OPTIMUM PROGRAMMES FOR IRRIGATION FARMS

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Parametric linear programming is used to derive optimum programmes for 590 different resource situations representing the range existing in the Murrumbidgee Irrigation Area of New South Wales. Enterprises comprising optimum plans included rice, commercial lucerne hay using farmer owned equipment, merino ewes x border leicester rams for spring lambing (carry over), linseed (or a 54 bushel wheat crop), sod-sown malting barley and grazing oats in rice stubble, grain feeding of sheep in autumn and early summer. When labour is a limiting factor, autumn calving beef cows for vealer production together with purchase of spring drop crossbred lambs in March for sale in October replace the breeding sheep enterprise. Popular enterprises on the M.I.A. which had high opportunity costs in the solutions were sudax, grain sorghum (contour method, yield 1.5 tons) fallowed wheat (39 bushels), grain oats (yield 45 bushels), fallowed malting barley (yield 42 bushels), crossbred ewes x dorset horn rams and merino wethers.

1. INTRODUCTION

The planning of irrigation schemes in Australia, whether of the intensive, Irrigation Area type, the more extensive District, or the provision of a dam primarily to regulate river flows for down river private pumpers, has been hindered by a dearth of factual input-output data. It is only recently that any formal benefit-cost analyses of proposed water resource developments have been undertaken prior to the commencement of the construction of such schemes. Even these evaluations suffer because of lack of fundamental farm production and performance data, particularly where the proposed development is in a hitherto non-irrigated area. Referring to the investigations into the possible uses for additional water available from the Murrumbidgee River upon completion of the Blowering Dam Prunster stated:

> All investigations of farm development have been limited by the lack of factual information even for the preparation of budgets, and farm size and land use recommendations have been made with some reservation.[1]

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* This paper presents part of the results of a detailed study of the economics of large area irrigation farms in the Murrumbidgee Irrigation Area of New South Wales. The whole study was submitted as a thesis in partial fulfilment of the requirements for the Degree of Master of Science in Agriculture at the University of Sydney in 1968. The author wishes to acknowledge the invaluable assistance of Mr S. J. Filan with the computational aspects of this study.

[1] R. W. Prunster, "Agricultural Use of the Snowy Waters: Agricultural Aspects", *Australian Journal of Agricultural Economics*, Vol. 4, No. 1 (July, 1960), p. 75.

He suggested the basic data could not be adequately obtained by survey techniques; rather, long-term experimentation would be required. While agreeing that the latter should continue, with greater emphasis on the economically important problems, it was felt an extensive farm survey was essential to obtain labour and machinery performance data, together with other enterprise input-output information for the present study. This aspect provides one of the aims of the study, namely to derive acceptable farm production data for an established Irrigation Area, which can be used with suitable modifications, in the planning of future schemes and in the improvement of existing ones. The use of such data is preferable to the exclusive reliance on experimental results, as the latter generally provide an optimistic picture of what even the above-average commercial farmer can expect in commercial practice.

Duane also recognized the deficiency of planning data for irrigation development and pointed to the need for work on the economics of farm size, involving the use of advanced farm management techniques such as linear programming. Referring to the developing Coleambally Irrigation Area of southwestern New South Wales, he said:

> . . . the farms now taking shape could benefit considerably from the application of farm management analysis in solving their problems of resource allocation. This is farm planning in terms of what is the best use of the resources which have been decided for them. This type of extension work requires factual information about the farms.[2]

In addition to the derivation of input-output data, the present study also aims to determine the optimum combination of enterprises and methods of production for large area farms in the Murrumbidgee Irrigation Area of New South Wales.[3] The technique used is parametric linear programming, and the data are drawn largely from surveys conducted in the M.I.A. for this purpose, supplemented by information supplied by research and extension workers where farmers were unable to quantify the variables sufficiently. Two important purposes are thus served by the study. The first is the provision of meaningful farm planning advice to existing settlers. The second is the measurement of the relative benefits and costs on farms of different sizes, with different permanent labour supplies. This latter aspect has particular relevance for future farm size determination in Irrigation Areas which, as mentioned previously, is a neglected field and one which is deserving of more attention in the future. However, the results of this aspect of the study are not presented here, but will be treated in a subsequent paper.

Whilst the data are primarily drawn from the developed farms of the M.I.A., it is felt the results apply equally to the newly opened Coleambally Irrigation Area, south of the M.I.A., particularly after these newer farms complete their "developmental" phase. Both areas have a similar climate with comparable soils and water availability. However, at

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[2] P. Duane, "The Agricultural Use of the Snowy Waters: Economics and the Use of the Snowy Waters", *Australian Journal of Agricultural Economics*, Vol. 4, No. 1 (July, 1960), p. 50.

[3] Hereafter referred to as the M.I.A.

present, C.I.A. farms are generally further from railheads and major towns, which increases their freight costs somewhat *vis-à-vis* the M.I.A. Optimum solutions derived from the linear programming analyses would not be affected by this freight differential as it affects all enterprises proportionately. Net farm incomes would be affected, but not substantially. The new township of Coleambally will reduce this differential in the long-run. The pricing of water is also different in the two areas but the average charge is approximately $2 per acre foot in both cases.

