy Cattle in milk (adults only)	Drinking	57	15
	Cleaning	10	
All Other Cattle		61	15
Pigs		20	not significant
Sheep		15	12
Poultry		7	not significant
TOTAL		170	42

WASHING AND PROCESSING

52 Although the on-farm washing of vegetables is not significant now, it may become so in the future as small grower co-operatives and groups increasingly turn their attention to prepacking and processing on the farm. The expansion of farm gate sales is providing a further stimulus. Our estimates of consumption for these purposes relate only to installations on farms and take no account of the large off-farm enterprises.

53 Washing has become a virtual pre-requisite for some crops demanded by supermarket chains, processors and other large buyers, but the amounts of water for this purpose do not currently make a significant impact either nationally, or over any region as a whole. Nevertheless, in particular locations, large quantities of water may be required at certain times of the year, placing an appreciable load on the source of supply. This is especially the case with *carrots* which require a great deal of washing water per tonne; where most of the crop is washed; and where cultivation is concentrated in one region (Eastern). The requirements for *beetroot* and *parsnips* are similar but less are grown and water usage is correspondingly lower. As regards *potatoes*, most of this crop needing to be cleaned before sale is brushed and not washed.

54 Estimating the total amount of water used for these purposes is difficult because of the varied pattern of consumption from farm to farm – depending on the crop, the machinery employed, soil type, lifting conditions, and whether or not the water is recycled. As far as possible all these considerations have been allowed for in the figures in Table 11 below.

TABLE 11: ESTIMATED USE OF WATER FOR WASHING AND PROCESSING ON THE FARM, BY CROP (NET CONSUMPTION) '000 M^3

Crop	Eastern	South Eastern	East Midlands	West Midlands	Others	Total
Carrots	450	4	60	30	43	587
Celery	107	18	-	-	91	216
Leeks	44	86	6	6	39	181
Parsnips	7	4	7	3	6	27
Beetroot	5	3	18	1	2	29
Spring onions	12	46	-	10	11	79
Swedes and turnips	3	2	27	8	39	79
Watercress	18	1	-	-	1	20
Outdoor lettuce	55	23	2	1	5	86
Radishes	-	-	-	-	32	32
TOTAL	701	187	120	59	269	1,336

DOMESTIC CONSUMPTION

55 It has proved impossible to estimate domestic consumption within agriculture on the basis of measured quantities since supplies are usually drawn from the same main as the farm water when the farmhouse is sited on the farm. We have therefore taken the current national average rural usage of 120 litres per person per day as our base figure. On the further assumption of a total agricultural population of 900,000 we estimate consumption to be of the order of 36 Mm^3 per year.

56 It is not possible to say what proportion of this total is provided from private sources, but according to the December 1978 MAFF Quarterly Census approximately 20 per cent of holdings are likely to rely on these. We conclude that about 7 Mm^3 per year might be derived from private sources, for the most part from boreholes or wells.

OTHER USAGES

57 The water needs for other agricultural purposes are negligible compared with the three major categories of irrigation, livestock watering, and domestic farm use. The annual requirement for pesticide spraying, for example, is estimated at only about 0.25 Mm^3, and that for sheep dipping is similarly small. There would seem little prospect of significant new usages developing.

Summary

58 Our estimates suggest a current total agricultural consumption of water of the order of 300 Mm^3 per year, of which about 60 per cent is being drawn from the public mains and the remainder from private sources. Water for livestock (both for drinking and cleaning purposes) constitutes the single largest use; and out of approximately 170 Mm^3 per year put to this purpose we estimate that about 70 per cent is drawn from the mains. We have arrived at a usage figure for outside irrigation in a dry year of 86 Mm^3, very largely derived from private source abstractions, with an additional 12 Mm^3 for use under glass, mostly from the mains. Domestic consumption accounts for about 36 Mm^3 per year, of which 80 per cent might be taken from the mains and the remainder mostly from boreholes or wells. Vegetable washing and processing are estimated to use only 1 Mm^3 per year, but may be locally important.

59 With the exception of irrigation, all the above requirements show only minor changes over the year, and there are normally few significant variations in the aggregate demand from year to year. Irrigation needs are on the other hand markedly seasonal and effectively confined to the period May-August. Under dry conditions in East Anglia crop irrigation may take up as much as

40 per cent of available total supplies at peak periods. Demand from year to year can also show very wide fluctuations depending on variations in rainfall.

60 Among our main tasks we have to assess the future demand for water by the agricultural and horticultural industries and this Section has attempted to establish the existing pattern of demand, thus providing a base from which to project future needs.

