INTEGRATION OF IRRIGATED AND DRY LAND AGRICULTURE—PROFITABILITY AND PRODUCT MIX

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Budgeting, linear programming and benefit-cost analysis were used in an economic investigation of a private irrigation project which serves 54 individually operated farms. On each of these farms, the opportunity exists for the integration of irrigated and dry land agriculture. The results of this study allow some comments to be made concerning the advantages which are claimed for this type of integration. One of the most appealing of these claims is that integration will encourage extensive types of agricultural production, rather than the intensive and often highly subsidized enterprises which have dominated many acres where farms are wholly or largely irrigated. This study indicates that, should farmers aim to maximize profits, the irrigation water would be used mainly in the production of forage for dairy cattle. Yet, the farmers have indicated that they would prefer to operate farm programmes which almost completely exclude dairying.

1. INTRODUCTION

For the first half of this century, irrigation development on the riverine plain of southeastern Australia has been dominated by public investment in the construction of water storages and channel systems for delivery of water to farms. Where government agencies have constructed the water delivery systems, they have also assumed responsibility for maintenance of the works and for actual delivery of water to farm boundaries. In those irrigation projects which have been based upon government-sponsored closer settlement, farms are usually almost wholly irrigated.

However, there have also been public irrigation developments not based upon government-sponsored closer settlement. In New South Wales, the southern Irrigation Districts are examples of such projects. They were originally designed to encourage on-farm integration. However,

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Rutherford has observed a tendency toward voluntary closer settlement in the Irrigation Districts and in similar projects in northern Victoria.[1]

This occurred when farmers were able to intensify irrigation on their farms, allowing them to earn a satisfactory income from part of their original holding, and to sell the remainder at a substantial capital gain. Irrigation enterprises now tend to use a large proportion of the total land on farms in the Districts, to account for an even larger proportion of total income and, naturally, to dominate the farmers' management strategies.

It seems, then, that government-sponsored irrigation developments in the Murray basin have led to intensive irrigation rather than to integration. In his study of integration, Rutherford expressed concern at the extent of intensification of irrigation taking place in the integrated irrigation projects of southern New South Wales and northern Victoria. Meat and wool production are declining while dairy production, and the area of land devoted to it, are following a substantial long-term upward trend. He made no claim to have made a serious attempt to consider "the numerous social and economic problems raised by the concept of integration", nor to have proven the case in favour of integration.[2] Nevertheless, he suggests that the placing of controls on the subdivision of integrated properties should be seriously considered in an attempt to reverse the tendency towards intensification of irrigation and increasing utilization of water for dairy production.[3] He also expressed the hope that subdivision of farms in the Coleambally Irrigation Area would be strictly controlled, to avoid any move towards dairying in that area.

The alternative to intensive irrigation is the irrigation of relatively small sections of land on mainly dry-land properties. This type of development has attracted little direct public spending in the Murray basin. It is, however, dependent on the existence of publicly constructed water storages. Up until 1955, this practice was largely confined to irrigation projects on single farms adjacent to rivers. The farmer concerned installed the necessary pumps, constructed channels, and applied the water to his own land at his own expense. Government agencies (in New South Wales, the Water Conservation and Irrigation Commission) granted irrigation licences for a relatively small fee, and limited the number of acres to which the farmer could apply water in any one year.

Since 1955, this type of development has expanded rapidly. An important aspect has been the emergence of group private irrigation schemes in the Murrumbidgee and Murray valleys. The Romani scheme near Hay serves 13 farms. The Moira project south of Deniliquin

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[1] John Rutherford, in Part II of Trevor Langford-Smith and John Rutherford, *Water and Land—two case studies in irrigation*, (Canberra: Australian National University Press, 1966), and a series of three papers in this *Review*, Vol. 26, No. 4 (December, 1958), pp. 227–283; Vol. 27, No. 3 (September, 1959), pp. 147–233; and Vol. 28, No. 2 (June, 1960), pp. 97–150.

[2] *Ibid.*, p. 129.

[3] *Ibid.*, p. 249.

serves 54 farms, and the planned Corurgan project, east of the Berriquin Irrigation District, will serve approximately 250 farms. The expansion of group irrigation projects indicates that the farmers involved are willing to use private capital, not only to pump water from rivers, but also to establish and operate reticulation systems of considerable size and complexity. In terms of size, complexity, and number of farms served, private group irrigation schemes are now comparable with the irrigation schemes developed and maintained by public agencies.