2. DESCRIPTION OF STUDY AREA

At 30th June, 1966, there were 491 large area irrigation farms in the M.I.A. and 194 in the C.I.A.[4] Eventually Coleambally will contain about 570 large area farms with an average size of some 520 acres. Hence the linear programming results will be immediately applicable to at least 700 irrigation farms and eventually to more than 1,050. The parametric facility was used to derive optimum programmes for farms ranging in size from 300 to 1,700 irrigable acres, with permanent supplies of from one to four men, plus the option of hiring up to 6 months casual labour in any one year. This farm size range measured in terms of total acres covers about 90 per cent of the existing farm population in the two areas.

The production of rice forms a major part of the existing farm programmes in these areas and contributes almost 50 per cent of gross income.[5] The crop is marketed by the statutory Rice Marketing Board for the State of New South Wales, and growers receive a pool price which represents the average returns from domestic and export sales, the latter being the lower priced market. Acreage restrictions apply to all farms by way of a rice-growing "permit" which is administered by the Water Conservation and Irrigation Commission in collaboration with the Rice Marketing Board and the Rice-grower's Association. The three bodies meet each year and after a decision is made on the total quantity of rice required to satisfy market demands, individual farm allocations are made. The Water Conservation and Irrigation Commission ensures that allocations are not exceeded by requiring special approvals for the supply of water for rice to individual farms. Only where high water tables and high consumption are problems does the Commission completely withdraw the rice "permits" from a farm. Apart from these instances, market considerations largely determine acreage allotments. Growers cannot take two successive crops of rice from the same land. In the Yanco Irrigation Area, rice-growing is restricted to 60 acres per farm per annum in those localities overlying sandbeds.

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[4] See the *Annual Report of the Water Conservation and Irrigation Commission of New South Wales*, 1965–66 (Sydney, New South Wales Government Printer, 1967), pp. 12–20.

[5] See J. G. Ryan, *Financial Results of a Sample Survey of Rice Farms in Murrumbidgee Irrigation Area* (N.S.W. Department of Agriculture, Division of Marketing and and Agricultural Economics: Miscellaneous Bulletin No. 3, June, 1968), p. 2.

In those areas not overlying sandbeds the maximum annual acreage is at present 90 acres, but has been up to 100 acres.

Linear programming is the ideal technique to use in this study because irrigation farms, by virtue of an assured water supply except in the most adverse years, are faced with numerous alternative enterprises and practices from which to choose. The input requirements and production levels for the majority of these can be predicted with a reasonable degree of accuracy, which also makes the linear programming results more meaningful than those derived from natural rainfall areas.

Farms in the M.I.A. and C.I.A. have comparable soils although at the present time those in the latter area are virtually in their virgin state, as settlement only commenced in 1960–61. There also appears to be more of the less fertile red "Willbriggie" type soils in the C.I.A., although the area contains more of the black "Wunnamurra" type, which is rich in nutrients, well structured, and has a calcareous crumbly nature.[6]

Irrigation Area farms have been designed, as far as possible, to include a range of soil types rather than a predominance of a single one. This makes classification of farms on the basis of soil types extremely difficult, as there can be numerous soil associations on any one farm with no clear areas within either the C.I.A. or M.I.A. which contain homogeneous soil associations. On the other hand this means that one set of typical input-output data will have application, from the point of view of soils, to all large area farms on the two Irrigation Areas, assuming roughly the same distribution of soils on all farms.

Row crop enterprises such as cotton, sorghum, maize and soybeans are relative newcomers to the irrigation areas and their input requirements and production potential have yet to be determined. For this reason they are excluded from the study, although "broad-acre" sorghum is included, as are other "conventional" irrigation enterprises such as wheat, oats, barley, linseed, safflower, pastures, hay, sheep, cattle, fodder crops and grain feeding. These are all common on the Irrigation Areas and do not necessitate alteration of the contour irrigation layout which is required for rice. It would be premature and misleading to incorporate row crops into the linear programme in view of the existing uncertainty surrounding their production and marketing, and the lack of knowledge of the effects of expanded cropping on rotations, soil fertility and structure, and long term yields.

Detailed research into the economics of the cotton industry has been carried out by the writer since its recent introduction into the southern Irrigation Areas and Districts.[7] The general conclusion is that profitable cotton growing appears unlikely in the absence of the Commonwealth

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[6] See S. E. Flint, "The Assessment of Land Resources for Irrigation with Special Reference to Coleambally Irrigation Area", *Proceedings of Banker's Residential Conference on the Use of the Snowy Waters for Irrigation in New South Wales* (The Rural Liaison Service, Reserve Bank of Australia, 1961), pp. IV–11.

[7] See J. G. Ryan, "Cost-Size and Revenue Relationships in the Cotton Growing Industry of Southwestern New South Wales," This *Review*, Vol. 33, No. 2 (June, 1965), pp. 53–100.

Government's bounty for yields less than 500 lb of lint per acre. With continuation of the bounty at 1964–65 levels, yields well in excess of 300 lb would be required. The average yield per sown acre over the past four years is shown in table 1.

TABLE 1

Year	Area sown	Yield
	ac.	lb lint
1962–63	1,400	n.a.
1963–64	1,800	223
1964–65	5,000	169
1965–66	3,300	150
1966–67	1,700	379
1967–68	1,100	n.a.
	Weighted average ..	202

Source: Information collated from Ricegrower's Co-operative Mills, Ltd, Leeton and local research and extension officers.