SECTION THREE

TECHNICAL RESEARCH AND DEVELOPMENT

61 There is a continuing programme of R & D into most aspects of water supply and usage, including irrigation, in agriculture. At first sight, the scope of this work would appear to be comprehensive and it would also seem that British agriculture is being well served in this regard. A closer examination, however, reveals that R & D into irrigation in all its aspects is generally given low priority, perhaps because, prior to the drought of 1976, interest in irrigation could only be described as static: as a result, there was no pressure from farmers for any significantly increased R & D effort. But there are currently many indications of a radical change in farmers' attitudes towards irrigation, and the rate of uptake is likely to accelerate during the next two decades, so that by the year 2000 irrigation will be playing a far more important role in British agriculture than it is today.

62 We believe that the priorities accorded to R & D, especially in irrigation, should be reassessed in the light of foreseeable developments in British farming. The purpose of this Section is to examine what these future developments are likely to be, and what implications they have for R & D programmes and priorities.

Changing Technology in Farming

63 Economic pressures on farming continue to provide momentum for change. Fixed costs are rising steeply and are likely to continue to do so; in particular, the increasing cost of land will make its more intensive use an essential part of farm management. At the same time, markets are more likely to be over-supplied than at present, which places special emphasis on quality of product and reliability of supply. In general, technology is keeping pace with these changing economic conditions. Recent work on crops, for example on potatoes and cereals, has pushed up yields far beyond those achieved commercially a decade ago. With grass, progress has been rather less striking: although stocking rates have been increasing as a result of higher application of nitrogen, there is still scope for greatly improved productivity. High cereal prices and the rapidly increasing cost of nitrogen fertiliser should however give a fresh stimulus to re-appraisal of grass technology.

64 Increases in yield have been achieved as a result of a combination of effort: new varieties from the plant breeders; improved methods of controlling pests and diseases; better cultivation and harvesting machinery; and an improved understanding of soil structure and its management. It is nevertheless evident that progress must proceed on a broad front – the taking up of one item of technology without the other elements in the package can be counter-productive – and this is particularly true of water use. As crop densities, and total surface area of leaf, increase, so does the need for water, and the penalties for allowing drought stress to develop become more severe. This is not only true for crops which, like potatoes, have traditionally been recognised as responsive to irrigation, but also for other crops, including grass, which have not hitherto been taken so seriously.

The Important Areas of Technical Development

65 We need to identify those areas of concern, at farm level, where development is already taking place, and where it is evident that further work is required.

66 *Crop Technology.* Crop production methods continue to evolve and whilst in some areas the objective is to increase quality, the main aim is to increase yield. The potential that remains for doing this is widely recognised and an important part of the R & D programme in hand is directed towards realising it. We now have a greater understanding of the basic physiology of the plant – with cereals for instance – which is leading to higher yields. There is also the prospect of lengthening the growing season as a result of development in seed treatments and transplanting techniques. Nevertheless, this recent experimental work has indicated that in many situations the full yield potential is not being achieved because of the inability of the soil to provide sufficient moisture. As this is confirmed, higher yields and a reduction in yield variability will require irrigation over a wider range of crops, climate and soil conditions than is currently recognised.

67 *Grass Technology.* The availability of cheap nitrogenous fertilisers has dominated developments in grassland management over the past 30 years and as a consequence grass mixtures presently consist mainly of different strains of ryegrass highly responsive to nitrogen. Clovers, on the other hand, have had only a minor role to play. Current changes in energy costs are however leading to nitrogenous fertilisers becoming relatively much more expensive and this leads us to believe that the contribution of clovers to the productivity of the sward must be reassessed. But they are more sensitive to soil moisture deficiencies than are the grasses and it can therefore be expected that a return to clover-based swards would increase the need for irrigation.

68 Lucerne behaves rather differently from the clovers in that it is very deep-rooting and consequently much more resistant to water shortage. It may therefore replace some of the grass area in the drier parts of the country. However, there are still practical difficulties in the utilisation of lucerne by the grazing animal, and more effort needs to be put into acquiring knowledge under commercial conditions.

69 It has been generally accepted that irrigation on grassland can only be justified when that grass is utilised by the dairy cow. Even then, much doubt is expressed as to its viability under present cost/return conditions. We believe that this picture is changing and that it will be particularly affected by the interchangeability of nitrogen and water. Research in the 1960s showed that reduction in nitrogen fertiliser levels could be offset by the application of water. We think that more work now needs to be done on this aspect and that it should be extended to cover intensive systems of beef and sheep production.

70 *Soil Management and Structure.* Correct soil management has a considererable influence on the availability of soil water and the uptake of plant nutrients. Farmers are becoming much more conscious of the need to preserve a good soil structure not only on the surface but also in the subsoil, because it is evident that they get higher yields as a result. Subsoil cultivation and deep fertiliser placement encourage greater root growth and help to utilise water from greater depths of soil. At the same time, increasing fuel costs are underlining the attraction of minimal cultivation which not only reduces the number of working operations but also moisture loss. All these changes will tend to reduce the need for irrigation, although they are not usually sufficient to make up for the full moisture deficit in the soil.