Private group irrigation schemes are of interest for two reasons. The micro-economics and aggregate economics of such developments are of interest because of the novelty of such major co-operative ventures, and because these ventures appear to represent a viable alternative to publicly constructed and operated projects. Secondly, private irrigation has usually led to integration of irrigated and dry land farming, in contrast with the intensive irrigation encouraged by public projects. It seems that the economic effects of integration can best be examined by studies of private group or individual irrigation projects.

This paper reports some results of a case study which was carried out on the Moira Irrigation Project. Farm programmes were analysed under a variety of assumptions, using budgeting and linear programming. The basic information obtained in this way allowed benefit-cost analysis of the project from the points of view of the participating farmers and of the national economy.

The irrigation project concerned is situated within the general area where Rutherford carried out his study of integration in the Murray basin.[4] So, Rutherford's conclusions were examined. Rutherford did not carry out an analysis of the economics of integration; rather, his survey established the extent to which irrigation was practised on the farms he surveyed. He made some tentative recommendations for the encouragement of integration, but suggested that further economic analysis would be required to establish the validity of his recommendations. It was considered that the results of the present benefit-cost analysis of one private irrigation project might be a contribution towards further economic analysis of the merits of integration in the Murray basin.

2. A BENEFIT-COST ANALYSIS OF THE MOIRA IRRIGATION SCHEME

The Moira Irrigation Scheme supplies irrigation water for approximately 20,000 acres of about 80,000 acres of land in southern New South Wales situated between Deniliquin and the Murray River. The total area is divided into 54 separate managerial units.[5] The participating farmers

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[4] *Ibid.*

[5] A "managerial unit" is defined as that area of land which is managed, for both day-to-day and long-range purposes, by a single manager or group of managers. In the Moira project, there are 62 individually owned properties, but only 54 managerial units. For the rest of this study, the terms "farm" and "managerial unit" are inter-changeable.

formed a company which constructed a channel system to deliver water to the boundaries of all farms in the scheme and installed equipment to pump water from the Murray. The company now looks after operation and maintenance of the system. Water has been available to the farmers since the summer of 1965–66. When on-farm development for irrigation is complete, the farmers will use a total of 40,000 acre feet of water annually. Farm size within the project varies from 300 to 6,500 acres, with a mean of 1,508 acres. The size of the irrigated area on these farms varies from 100 to 1,200 acres, with a mean of 359 acres.

An economic evaluation of the Moira Irrigation Scheme was undertaken in 1966–67. Complete details of the methodology are available elsewhere.[6] A brief summary will be sufficient here. Following a survey of the Moira farms,

(a) budgeting was used to calculate the annual net profit from irrigation for each farm under the assumption that farmers followed their actual farm programmes in both the "without irrigation" and the "with irrigation" period.

(b) resource-variable linear programming and subsequent budgeting were used to calculate the annual net profit from irrigation under the assumption that farmers followed optimum programmes in the "without irrigation" period and, in the "with irrigation" period, optimum farm programmes

   (i) excluding dairy and pig enterprises

   (ii) including all feasible enterprises, with permanent labour limited to that amount found optimum in (i)

   (iii) including all feasible enterprises, with permanent labour limited to twice that amount found optimum in (i).

For each type of farm programme considered, the annual net profits from irrigation calculated for each farm were added to arrive at an estimate of the annual net profit from irrigation for the whole Moira irrigation project.

The numerator of the benefit-cost ratios, as calculated from the point of view of the participating farmers, was the stream of aggregate annual net profit from irrigation discounted at seven per cent per annum over 50 years. Aggregate annual net profit from irrigation was equal to the sum of annual benefits minus the sum of on-farm annual costs. The denominator of the ratio was the total capital cost of the pumps and channels in the Moira irrigation project. This cost occurred in year zero.

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[6] The detailed methodology is explained at length, and all input-output coefficients used are listed in A. J. Randall, *The Economic Utilization of Water in a Private Irrigation Scheme*, (University of Sydney: Unpublished M.Sc.Agr. thesis, December, 1968).