There is a possibility that yields may improve as a result of the development of new varieties better suited to the relatively short growing season in southwestern New South Wales, and the introduction of "broadcast" cotton in place of the traditional row-crop method with consequent cost savings and the possibility of yield increases. However, the long-term potential for this crop is undetermined at this stage and it is excluded from further consideration on these grounds.

When more economic information is forthcoming from irrigated maize, sorghum and soybeans, their place in an optimum programme for large area irrigation farms can also be determined. However, some idea of the kind of yields required before they should be considered can be gleaned from the shadow prices generated by the linear programming results for similar enterprises such as sorghum grown under contour farming methods. Incorporation of these "unconventional" enterprises into a linear programming analysis will be a relatively easy matter when more reliable planning information becomes available.

3. CONSTRUCTION OF THE MATRIX

The matrix consisted of 101 activities and 43 rows. Tables 2 and 3 contain a list of the activities and constraints used in the analysis and their respective $z - c$ and b coefficients.[8]

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[8] For a detailed discussion of the survey results and the input-output data used in the construction of the matrix, see J. G. Ryan, *Input-Output Data, Resource Restrictions and a Programming Matrix for Rice Farms* (N.S.W. Department of Agriculture Division of Marketing and Agricultural Economics: Miscellaneous Bulletin No. 9), forthcoming.

TABLE 2

Activities used in Linear Programmes

Activities	Unit	$z - c$
Winter Pasture	acre	+ 6·41
Sod-sown Rice	,,	—116·56
Summer Pasture	,,	+13·62
Lucerne Hay (owned equipment maximum production)	,,	+55·27
Lucerne Hay (owned equipment minimum production)	,,	+24·76
Grazing Lucerne	,,	+14·46
Pasture Hay (owned equipment)	,,	+10·29
Hay Machine Hire (off farm)	ton	— 7·93
Pasture Hay Buy	,,	+16·00
Pasture/First Cut Lucerne Hay Sell	,,	—14·80
Prime Lucerne Hay Sell	,,	—22·80
Prime Lucerne Hay Buy	,,	+24·00
Pasture/Lucerne Hay Feed	,,	+ 0·69
Vealer Beef (Autumn calving)	cow and followers.	—75·19
Vealer Beef (Spring calving)	cow and followers.	—66·35
Yearling Beef (Spring calving)	cow and followers.	—82·10
Sudax	acre	+20·79
Grain Sorghum (contour method)	,,	—28·88
Safflower	,,	—32·38
Linseed	,,	—40·77
First Crop Wheat	,,	—25·77
Second Crop Wheat	,,	—16·23
First Crop Grain Oats	,,	—12·82
Second Crop Grain Oats	,,	—16·16
First Crop Grazing Oats	,,	+ 2·77
Second Crop Grazing Oats	,,	+ 6·17
Sod-sown Grazing Oats into Winter Pasture	,,	+ 5·90
Sod-sown Grazing Oats into Rice Stubble	,,	— 0·53
First Crop Malting Barley	,,	—20·00
Second Crop Malting Barley	,,	—14·65
Sod-sown Malting Barley	,,	—22·55
First Cross Ewes x D.H. Rams (autumn lambing) ..	ewe	— 7·89
First Cross Ewes x D.H. Rams (winter lambing) ..	,,	— 7·20
First Cross Ewes x D.H. Rams (spring lambing) ..	,,	—10·46
Merino Ewes x B.L. Rams (autumn lambing) ..	,,	— 7·69
Merino Ewes x B.L. Rams (winter lambing)	,,	— 7·36
Merino Ewes x B.L. Rams (spring lambing)	,,	—10·87
Merino Wethers	head	— 2·86
Casual Labour	hour	+ 1·61
Fatten Weaner Cattle	head	—31·75
Fatten Lambs (buy March, sell October)	,,	— 5·54
Fatten Lambs (buy October, sell October)	,,	— 6·40
Fatten Lambs (buy February, sell wethers April, ewes October)	,,	— 3·67
Fatten Lambs (buy December-January, sell April) ..	head	— 2·44
Grain Feeding†	bushel	+ 0·75
Lucerne Hay (contract, maximum production).. ..	acre	+98·43
Lucerne Hay (contract, minimum production).. ..	,,	+36·42
Pasture Hay (contract)	,,	+21·74

* Includes feeding out costs only.

† Includes grain and feeding out costs.

The matrix was compiled on the basis of above average levels of technical efficiency with respect to output levels but with machinery and labour requirements set at the average rates from the survey. Seed, fertilizer, water, pesticide, weedicide, insecticide and chemical input levels were derived primarily from research and extension officers with the aid of the survey results. Mean prices for the saleable commodities over the past 3 to 4 years were used to value output categories, while costs reigning in early 1967 were used to cost the inputs.

