



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search  
<http://ageconsearch.umn.edu>  
[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*



**NORTH OF SCOTLAND COLLEGE OF AGRICULTURE**  
**School of Agriculture, Aberdeen**  
**Agricultural Economics Department**

GIANNINI FOUNDATION OF  
AGRICULTURAL ECONOMICS  
LIBRARY

JUL 12 1966

**Farm Crop Irrigation  
in the North of Scotland  
1964 and 1965**

*by J. S. Bone, M.Sc.*

*June, 1966*

*Price 3/-*

*Economic Report No. 117*



#### ACKNOWLEDGEMENTS

The Agricultural Economics Department of the North of Scotland College of Agriculture wishes to thank those farmers and members of the County Advisory Staff who supplied the records and information on which this report is based.

THE NORTH OF SCOTLAND COLLEGE OF AGRICULTURE

AGRICULTURAL ECONOMICS DEPARTMENT

FARM CROP IRRIGATION

IN THE NORTH OF SCOTLAND

1964 and 1965

by

J. S. Bone. M.Sc.

June, 1966.

# FARM CROP IRRIGATION IN THE NORTH OF SCOTLAND

1964 AND 1965

## CONTENTS

	<u>Page</u>
<u>INTRODUCTION</u>	1
Weather During Survey Period 1964 and 1965	8
The Sample	10
<u>SURVEY RESULTS</u>	13
Water Sources	13
Equipment	15
Utilisation of Equipment 1964 and 1965	17
<u>IRRIGATION COSTS AND RETURNS IN THE NORTH OF SCOTLAND</u>	19
<u>SUMMARY AND CONCLUSIONS</u>	26
<u>APPENDICES</u>	
Appendix I - River Purification Board Areas, North of Scotland College of Agriculture Mainland Area.	29
Appendix II - Acreage of Horticultural Crops at June, 1964, North of Scotland College of Agriculture Area.	30
Appendix III - Total Acreage of Agricultural Crops at June, 1964, North of Scotland College of Agriculture Area.	31
Appendix IV - Glossary of Terms Used.	32
<u>BIBLIOGRAPHY</u>	33

# LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Frequency of Irrigation Need - Inverness (Dalcross) Area, April-September	4
2	Frequency of Irrigation Need - Inverness (Dalcross) Area, April-July	5
3	Irrigation Sets in the North of Scotland - February, 1964	6
4	Price Guide to Portable Irrigation Equipment	7
5	Cropping of Sample Farms	10
6	Distribution of Cropping	11
7	Stocking of Sample Farms	12
8	Distribution of Summer Grazing Livestock	13
9	Distribution of Farms by Courses of Irrigation Water	13
10	Water Sources for Spray Irrigation (England and Wales) 1963	14
11	Distribution of Farms by Total Length of Irrigation Pipeline	15
12	Distribution of Farms by Maximum "Reach" of Irrigation Equipment	16
13	Distribution of Farms by Total Crop Acreage Irrigated, 1964	17
14	Distribution of Farms by Crops Irrigated, 1964	18
15	Diversity of Irrigation Use, 1964	18
16	Distribution of Farms by Purchase Dates of Irrigation Equipment	19
17	Distribution of Farms by Net Capital Investment in Irrigation Equipment	20
18	Distribution of Farms by Annual Fixed Costs per Acre	21
19	Distribution of Farms by Fixed Costs per Acre-Inch Applied 1964	21
20	Distribution of Farms by Variable Costs per Acre-Inch	23
21	Distribution of Farms by Total Operating Costs per Acre-Inch 1964	23
22	Distribution of Farms by Average Fixed Costs per Acre-Inch	24

# LIST OF FIGURES

<u>Figure</u>		
1	Average Annual Rainfall - North of Scotland College of Agriculture Mainland Area	2
2	Estimated Soil Moisture Deficit - Elgin Area 1964 Season	9
3	Estimated Soil Moisture Deficit - Elgin Area 1965 Season	9

# FARM CROP IRRIGATION IN THE NORTH OF SCOTLAND

1964 AND 1965

## INTRODUCTION

Crop failures due to drought are uncommon in the North of Scotland, an area associated in the popular mind with relatively high humidity. This impression is substantiated by figures for parts of the west coast, where the mountainous nature of the land contributes to above-average rainfall. However, the more fertile east coast belt lies in a rain shadow, and it is in this region that interest in farm irrigation is concentrated. Having experienced difficulty in establishing crops, and faced with reduced yields in a dry season, a number of farmers in the area served by the North of Scotland College of Agriculture have acquired irrigation equipment. Some practical experience has now been gained, and in certain cases, worthwhile crop responses are claimed. In order to assess the pattern of irrigation use, and in an attempt to investigate its profitability, a survey of farm-scale systems was carried out during 1964 and 1965.

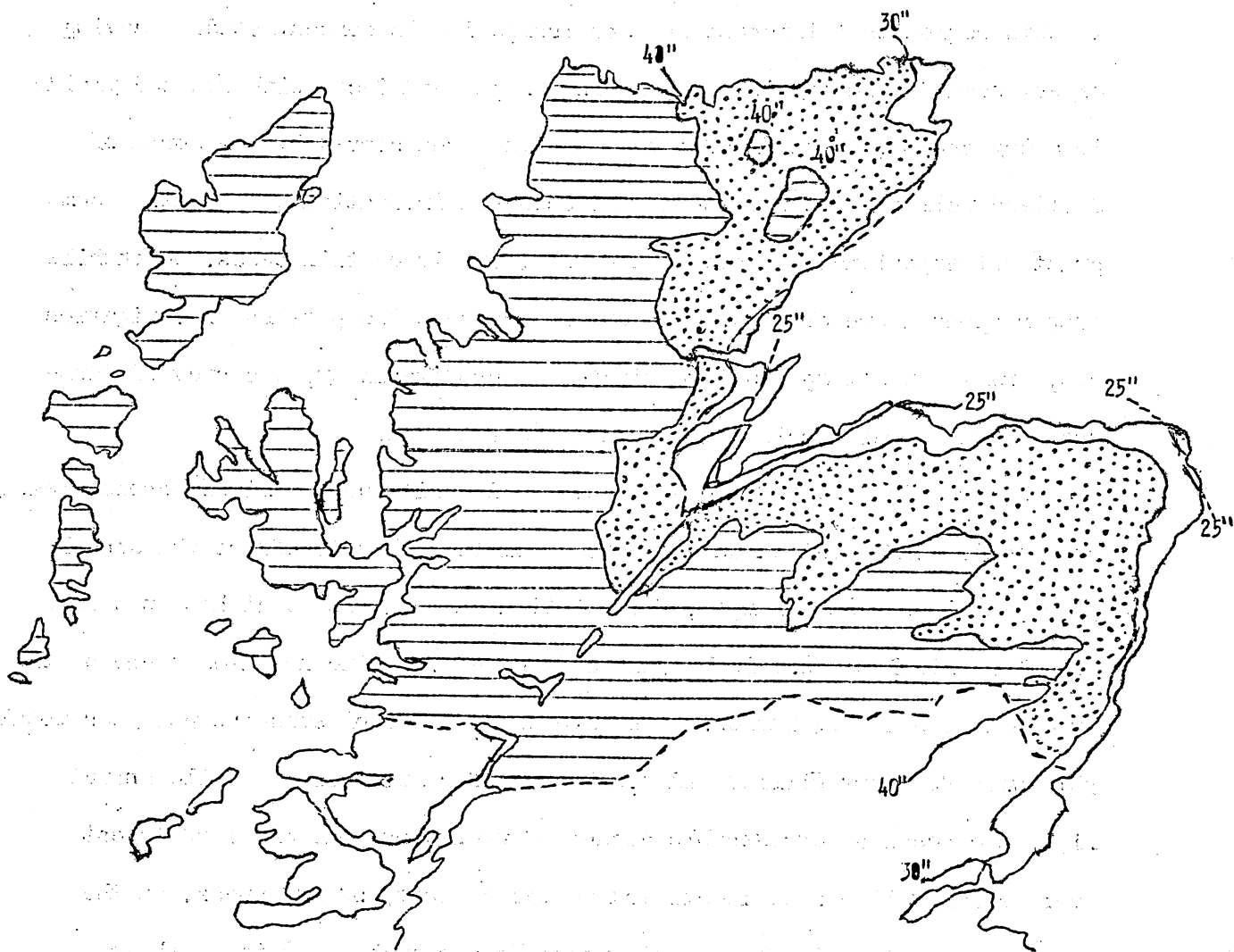
The rainfall map of the area covered in this survey (Fig.I) shows clearly how ground configuration and distance from the Atlantic affect the annual precipitation. For example, Fort William on the west coast has an average annual rainfall of 78.7 inches, while Inverness, at the north-east end of the Great Glen, has 28.4 inches. The average amounts of sunshine per year total 981 hours for Fort William and 1,239 hours for Inverness. While annual figures conceal a considerable amount of variation, the areas of lowest average rainfall can be identified in the vicinity of Inverness, on the coastal strip towards Elgin, and around Fraserburgh. It is in these districts, where annual rainfall averages less than 25 inches, that irrigation is likely to be of most benefit. Nevertheless, the whole of the east coast experiences quite dry conditions, since a belt of land extending roughly 10-20 miles inland from Montrose to the Dornoch Firth receives an average of less than 30 inches, and this distinction is shared by the northern tip of Caithness, around John o' Groats.