Benefit-cost ratios calculated from the farmers' point of view do not fully reflect the flow of benefits and costs to the national economy. Farmers obtain some benefit from subsidies and protection of agricultural commodities. Secondly, the social cost of irrigation water is greater than the costs which farmers pay for the use of water. Farmers benefit from publicly constructed capital works such as dams and other river regulatory devices. These cost substantial amounts to the whole economy which are not reflected in the farmers' cost structure.

The numerator of the social benefit-cost ratios was the discounted stream of the aggregate annual net profits from irrigation minus the annual contributions of subsidies and protection to farmers' net incomes. Work by Harris has indicated that, of all commodities expected to be produced on the Moira farms when the irrigated sectors were fully established, only dairy products benefit substantially from subsidies and protection.[7] All dairy produce from these farms can be expected to enter the manufacturing sector. As Australia already exports substantial quantities of manufactured dairy products, the marginal increase in output of these products attributable to the Moira farms could be regarded as production wholly for the export market. Therefore, to remove the effects of subsidies and protection, the actual returns to farmers from the sale of dairy produce should be deflated by the following ratio:

$$\frac{\text{Total sales valued at export parity}}{\text{Total actual returns to the farmers}}$$

Based on data collected by Harris for the period 1963–64 to 1965–66, it was calculated that the gross returns to farmers from the sale of dairy products should be deflated by the ratio, $\frac{100}{142}$. Net social benefits were calculated after making this correction.

The denominator of the social benefit-cost ratios included the capital costs of pumps and irrigation channels, as paid by the farmers, and the share attributable to the Moira irrigation project of the capital costs of water storages and river regulatory works. Using data from the Snowy Mountains Authority, and estimates of water loss in rivers and channels provided by the Water Conservation and Irrigation Commission, it was calculated that a public capital cost of $81.50 was required to supply 1 acre foot of water annually to the Moira farms. The Moira scheme was designed to provide 2 acre feet of water for every acre licensed for irrigation. Thus, 38,800 acre feet of water must be provided annually to the boundaries of the farms in the scheme. The total capital cost of public river regulation and water storage attributable to the Moira project was $3,201,000. This was added to the denominator to determine benefit-cost ratios of the Moira scheme from the point of view of the national economy.

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[7] S. F. Harris, "Some measures of costs of protection in Australian rural industries", *Australian Journal of Agricultural Economics*, Vol. 8, No. 2 (December, 1964), pp. 124–144 and (personal communication), November, 1966.

Secondary benefits are of no relevance to the farmer's management decisions, but must be considered in the analysis from the viewpoint of the whole economy. Net secondary benefits are defined as secondary benefits minus secondary costs and opportunity costs. According to this definition, net secondary benefits will be greater than zero when there are slack resources in the economy which could be employed servicing the farmers of this project. The substantial and continuing annual net inflow of both labour and capital into the Australian economy provides evidence that very few slack resources exist. Secondary benefits are therefore likely to be significant only at the local level, and therefore were not included in the benefit-cost analysis from the viewpoint of the economy.

TABLE 1

Computed Benefit-Cost Ratios for the Moira Irrigation Project

Farm Programme Assumptions	Benefit/cost ratios		No. of men employed full-time in the Moira irrigation scheme	No. of man-weeks of casual labour hired by Moira scheme farmers each year*
	From the farmers' point of view	From the point of view of the national economy		
(a) Farmers' Actual Programmes	0·93	0·08	122	506
(b) Optimum Farm Programmes—				
(i) Excluding dairy and pig enterprises	2·99	0·30	142	832
(ii) All enterprises considered, with labour limited to that amount shown optimum for programme type (b) (i) ..	7·76	0·15	142	1,890
(iii) All enterprises considered, with labour restricted to 2 times the amount shown optimum in (b) (i)	14·26	0·25	264	1,890

* The upper limit of casual labour hiring was set at 35 manweeks/year/farm (i.e. 1,890 manweeks/year in the whole scheme).

Table 1 presents the benefit-cost ratios for the Moira Irrigation Scheme calculated under the assumptions described above. Some conclusions can be drawn from this table.

(i) Under present water allocation and pricing mechanisms, this type of private investment in water pumping and delivery systems for irrigation is potentially very rewarding to farmers who can participate. Nevertheless, to gain full rewards, it is necessary to reorganize farm management planning and consider introduction of new enterprises, particularly dairying.