The seasonal feed production patterns of crops and pastures were estimated from information supplied by research and extension officers, and farmers who were able to provide grazing details. The feed requirements of livestock were derived from Molnar and Killeen.[9]

TABLE 3

Constraints used in Linear Programmes

Constraints	Unit	*b*
Total Labour:		
One man—		
Summer	man-hours	863
Autumn	,,	854
Winter	,,	653
Spring	,,	800
Total	,,	1,921
Two men—		
Summer	,,	1,459
Autumn	,,	1,410
Winter	,,	1,119
Spring	,,	1,321
Total	,,	3,271
Three men—		
Summer	,,	2,055
Autumn	,,	1,966
Winter	,,	1,585
Spring	,,	1,842
Total	,,	4,621
Four men—		
Summer	,,	2,651
Autumn	,,	2,522
Winter	,,	1,991
Spring	,,	2,363
Total	,,	5,971
Irrigable Land	acres	300–1,700*
Lucerne Land	,,	85
Haymaking Restriction†	man-hours	208
Casual Labour	,,	1,456
Rice Area	acres	50–80‡

* This is the range of values analysed for the land constraint.
† Represents the maximum time available for spring haymaking.
‡ This is the existing range of institutional restrictions.

[9] I. Molnar, *A Manual of Australian Agriculture* (Melbourne: Heineman, 1961), p. 843 and I. D. Killeen, Leeton, Agricultural Research Station (personal communication).

TABLE 3 (continued)

Constraints	Unit	*b*
"*Two-man Labour*":§		
Two men—		
Summer	man-hours	596
Autumn	"	556
Winter	"	466
Spring	"	521
Three men—		
Summer	"	1,192
Autumn	"	1,112
Winter	"	932
Spring	"	1,042
Four men—		
Summer	acres	1,788
Autumn	"	1,668
Winter	"	1,398
Spring	"	1,563
Feed Supplies: January-December	d.s.e's	0
Winter Pasture Supply	acres	0
Winter Pasture Renovation	"	0
First Cut Lucerne and Pasture Hay Supply	ton	0
Prime Lucerne Hay Supply	"	0
Summer Pasture Supply: November–February	d.s.e.	0
First Cereal Crop Supply	acre	0
Rice Supply	"	0
December Stubble Supply	d.s.e.	0
January Stubble Supply	"	0
Winter Pasture Feed Supply: August–November	"	0

§ These are the supplies of "team" labour for duties such as lamb marking which require two men.

One "typical" machinery and equipment combination was used in the analyses and corresponds to that used on virtually all of the farms surveyed, regardless of size. A larger size combination was not considered. The inefficiencies resulting from the use of bigger machines and implements for cultural operations within the small and irregularly shaped contour bays required for rice farming would offset to a large extent any gains from increased rates of performance.

With one or two exceptions, all the farmers surveyed indicated that capital was not a severe restriction on their operations. For this reason, together with their sound equity position, investment and working capital were not included as restrictions.[10]

4. OPTIMUM FARM PROGRAMMES

Using the MPS parametric linear programme of the IBM Series 360 computer, optimum farm programmes were derived for 590 different resource situations, as follows:

[10] See Ryan, *Financial Results*, *op. cit.*, p. 6.

(a) one, two, three and four permanent men;

(b) farm sizes of from 300 to 1,700 irrigable acres in increments of 40 acres up to 980 acres and in 100 acre increments thereafter;

(c) institutional rice restrictions of 50, 60, 70 and 80 acres;

(d) haymaking activities with (i) machinery ownership and (ii) contract costs used.

Solutions for farm sizes of 1,100, 1,200 and 1,400, 1,500, 1,600, and 1,700 irrigable acres were obtained only for the four permanent men situations with rice restrictions of 60 and 80 acres respectively. This was found necessary after analysis of the results for farm sizes from 300 to 980 acres showed there were still likely to be some size economies for farms in excess of this.

The four institutional rice restrictions were chosen to represent the range which exists at present on the M.I.A.

4.1 "HAY MACHINERY OWNERSHIP" PROGRAMMES

Net farm incomes were calculated for each of the 590 optimum solutions by subtracting overhead costs from the total farm gross margins.[11]

(a) *Rice Restriction* 50 *acres*

Besides the constant appearance of rice, the main feature of this and most other programmes is the predominance of the commercial lucerne hay enterprise, which enters at its maximum level of 85 acres for all farm sizes and permanent labour supplies, except for one-man farms. The hay is all sold at harvest time, apart from some of the first cut which is fed in winter and spring to beef cattle where they enter the programmes. For the one-man farms a shortage of labour forces the lucerne enterprise out at a farm size of 780 acres, in favour of the less labour intensive enterprises, lamb fattening, off-farm contract haymaking and beef cattle (autumn calving).

Linseed also enters all programmes and shows a gradual increase as farm size increases for all labour situations. Winter pasture also increases with farm size due primarily to its essential role in the rotation. The area of oats sod-sown into the rice stubble for winter grazing generally increases with farm size as does the number of merino ewes carried for crossing with border leicester rams in the autumn for September-October lambing, with lambs carried over until April-May. The area of summer pasture also increases with farm size. Malting barley in the rice stubble enters every programme, and its level increases where labour is a more limiting factor.

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[11] Tables containing details of optimum programmes are available on request from the Editor.

Purchasing spring drop crossbred lambs in March and selling them in October appears at substantial levels on the one-man farms of more than 700 acres. In excess of 1,300 head are fattened on a 980 acre one-man farm. This enterprise does not comprise part of optimum programmes for farms with more than one permanent man.

The significance of the autumn calving beef cattle enterprise is evident, particularly for the larger farm sizes. However, where labour is in abundant supply, spring lambing merino ewes x border leicester rams with carryover lambs replace them, combined with purchasing weaner cattle in March to be fattened for sale in August-September.