The availability of water for plant growth is governed by the moisture-holding capacity of the soil, and also by the effective rooting depth of the crop. Light sandy soils are able to retain much less moisture than heavier

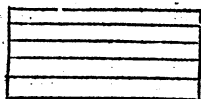
Figure 1

Average Annual Rainfall

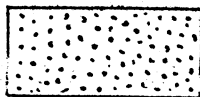
North of Scotland College of Agriculture Mainland Area



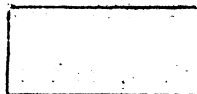
North of Scotland  
College Area Boundary



Over 40"



30 - 40"



Under 30"

Source: Climatological Atlas of the British Isles H.M.S.O. London, 1952.



clays, consequently the effects of drought are more pronounced on light land. In general, the soils within the low rainfall belt along the north-east coast can be classified as light land. Raised beaches are a well-defined feature of the Moray Firth coastline, while glacially-derived gravels are common in lowland areas skirting the mountains. These formations are prone to drought, and are difficult to crop in a dry season. In extreme cases, where the surface is exposed, or only partly stabilised by vegetation, wind erosion occurs. The classic example of this took place in the late 17th century, when the estate of Culbin was engulfed by drifting sand. A desert six miles long and two miles in width was created, and sixteen farms, a church and the mansion house were lost. The Culbin forest, some 6,000 acres in extent, now covers most of this previously mobile area. Although disasters of this magnitude are no longer experienced, wind erosion still takes place, and snow-clearing equipment is occasionally employed to clear blown sand from public roads in Moray. Many farmers in this area have found that the combination of light land and low rainfall restricts production, in some cases precluding cultivation altogether.

For any given area, it is possible to calculate a theoretical figure for the water use of a growing crop adequately supplied with moisture (1). This quantity, the potential transpiration, does not vary much between crop species, and is not influenced by soil type, so standard values for each month can be published for all parts of the United Kingdom (2). It is then a fairly simple matter to construct a 'water balance sheet' for the April-September growing season, in which potential transpiration, broken down into approximate weekly amounts, appears on the expenditure side, while income is represented by actual rainfall for the week. Using this method, it is possible to estimate the soil moisture content, at any time during the season, with reasonable precision. Although potential transpiration can be quoted on a county or sub-county basis, the individual farmer is recommended to check local rainfall by means of a rain-gauge, since wide variations can occur over a relatively short distance.

Rainfall during the growing season may be adequate in total, but its distribution seldom matches crop requirements for water.

---

(1) (2) For references see Bibliography p. 33.

Where rainfall over the six-month period exceeds the total potential transpiration, it is not uncommon to find that a shortage of water at a critical stage in the growth of a crop has limited production. In one of the driest areas, to the east of Inverness, the average April-September rainfall is 13.3 inches, while the corresponding potential transpiration is 14.75 inches - leaving an average deficit of about 1.5 inches during the summer months.

Although potential transpiration shows little change from year to year, the annual rainfall over a ten-year period can be expected to deviate from the average, according to patterns established over half a century. It is therefore possible to estimate the frequency of irrigation need for any particular locality, and the results for the Inverness area are shown in Table I.

Table I      Frequency of Irrigation Need - Inverness (Dalcross) Area  
April-September

Years	YEAR 1 (Driest)	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10 (Wettest)
Rainfall as % of average	67%	78%	84%	90%	95%	101%	107%	114%	122%	142%
Expected Rainfall (inches)	8.92	10.38	11.18	12.00	12.64	13.44	14.24	15.17	16.23	18.90
Average Potential Transpiration	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75
Expected Rainfall Deficiency	5.83	4.37	3.57	2.75	2.11	1.31	0.51	-	-	-
Irrigation Need	4.83	3.37	2.57	1.75	1.11	0.31	-	-	-	-

(Source: Meteorological Office, Edinburgh)

The table above indicates that, for any ten-year period, the expected rainfall during the driest year is only 67 per cent of the average six-month total. Under Inverness conditions therefore, a rainfall deficiency (or soil moisture deficit) approaching 6 inches can be expected once each decade. At the other end of the scale, rainfall is likely to exceed potential transpiration on three out of the ten years.

These figures for irrigation need are applicable to grassland, since this

occupies the ground for the whole of the growing season, and is the crop most likely to suffer from drought. When irrigating grass, the normal recommendation is to maintain the soil close to field capacity throughout the season, but in practice, a deficit of about one inch is frequently allowed to build up. Attempts to restore the soil moisture content to field capacity are unwise, since heavy rainfall following irrigation can result in waterlogging and the leaching of nutrients. Water and application costs can thus be saved without appreciably lowering herbage yields, so that the theoretical irrigation need can be reduced by one inch. The conclusion to be drawn from this is that, for the April-September period, irrigation is likely to be required only five or six years in ten for the most demanding crop in the driest parts of the North of Scotland.

The most critical period for plant growth is April-July, and over these four months, expected rainfall variations about the average are even more extreme. Table 2 gives details of the frequency of irrigation need for the Inverness area for this particular period.

Table 2      Frequency of Irrigation Need - Inverness (Dalcross) Area  
April-July

Years	YEAR 1 (Driest)	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10 (Wettest)
Rainfall as % of average	62%	74%	81%	89%	95%	101%	108%	116%	127%	147%
Expected Rainfall (inches)	5.09	5.99	6.65	7.31	7.80	8.29	8.87	9.52	10.43	12.07
Average Potential Transpiration	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80
Expected Rainfall Deficiency	5.71	4.81	4.15	3.49	3.00	2.51	1.93	1.28	0.37	-
Irrigation Need	4.71	3.81	3.15	2.49	2.00	1.51	0.93	0.28	-	-

(Source: Meteorological Office, Edinburgh)

It is clear that rainfall deficits are likely to occur with greater frequency when the four-month period only is considered. To ensure the maximum growth of a crop such as grass, supplementary irrigation would be

required seven or eight years in ten after allowing a one inch deficit.

Potential transpiration is greatest in May, June and July, and in low rainfall areas, the effects of drought on crop production are frequently observed during these months. Not only is grass production affected, but the establishment of cash crops such as vegetables and potatoes becomes difficult. In these circumstances, a number of farmers have purchased irrigation equipment.

A 1964 Machinery Census, carried out by the Department of Agriculture and Fisheries for Scotland, (3) revealed that a total of 415 irrigation sets were in use in Scotland. While the majority of these were situated in the southern half of the country, the following distribution was found within the area served by the North of Scotland College of Agriculture.

Table 3      Irrigation Sets in the North of Scotland - February, 1964

County	No. of Sets
Shetland	-
Orkney	2
Caithness	-
Sutherland	-
Ross & Cromarty	5
Inverness	5
Nairn	1
Moray	16
Banff	8
Aberdeen	26
Kincardine	5
TOTAL	68

(Source: Dept. of Agric. & Fisheries  
for Scotland. Machinery Census)

It is probable that these figures include a high proportion of market-garden sets, particularly in the County of Aberdeen, where the number of farm-scale outfits is thought to be less than half a dozen.