71 *Equipment.* Unquestionably one of the main reasons for increased irrigation over the past few years has been the introduction of automated methods of application. Sprinkler systems which were very demanding on labour have become much less attractive by comparison with the new rain gun equipment and solid set systems, which have reduced labour needs and also made 24 hour operation possible. Water and equipment can accordingly be used much more extensively and efficiently, with an increased demand for water as a result.

72 This improved equipment has some distinct disadvantages, however. Droplet size tends to be large, the water falling on the crop and the soil with considerable force, leading to the danger of damage to both plant leaf and soil structure. Furthermore much of the equipment currently on the market entails a high consumption of fuel, an increasingly expensive item. Future developments must take these problems into account, and low pressure systems sought, always providing that at the same time system capacities can be retained.

73 *Weather forecasting.* It is inefficient to apply water in quantities greater than the plant can use, with the surplus being lost to the drains. Furthermore, growth can be inhibited under waterlogged conditions. It is essential therefore that irrigation should be properly scheduled and related both to the limiting soil moisture deficit and to the current deficit in the soil. An important element in these calculations is some knowledge of the rainfall to be expected. Work is in progress aimed at refining weather forecasting techniques, but much more needs to be done before it could be said that the farmer has reliable foreknowledge on which to base his irrigation schedules.

74 *Plant Breeding.* It seems unlikely that plant breeders will be able to produce new crop varieties requiring less total moisture and which would compare economically with present varieties. To that extent, the breeders will not be able to help in reducing the demand for water. What can be done, however, is the selection of strains – of grasses for example – which are much less susceptible to drought stress, for use in areas where irrigation is not practicable. There is also the longer-term prospect that the breeder may be able to develop plants such as cereals which, like the legumes, would have their own nitrogen-fixing capacity. The increasing cost of fertilisers will obviously stimulate this work. In general, annual or short-lived plants so equipped are highly sensitive to variations in soil moisture and this may increase irrigation need.

The need for R & D

75 A classified list of the work being currently undertaken in the UK is to be found at Appendix 2. Having reviewed the present state of knowledge within the industry, we conclude that a great deal is already known about the physics of water loss from cropped and uncropped soils, the response of crops to water, the scheduling of irrigation, and the design and operation of irrigation systems. Generally speaking, however, we are struck by the fact that in Research Station and EHF programmes irrigation is rarely included as a standard treatment in experimental work. We *recommend* therefore that the ARC and MAFF should where appropriate include irrigated treatments as a standard component in their experimental work.

76 We have identified other areas where knowledge is insufficient and where further work is justified, and accordingly *recommend* that the sponsors of state-aided R & D should give a higher priority to the following topics:–

a. The basic principles of water and nutrient availability and movement in soils; the flow of water through plants; and the effects of moisture stress on biochemical processes.

   All are essential to improve the efficiency of irrigation.

b. Low pressure systems of water application that are much more economical in energy consumption.

   The equipment required for trickle and spot water systems of irrigation is already available but it needs to be further developed to the stage where it is a commercial proposition on a large scale.

c. The efficiency of the technique of applying fertilisers and pesticides in irrigation water.

d. The response of grass/legume swards to water.

   In view of fertiliser costs, this information is urgently required.

e. The responses of new crop varieties generally to water.

   Although a great deal is already known about crop response patterns, including those of vegetables, new varieties coming forward may behave differently.

f. New and more reliable techniques of weather forecasting aimed at greater precision in irrigation practice.

g. Lower cost methods of waterproofing surface reservoirs.

   The present cost of storage in lined earth reservoirs is often too high to make irrigation an economic proposition on other than the highest value crops.

Summary

77 Although there is a broad-based R & D programme concerned with water use in agriculture, in general the priority given to irrigation falls short of that demanded by changing technology and economics at farm level. A considerable increase in the total amount of R & D being carried out is not thought necessary, nor is a fundamental change required in present work programmes. However, changes in emphasis are required so as to give higher priority in particular to irrigation and the development of cheaper storage methods. Topics calling for enhanced effort have been identified and the recommendation made that irrigation should be accepted, where appropriate, as a component in investigations into alternative crop management systems.

SECTION FOUR

ECONOMICS OF IRRIGATION

78 This Section deals exclusively with irrigation, this being the area where we see the greatest need for systematic assessment of benefits and costs. We identify the main factors which affect farmers' investment decisions; illustrate one method of economic appraisal; and assess the present and potential national benefits conferred by irrigation.