Grain feeding enters all optimum solutions and increases directly with the increase in sheep numbers. It is mainly fed in March, April, May, November and December.

Substantial transfers of the spring flush from winter pastures to the months of March, April, May, November and December are also a feature of all optimum farm programmes, together with stubble grazing transfers from December and January to February and March.

On the one-man farms, total labour supply is fully utilized at all farm sizes, and casual labour is used in every solution. At a farm size of 580 acres, the full 6 months of casual labour is employed. On the two-man farms total labour is not depleted until the 500-acre farm size. Casual labour hiring commences at 620 acres and is used up to its maximum level at 900 acres. Total labour expires at 740 acres on the three-man farms and casual labour is used from 940 acres onwards. No casual labour is employed on the four-man farms as the total labour supplies are not fully utilized up to the 980-acre farm size, the maximum farm size studied for this rice restriction.

Net farm income generated by the optimum solutions for the one-man farms increases from around $13,000 at 300 acres to $22,000 at 900 acres, as shown in table 4. As farm size increases beyond this, net farm income declines. For the two, three and four-man farms, net farm income shows a constantly rising trend, reaching a peak of just on $25,000 for a three-man farm of 980 acres.

(b) *Rice Restriction* 60 *Acres*

The composition of the optimum programmes for one-man farms with a rice restriction of 60 acres is similar to that for the 50-acre group with the exception that cattle fattening now enters the plans for farm sizes of 300–420 acres and the commercial lucerne hay enterprise is more restricted. The actual levels of each enterprise are slightly different in the two groups owing to the difference in rice acreage.

The labour situation is also similar in the two sets of solutions, as explained, in (a) above. However, at a farm size of 1,100 acres, the four-man farm begins to employ casual labour as total permanent labour supplies become depleted. At this point labour intensive enterprises, such as commercial lucerne hay and merino ewes, are reduced in favour of an increase in beef cattle and linseed. There is also a surplus of 116 man-hours for the 300 acre, one-man farm solution.

No comparison with the 50-acre rice situation was possible for farm sizes in excess of 980 acres owing to limited computer time, although it is apparent that the solutions would be similar.

There is a disparity in net farm incomes in favour of the 60-acre rice farms which increases directly with farm size, as can be seen from table 4. The largest difference is approximately $1,000.

(c) *Rice Restriction* 70 *Acres*

The differences between the solutions for the 70 and 60-acre rice farms are more pronounced than those between the 60 and 50-acre rice farms mentioned above. Again the net farm income disparity between the 70 and 60-acre rice farms increases with farm size, but is never greater than $1,000.

The 300-acre one-man farm solution has 342 man-hours of total labour in disposal. Thereafter, all optima fully utilize the available permanent labour plus some casual labour. At 580 acres, 6 man-months of casual labour are employed, which is similar to the 50- and 60-acre rice farms. On two-man farms total labour is fully occupied at 500 acres and casual labour is employed at 580 acres, being used to its maximum level at 900 acres. Permanent labour is exhausted at 740 acres on the three-man farm but casual labour is not employed until farm size is 900 acres. On four-man farms no casual labour is employed over the 300–980 acre range, as some labour is always in disposal.

(d) *Rice Restriction* 80 *Acres*

The same basic programmes apply to the 80-acre rice farms as to the others. The main difference is that commercial lucerne hay again enters the programmes at lower levels as farm size increases from 300 to 460 acres, and leaves more rapidly as farm size exceeds 580 acres, particularly for one-man farms. All 300-acre solutions include rice at a level of only 74 acres. All other programmes contain rice at its maximum institutional limit. This is probably due to the rotational restriction requiring three acres of winter pasture per acre of rice.

Permanent labour supplies are in disposal up to a farm size of 380 acres on one-man farms. Six months casual labour is employed for all farm sizes in excess of 580 acres. The labour situation and net farm incomes for two, three and four-man farms are very similar to the 70-acre rice farms.

It is significant that over the farm size range 300–780 irrigable acres, regardless of the rice restriction, the one-man farms achieve the highest net farm incomes. From about 780 acres to 1,400 acres the two-man farms appear superior on the basis of this criterion. However, this takes no account of the relative capital requirements of the different farm programmes, which will be discussed in more detail in a subsequent paper.