Water availability can be a problem on some farms, particularly where reliance is placed on a small stream or ditch. The quantity of water required during irrigation is very large, since the standard application of one acre-

inch is equivalent to 22,600 gallons of water per acre. In a dry season, the total requirement can therefore reach several million gallons. Methods of water conservation have been adopted by some farmers, and grants of up to 50 per cent of the approved costs are available for the construction of boreholes, wells and reservoirs. The installation of pumping machinery and permanent underground piping is similarly grant-aided, but in an area where the six-month irrigation need is confined to five or six years in ten, few farmers have so far risked capital investment in fixed equipment.

The majority of irrigation schemes in the United Kingdom employ portable equipment, which reduces the overall capital cost. Table 4 gives a general guide to typical costs of new portable equipment, based on manufacturers' current price lists.

Table 4 Price Guide to Portable Irrigation Equipment

Item	Approximate Cost
Pumps - Tractor P.T.O. driven, centrifugal	£150-250
- Diesel engine driven "	£250 upwards
Pipeline 2" Aluminium lateral (including sprinklers)	17/- per yard run
3" " " " "	21/- " " "
4" " main line (including fittings)	24/- " " "
5" " " " " "	30/- " " "
Sprinklers, Medium Size	30/- Each
Rainguns	£25 Each

The problem of water supply is understandably greater in areas further south, where irrigation has gained acceptance as a valuable farming tool, but concern over possible future development in the north has led to recent Scottish legislation. The Spray Irrigation (Scotland) Act 1964 enables river purification boards to obtain powers to control the abstraction of water by farmers for irrigation purposes. If irrigation in any board area causes a serious reduction in river levels, water use may be regulated by the issue of annual licences to each irrigator. The board retains the right to



restrict or suspend the operation of any licence during times of exceptional shortage. Only two boards function within the College area - the Dee and Don board, administered from Aberdeen, and the Banff, Moray and Nairn board, administered from Elgin (See Appendix I). So far these boards have not sought control orders for their areas. In the remainder of the North of Scotland, water resources are the responsibility of local authorities, which do not have statutory powers to grant or withhold licences. Under the Rivers (Prevention of Pollution) (Scotland) Act, 1965, the quality of the supply will be safeguarded by the two river purification boards, and in other areas by river purification authorities, which are the county councils or large burgh councils concerned.

#### WEATHER DURING SURVEY PERIOD - 1964 AND 1965

The two years provided contrasting conditions. During the first four months of the 1964 "irrigation season" (April - September), rainfall in the North of Scotland was below average, and a deficit of over five inches was reached by the end of July in the Moray Firth area. Heavy rain in August and September, however, had reduced the deficit to about two inches by the end of September. Overall, the annual rainfall was rather lower than average, and at Lossiemouth, on the coast of the Moray Firth, the total rainfall was only 19.70 inches.

In 1965, owing to the very dry winter, the season began with an estimated soil moisture deficit of half an inch. Rainfall in April and June was below average, but the May figure was slightly greater than normal. A maximum estimated soil moisture deficit of almost three inches was reached at the beginning of July, but rainfall during July and September was sufficient to restore the soil to field capacity by the end of the season.

Estimated soil moisture deficits for the area around Elgin have been plotted at fortnightly intervals, using actual rainfall and potential transpiration figures, and the results for 1964 and 1965 are illustrated in Figures 2 and 3.

For a crop such as grass, it is generally considered that the greatest yield per acre is obtained where the soil moisture deficit is maintained in the vicinity of one inch. Had a maximum deficit of  $1\frac{1}{2}$  inches been permitted in 1964, 5 acre-inches of water would have been required during the months of May, June and July. Under the same conditions the 1965 grass crop would have received two acre-inches, supplied in June.

Figure 2      Estimated Soil Moisture Deficit - Elgin Area

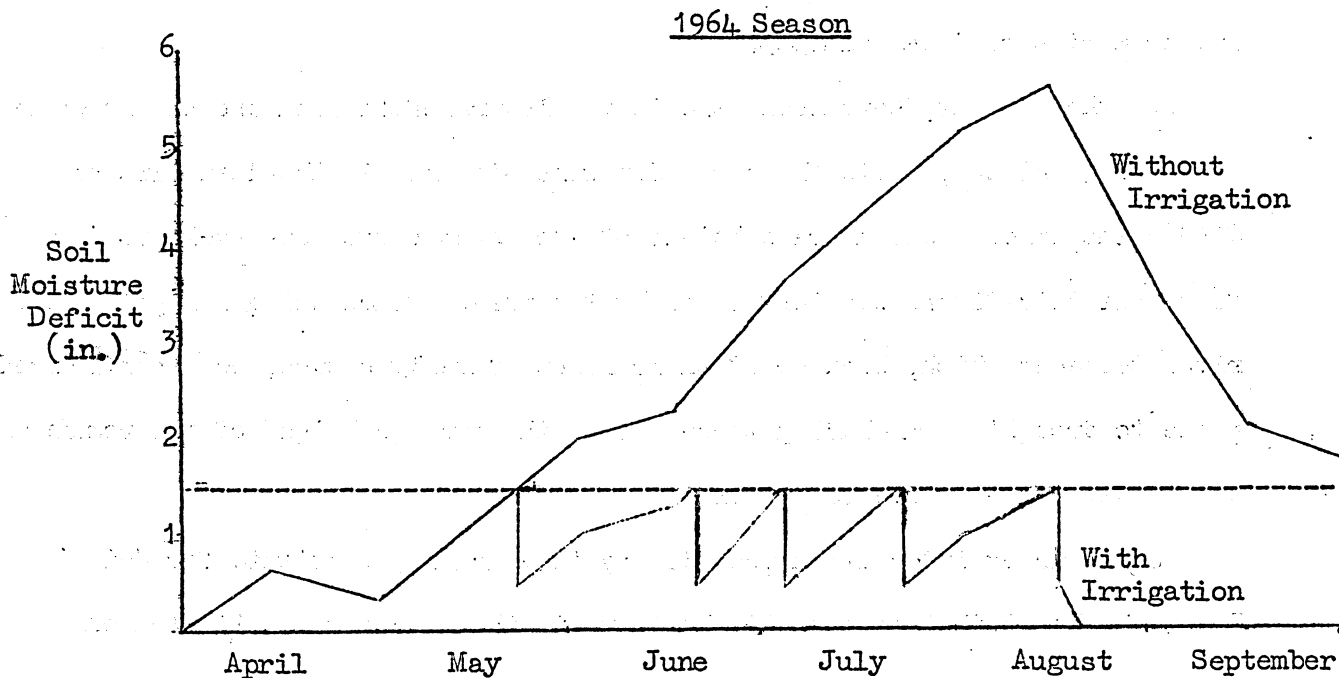
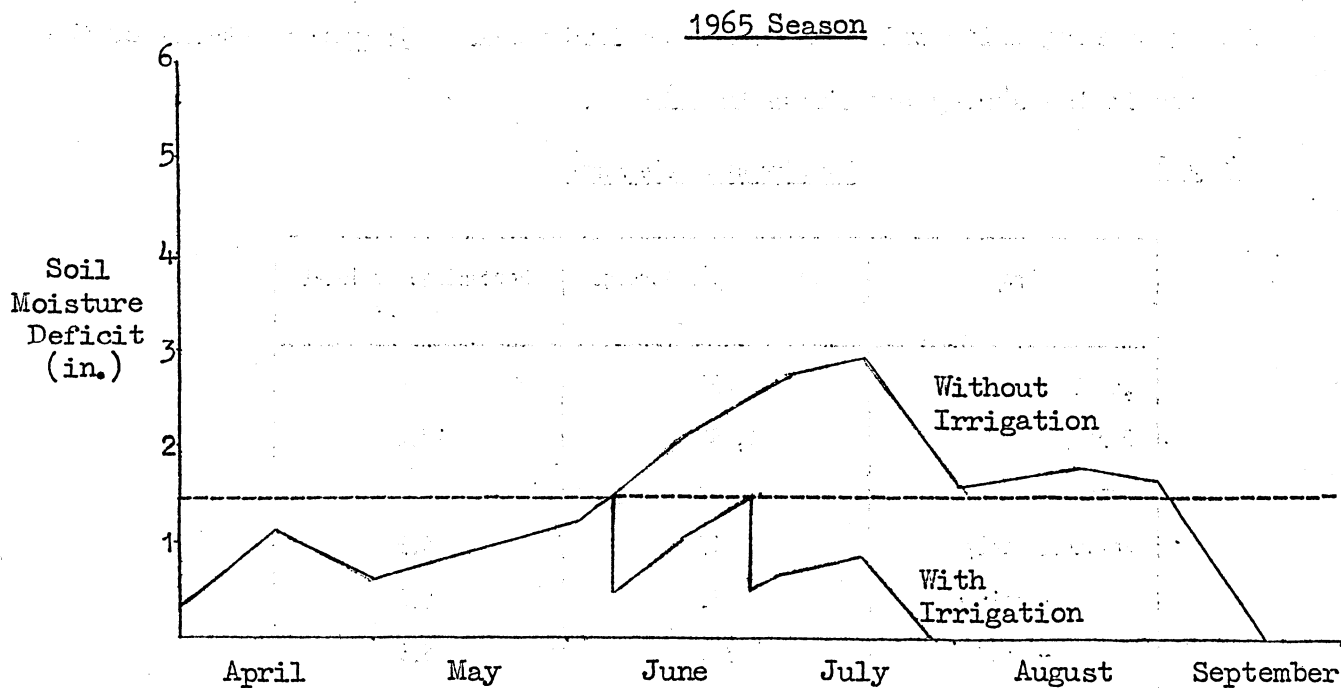