The farmers' decision to invest in irrigation

79 The MAFF 1977 Census showed that over 130,000 ha of outdoor crops in England and Wales were likely to be irrigated in a dry year, and occupiers of 7,000 holdings indicated that they might irrigate during such a year. These farmers have a wide range of business objectives, depending upon their farm resources and their attitudes to risk and uncertainty, but it can be assumed that they expect irrigation to pay in the long run. Numerous types and varieties of crops are irrigated under widely different conditions of farm size, topography, climate, and availability of water. Thus irrigation systems take many forms. This makes generalisation difficult, and in practice any worthwhile examination of expected benefits and costs must have regard to the specific circumstances of the individual farm. Farmers will also have to take a view on what the future may hold for prices of agricultural products, movements in the relative prices of inputs and changes in Government grants.

80 In most situations the following factors are important in determining the economy of irrigation:–

Capital

a. reservoir and storage costs
b. costs of mains networks on farms
c. costs of spraying equipment
d. the useful life of the assets
e. tax considerations

Running costs

f. fuel
g. equipment repairs
h. labour
i. water charges

Crop responses

j. the combination of crops in the cropping system
k. the likely yield responses and values of crops
l. the frequency and timing of wet years during the useful life of the investment.

81 A systematic analysis requires that, taking account of all these factors, a potential irrigator should attempt to forecast the annual costs and revenue arising from the investment over the life of the assets. From this basis a rate of return on the investment can be calculated which will assist in deciding whether the project can be afforded. The irrigator can also compare this expected rate of return with the potential return from alternative projects, and then decide whether to proceed with the irrigation scheme rather than use these resources in some other way.

82 *Crop responses to irrigation.* These vary greatly from crop to crop, and ADAS has provided estimates based on available experimental data and field experience for well-managed crops in areas of established irrigation need. Table 12 below reproduces these estimates, from which "gross margin responses per ha/mm" are derived. These gross margins exclude the cost of irrigation itself. 1977 prices have been used, but subsequent movements of prices have not, as far as we can gauge, materially altered the relativities shown. At one end of the scale *early potatoes* and *blackcurrants* can be expected to yield £11 per ha/mm of water: at the other, irrigation of *cereals* shows a response of only £1.62 per ha/mm.

TABLE 12: IRRIGATION CROP RESPONSES AND ADDITIONAL GROSS MARGINS BEFORE DEDUCTION OF WATER APPLICATION COSTS (1977 PRICES)*

Crop	Average yield response per ha per mm of water applied	Price £/Tonne	Gross margin response £/ha mm
Agricultural Crops			
Cereals	0.018	90	1.62
Grassland – Dairy	0.025 (Dry Matter)	680 GM/cow	2.74
Peas – Vining	0.04	110	3.84
Peas – Dried	0.04	120	4.80
Potatoes – Early	0.08	150	11.10
Potatoes – Second Early	0.08	70	4.70
Potatoes – Maincrop	0.08	50	3.58
Sugar Beet	0.13	21.20	2.50
Vegetable Crops			
Beans Broad – Processing	0.04	175	6.40
Beans French – Freezing	0.06	86	4.26
Beans Runner	0.05	225	5.30
Brussels Sprouts – Early	0.04	140	3.26
Cabbage – Summer	0.14	100	8.77
Carrots – Early	0.03	100	2.00
Cauliflower – Summer	10 (Crates)	1.50 Crate	7.62
Lettuce – Drilled	10 (Crates)	1.00 Crate	4.65
Onions	0.08	60	1.90
Fruit			
Apples – Cox	0.015	0.195/kg	3.40
Blackcurrants – Fresh	0.03	0.65/kg	11.92
Blackcurrants – Processing	0.03	325	6.75
Raspberries – Fresh	0.25	0.75/kg	7.30
Strawberries – Fresh	0.025	0.45/kg	4.61
Strawberries – Processing	0.025	250	3.75

* This table assumes that there will be a constant response to each mm of water applied whether in a wet or dry year. The total amount of water applied per ha will of course vary from season to season.

Source: Economics of Irrigation. Report of ADAS Working Party 1977. MAFF.

83 The figures show the average responses per ha/mm of water. We are advised that for the extent of irrigation considered in this report, diminishing returns – as they relate to successive applications of water to a particular crop – will not apply. We have not taken them into account in our calculations, nor have we made allowance for the possible saving on other inputs, notably fertilisers, as a result of irrigation.

84 The gross margins listed above are based wholly on increased yields and ignore the beneficial effects on quality, continuity of production and marketing, the insurance value of a secure and guaranteed yield, or other factors also contributing to increased returns. Moreover, when shortages are caused by drought, and market prices rise, the farmer who irrigates will receive a higher return for a larger crop. This effect could of course become less significant if more growers resort to irrigation and annual fluctuations in yields diminish.