TABLE 4

*Net Farm Income Generated by Optimum Programmes**

	Farm Size (acres)											
	300	340	380	420	460	500	540	580	620	660	700	740
50 Acre Rice Restriction:												
One man farm	13,187	14,033	14,810	15,510	16,172	16,787	17,520	18,244	19,268	19,767	20,369	20,946
Two man farm	10,491	11,676	12,803	13,839	14,821	15,739	16,716	17,579	18,518	19,258	19,988	20,722
Three man farm	7,421	8,606	9,733	10,769	11,751	12,678	13,746	14,803	16,063	17,129	18,191	19,245
Four man farm	4,351	5,536	6,663	7,699	8,681	9,608	10,676	11,733	12,993	14,059	15,121	16,182
60 Acre Rice Restriction:												
One man farm	13,509	14,768	15,639	16,346	17,031	17,625	18,366	19,067	20,086	20,583	21,175	21,753
Two man farm	10,586	12,221	13,587	14,714	15,690	16,608	17,579	18,422	19,355	20,096	20,829	21,568
Three man farm	7,516	9,151	10,517	11,644	12,629	13,556	14,624	15,682	16,947	18,012	19,071	20,118
Four man farm	4,446	6,081	7,447	8,574	9,559	10,486	11,554	12,612	13,877	14,942	16,001	17,063
70 Acre Rice Restriction:												
One man farm	13,692	15,359	16,328	17,163	17,829	18,453	19,199	19,889	20,892	21,385	21,974	22,551
Two man farm	10,798	12,468	14,106	15,428	16,573	17,473	18,557	19,244	20,189	20,925	21,657	22,393
Three man farm	7,728	9,398	11,036	12,358	13,503	14,429	15,496	16,556	17,818	18,886	19,945	20,985
Four man farm	4,658	6,328	7,966	9,288	10,433	11,359	12,426	13,486	14,748	15,816	16,875	17,937
80 Acre Rice Restriction:												
One man farm	13,910	15,542	16,981	17,847	18,628	19,279	20,022	20,853	21,699	22,189	22,771	23,354
Two man farm	10,976	12,696	14,385	15,954	17,205	18,338	19,298	20,076	21,016	21,757	22,490	23,225
Three man farm	7,906	9,626	11,315	12,875	14,135	15,309	16,372	17,428	18,691	19,755	20,818	21,853
Four man farm	4,863	6,556	8,245	9,805	11,065	12,239	13,302	14,358	15,621	16,685	17,748	18,815

* Figures in brackets refer to contract haymaking solutions.

TABLE 4 (continued)

*Net Farm Income Generated by Optimum Programmes**

	Farm Size (acres)											
	780	820	860	900	940	980	1,100	1,200	1,400	1,500	1,600	1,700
50 *Acre Rice Restriction:*												
One man farm	21,522	22,090	22,313	22,183	..	21,602	..	..	..	..	..	..
				(22,315)		(21,868)						
Two man farm	21,457	22,178	22,902	23,626	24,312	24,978	..	..	..	..	..	..
Three man farm	20,235	21,203	22,058	22,939	23,690	24,411	..	..	..	..	..	..
Four man farm	17,236	18,277	19,332	20,387	21,430	22,480	..	..	..	..	..	..
60 *Acre Rice Restriction:*												
One man farm	22,317	22,897	23,002	22,844	..	22,233	..	..	..	..	..	..
				(23,088)		(22,500)						
Two man farm	22,293	23,020	23,745	24,466	25,153	25,800	..	..	..	..	..	..
Three man farm	21,111	22,057	22,927	23,815	24,535	25,255	..	..	..	..	..	..
Four man farm	18,122	19,159	20,216	21,269	22,318	23,362	26,254	28,362	31,136	34,516	35,367	36,853
70 *Acre Rice Restriction:*												
One man farm	23,117	23,681	23,647	..	..	22,849	..	..	..	..	..	..
						(23,115)						
Two man farm	23,123	23,850	24,577	25,289	25,976	26,605	..	..	..	..	..	..
Three man farm	21,980	22,917	23,791	24,647	25,367	26,087	..	..	..	..	..	..
Four man farm	18,997	20,034	21,090	22,146	23,191	24,239	..	..	..	..	..	..
80 *Acre Rice Restriction:*												
One man farm	23,916	24,425	24,296	..	..	23,489	..	..	..	..	..	..
Two man farm	23,957	24,685	25,412	26,109	26,798	27,415	..	..	..	..	..	..
Three man farm	22,837	23,780	24,680	25,483	26,205	26,912	..	..	..	..	..	..
Four man farm	19,875	20,911	21,968	23,024	24,068	..	27,987	30,009	32,824	36,193	36,960	38,506

* Figures in brackets refer to contract haymaking solutions.

4.2 "CONTRACT HAY-MAKING" PROGRAMMES

The second parametric run involved the substitution of contract haymaking costs and input-output data in the three haymaking activities and the deletion of the off-farm contract haymaking activity, in order to discover if the haymaking activities which appeared in the "ownership" solutions remained optimal in the face of the higher direct costs of contract activities.

All optimum solutions were budgeted out to calculate net farm income. Only in five cases does the "contract" solution have a higher net farm income than its "ownership" counterpart. These are the one-man farms of 900 and 980 acres with 50 and 60 acre rice restrictions, and the one-man farm of 980 acres with a 70-acre rice restriction. As shown in table 4, these five cases have only marginally better net farm incomes than the "ownership" programmes.

The main differences in the optimum programmes for the two situations are:

(i) Commercial lucerne haymaking is at zero level for all "contract" solutions.

(ii) Merino ewes x border leicester rams with spring lambing and carry-over lambs enter at much higher levels in "contract" solutions than in their "ownership" counterparts, particularly for farm sizes less than 600 acres; for example, the 300-acre "contract" farms with a 50-acre rice restriction have about 450 per cent more merino ewes than the "ownership" farms.

(iii) As a consequence of larger sheep numbers, the "contract" solutions contain more winter and summer pastures and grain feeding.

(iv) "Contract" solutions contain fewer beef cattle and reduced acreages of malting barley sod-sown into the rice stubble.

(v) Larger areas of grazing oats are sod-sown into rice stubble for "contract" to provide winter grazing for the additional sheep.

(vi) On one and two-man "contract" farms, the full 6 months of casual labour is employed at farm sizes of approximately 200 acres more than on the "ownership" farms; in other words, because the commercial lucerne hay enterprise is not profitable when contract costs are used, a considerable amount of permanent labour is released, which substitutes for casual labour in "contract" solutions.

