RESOURCE PRODUCTIVITIES IN AN IRRIGATED DAIRYING AREA*

G. J. HICKEY and A. G. LLOYD

University of Melbourne

In 1962-63 a survey was conducted of forty-three dairy farmers in the Nambrok-Denison area of the Central Gippsland Irrigation District, near Maffra, in Victoria. One of the main purposes of the survey was to obtain estimates of resource productivities, using the Cobb-Douglas production function approach.

This approach, to be successful, requires (*inter alia*) a high degree of uniformity between farms as regards soil, climate, stage of development and technical efficiency in management. A detailed soil survey of the area was available, and all eligible farms on a group of closely similar soil types were included in the sample. The restricted area ensured uniformity of climate (23″ rainfall) and the fact that the farms were part of a Soldier Settlement Commission development, commenced in 1951, suggested that there would be less variance in stage of development and technical efficiency than is encountered in most farm surveys (assuming the Commission's selection procedures have some efficacy).

Type of Farm

The following data for the years 1959-60 to 1961-62 (average) provide some background on the type of farm studied.

The average farm was of 105 effective acres, of which 75 acres were irrigated at an intensity of 1·63 feet of water per acre per annum, and carried 55 milkers each producing an average of 295 lb. butterfat per annum. The labour input averaged 1·22 adult-male-equivalents per farm, and the "walk-in-walk-out" value averaged £18,800. Gross income averaged £4,109 per annum (94 per cent of milk was sold at the butterfat price) and deductions of £1,542 cash costs and £490 imputed costs (depreciation and family labour) brought net farm income to £2,077. Using the residual imputation method, and deducting £824 per annum for the owner-operator's labour, the return on capital at market value averaged 6·7 per cent, and ranged from —1·3 to 12·7 per cent per annum. Clearly, this is one of Australia's more prosperous butterfat areas.

Selection of Inputs

The choice of input categories was based on a number of criteria: (i) wherever possible, inputs were defined in physical terms; (ii) the rules of optimum aggregation were specifically observed in the formulation of certain input categories (e.g. plant and machinery services);[1]

* This article presents some of the results from an unpublished M.Sc.Agr. thesis submitted by Mr. Hickey to the Faculty of Agriculture, University of Melbourne. Thanks are due to R. Jardine, Biometrician, Victorian Department of Agriculture, and R. M. Seebeck, Faculty of Agriculture, Melbourne University, for statistical advice, and to the Reserve Bank for financial support.

[1] As set out in L. A. Bradford and G. L. Johnson, *Farm Management Analysis* (New York: John Wiley, 1953), pp. 144-5 and J. S. Plaxico, "Problems of Factor-Product Aggregation in Cobb-Douglas Value Productivity Analysis", *Journal of Farm Economics,* Vol. 37, No. 4.

and (iii) specific resources of particular interest in themselves were isolated as separate inputs (irrigation water and superphosphate, which local research suggested to be highly important determinants of output).

Hay, concentrates, and agistment have been specified separately in some other Australian studies of resource productivity on dairy farms.[2] However, in this sample, only nine farmers bought agistment and only one fed grain, whilst hay, though used by all farmers, was fed at near-uniform rates. (Hay was included as a separate category in a preliminary regression but proved insignificant.)

The variables employed, together with their geometric means and unit costs, are shown in Table 1. The categories are self explanatory except for "other cash expenses" which includes charges for veterinary, artificial breeding and herd testing services, labour costs for casual and contract work, chemical sprays, fertilizer other than superphosphate and dairy sundries. The category also includes a less important group of expenses, fairly standardised for each farm and not closely related to output levels, such as registration fees, insurance and subscriptions.

TABLE 1

Input and Output Components of the 100 Total-Acre Basis Production Function

		Item	Geometric mean	Unit cost
Output	Y	Butterfat	19,470 lbs.	57·26d.*
Inputs	X_1	Irrigation land	73·10 acres	£9·9 per annum†
	X_2	Dryland‡	26·90 acres	£3·0 per annum†
	X_3	Labour	77·52 A.M.W.E.¶	£15·85§
	X_4	Milking cows	67·23 cows	£6·4 per annum†
	X_5	Superphosphate	10·15 tons	£14·0§
	X_6	Irrigation water	108·1 acre feet**	£1·2§
	X_7	Plant and machinery services	£1,141††	£1·0
	X_8	Other cash expenses	£683·6	£1·0

* Average net final price over the three years.
† Interest and depreciation.
‡ When the adjustment to a 100 total-acre basis is made (see text), X_1 becomes the proportion of the 100 total acres irrigated and X_2 is omitted.
¶ Adult-male-week-equivalents.
§ Average cost over the three years.
** Due to errors of measurement by the farm metering devices, irrigation water-use figures underestimate the actual quantities delivered to the farms by an average of 7% (range 0—14%), which means that the figure of £1.2 per acre foot overestimates the real cost of water to the farmer by 7% on average. Estimates of these errors became available too late to allow for adjustments to the data, so that the ensuing analysis is in terms of uncorrected water use figures.
†† Interest, depreciation and running costs.