85 It should also be remembered that in many cases the equipment can be used for secondary purposes and that irrigation can be profitable for lower return crops when associated with others which yield a high return. For example, a farmer can easily make use of a system devised to irrigate 24 ha of maincrop potatoes for irrigating an additional 12 ha of sugar beet. Since the additional expenditure may consist of running costs alone the associated outgoings will be low. This aspect is particularly relevant to the irrigation of cereals and grassland and it should not be assumed from simple comparisons of Table 12 and Table 13 that the irrigation of these crops is necessarily uneconomic.

86 *Costs of irrigation.* These can be divided between those related to the capital outlay, and annual running costs. The former include investments in storage reservoirs, mains and pumping systems, towards which MAFF grants may be available, and also capital in the form of water application equipment for which grant assistance may also be forthcoming if it is for a horticultural business. Running costs include fuel, labour costs, repairs and maintenance, and water charges.

87 The Report of the ADAS Working Party indicated that the level, and more particularly the composition, of running costs varies considerably between irrigation systems. Fuel is generally a major item representing about 30 per cent of running costs for systems depending on direct abstraction and up to 60 per cent for systems using reservoirs. Repairs are of the order of 10 per cent of running costs for sprinkler systems but can be as high as 40 to 50 per cent for systems using mobile irrigators. Water charges for systems using reservoirs represent only about 4 per cent of running costs but can exceed 20 per cent for direct abstraction. Labour requirements are relatively high for sprinkler systems and low for mobile equipment. The ADAS Working Party Report assumed that half of the labour requirements of irrigation would be met at no additional cost but the remainder would be paid at overtime rates: on this basis extra labour represents about one-third of running costs for sprinkler systems but less than 3 per cent for mobile sprinklers.

88 Specimen costs for nine different irrigation schemes are summarised in Table 13 below. Capital costs are, where appropriate, net of grant payable at 20 per cent: this has been the prevailing rate over recent years and is used in the calculations even though in 1977 a higher rate of grant of 40 per cent was paid on reservoir construction. In order to simplify the calculation of specimen costs, certain other assumptions are made:

a. that the installation is capable of applying, throughout the growing season, 75 mm of water over 12 ha of crops, except in the case of large mobile spray irrigators where it is assumed the capacity is 36 ha;

b. that the capital costs of reservoirs and mains, net of grant, are written off in 15 years at an interest charge of 12 per cent;

c. that pumps and irrigation equipment are written off in 10 years at 12 per cent.

The first of these assumptions needs to be specified in order to determine the relationship between the size of the reservoir, the capacity of the equipment, and the extent of the piped network.

TABLE 13: SPECIMEN IRRIGATION COSTS FOR NINE SYSTEMS (£ per ha/mm)*

Storage system	Sprinkler	Small mobile spray irrigator	Large mobile spray irrigator
	£	£	£
Direct summer abstraction	1.12	1.88	1.55
Winter abstraction: unlined reservoir	2.05	2.80	2.09
Winter abstraction: lined reservoir	5.15	5.89	4.29

* Source: Economics of Irrigation. Report of ADAS Working Party 1977. MAFF

89 A first impression of the worthwhileness of installing and operating an irrigation system can be gained by comparing these costs with the gross margin responses listed in Table 12. They may not, however, be appropriate in considering *grassland* and *cereals* irrigation if, as we have suggested, these crops are regarded as marginal uses for irrigation equipment and therefore incur only running costs. We attach great importance to the need for individual appraisal of each project and we now examine one method of approach.

Measuring rate of return

90 We have already stressed the importance of the individual farmer making his own decision in the light of the particular circumstances on his farm. We have also referred to the long-term nature of the investment in irrigation equipment and the need to frame estimates over a period of up to 15 years. Another factor in investment appraisal is the year-by-year fluctuations in the response to water application as a result of climatic variations.

91 For illustrative purposes we show, in the appendices to this Section, investment appraisal calculations relating to three irrigation systems using different assumptions as to cropping patterns, rates of water application, and type of storage installation. The "internal rate of return" method is employed but in order to simplify the presentation we have omitted taxation considerations whilst recognising that in practice capital allowances and their timing, and the investor's average and marginal rate of tax, can greatly affect annual net cash flows. We carried out a separate analysis which indicated that the extra income generated by irrigation generally exceeded the tax allowances and that, as a result of the additional income tax payable, the internal rate of return was in fact reduced. There is however one additional taxation factor which is always difficult to quantify. This is the incentive to the individual farmer to invest in capital projects such as irrigation in times of high profits in order to lessen his tax liability.