Figure 3      Estimated Soil Moisture Deficit - Elgin Area



- Irrigation with one inch

THE SAMPLE

Twenty-one farmers in the area served by the North of Scotland College of Agriculture agreed to provide details of their investment in irrigation equipment, and a record of its use was maintained during the summer months of 1964 and 1965.

Of these farms, seventeen were in the low rainfall area around the Moray and Dornoch Firths, while the remainder were situated in Aberdeenshire or Kincardineshire. The average height of the farms above sea-level was 120 feet, but this figure was influenced by two inland farms using irrigation on river terraces which, because of their light gravelly nature, were particularly prone to drought. Excluding these cases, the average height of the remainder was about 90 feet above sea level.

Soil survey information provided by the Macaulay Institute for Soil Research showed that almost all the farms in the sample were situated on freely-draining material, frequently combined with sand. One or two farms were on less well drained alluvium or silty clay, related to nearby water courses and former areas of flooding. At the other extreme, on the raised beaches, the soil association was simply 'sand on sand' with an estimated moisture retention of no more than  $\frac{1}{4}$  inch per foot depth.

The farms in the sample ranged from 63 acres to 500 acres, with an average size of 260 acres. The smallest farm was run in conjunction with other neighbouring units which could not be irrigated. Cropping details of the farms in the survey are shown in Table 5.

Table 5                      Cropping of Sample Farms

Crop	Total Sample Acreage	Percentage of Total Acreage
Wheat	251	4.6
Barley	1,492	27.2
Oats	282	5.2
Potatoes early	17	0.3
" - maincrop	10	0.2
" - seed	354	6.5
Turnips	224	4.1
Kale/Rape	23	0.4
Fruit and Vegetables	21	0.4
Arable Silage	48	0.9
Grass	2,696	50.2
Total	5,468	100.0

Table 5 reveals that grass occupied about half the total acreage of the farms included in this survey. Cereals accounted for over one-third, with barley alone covering about a quarter of the total acreage. Seed potatoes were next in importance, followed by turnips and arable silage. The acreage devoted to other crops was small, and it is interesting to note that no more than 0.4 per cent of the total area was under fruit and vegetables. The acreage of vegetables was made up mainly of cabbage, with some cauliflower and sprouts. These crops were produced in some cases for sale to local retailers, but in years when the market was oversupplied, they could be utilised by livestock. Only one farm in the sample irrigated fruit, and this was confined to a small acreage of strawberries and raspberries.

Table 6                      Distribution of Cropping

Crop	No. of Farms Growing Crop	Percentage of Farms Growing Crop	Average Acreage Per Farm Growing Crop
Wheat	7	33	35.8
Barley	19	91	78.5
Oats	9	43	31.3
Potatoes early	3	14	5.7
"    --maincrop	4	19	2.5
"    -- seed	16	76	22.1
Turnips	12	57	18.7
Kale/Rape	3	14	7.7
Fruit and Vegetables	4	19	5.3
Arable Silage	3	14	16.0
Grass	21	100	128.3

An appreciation of the importance of individual crops within the sample can be derived from Table 6. Each farm had a substantial acreage of grass, and barley was grown on nineteen out of the twenty-one holdings. Seed potatoes were produced on three-quarters of the farms, but only three grew earlies, while four had small acreages of maincrop (mostly Kerr's Pink for local consumption). Roughly half of the farms in the sample grew turnips while three had small acreages of kale or rape.

Potentially high-value fruit and vegetable crops were grown on only four of the farms in the sample. This is surprising, in view of the yield responses and extra cash returns which can be obtained from such crops after

irrigation in a dry season. Although most of the experimental work on irrigation has been carried out in England, it may be assumed that the pattern of crop responses to irrigation would be similar in the North of Scotland. A report from the Office of the Minister for Science (4) indicates that, under suitable conditions, crops such as celery, cauliflower and lettuce are likely to give the greatest increase in value per acre following irrigation. Fruit, including blackcurrants, raspberries and strawberries can also give a very worthwhile response, while the increased yields from early potatoes and maincrop varieties can be highly profitable. The irrigation of grassland can result in yield increases varying from 20--60 per cent, but the increase in the value of the output per acre depends on the efficiency with which the grass is utilised. Spring cereals are considered to give the least worthwhile response to irrigation, with a likely yield increase of only 15 per cent.

An order of priority has been drawn up on the basis of these figures, indicating that irrigation can be applied most profitably to vegetables, followed by fruit, potatoes and grass (if intensively used). It is evident from Tables 5 and 6 that fruit and vegetables are of very minor importance on the farms included in this survey, and that the availability of irrigation has so far exerted little influence on traditional cropping patterns for the area. Even the possibility of early or maincrop potato production has received little attention, and it appears that irrigation has been used mainly to improve grass production in dry periods. The present importance in the North of Scotland of vegetables and small fruit crops for human consumption can be gauged from Appendix II which shows the acreage distribution of these crops within the College area. Appendix III gives details of the distribution of other agricultural crops within this area.

Each farm in the survey carried livestock, and Tables 7 and 8 show details of the distribution of stock within the sample.

Table 7

Stocking of Sample Farms

Stock	Total L.S.U.s. in Sample	Percentage of Total L.S.U.s.
Dairy Cattle	577	25.6
Beef Cattle	1,108	49.1
Sheep	571	25.3
Total	2,256	100.0



Table 8

Distribution of Summer Grazing Livestock

Stock	No. of Farms Carrying Stock	Percentage of Farms Carrying Stock	Average L.S.U.s. per Farm Carrying Stock
Dairy Cattle	7	33	82.4
Beef Cattle	14	67	79.1
Sheep	11	52	51.9

Although dairy cows and their followers were grazed on one-third of the farms, the emphasis was on beef production. - generally the fattening of store animals. Sheep were the only grazing livestock on two of the holdings.

SURVEY RESULTS

WATER SOURCES:

Most of the farms in the sample were able to extract water from a nearby water course. In a few cases, low cost temporary or permanent dams were constructed across streams to provide an adequate volume, while one lined storage reservoir had been excavated. Lochs provided two farmers with a very convenient supply of water. Table 9 shows the distribution of the various sources. On some farms, more than one source of water was available. Free water from rivers and streams represents the most convenient supply for irrigation, since it is often possible to use several pumping sites, thus reducing the requirement for main line piping.

Table 9

Distribution of Farms by Sources of Irrigation Water

Water Sources	Number of Farms
River	5
Stream or Ditch	17
Stream with permanent dam	3
Loch	2
Storage Reservoir	1

The wide availability of pure water is one of the great natural assets of the North of Scotland, and few farmers have so far found it necessary to construct storage facilities. A comprehensive survey, carried out in 1963,(5) of irrigation in England and Wales, illustrates the considerable diversity of

sources employed, details being shown in Table 10.