(ii) Present water pricing and allocation mechanisms allow private irrigators to make sufficiently high profits to satisfy many of them (e.g. farm programmes of the type (a)), while returns to the national economy are remarkably low. This is due to the high capital cost of river regulation, which is not reflected in the farmer's cost structure.

(iii) As noted above, these social benefit-cost ratios were calculated after the effects of subsidies and protection of agricultural commodities had been removed, allowing an accurate ranking from the point of view of the whole economy, of the four types of farm programmes considered. The social benefit-cost ratios would also be suitable for comparison with similarly calculated benefit-cost ratios for other agricultural projects.

However, the effect of protection on the farmers' cost structure has not been considered. In Australia, parts of the manufacturing sector of the economy benefit from substantial protection, which increases the costs of material inputs in agriculture and, indirectly, the costs of labour. In this investigation, it was impossible to remove the effects of protection from the costs, as an authoritative study of the effects of industrial protection upon the cost structures facing the various types of agricultural production is not yet available.

The calculated social benefit-cost ratios shown in table 1 have been corrected to take account of the effects of protection on farmers' income but not on farmers' costs. Thus, it would be unreasonable to compare these benefit-cost ratios with the standard of 1.0.

3. THE INTEGRATION OF IRRIGATED AND DRY LAND

3.1 INTEGRATION DEFINED

Rutherford has defined the various types of economic integration of irrigated and dry land agriculture.[8] This study is concerned with one particular type of integration, on-farm integration of contiguous areas of irrigated and dry land. Thus, integration is defined here as the establishment of, or existence of, a complementary relationship between contiguous areas of irrigated and dry land owned and managed jointly. Managers of integrated farms would be expected to adopt management strategies featuring many interactions between the irrigated and dry land areas of the farms. Three types of advantages often claimed for integration are considered below.

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[8] John Rutherford, in *Water and Land, op. cit.*

(a) *Increased production and profitability*

It is easy to give examples of farm enterprises which can take advantage of the joint management of integrated and dry land. Lambs bred on the dry portion of the farm may be fattened for market on the irrigated portion. Dairy cows may graze irrigated land when lactating, and dry land during their dry period. Where the annual production cycle of dry land pastures shows marked peaks and troughs, strategic forage production on the irrigated land may be used to raise the overall stocking rate of the whole farm.

The existence of many opportunities to exploit interrelationships of irrigated and dry land does not prove the case for integration. It is necessary to establish that production and net profit from x acres of irrigated land and y acres of dry land managed jointly is greater than production and profit from an irrigated farm of x acres and a separately managed dry land farm of y acres (the quality of the land and the management applied to it being the same in each case).

(b) *Increased stability of income*

More than 20 years ago Willoughby suggested that serious consideration be given to the use of irrigation water to combat production uncertainty in the merino wool industry.[9] On the riverine plain, both the sheep industry and the wheat industry suffer substantial annual fluctuations in output. These fluctuations are largely attributable to variations in rainfall, so it is reasonable to expect that artificial irrigation could provide relief.

Instability of incomes can also be derived from fluctuations in product prices. Integration allows the individual farmer to choose from among a wider range of enterprises than is available on wholly dry land or irrigated farms. Integration would encourage diversification of enterprises, which is one recognized method of offsetting the effects of price uncertainty.[10]

Once again, it is easy to think of examples where integration is used to combat price and production uncertainty. However, it remains to be proven that integration is an efficient method of uncertainty reduction and, as such, will increase discounted long-run profits.

(c) *Diversion of water resources towards unsubsidized products*

It is often suggested that integration is most likely to result in stabilized and increased production of wool, meat and grains, products which Australian farmers have traditionally been able to produce and sell profitably on home and international markets. Much of the output

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[9] W. M. Willoughby, "Irrigation and the Wool Industry", *Journal of the Australian Institute of Agricultural Science*, Vol. 10, No. 3 (September, 1944), pp. 102–107.

[10] Earl O. Heady, *Economics of Agricultural Production and Resource Use* (Englewood Cliffs: Prentice-Hall, 1952), pp. 511–19, points out that diversification of enterprises will succeed in reducing price uncertainty only when the price fluctuations of the commodities concerned are negatively correlated.

from intensive irrigation settlements has been in the form of rice, dairy products and dried and canned fruits. All of these commodities have benefited from protection on the home market, and/or subsidies to growers. Export prospects facing the dairy and fruit industries are not bright. Therefore, it seems sensible, on the surface, to direct scarce irrigation water away from intensive irrigation projects and into projects where irrigated and dry land are integrated.