92 We have assumed a 10 year period of economic appraisal in the examples and that only the irrigator equipment will need replacing during this time. To simplify the presentation further we have also assumed for the appraisal period that average weather will obtain in each year, requiring the application of average amounts of water, resulting in a constant response each year. An illustration of the projected cash flow underlying the appraisal of an unlined reservoir at example 1 has also been given. It should be reiterated that these examples are purely for the purpose of illustrating the basic elements of one method of investment appraisal: some of the assumptions made, for instance, are not consistent with generalisations made elsewhere in this Section about the length of life for particular assets.

93 Nevertheless, the examples serve to indicate that the internal rate of return is relatively high for systems involving unlined reservoirs (61 per cent, 65 per cent and 72 per cent) but only moderate for lined reservoir systems (16 per cent, 21 per cent and 17 per cent). The additional costs involved in lining reservoirs do result in substantially lower rates of return. However, rates of return calculated in this way need careful interpretation. They are influenced by the prices used to translate physical responses from irrigation into cash values for each year of the period of appraisal and, similarly, by the costs assumed over the same period.

94 Our three examples assume that output prices and the running costs of irrigation will remain constant at their 1977 levels. One implication of this assumption is that it removes the effects of inflation from the assessment and thus from the computed rates of return. Consequently, if farmers wish to compare these rates of return with the cost of borrowing money (or with the return that might be obtained by investing their funds outside the farm business) it is necessary to make the comparison with a rate of interest from which the effects of inflation have also been removed (i.e. a real rate of interest). One possible method is to deflate the market interest rate (e.g. the actual rate paid on bank borrowing) by the expected percentage increase in the retail price index. An alternative to using constant prices in the investment appraisal is to predict the course of market prices over the period, in which case the rates of return could be compared directly with market rates of interest.

95 We should also stress that the incidence of very wet years, or very dry ones, occurring during the 10 year period of the project has not been considered in the examples and they are thus unrealistic to the extent that they disregard year-to-year fluctuations in the weather which can have a considerable effect on the rate of return. Should the wet years, and hence the relatively low returns, arise in the period immediately following the initial investment the rate of return would be reduced a great deal. By the same token, if the very dry years, and the large returns to irrigation, occur during the initial years of the investment, the rate of return will be appreciably enhanced. The weather element is crucial in determining the return on investment and makes economic appraisal very difficult.

National Benefits and Costs

96 We have already stated that irrigation can lead to increases in yield, better crop prices due to improved quality or more timely marketing, and a less variable annual income. This is to the producer's benefit, but it is important to realise that it is to the nation's benefit as well. Using the 1977 MAFF Census statistics as a starting point, and making judgments about the crop responses and irrigation expenses, it is possible to measure today's costs

and benefits in the aggregate. A similar assessment can be made for the year 2000, basing it on the irrigated areas we have predicted for that date.

97 To assess the costs of irrigation, certain broad assumptions about the nature of irrigation systems have been used and these are set out below. They vary for each of the major crops and reflect what seems most economic under the various circumstances. They are assessed without taking grant aid into account, since it is the cost to the nation as a whole which is being measured. The assumptions are:—

a. *Potatoes:* that 60 per cent of irrigation water is at present taken by direct summer abstraction, and that the remaining 40 per cent and all expansion in the future is provided from unlined reservoirs. The irrigators used are one-third each sprinklers, small mobile machines and large mobile equipment;

b. *Sugar beet:* that half of all irrigation of sugar beet is secondary to the irrigation of another crop, thus incurring running costs only. The equipment used is in the same proportions as in a. above;

c. *Fruit* is irrigated by means of sprinkler equipment;

d. *Vegetables:* that 70 per cent of water is taken at present by direct summer abstraction, with the remaining 30 per cent and all future expansion met from unlined reservoirs. Equipment is in the proportions given in a. above;

e. *Grass:* that grassland is irrigated mainly with large mobile irrigators, the water being drawn primarily from direct summer abstractions, and that this will remain the case;

f. *Cereals:* that irrigation is exclusively opportunist, incurring running costs only; and that

g. *Other crops* are irrigated with water stored in unlined reservoirs, the equipment being as in a. above.

98 Using these hypotheses, and further assuming certain average levels of water application by farmers for each of the crops, we have been able to estimate aggregate costs and benefits for both 1977 and 2000 at constant prices. A very important factor in these calculations is the assumption that farmers as a whole applied 50 per cent of the optimum crop needs in 1977 and would apply 80 per cent of the optimum in the year 2000. This reflects our hope, and indeed our expectation, that there will be a greater awareness of the advantages of irrigation as well as a deeper understanding of the science and husbandry aspects of the interaction of soil and water.