Table 10 Water Sources for Spray Irrigation (England and Wales) 1963

Water Sources	No. of Holdings	Percent of Total
River, stream or other water course	2,914	36.2
Spring	455	5.6
Shallow Well	519	6.4
Deep Borehole	436	5.4
Pond or Lake	689	8.6
Public Supply	2,808	34.8
Other Sources	237	3.0

Source: Ministry of Agriculture, Fisheries and Food

Since the figures for England and Wales include all holdings from  $\frac{1}{4}$  acre upwards, market gardens will constitute an important part of the total. Under very intensive conditions the use of a public water supply may be justified, and the enquiry showed that mains water was the most common source on holdings of less than 50 acres. The importance of this source diminished rapidly on larger holdings, owing to the cost (at perhaps 2s. 6d. per 1,000 gallons) and the uncertainty of supplies in a dry season. The use of mains water may therefore be discounted for farm-scale irrigation of relatively low-value crops.

Although water supplies were described as adequate on most farms in this survey, some interest was evident in methods of water conservation. In one instance, where two farmers relied on the same stream, it was found that the reduction in flow caused by one pump made it difficult for irrigation to be carried out downstream. In such circumstances, the provision of some form of reservoir may allow storage of water during "off-peak" periods. Storage facilities may take several forms:-

- a) impounding reservoirs - where a dam is constructed across the stream;
- b) off-stream reservoirs - where a proportion of the stream flow is directed or pumped into the reservoir, which may require to be lined with impervious sheeting;
- c) seepage reservoirs - excavations into the water table to form a large well.

Costs are very variable, depending on factors such as contour and soil type, but one or more of these methods of conservation may have to be used if the existing supplies are insufficient to meet demand in a dry season. It is anticipated that, in the future, the use of farm storage reservoirs will become more common, and the 1963 survey in England and Wales showed that some 440 earth reservoirs had been constructed for irrigation purposes. These reservoirs had an average capacity of approximately  $1\frac{1}{4}$  million gallons, or roughly 55 acre-inches.

#### EQUIPMENT

The capital cost of irrigation equipment is governed largely by the layout of the farm in relation to water sources. Where more than one source is available, or if an adequate water course runs through the middle of the holding, it may be possible to irrigate with a minimum amount of piping. The amounts of pipeline in use on the farms covered by the present survey are shown in Table 11.

Table 11      Distribution of Farms by Total Length of Irrigation Pipeline

Length of Pipeline	Number of Farms
0 - 199 yards	Nil
200 - 399 "	2
400 - 599 "	10
600 - 799 "	5
800 - 999 "	1
1,000 - 1,499 "	2
1,500 yards and over	1

These figures include permanent underground main line - cement asbestos pipe varying from 4 inches to 8 inches diameter on three farms, and 6 inch diameter cast iron water pipe on a fourth.

Owing to differences in the accessibility of water on individual farms, a given length of pipeline may serve to irrigate quite different acreages. Farmers were asked how many acres of their holding could be reached by their existing equipment, and the results are shown in Table 12.

Table 12     Distribution of Farms by Maximum "Reach" of Irrigation Equipment

Maximum Irrigated Acreage	Number of Farms
0 - 49 acres	1
50 - 99 "	5
100 - 149 "	3
150 - 199 "	7
200 - 249 "	2
250 acres and over	3

In planning a farm irrigation scheme, it is common to work on the basis that the uptake of water by a green crop such as grass is one inch every 10 to 14 days. An irrigation system covering (say) one acre at a setting normally requires about three hours to apply one inch of water. If four settings can be arranged on one day, then roughly 40 to 50 acres will be covered in one "irrigation cycle". This is the effective capacity of such a scheme, since allowance should be made for the driest years when crops may require to be properly irrigated over a lengthy period.

As an alternative approach, the water requirements of the existing or proposed cropping programme can be estimated, and, using this information, it is possible to specify the amount of irrigation equipment necessary for adequate coverage.

In this survey, the majority of farmers had irrigation systems capable of covering between one and two acres at a setting. Assuming a 14-day irrigation cycle, such systems would effectively irrigate between 50 and 100 acres during the season.

Sprinkler equipment was employed on 15 farms, while the remaining 6 used rainguns. Where sprinklers were used, the average number per farm was 26. In the case of rainguns, the number varied from 1 to 4 per farm. Single-stage centrifugal pumps (usually P.T.O. driven) were by far the most common, being found on 20 farms, but two piston pumps were also used, as one farm on undulating ground had a centrifugal and a piston pump to raise water to high fields. The piston pump, operating by positive displacement, is more efficient in raising water, although the throughput is less than that of centrifugal

types, which move a large volume at lower pressure. Both farms using piston pumps had additional fixed equipment for effluent disposal, although difficulties caused by blockages had curtailed this activity on one farm.

UTILISATION OF EQUIPMENT, 1964 AND 1965

During 1964 the estimated soil moisture deficit in parts of the College area exceeded 5 inches. There was, therefore, an evident requirement for supplementary water - indeed, 1964 could be regarded as one of the driest years likely to be encountered in any decade. Records provided by farmers co-operating in the survey, however, showed that the use made of irrigation was, on most farms, surprisingly small. The distribution of farms by total acreage of crops irrigated during 1964 is shown in Table 13.

Table 13      Distribution of Farms by Total Crop Acreage Irrigated, 1964

Acreage Irrigated	Number of Farms
NIL	2
1 - 19	9
20 - 39	3
40 - 59	2
60 - 79	2
80 - 99	1
100 and over	2

Two farms equipped for irrigation made no use of their sets during the 1964 season. Both were on heavier ground, in areas outwith the obvious "irrigation belt". Nevertheless, a notable feature to emerge was the high proportion of farmers irrigating less than 20 acres of crops in this dry season. Only three farms irrigated more than 80 acres.

Of the farms using irrigation, the majority irrigated grass for grazing, hay, or silage. Rather less than half irrigated potatoes, while three applied water to vegetables and soft fruit crops. Details of the type of crops irrigated and of the average application per acre are given in Table 14.



Table 14

Distribution of Farms by Crops Irrigated, 1964

Crop	No. of Farmers Irrigating Crop	Average Acreage Irrigated per Farm	Average Irrigation Applied per Acre (inches)
Grass - grazing	17	31	1.7
" - silage	4	17	1.2
" - hay	2	10	1.0
Potatoes - early	1	6	1.0
" - maincrop	1	4	2.0
" - seed	6	13	1.2
Barley and Oats	3	14	0.8
Turnip and Rape	2	13	1.0
Cabbages, Cauliflower, Sprouts	2	8	1.0
Soft Fruit	1	2	2.0

The results shown in Table 14 indicate that the use of irrigation in the North of Scotland has largely been confined to traditional farm crops. There is also evidence of under-watering during the year, since up to five acre-inches of supplementary water could have been utilised by a crop such as grass. The lack of diversification in the use of irrigation is further emphasised in Table 15.

Table 15

Diversity of Irrigation Use, 1964

Irrigation Applied to	No. of Farms
Grass only	9
Grass and one other crop	3
Grass and two other crops	4
Grass and three or more other crops	1
Crops other than grass	2
Not used during 1964 season	2

It is clear that, in common with English experience, the main use of irrigation has been on grass.

In the following year (1965), although an estimated soil moisture deficit of almost three inches was recorded in July, irrigation was used on only one farm in the sample. One and a half acres of grass were irrigated before

heavy rain brought operations to a close. While there were periods during 1965 when grass production may have been restricted owing to lack of water, the spring months were relatively wet, so that most crops became fully established and able to withstand the slight degree of moisture stress to which they were later subjected.

In effect, therefore, the two years illustrate the problem which faces existing and potential irrigators in the North-East of Scotland. Expensive irrigation equipment is unlikely to be in use every year, and experience suggests that, even in years when its use might be justified, practical difficulties of labour organisation or other factors operate against its employment. This reduces the number of acres over which fixed costs can be spread, resulting in some cases, in an excessively high cost per acre. The cost structure of irrigation in the College area is examined in the following section.

#### IRRIGATION COSTS AND RETURNS IN THE NORTH OF SCOTLAND

In examining the cost structure of any irrigation scheme, two aspects must be considered. Each year, ownership charges have to be met. These 'fixed costs', covering depreciation and interest on capital, are incurred whether or not the equipment is actually used. In addition, variable costs must be taken into consideration in years when the plant is required. It follows that irrigation costs will vary widely according to the amount of use which can be made of the equipment. Average costs taken over a number of years are the best guide, but these cannot be estimated with reliability from the results of two years' experience, even under widely differing conditions.

Most of the equipment encountered in the survey was of fairly recent origin, and the purchase dates were distributed as follows.