Adjustments to the Data

Three forms of the variables were employed—the raw data, data adjusted for non-milking livestock, and data further adjusted to a 100 total-acre basis, *the latter being the data presented here.*

[2] See F. G. Jarrett, "Estimation of Resource Productivities as Illustrated by a Survey of the Lower Murray Valley Dairying Area", *Aust. Journal of Statistics,* Vol. 1, No. 1; and H. P. Schapper and R. G. Mauldon, "A Production Function from Farms in the Whole Milk Region of Western Australia", *Economic Record,* Vol. 33, No. 64.

The first adjustment involved the reduction of input categories X_1, X_2, X_5 and X_6 [3] by the ratio of milkers to total milker equivalents and was aimed at overcoming differences between farms in the proportion of non-milking livestock, by specifying only that portion of the input actually utilised by the milking cows.

All the farms were then converted to a 100 total-acre basis (excluding non-usable land) by applying the ratio, 100/total acres, to all inputs and output; the ratio, determined separately each year for each farm, ranged from 0·61 to 2·05 and averaged 1·28. This second adjustment reflects our preoccupation with the "short-run" situation where total acreage is held constant, while the proportion irrigated and other specified productive inputs are allowed to vary within the limits set by the data. It seemed most unlikely that true economies of scale could be of any importance given the small variance of farm size within the sample.

Choice of Function

One of the most controversial matters in current discussions of production function analysis relates to the importance of the problem of hybridity. Managerial ability is a problem factor in this regard, since it is difficult to measure. On the one hand, Hoch, assuming this factor to be correlated in most cases with one or more of the specified inputs, suggests the use of covariance analysis for the estimation of unbiased intrafarm production functions.[4] On the other hand, Rasmussen,[5] arguing that the level of "global" inputs is relatively independent of the management factor, and Duloy, arguing that capital constraints more often than management determine input levels, defend the use of interfarm functions.[6] In fact, Rasmussen suggests the use of an extreme interfarm function, his Variance Components regression, for marginal productivity analysis.[7]

In the original study five regressions were estimated—the Common or Within-Year Regression, and the Individual Year, Between Farms, Residuals and Variance Components Regressions.[8] The Common or Within-Year Regression was chosen for the analysis presented in this paper, partly as a result of a critical appraisal of the above authors' arguments, and partly as a means of compromise in this still controversial field.

Survey data commonly suffers from the disadvantage that inputs are

[3] It was considered that the other inputs were much less dependent on the number of non-milking livestock and were thus more relevant in their original form.

[4] I. Hoch, "Estimation of Production Function Parameters Combining Time Series and Cross Sectional Data", *Econometrica,* Vol. 30, No. 4.

[5] K. Rasmussen with M. M. Sandilands, *Production Function Analysis of British and Irish Farm Accounts* (University of Nottingham, Department of Agricultural Economics: 1962).

[6] J. H. Duloy, *Simultaneous-Equations Bias in the Context of Agricultural Production Function Estimation.* Paper presented to Econometrics Conference, University of Adelaide, August, 1963.

[7] Rasmussen with Sandilands, *op. cit.*

[8] See G. J. Hickey, *The Economics of Irrigated Dairyfarming in the Central Gippsland Irrigation District,* unpublished M.Sc.Agr. thesis, Faculty of Agriculture, University of Melbourne, 1964, pp. 96-99.

intercorrelated to varying degrees; such intercorrelation gives rise to the problem of multicollinearity, which in turn leads to regression coefficient estimates having large variances and being relatively unstable. In an attempt to diminish these effects, the final form of the production function retained only those inputs for which the partial regression coefficients were significant. However, some of these are "joint" inputs, in the sense that they explain not only their own effect, but also that of some of the omitted inputs. Therefore "subsidiary equations" were used, following Cozens and White.[9] This procedure involved estimating the regressions of each of the excluded inputs on all those retained (again, only those inputs for which the regression coefficients were significant were retained), and these regressions were used to improve the accuracy of the estimated marginal net returns of the "joint" production function inputs.