99 On the basis of the data from the MAFF Census of 1977, we estimate that the net benefit from irrigation amounts to about £16 million in an average year. The greater part of this, roughly £12 million, would come from *potatoes* and *vegetables*, and most of the balance from *grass*. Assuming the year 2000 were to be an average year, our estimate of the net benefit then, at 1977 price levels, is about £50 million. This is a three fold increase over two decades, resulting from an expansion in the irrigated area of the crops specified in Section Two from 123,000 to over 300,000 ha, and an increase

in the rates of water application to nearer the optimum level. Of the above aggregate benefit, *potatoes* and *field vegetables* would account for £28 million; but *grass* at around £14 million, and *sugar beet* at £3.5 million, would provide a more prominent contribution than in 1977. This expansion would entail a capital investment in storage and equipment of around £200 million, at constant 1977 prices and before grant, over and above that required to replace existing facilities.

100 The main features of our estimates of the aggregate costs and benefits of irrigation are summarised in Table 14 below. The figures for the area irrigated in the year 2000 are those used in Section Five, and the crop responses from which the gross benefits are derived are those set out in Table 12, assuming average water applications of 50 per cent of optimum needs in 1977 and 80 per cent of optimum in 2000. The costs for each constituent crop are estimated on the basis of the assumptions described in paragraph 97 above.

TABLE 14: IRRIGATION – AGGREGATE COSTS AND BENEFITS IN AN AVERAGE YEAR

	1977	2000
Area Irrigated	123,000 ha	309,000 ha
Water Applied	70 Mm^3	285 Mm^3
Gross Benefit at 1977 Prices	£28 million	£102 million
Gross Cost at 1977 Prices	£12 million	£ 52 million
Annual Net Benefit at 1977 Prices	£16 million	£ 50 million

101 Thus, in the aggregate, the potential gain from irrigation is considerable, but so is the capital investment needed to make it possible. Most new installations are likely to need winter storage facilities of some description and this in itself is a major item of capital expenditure. Indeed we are bound to admit that these heavy demands on capital investment, and the year-to-year uncertainties about the profitability of irrigation, caused us to question whether we were over-optimistic in our estimates of the extent of irrigation in the year 2000, despite the benefit we foresee. We decided, taking a strategic view, that it is clearly both in the national interest, and that of the individual farmer, that irrigation should expand. In the end, the expansion can only come from commercial decisions by farmers, but we believe that through their business acumen, supported and encouraged by Government as a matter of national policy, our forecasts for the year 2000 are attainable.

Summary

102 Many factors affect the farmer's decision on irrigation, and individual circumstances vary widely, but in general it appears that high rates of return can be obtained on *potatoes, vegetables,* and certain *fruit crops,* especially where lined reservoirs are not necessary. At today's prices these high-return crops show gross margin responses of the order of £9–£12 per hectare for each mm of water applied. Costs tend to be lowest where direct summer abstraction is practised and these may be only 50 to 70 per cent of the costs of systems using unlined reservoirs for winter storage. Costs for lined reservoir systems, however, are about double those of unlined reservoirs, resulting in a substantially lower rate of return. For the individual farmer the uncertain incidence of wet years and dry years makes formal investment appraisal particularly difficult, even though irrigation may pay in the long run, but we have nevertheless shown a simplified rate of return method purely for illustrative purposes. In total, we estimate that the annual net benefit from irrigation is about £16 million per year and foresee this growing to £50 million per annum, at present prices, by the year 2000. This is an important potential which should commend the attention of all those concerned with agriculture.

EXAMPLE I

Crops: 12 ha Early potatoes requiring an average annual water application of 50 mm
12 ha Maincrop potatoes requiring an average annual water application of 100 mm
12 ha Sugar beet requiring an average annual water application of 75 mm

Water requirement: (1) Lined reservoir 37800 m^3
Unlined reservoir 40500 m^3

Capital costs: (2)

	Lined £ GROSS	Lined £ NET (5)	Unlined £ GROSS	Unlined £ NET (5)
Reservoir	56700	45360	10125	8100
Mains	6000	4800	6000	4800
Pump	1925	1540	1925	1540
Irrigator	4500	4500	4500	4500
		56200		18940

Running costs: (2)

	Lined	Unlined
Fuel 2p/m^3	756	810
Repairs	471	471
Water £2/1000 m^3	76	81
Labour (6)	41	41
	1344	1403

Extra gross margin: (3)

			£
Early potatoes	@ £555/ha	=	6660
Maincrop potatoes	@ £358/ha	=	4296
Sugar beet	@ 187.5/ha	=	2250
			13206

Extra annual average cash inflow after running costs:

Lined = £11862 Unlined = £11803

Internal rate of return: (4)

Lined = 16.2% Unlined = 61.5%

NOTES: (1) Requirement based on basic demand + 40% for lined and + 50% for unlined reservoirs to allow for evaporation, seepage and 5th driest year.
(2) Costs based on 1977 figures as per Report of ADAS Working Party.
(3) Returns based on 1977 figures as per Report of ADAS Working Party.
(4) Calculations assume constant cash inflows over a ten year period with replacement of irrigator in year 7.
(5) Grant at 20%.
(6) Relates to additional labour costs – assumed here to be half the total additional labour requirement valued at over-time rate.