Table 16   Distribution of Farms by Purchase Dates of Irrigation Equipment

Year of Purchase	No. of Farms
1955	1
1959	1
1960	2
1961	5
1962	7
1963	5

For those co-operating in this survey, the average net capital cost of irrigation equipment was £942 per farm, although a very wide range in costs was experienced, depending on proximity to water source, size of plant, etc. Table 17 shows the extent of this variation.

Table 17 Distribution of Farms by Net Capital Investment in Irrigation Equipment

Net Capital Investment £	No. of Farms
0 - 499	2
500 - 599	2
600 - 699	5
700 - 799	3
800 - 899	1
900 - 999	-
1,000 - 1,099	2
1,100 - 1,199	2
1,200 and over	4

Thirteen farmers operated "medium sized" plants costing up to £900, while eight farms were equipped with more elaborate installations, costing over £1,000. Some incorporated a length of permanent underground main, which, although costly in the first instance, can result in a considerable saving of labour.

In order to determine annual fixed costs per acre, the effective coverage of the irrigation plant has been estimated, assuming that 20 medium-sized sprinklers or 2 rainguns irrigate one acre at a setting, and allowing  $3\frac{1}{2}$  hours per acre-inch, with 4 shifts per day. Thus, if a 10 day "irrigation cycle" be accepted, a 20 sprinkler plant would have a coverage of 40 acres. On this basis the units visited during the survey had capacities ranging from 20 to 92 acres, with an average of approximately 50 acres. Since the net capital investment averaged £942 per farm, the mean capital outlay per irrigated acre was £18:16s.

For the purpose of calculating annual fixed costs, a life of 10 years has been assumed for portable irrigation plant, and 15 years for permanent equipment, with an interest rate of 6 per cent on capital. Using these

figures, the annual fixed costs per acre ranged from as little as 17s. up to a maximum of £4:8s. The lowest cost was recorded on a farm making extensive use of ex-Fire Service equipment, while the highest figure was for a large-scale semi-permanent installation. The costs were distributed as shown in Table 18.

Table 18 : Distribution of Farms by Annual Fixed Costs per Acre

Annual Fixed Costs per Acre	No. of Farms
15/- to 19/11	1
20/- to 29/11	1
30/- to 39/11	5
40/- to 49/11	5
50/- to 59/11	2
60/- to 69/11	3
70/- to 79/11	3
80/- to 89/11	1

Annual fixed costs per acre-inch depend on the degree of utilisation of the equipment, so that costs fall as the use increases (6). Since considerable differences in utilisation were recorded, even in the dry 1964 season, there was a wide range of fixed costs per acre-inch. Two farmers made no use of their equipment during 1964 and 1965, but others applied several inches per acre during 1964, particularly to grass. The distribution of farms by fixed costs per acre-inch applied is shown in Table 19.

Table 19 Distribution of Farms by Fixed Costs per Acre-Inch Applied 1964

Fixed Costs per Acre-Inch	No. of Farms
10/- to 19/11	3
20/- to 29/11	2
30/- to 39/11	3
40/- to 49/11	1
50/- to 59/11	-
60/- to 69/11	-
70/- to 79/11	1
80/- to 89/11	1
90/- to 99/11	1
Over £5	7

From the Table above it is clear that fixed costs per acre-inch can become abnormally high when irrigation plant is under-utilised. 'Reasonable' fixed costs of under £2 per acre-inch were recorded on less than half the farms visited, while an equivalent number had costs of over £5 per acre-inch, since only small quantities of water were applied.

On the other hand, variable costs per acre-inch applied remain relatively constant. None of the farms visited required to use mains water, and all enjoyed a free supply which was generally adequate. The major variable cost components were therefore labour, fuel and repairs.

It is not always appreciated that a substantial amount of labour may be involved in attending to irrigation equipment. The initial movement of pump and pipeline from field to field is time-consuming and can occupy 3 or 4 men for several hours - usually at a time of peak labour demand elsewhere. In addition, a man is required to move sprinkler line at regular intervals, and to attend to the pump. Such work may devolve upon the farmer in the early hours of the morning, or late at night, but during the day an employee is frequently detailed to look after the equipment. This is by no means a full-time job, but many farmers find it advantageous to have a worker on the spot to deal with blocked jets, bursts, and other contingencies. At best, the task is carried out in conjunction with fence maintenance or similar 'estate work' in the vicinity, in order to reduce time wasted by travelling.

Farmers co-operating in this survey were asked to keep a record of the labour hours spent in servicing and moving irrigation equipment, and a note was also made of fuel consumption and repairs. In the final analysis, however, detailed records of labour were available for only about half of the participating farms. Where information was not obtained, an estimate for hours has been used, based on a rate of 2 man hours per acre-inch applied (7,8)

In Table 20 below, man labour for irrigation has been treated as a variable cost, and has been charged at 5s. per hour. Fuel has been charged at cost, and other tractor expenses excluding fuel (mainly depreciation) have been estimated at 2s.6d. per hour for tractor-driven pumps. A charge has also been made for vehicles used to transport portable equipment about the farm, on a rate of 1s. per acre-inch (4).



Only one farm used a specially built trailer to transport irrigation piping. The majority employed an ordinary two or four wheeled farm trailer or platform lorry with bales or frames to carry the pipes. Others with a more inventive approach had adapted a variety of transport, including a car chassis, bomb trolley, milk float and yacht trailer.

Table 20      Distribution of Farms by Variable Costs Per Acre-Inch

Total Variable Costs per Acre-Inch	No. of Farms
10/- to 14/11	2
15/- to 19/11	6
20/- to 24/11	10
25/- to 29/11	-
30/- to 34/11	-
35/- to 39/11	1

An element of estimation is involved in the figures summarised above, since relatively few co-operators maintained detailed time-sheets. Nevertheless, the results are in broad agreement with other investigations, summarised by Laverton (9).

When total operating costs per acre-inch are examined, the distribution shown in Table 21 is obtained, covering the 1964 season.

Table 21      Distribution of Farms by Total Operating Costs per Acre-Inch 1964

Total Operating Costs per Acre-Inch	No. of Farms
£1 to £1:19s.	5
£2 to 2:19s.	3
£3 to 3:19s.	1
£4 to 4:19s.	-
£5 to 5:19s.	4
£6 to 6:19s.	-
£7 to 7:19s.	1
£8 to 8:19s.	1
£9 to 9:19s.	1
£10 and over	3

The range in total costs per acre-inch was very wide, ranging from £1:14s. in the case of a moderately priced plant applying 82 acre-inches, to £16:2:3d. for a rather more expensive installation which applied only 10 acre-inches during the season.

Table 19 reveals that much of this variation is explained by differences in annual fixed costs per acre-inch which stem largely from the availability of water in relation to the layout of the farm, and the amount of use which can be made of the equipment. Costs can only be kept within reasonable limits if a real requirement exists for irrigation, and the farm is organised to meet this by making the fullest possible use of the equipment in a dry season. In a year such as 1965, when almost no use was made of irrigation in the North of Scotland, annual fixed costs of ownership must still be met. The incidence of these costs therefore increases the overall average fixed costs per acre-inch. If the results for 1964 and 1965 are analysed on this basis, the average fixed costs per acre-inch applied over the two year period are distributed as in Table 22.

Table 22    Distribution of Farms by Average Fixed Costs per Acre-inch

Average Fixed Cost per Acre-inch	No. of Farms
NIL - £4:19:11	8
£5 - 9:19:11	3
£10 - 14:19:11	3
£15 - 19:19:11	2
£20 - 24:19:11	2
£25 - 29:19:11	-
£30 - 34:19:11	1

The lowest cost per acre-inch (averaged over the two seasons) was £2: 9: 3d. This was achieved using a portable system to apply a total of 146 acre-inches, during 1964 only, to a variety of crops, including grass, potatoes, and a small area of oats. The highest cost, which averaged £31: 2: 3d. per acre-inch, was incurred on a farm with a medium-sized portable system, but the construction of source works increased the annual charge, and 10 acre-inches only were applied in 1964.

In view of the probable cost of irrigation in the North of Scotland -

perhaps £5 or more per acre-inch - it is important to consider the likely response which can be obtained. While it is relatively straight-forward to estimate costs for any particular farm, measurement of the value of yield increases presents difficulties, especially in the case of forage crops utilised by livestock.