The matrix of correlation coefficients for the independent variables indicated that relatively high correlations existed for a number of pairs of inputs, but if as suggested by Heady and Dillon,[10] a figure of 0·8 is chosen as the critical level, then only one of these pairs, viz. X_1 and X_4, may be expected to be troublesome. In fact, only one of these inputs, X_4, was specified in the final form of the production function as discussed below.

Results and Analysis

The production function and subsidiary equations obtained from the survey data for the 43 farms are listed below.

Production Function

$$\begin{aligned} \text{Log } Y = 1{\cdot}9623 &+ 0{\cdot}5566\ (0{\cdot}0758) \log X_4 \\ &+ 0{\cdot}1271\ (0{\cdot}0501) \log X_6 \\ &+ 0{\cdot}1399\ (0{\cdot}0611) \log X_7 \\ &+ 0{\cdot}2200\ (0{\cdot}0318) \log X_8 \end{aligned}$$

$$R^2 = 83\% \qquad \Sigma b_i = 1{\cdot}0436$$

where the figures in brackets are the standard errors of the corresponding regression coefficients.

Subsidiary Equations

$$\log X_1 = 0{\cdot}1206 + 0{\cdot}6072\ (0{\cdot}0670) \log X_4 + 0{\cdot}3115\ (0{\cdot}0497) \log X_6$$

$$R^2 = 73\% \qquad \Sigma b_i = 0{\cdot}9187$$

$$\log X_3 = 0{\cdot}3403 + 0{\cdot}6366\ (0{\cdot}0954) \log X_4 + 0{\cdot}1896\ (0{\cdot}0708) \log X_6$$

$$R^2 = 51\% \qquad \Sigma b_i = 0{\cdot}8262$$

$$\log X_5 = -1{\cdot}0277 + 1{\cdot}1128\ (0{\cdot}1931) \log X_4$$

$$R^2 = 21\% \qquad \Sigma b_i = 1{\cdot}1128$$

Table 2 summarizes the calculation involved in the estimation of the marginal net returns of the four main inputs at their geometric mean levels of use.

[9] L. E. Cozens and H. A. White, *A Survey of Dairy and Pig Farms in Woorayl Shire, South Gippsland, Victoria,* Victorian Department of Agriculture, 1959, (roneo).

[10] E. O. Heady and J. L. Dillon, *Agricultural Production Functions* (Ames, Iowa: Iowa State University Press, 1961), 136.

TABLE 2

Marginal Net Returns of Production Function Inputs (£)

(Estimated at geometric means)

Input	X_4	X_6	X_7	X_8
Marginal returns*	38·457	5·464†	0·570	1·495
Marginal costs				
Direct	6·400	1·200	1·000	1·000
Indirect				
Irrigation land‡	4·554	1·456		
Labour	11·634	2·156		
Superphosphate	2·352			
Total marginal costs	24·940	4·812	1·000	1·000
Marginal net returns	13·517	0·652	—0·430	0·495

* Butterfat valued at 57.26d. per lb. (three year average).
† Subject to overestimation due to the incorrect measurement of farm irrigation water use (footnote (**), Table 1).
‡ Irrigation land charged at £6.9 per acre, since a one acre increase in irrigated acreage, with total acreage constant at 100, involves the difference between the cost of irrigated land and dryland.

Table 3 lists the optimum level of each input category as calculated separately, holding all other inputs at their geometric mean levels. This optimum is defined as that level at which the ratio of marginal returns to marginal cost becomes unity.

TABLE 3

Optimum Levels of Employment of Production Function Inputs

(Estimated for each input in turn, with others held at geometric means)*

Input	Approximate optimum level
Milking cows (number)	380
Irrigation water (acre feet)	160
Plant and machinery services (£)	600
Other cash expenses (£)	1,200

* Per 100 total-acre basis.

Duloy's method of estimating various least-cost combinations of production function inputs is employed in the further analysis of the production function results.[11] Since such an approach assumes that a value production function is available, the marginal costs of the production function inputs at their geometric means are accepted as reasonable estimates of their prices (including associated inputs), and are employed as such in the conversion of the function to its value equivalent. (This is not strictly legitimate in the present case, where the marginal costs of some of the main inputs vary with their level of use due to their partial dependence on the costs of associated inputs as expressed through the subsidiary equations.)

As a first estimate, the least-cost combination of production function inputs is determined under the constraint that total resources available for reallocation are limited to those already available on the farm. These

[11] J. H. Duloy, "Resource Allocation and a Fitted Production Function", *Aust. Journal of Agricultural Economics,* Vol. 3, No. 2.

total resources, for the geometric mean farm of the sample, are calculated in Table 4, and the least-cost combination of the production function inputs, for the same total cost, is as set out in Table 5.