ILLUSTRATIVE PROJECTED CASH FLOW UNDERLYING EXAMPLE I – UNLINED RESERVOIR

£ 1977 constant prices

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Capital Expenditure											
(net of grant)											
Reservoir	8,100										
Mains	4,800										
Pump	1,540										
Irrigator	4,500							4,500			
1. Total	18,940	0	0	0	0	0	0	4,500	0	0	0
Running Costs											
Fuel		810)									
Repairs		471)	→								
Water		81)									
Labour		41)									
2. Total	0	1,403	1,403	1,403	1,403	1,403	1,403	1,403	1,403	1,403	1,403
Additional Revenues											
Early potatoes		6,660)									
Maincrop potatoes		4,296)	→								
Sugar beet		2,250)									
3. Total	0	13,206	13,206	13,206	13,206	13,206	13,206	13,206	13,206	13,206	13.206
Net Revenues											
4. (line 3 minus lines 1 and 2)	- 18,940	11,803	11,803	11,803	11,803	11,803	11,803	7,303	11,803	11,803	11,803

Internal rate of return = 61 per cent = discount rate which, when applied to line 4, reduces the sum of the discounted value of the net revenues to zero in Year 0.

EXAMPLE II

Crops:	12 ha Early potatoes requiring	50 mm
	12 ha Maincrop potatoes requiring	100 mm

Water requirement: (1)	Lined reservoir	25200 m^3
	Unlined reservoir	27000 m^3

Capital costs: (2)

	Lined £ GROSS	Lined £ NET (5)	Unlined £ GROSS	Unlined £ NET (5)
Reservoir	37800	30240	6750	5400
Mains	4500	3600	4500	3600
Pump	1925	1540	1925	1540
Irrigator	4500	4500	4500	4500
		39880		15040

Running costs: (2)

	Lined	Unlined
Fuel	504	540
Repairs	434	434
Water	50	54
Labour (6)	30	30
	1018	1058

Extra gross margin: (3)

		£
Early potatoes	=	6660
Maincrop potatoes	=	4296
		10956

Extra annual average cash inflow after running costs:

Lined = £10038 Unlined = £9898

Internal rate of return: (4)

Lined = 21.19% Unlined = 65.03%

NOTES:

(1) Requirement based on basic demand + 40% for lined and + 50% for unlined reservoirs to allow for evaporation, seepage and 5th driest year.
(2) Costs based on 1977 figures as per Report of ADAS Working Party.
(3) Returns based on 1977 figures as per Report of ADAS Working Party.
(4) Calculations assume constant cash inflows over a ten year period with replacement of irrigator in year 7.
(5) Grant at 20%.
(6) Relates to additional labour costs – assumed here to be half the total additional labour requirement valued at over-time rate.

EXAMPLE III

Crops:		
	4 ha cauliflower	requiring 100 mm
	3 ha lettuce	” ”
	3 ha runner beans	” ”
	2 ha raspberries	” ”

Water requirement: (1) Lined reservoir 16800 m^3
Unlined reservoir 18000 m^3

Capital costs: (2)

	Lined (6) £		Unlined (6) £	
	GROSS	NET	GROSS	NET
Reservoir	36960	27720	8100	6075
Mains	3000	2250	3000	2250
Pump	400	300	400	300
Sprinklers	800	680	800	680
		30950		9305

Running costs: (2)

	Lined	Unlined
Fuel	336	360
Repairs	135	135
Water	34	36
Labour (7)	162	162
	667	693

Extra gross margin: (3)

			£
Cauliflower	@ £762/ha	=	3048
Lettuce	@ £465/ha	=	1395
Runner Beans	@ £530/ha	=	1590
Raspberries	@ £730/ha	=	1460
			7493

Extra annual average cash inflow after running costs:

Lined = £6826 Unlined = £6800

Internal rate of return: (4)

Lined = 17.63% Unlined = 72.68%

NOTES:
(1) Requirement based on basic demand + 40% for lined and + 50% for unlined reservoirs to allow for evaporation, seepage and 5th driest year.
(2) Costs based on 1977 figures as per Report of ADAS Working Party.
(3) Returns based on 1977 figures as per Report of ADAS Working Party.
(4) Calculations assume constant cash inflows over a ten year period with replacement of irrigator in year 7.
(5) Grant of 20%.
(6) Net of HCGS grants at 1979 rates.
(7) Relates to additional labour costs – assumed here to be half the total additional labour requirement valued at over-time rate.