Very little information is available from controlled experimental work on irrigation in Scotland, although small plot studies on the response of grass have been carried out, notably at the Hannah Dairy Research Institute. Studies there show that, in suitable years, a significant response to irrigation can be obtained even in the humid south-west (10). Although irrigation can give a worthwhile increase in herbage production, the grass must be utilised to the full before a positive benefit is obtained. Very high stocking rates have been achieved with dairy cows in the south of England, using irrigation in conjunction with heavy fertiliser dressings (11). The main justification for grassland irrigation is to allow a greater intensity of stocking on a fixed acreage, thus releasing land for arable cropping. While farmers possessing irrigation equipment no doubt made use of its 'insurance value' in this way, insufficient information is available to reveal whether actual increases in stocking intensity had taken place.

Herbage yields of irrigated and non-irrigated grassland were available from one farm (North of Scotland College of Agriculture, Aldroughty Farm, Elgin) which showed an increase of 7.4 per cent in the amount of herbage produced due to irrigation in the 1964 season. In the same year, an increase of 3.4 per cent in potato yields following irrigation was recorded, although the most noticeable feature was an increase in the proportion of ware sized tubers (over  $2\frac{1}{4}$ " ) on the watered area. Whereas 72.8 per cent of the crop was of seed size ( $1\frac{1}{4}$ " -  $2\frac{1}{4}$ " ) on non-irrigated plots, only 59.4 per cent was within this category on irrigated treatments. A reduction in the proportion of 'cracked' or 'split' tubers was noted on irrigated treatments, and Common Scab was also less evident on these plots.

One other farm was able to provide (in conjunction with the Potato Marketing Board), check weighings of an irrigated potato crop. Sections of the field received no irrigation, irrigation amounting to one acre-inch, and two acre-inches. Irrigation with one acre-inch increased total yield by

27 per cent, although the two inch application resulted in a total yield 9 per cent below the non-irrigated treatment. A 90 per cent increase in the proportion of seed resulted from the one inch application, but the two inch treatment increased seed-sized tubers by only 17 per cent in comparison with unwatered areas. The incidence of Common Scab and growth cracks was again greatly reduced. Because of practical limitations and the lack of replication, this result must, however, be interpreted with caution.

From the point of view of potato growers in the North of Scotland, who are mainly interested in the production of seed, the timing of irrigation, in order to secure the maximum yield of seed-sized tubers, is most important. Experimental work on the irrigation of seed potato crops is very limited, but it is probable that late-season irrigation will have little value since it will tend to increase the size of existing tubers.

In the case when one acre-inch of irrigation increased total crop yield and the proportion of seed-sized tubers, a substantial increase in revenue resulted, amounting to over £50 per acre. Costs on this farm calculated for the two seasons surveyed showed that the average cost per acre-inch was just under £3. Dramatic returns of this sort, it must be emphasised, cannot be expected for every season, and mis-timing or over-application of water can result in a substantial loss of revenue. Nevertheless, the example serves to illustrate the potential of irrigation under suitable conditions.

#### SUMMARY AND CONCLUSIONS

Irrigation appears to have a place on a restricted number of farms in the North of Scotland. These farms are situated mainly on the coastal strip bordering the Moray Firth, where soils are light and rainfall averages only some 25 inches per annum. In other cases, if a high value crop such as fruit, vegetables or seed potatoes can be produced on a holding where water is readily available, a limited expenditure on irrigation equipment may be economically justified.

On the farms visited during this survey, grass was the crop most frequently irrigated. If stocking intensity can be increased with confidence, freeing land for arable cash cropping, then it may be that the equipment, by its very presence, can increase the overall profitability of the farm. It is probable, however, that milk production from irrigated grassland will be more

remunerative than the production of meat (12). Nevertheless, the utilisation of irrigated grass by beef cattle and sheep was an interesting feature of the survey.

Irrigation is an expensive tool, particularly so in an area where the frequency of April-September need is only five or six years in ten. Under these conditions, it is imperative that full use is made of the equipment during a dry year, in order to reap the maximum possible benefits. This implies that a careful check on the soil moisture status is maintained throughout the season. The best means of doing this is for the farmer himself to record local rainfall, and to construct a simple 'water balance sheet', knowing average potential transpiration. Six farmers had rain-gauges on their farm for this purpose, while four others stated that they made use of meteorological information supplied by their local county adviser. The remaining eleven applied water on subjective "rule of thumb" judgements, which no doubt resulted frequently in under-utilisation of the equipment.

To withhold supplementary water until drought effects manifest themselves is an unsatisfactory and costly procedure. Although having equipment at their disposal, just over half of the farmers visited were unable to make the fullest use of it because of lack of information on the soil moisture status. Since the profits from irrigation are so dependent on this knowledge, it is not surprising that on the evidence of the two seasons covered, the equipment on some farms was not paying its way.

There was little sign that any of the farms possessing irrigation had re-organised their cropping or stocking programmes with the acquisition of this facility. In the south of England, the availability of irrigation is frequently a determining factor in farm planning, and high value cash crops may be introduced into the rotation. The equipment can be used to protect crops from frost damage, while a marked improvement in the quality of fruit and vegetables is frequently observed. Despite the existence of market outlets for this type of produce in the North of Scotland College of Agriculture area, few of the farmers visited had explored these possibilities.

The key to successful irrigation may in fact be found in the attitude which farmers adopt towards the practice. At the present time, most farmers

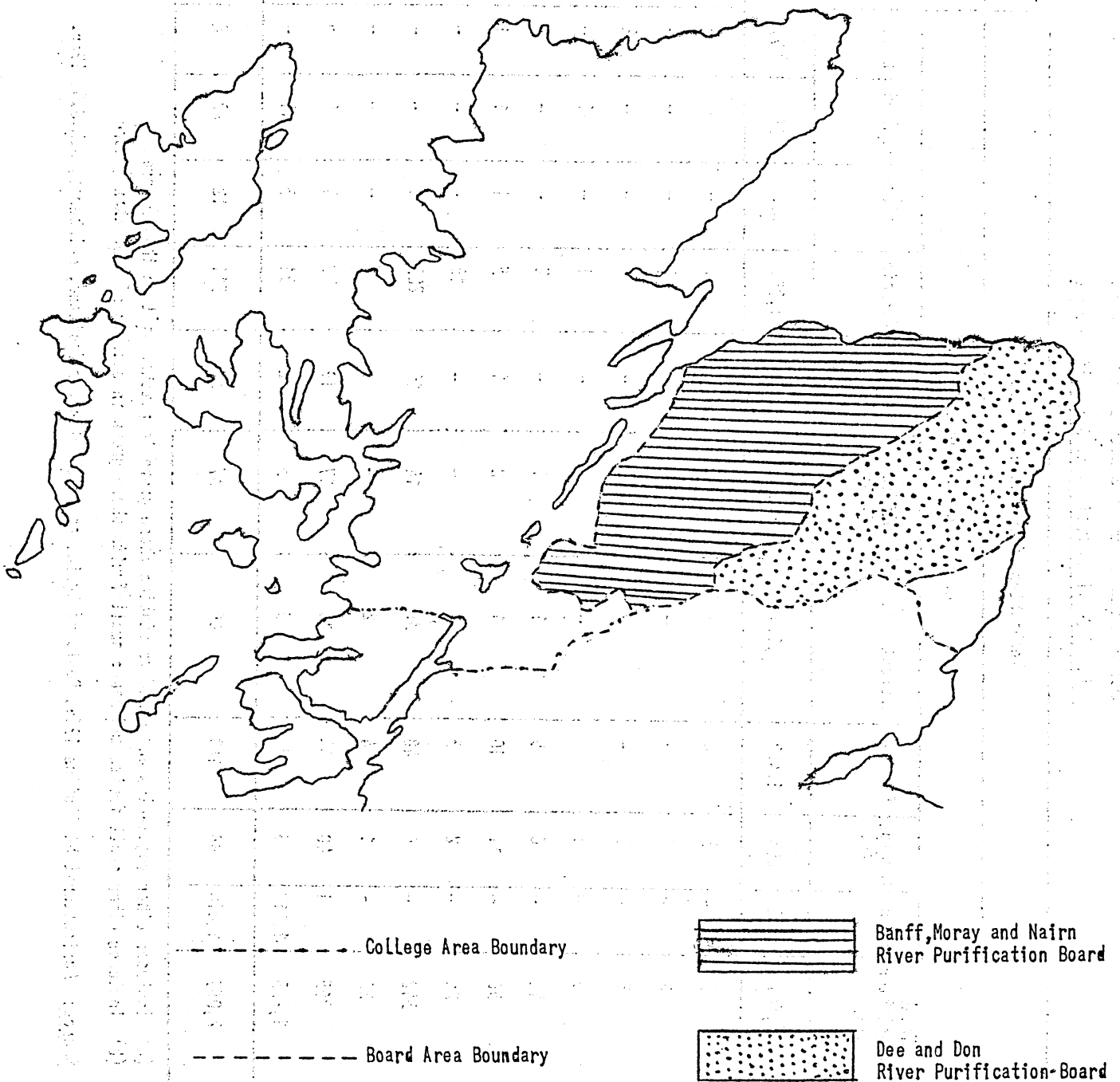
in the College area view irrigation as a technique which could enable them to produce more grass for grazing stock during the occasional dry year. Few have considered installing irrigation as the central pivot of their farming system, guaranteeing a heavier stocking rate overall, and higher yields, perhaps of cash crops such as vegetables or fruit. Without this broader vision, an irrigation plant 'tacked on' to a traditional farm can be an expensive luxury.