5. FEASIBILITY OF OPTIMUM PROGRAMMES

The primary difference between existing and optimum farm programmes is the predominance in the latter of commercial lucerne haymaking and merino ewes x border leicester rams for spring lambing with lambs carried over until April-May. Many irrigation farms do not have suitable soil for the establishment of pure stands of lucerne. On these farms, optimum programmes would probably resemble those for the "contract" haymaking situations, namely increases in the number of sheep and areas of pastures. Net farm incomes would undoubtedly be lower for such farms, although not substantially so.

The average price charged for lucerne hay on-farm in the matrix is $15.71 per ton.[12] This is made up of $10 per ton for the first cut of 1.70 tons per acre containing barley grass and weed impurities, and $18 per ton for the other five cuts of 0.85 tons each. This compares with the average price of $25.84 per ton on farm quoted by Dennett for the Cowra district during the period October to April, over the years 1955–65.[13] This differential would be partly explained by freight charges between the two areas of some $10 per ton (rail). Even at the relatively conservative hay price used in the present study, lucerne hay proves to be a significant part of optimum programmes, except on the one-man farms at very small and very large farm sizes. In many years average prices up to $30 per ton can be obtained locally, making this enterprise even more profitable. It is safe to say, therefore, that where there are suitable soils and sufficient labour, commercial lucerne hay production using farmer-owned equipment should be introduced into the farm programme. Opportunity costs of from $7 to $20 per acre for the maximum lucerne haymaking enterprise occur for all optimum "contract" solutions with the exception of the one-man farms in excess of about 800 acres, where they reach $50 per acre. This implies that maximum commercial lucerne haymaking using contractors would enter optimum programmes for farms without haymaking equipment, provided that the average price of lucerne hay is in excess of about $19 per ton on farm.

The merino ewe x border leicester ram enterprise, which appears in virtually all optimum solutions, seems feasible on irrigation farms in place of the existing predominant sheep enterprise, first cross ewes x dorset horn rams for prime lamb production. The merino x border leicester enterprise with spring lambing and the carryover of lambs until April-May, selling the ewe portion as first cross mothers, would still remain superior to all other sheep alternatives even if there were a substantial changeover to this type of enterprise in the irrigation areas.

Only if the relative prices of prime and first cross lambs were to alter markedly in favour of the former would the present system be preferable. The better yield and quality of wool from merinos, together with higher stocking rates per acre, are the main factors in their superiority over crossbreds. As it is likely that the differential between the prices received for merino and crossbred wools will widen even more in favour of merinos in the future, any tendency for lamb prices to move in favour of the crossbreds will be offset to a large extent.

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[12] Excluding the saving to the grower of $4.80 per ton for carting and stacking when it is sold in the paddock.

[13] C. J. Dennett, *An Economic Appraisal of the Lucerne Industry* (University of Sydney: unpublished Dip.Ag.Ec. thesis, 1966), p. 108.

The shadow prices shown in table 5 for nonoptimum activities and operative restrictions illustrates the stability of the optimum programmes for three typical farm size and labour combinations. This table shows that before pasture hay feeding would be profitable for production purposes its price would have to fall by more than \$3.50 per ton, to about \$12 into store. Lucerne hay would have to fall by between about \$9 and \$15 per ton into store.

TABLE 5

Shadow Prices for some Activities and Restrictions

(Own Hay Machinery)

	Unit	One man 420 acres 60 acres rice	One man 620 acres 60 acres rice	Two men 620 acres 80 acres rice
		\$	\$	\$
Activities:				
Pasture Hay Feed—				
March	ton	3·39	4·26	3·39
April	,,	3·39	3·90	3·39
Lucerne Hay Feed—				
March	,,	8·31	9·23	8·31
April	,,	8·31	8·78	8·31
Yearling Beef	cow	5·28	5·24	6·13
Sudax	acre	9·39	9·28	8·69
Grain Sorghum (contour) ..	,,	36·48	34·76	35·25
Fallow Wheat (1)	,,	10·25	10·28	10·25
Fallow Grain Oats (1)	,,	21·13	21·00	21·13
Fallow Grazing Oats (2B) ..	,,	1·94	in programme	1·52
Fallow Malting Barley (1) ..	,,	14·47	14·53	14·47
Crossbred Ewes x D.H.—				
Autumn	ewe	2·46	2·74	2·62
Winter	,,	2·29	2·44	2·34
Spring	,,	2·64	2·56	2·65
Merino Ewes x B.L.—				
Autumn	,,	1·29	1·60	1·43
Winter	,,	2·29	2·44	2·34
Spring	,,	2·64	2·56	2·65
Merino Ewes x B.L.—				
Autumn	,,	1·29	1·60	1·43
Winter	,,	0·90	1·11	0·94
Merino Wethers	head	2·60	2·72	2·63
Fatten Lambs (1)	,,	0·08	0·07	0·14
Restrictions:				
Rice Restriction	acre	81·94	80·19	82·47
Total labour	hour	1·78	2·43	1·79
Land (irrigable)	acre	25·97	23·37	25·88
Lucerne Land	,,	3·72	some slack	3·81
Hay Restriction	hour	6·43	5·78	6·43