The Moira irrigation scheme seems to be an excellent place to study some facets of private irrigation and integration. Irrigation water was made available to long established properties which had been viable dry land units. The vast majority of these farms moved from dry to integrated farming without any change in ownership, management or farm size. The mean area irrigated is approximately one quarter of the mean farm size, indicating that irrigation in the Moira project is truly integrated rather than intensive. Thus, it is possible to study the effects of integration by considering the "with irrigation" and the "without irrigation" situations on each farm.

The results of an economic study of the Moira irrigation scheme should have widespread application, due to location of the project. It is centrally situated on the riverine plain, with government-sponsored irrigation projects on all sides. Comparisons should be possible between economic performances of irrigation in the Moira and in these other projects. Secondly, as mentioned earlier, the Moira scheme is centrally situated in the general area within which Rutherford made his survey of integration. A study of integration in this scheme would have some relevance to a fuller economic analysis of Rutherford's general conclusions.

3.2 THE NATURE OF THE INTEGRATED FARM PROGRAMMES

The vast difference between the economic returns obtained under the different farm programme assumptions suggests that the nature of these farm programmes should be examined. In table 2, programmes for a 1,600 acre farm with 400 acres licensed for irrigation are shown. This farm size approximates the mean for the Moira project. The example of a farmers' actual programme (Farm Programme type (a)) shown is derived from the means of data from the 13 farms between 1,100 and 1,900 acres in size. The optimum programmes were calculated by linear programming with land limited to 1,600 acres and irrigated area limited to 400 acres.

Full details of the farm programmes are available elsewhere.[11] In table 2, enterprise type only is shown, rather than a full description of each process entering the programmes. As expected, the profitability of irrigation is very clearly associated with the types of enterprise combinations in the various types of farm programmes and their corresponding product mix. From the farmers' point of view, the

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[11] A. J. Randall, *op. cit.*

TABLE 2

Farm Programme Details for a Typical Farm of Area 1,600 *Acres with a Maximum of* 400 *Acres Irrigated*

Farm enterprise	Units	Farm programme type			
Description of major enterprise groups		(a) Farmers' actual programmes	(b) Optimum farm programmes		
			(i)	(ii)	(iii)
Irrigated crops and pastures—					
Cereals	acres	18	..	..	..
Grain Sorghum	,,	6	115	20	..
Winter pasture	,,	277	229	162	346
Summer pasture	,,	7	51	23	54
Lucerne	,,	36	5	.	..
Total area irrigated	,,	344	400	205	400
Dry land crops and pastures—					
Pastures	acres	839	542	770	632
Dry land lucerne	,,	99	117	112	98
Cereals	,,	318	541	513	470
Sheep—					
Prime lamb production	ewes	1,251	..	..	..
Merino breeding	,,	199	..	..	..
Corriedale breeding	,,	137	..	..	..
Merino wethers	wethers	151	..	..	..
Fattening purchased store lambs	lambs	270	..	..	..
Purchased crossbred ewe lambs	,,	54	..	..	..
Beef Cattle—					
Vealer production	cows	12	210	68	..
Fattening purchased steers ..	steers	39	133	128	130
Dairying—					
Milking cows	cows	..	..	97	230
Pigs*	sows	..	..	..	34
Benefit-cost ratio (for national economy)	..	0·13	0·30	0·86	1·13

* When dairying activities are included n arm programmes, farmers may either sell cream and raise pigs or sell bulk whole milk. In programme b (ii) all milk was sold as bulk; in programme b (iii) most of the milk was sold as bulk.

highest benefit-cost ratios are obtained when the irrigated sector of the farms is largely devoted to dairying. However, farmers' actual programmes include no dairy enterprises. In the survey of Moira farms, it was found that a vast majority of the farmers aimed to avoid dairying, although all were aware of the outstanding profitability of the enterprise.