An intrinsically low-output farming system will not be transformed by the sporadic application of water. Before capital is invested in irrigation equipment it is important to ensure that all other less costly means of intensification have been examined. For farmers in the North of Scotland, therefore, irrigation should be regarded as the ultimate step in the development of a system of high-intensity farming.

Appendix I

River Purification Boards

North of Scotland College of Agriculture Mainland Area



Acreage of Horticultural Crops at June 1964  
North of Scotland College of Agriculture Area

	Vegetables for Human Consumption											Small Fruit		
	Total Vegetables (a)	Grown in the Open										Total Small Fruit (b)	Strawberries	Raspberries
		Peas	Turnips Swedes	Cabbage	Brussel Sprouts	Cauliflower Breccoli	Beetroot	Carrots	Lettuce	Rhubarb	Leeks			
SCOTLAND	13,344	5,245	603	1,460	1,110	750	356	1,055	464	599	277	9,291	1,643	6,826
Shetland	17	-	3	4	-	-	-	4	-	-	-	-	-	-
Orkney	6	-	1	1	-	-	-	1	-	-	-	-	-	-
Caithness	5	-	3	-	-	-	-	-	-	-	2	-	-	-
Sutherland	5	-	1	1	-	-	-	1	-	1	-	3	-	1
Ross & Cromarty	42	-	6	9	1	1	-	2	-	-	-	40	3	31
Inverness	56	-	11	10	1	2	1	5	1	1	1	69	8	52
Nairn	26	-	2	3	1	-	-	18	-	-	-	4	1	2
Moray	342	-	6	48	36	14	15	203	1	-	-	109	30	69
Banff	20	-	1	4	2	-	-	7	-	-	-	11	3	3
Aberdeen	295	1	48	74	16	17	19	39	7	9	5	71	17	32
Kincardine	1,253	1,017	6	14	9	3	2	31	3	17	-	112	47	57
TOTAL (College Area)	2,067	1,018	88	160	66	37	37	311	12	28	8	419	109	247

(a) Includes other vegetables and named vegetables where grown in patches of less than  $\frac{1}{4}$  acre.

(b) Includes other small fruits and named small fruits where grown in patches of less than  $\frac{1}{4}$  acre.

Source: Agricultural Statistics 1964. Dept. of Agric. and Fisheries for Scotland, Edinburgh, H.M.S.O. 1966.



## Appendix III

## Total Acreage of Agricultural Crops at June 1964

## North of Scotland College of Agriculture Area

	Crops, Grass & Rough Grazings	Rough Grazing	Grass		Cereals	Potatoes		Roots	Kale, Rape etc.	Other Crops	Bare Fallow
			for mowing	not for mowing		1st early	Maincrop				
SCOTLAND	16,691,277	12,386,191	722,970	2,077,205	1,046,746	21,035	131,954	210,261	53,250	27,317	14,348
Shetland	354,660	334,644	5,427	9,614	2,837	53	733	515	372	102	363
Orkney	192,133	80,226	16,571	64,743	26,138	95	594	3,383	277	33	73
Caithness	399,390	305,989	12,671	52,561	21,126	76	437	5,410	976	120	24
Sutherland	1,198,027	1,169,687	6,601	13,840	4,984	42	659	1,457	414	53	290
Ross & Cromarty	1,893,509	1,762,469	22,595	57,908	33,287	337	4,900	7,363	2,208	445	1,997
Inverness	2,459,760	2,336,011	25,776	62,546	20,742	172	1,954	3,937	3,883	372	4,367
Nairn	77,269	52,583	3,786	9,790	7,633	27	703	1,919	597	210	21
Moray	192,259	100,188	16,417	32,688	31,304	238	3,899	5,424	1,224	734	143
Banff	323,085	166,530	21,759	69,764	49,400	116	2,613	11,370	1,216	216	101
Aberdeen	1,003,107	381,813	92,606	271,473	193,390	1,078	10,466	47,779	3,244	882	376
Kincardine	173,558	55,518	16,848	44,030	39,489	676	6,486	8,346	566	1,559	40
<u>TOTAL</u> (College Area)	8,266,757	6,745,658	241,057	688,957	430,330	2,910	33,444	96,903	14,977	4,726	7,795

Source: Agricultural Statistics 1964. Dept. of Agric. and Fisheries for Scotland, Edinburgh, H.M.S.O. 1966.

Appendix IV

Glossary of Terms Used

Potential Transpiration: the quantity of water, measured in inches, which would be removed from the soil by a short green crop covering the ground completely, and fully supplied with water.

Field Capacity: the maximum water holding capacity of the soil, i.e. the stage at which drainage after rainfall or irrigation has just ceased.

Soil Moisture Deficit: the quantity of water, measured in inches, required to restore the soil to field capacity.

Irrigation Need: the amount and frequency of irrigation required to make good a soil moisture deficit.

Irrigation Regime: the soil moisture deficit which is permitted before irrigation is applied to restore the soil to the chosen moisture content.

Acre-Inch: the quantity of water required to cover an acre with a depth of one inch. This is equivalent to 22,600 gallons, or approximately 100 tons of water.

Inch of Water: 22,600 gallons per acre, or approximately  $4\frac{1}{2}$  gallons per square yard.

Bibliography

- (1) Pearl, R.T. ed. (1964). 'The Calculation of Irrigation Need', Tech. Bull. Minist. Agric. Lond., No. 4., H.M.S.O.
- (2) Anon. (1962). 'Irrigation', Minist. Agric., Lond., Bull. No. 138., H.M.S.O.
- (3) Anon. (1964). Machinery Census, February, 1964. Dept. Agric. & Fish. Scotland.
- (4) Anon. (1962). 'Irrigation in Great Britain. A report by the Natural Resources (Technical) Committee'. Office of the Minister for Science, London, H.M.S.O.
- (5) Agric. Census Branch (1965). Spray Irrigation Enquiry - October 1963 (England and Wales) Minist. Agric., Lond.
- (6) Ingersent, K.A. (1964). 'Economic Aspects of Farm Irrigation'. Univ. of Nottingham, Dept. of Agric. Econ., F.R. No. 151.
- (7) Ingersent, K.A. (1962). 'Costs of Farm Irrigation'. Univ. of Nottingham, Dept. of Agric. Econ., F.R. No. 148.
- (8) Nix, J.S. and Prickett, C.N. (1961). 'Farm Crop Irrigation. The Economic Aspects'. Univ. of Cambridge Sch. Agric., Fm. Econ. Br. Rep. No. 55.
- (9) Laverton, S. (1964). 'Irrigation'. Oxford Univ. Press, London.
- (10) Castle, M.E. and Reid, D. (1960). Irrigation of grassland in south west Scotland, 8th Int. Grassl. Congr., Paper 5A/6.
- (11) Bone, J.S. and Tayler, R.S. (1963). The effect of irrigation and stocking rate on the output from a sward. J. Brit. Grassl. Soc., 18, 295.
- (12) Tayler, R.S. (1965). The irrigation of grassland. Outlook on Agric., 4, 234.