Enterprises in the table which are unlikely to enter optimum programmes because of their comparatively large opportunity costs are sudax, grain sorghum, fallowed wheat, grain oats and malting barley, crossbred ewes x dorset horn rams, and merino wethers.[14] Sorghum yields in excess of 100 bushels per acre would be required before this activity would prove profitable (assuming contour farming). Corresponding yields for other fallowed crops are:

Wheat	50 bushels
Grain oats	80 bushels
Malting barley	60 bushels

Assuming relative wool cuts and prices remain the same as those used in the matrix for crossbreds and merinos, the following increases in the prices received for prime lambs (crossbred ewes x dorset horn rams) would be necessary (first cross spring lambs remaining at $9.00) for any of them to appear in optimum programmes:

	Increase	New Price
Prime lambs—	$	$
autumn lambing	3.26	11.76
winter lambing	2.62	9.42
spring lambing	2.62	12.12

These increases could not be expected even under the most optimistic predictions, suggesting that merinos are likely to remain considerably more profitable than crossbreds.

Optimum programmes generally include a beef breeding enterprise, particularly where the labour/land ratio is small. Beef expansion is feasible on most existing farms, but in some cases fencing may require strengthening and re-construction. As cattle often "pug up" the soil in wet periods or if left on watered paddocks, a small area of hill country is an advantage.

Linseed is not widely grown at present, although a survey of oil crop growers carried out in 1964–65 showed it to be a profitable crop when yields in excess of 0.4 ton per acre were obtained. A yield of 0.5 ton was used in the budget and this generates a gross margin similar to an 18-bag wheat crop. Thus, high yielding winter crops generating a gross margin in the vicinity of $40 per acre have an important place in optimum programmes.

The rice yield of 2.76 tons used in the compilation of the enterprise budget was the average yield for the 1963, 1964 and 1965 crops. Subsequently the average yields climbed to just on 3 tons, although particularly good seasonal conditions contributed to this. Over a long period the 2.76 figure may well prove to be above average, and

[14] Those activities not mentioned in the table have even higher shadow prices and are more unlikely to enter optimum programmes.

this is why it was chosen. Even at this level it was the most profitable enterprise and any yield increases would serve only to increase net farm incomes and would not affect optimum programmes.[15]

The optimum programme for a two-man, 500-acre farm with an 80-acre rice restriction is similar to that derived by Duane and Rowe for an actual irrigation farm in the Riverina in 1959–60.[16] Although their matrix contained only nine activities and used actual input-output data from the case study farm, it does allow some comparison.

In conclusion, it can be said that, from a farm management aspect, the optimum programmes are feasible.

6. CONCLUSION

The primary conclusions relating to the farm management aspects of the study are that farmers should consider introducing the production of lucerne hay for sale and merino ewes x border leicester rams for spring lambing, with lambs carried over until April-May. Only where soils and labour supplies preclude these enterprises, should others be considered. In addition, the following crops should appear in programmes aimed at maximizing profits—rice, linseed (or a 54 bushel wheat crop), sod-sown malting barley and grazing oats in the rice stubble. Grain feeding of sheep in autumn and early summer should be practised when the above sheep enterprise is introduced.

When labour is limiting, autumn calving beef cows for vealer production, together with purchase of spring dropped crossbred lambs in March for sale in October, should replace the breeding sheep activity.

Enterprises with high opportunity costs which are unlikely to enter optimum programmes in the absence of substantial improvements in their relative market prices and/or reduction in their production costs, are—sudax, grain sorghum, fallowed wheat, grain oats and malting

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[15] There is some evidence, from a survey carried out by E. S. Malikides, formerly of the Water Conservation and Irrigation Commission, that rice yields are positively correlated with the length of rotation. From figures relating to the years 1944–45 to 1960–61 he derived a linear equation: $y = 1.486 + 0.159x$ where y = yield of rice in tons per acre and x = length of rotation interval in years. This had an r coefficient of 0.988 and was applicable up to a 7-year interval. However, it does not take account of land use in the interval or of the other productive inputs such as fertilizer, water, pesticides, and so on which were applied to the rice crops and have an effect on yield.

A rotation experiment at the Agricultural College and Research Station, Yanco, had to be curtailed due to excessive weed problems in the trial plots and little information was obtained from it. Providing a minimum of 3 years of pasture are included in a rice rotation, it does appear that artificial nitrogen can be used to substitute for soil nitrogen and no yield loss need result. Response may vary on different soil types, but because of the limits of computer programmes and time, only one "typical" enterprise budget was used.

[16] P. Duane and A. H. Rowe, "Planning the Response to Economic Change on an Irrigated Farm", *Quarterly Review of Agricultural Economics*, Vol. 13, No. 1 (January, 1960), pp. 15–24.

barley, crossbred ewes x dorset horn rams, and merino wethers. High yielding winter crops generating gross margins in excess of $40 per acre do have a place in optimum programmes. At present, cereal gross margins generally do not exceed $30 per acre. Sorghum yields in excess of 100 bushels per acre would be required for it to enter. Prime lambs from first cross ewes x dorset horn rams would have to sell for at least $2.70 per head *more* than merino x border leicester lambs of the same age, before the former would be more profitable.

Subsequent articles will cover the policy aspects of the study, namely the determination of optimum farm size and the impact of relaxed rice acreage restrictions and free market rice prices on optimum programmes, net farm incomes and returns to capital and management.