The social benefit-cost ratios indicate that optimum programmes, with dairy and pig enterprises excluded, were more profitable than optimum programmes including dairying enterprises. The ranking of farm programmes of type b(i) and b(iii) is dependent upon conditions in the export market for dairy products. A rise of 2.3 per cent in the export parity price of dairy products would place farm programmes of type b(iii) ahead of type b(i). However, work by Gruen *et al* indicates that export prices for dairy products can be expected to fall rather than rise.[12]

The data shown in tables 1 and 2 may be used to consider the three advantages claimed for integration by its proponents.

(a) The question of whether integration is the most profitable use of irrigation water and land is not directly considered, as the profit from integration was not compared with the profit from intensive irrigation in a similar environment. The analysis did, however, allow some comments to be made on this issue. Optimum farm programmes did include substantial interactions between the irrigated and dry land sectors of the farms. This inter-dependent relationship between the irrigated and dry land sectors was selected as optimal using a linear programming matrix which had no *a priori* requirement for such a relationship. This could be taken as *prima facie* evidence that integration is more profitable than separate management of irrigated and dry land. This conclusion is based upon the results of linear programming when a particular set of activities are considered. Intensive irrigation to produce commodities not considered in this analysis may be more profitable. It may also be more profitable to use the water on farms in some other district or region. These alternatives are not considered in this investigation.

(b) The question of the efficiency of integration in reducing fluctuations in farm income is not answered directly, due to limitations in the analytical techniques used. However, some intuitive comments are justified. Production on the irrigated sector of the farm should not be reduced during dry periods of moderate severity. This would allow farmers a basal income which would provide some financial security in the face of climatic fluctuations. Drinking water for livestock on the dry land sector would be provided by the irrigated sector. However, the calculated optimum programmes allow little excess capacity in the irrigated sector. It must be realized that drought protection for livestock from the dry land sector requires that unused capacity exist on the irrigated sector at all times (since one never knows just when to expect a drought). Thus, high profitability in normal years, and drought protection, are to some extent conflicting claims to make in favour of integration. One further limitation to the value of the Moira Irrigation Scheme for drought protection exists. This is due to government policy, rather than to any inherent defect in the nature of integration. In New South Wales, private irrigators have no Water Rights; they

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[12] F. H. Gruen *et al*, *Long Term Projections of Agricultural Supply and Demand*, (Clayton: Monash University, 1967).

are not guaranteed a minimum annual quantity of irrigation water in every year, as are irrigators on most publicly constructed irrigation schemes. It is conceivable that, in the very driest years, the Moira irrigators may receive a severely limited supply of irrigation water, or, indeed, none at all.

(c) Will integration lead to a diversion of irrigation water away from the production of highly subsidized commodities? The answer to this question depends upon the type of farm programmes the Moira farmers eventually operate. If they choose to persist with their present farm programmes, integration will result in increased production of wheat, wool and meat. All of these are virtually unsubsidized products. They were also the dominant products of the Moira area before irrigation facilities became available. If the farmers eventually move towards the type of farm programme which would yield them the greatest profits, dairying will become the dominant enterprise. The dairying enterprise is both exotic and highly subsidized. The most profitable type of farm programme from the point of view of the national economy includes substantial grain sorghum and beef production enterprises. Grain sorghum and beef are not subsidized commodities, but they were also not usually produced on the Moira farms before irrigation became available.

It seems that integration will direct irrigation water away from highly subsidized dairy production only if the farmers concerned are able to resist the attractions of the very much greater profits which dairying would return to them.

It seems that Rutherford's suggestion that dairying on integrated farms be discouraged could be wise, from the national point of view. Yet, it is uncertain whether his suggestion that this could be done by discouraging subdivision of properties is valid. The farmers have made no provision for dairy enterprises in their actual programmes. The survey of Moira farms indicated that, if farmers continue to operate these actual programmes, the present large mean size of the farms does discourage dairying. However, the linear programming work has shown that it is possible to operate highly profitable dairy enterprises without any reduction in farm size, if the farmers so desired. This would greatly increase the profitability of irrigation to the farmers. This issue can be resolved only when it is finally learned whether the profit motivation of the farmers is such that they gradually move towards optimum farm programmes including dairy enterprises.

The social benefit-cost ratios were all quite low (the highest was 0.3). But, as we have seen, it may be unreasonable to compare them with the standard of 1.0. We cannot know whether the Moira irrigation scheme will be profitable to the economy as a whole until we know the economic effects of industrial protection upon the farmers' cost structure.