TABLE 4

*Total Resources for Reallocation**

Input	Geometric mean	Unit cost†	Total cost
Milking cows	67·23 cows	£24·940	£1,677
Irrigation water	108·1 acre feet	4·812	520
Plant and machinery services	£1,141	1·000	1,141
Other cash expenses	£684	1·000	684
Total resources			£4,022

* Per 100 total-acre basis.
† Inclusive of direct and indirect costs as per Table 2.

TABLE 5

Least-Cost Combination of Production Function Inputs

(For same total cost as geometric mean inputs)*

Input	Least-cost combination
Milking cows (number)	86
Irrigation water (acre feet)	102
Plant and machinery services (£)	539
Other cash expenses (£)	848
Total cost (£)	4,022
Total butterfat (lb.)	20,920

* Per 100 total-acre basis.

Table 6 records the relevant levels of the associated inputs; as Tables 2 and 4 indicate, the cost of these latter are taken into account in the costing of the "joint" production function inputs comprising the least-cost combination.

TABLE 6

Associated Inputs

(With least-cost combination shown in Table 5)*

Input	Least-cost combination
Irrigation land (acres)	83·29
Labour (A.M.W.E.)	89·62
Superphosphate (tons)	13·34

* Per 100 total-acre basis.

Increasing output along the least-cost combination expansion path represents the most rational use of any additional resources available for allocation, and in the case of the Cobb-Douglas model such paths are linear, inferring that inputs should be held in fixed proportions as output is increased. Since the sum of the elasticities for the estimated function is greater than unity, expansion of output along the least cost combination path is increasingly profitable, but such expansion is only feasible as long as all inputs remain variable and capital is not limiting.

The production function model employed in the present analysis imposes an automatic limit on the expansion of output along the four-input least-cost combination path, when X_1 (irrigation land) becomes 100, i.e. when all of the land area is being irrigated. At this point both X_4 (milking cows) and X_6 (irrigation water) become fixed, and thereafter, with sufficient capital, X_7 (plant and machinery services) and X_8 (other cash expenses) may be increased in their least-cost combination to the optimum point, at which the ratios of their marginal value product to marginal cost become unity.

Table 7 lists the optimum combination of production function inputs for this limiting case and, in addition, optimum combinations for various intermediate levels of the proportion of the land area irrigated.

TABLE 7

Optimum Allocation of Resources Between Production Function Inputs

(With the proportion of land area irrigated (X_1) at various levels)*

Input	Proportion of land area irrigated 73.1%	80%	90%	100%
Milking cows (number)	74·61	82·32	93·56	104·90
Irrigation water (acre feet)	88·34	97·47	110·78	124·20
Plant and machinery services (£)	694	770	883	1,000
Other cash expenses (£)	1,091	1,211	1,389	1,570
Irrigation land (acres)	73·10	80·00	90·00	100·00
Labour (A.M.W.E.)	79·69	86·44	96·10	105·61
Superphosphate (tons)	11·39	12·70	14·65	16·64
Total Cost (£)	4,071	4,503	5,138	5,784
Output (lb. BF)	20,787	23,078	26,467	29,916

* Per 100 total-acre basis.

Tables 8 and 9 analyse situations in which both milking cows and irrigation water are held at their geometric means, and first, plant and machinery services and other cash expenses are increased in their least-cost combination to the optimum level, and secondly, each of these separately in turn holding the other at its geometric mean, is increased to its optimum point.

TABLE 8

Optimum Allocation of Resources Between Production Function Inputs

(With milking cows (X_4) and irrigation water (X_6) held at geometric means)*

Input	Quantity
Milking cows (number)	67·23
Irrigation water (acre feet)	108·1
Plant and machinery services (£)	660
Other cash expenses (£)	1,038
Total cost (£)	3,895
Total output (lb. BF)	19,779

* Per 100 total-acre basis.

TABLE 9

Optimum Allocation of Resources Between Production Function Inputs

(With only plant and machinery services (X_7), or other cash expenses (X_8) variable)*

Input	Quantity X_7 variable	Quantity X_8 variable
Milking cows (number)	67·23	67·23
Irrigation water (acre feet)	108·1	108·1
Plant and machinery services (£)	592	1,141
Other cash expenses (£)	684	1,141
Total cost (£)	3,474	4,482
Total output (lb. BF)	17,766	21,802

* Per 100 total-acre basis.

Discussion

Traditionally, the ratios of marginal returns to marginal costs have been taken to indicate the direction in which resources should be allocated (or reallocated) to improve the efficiency of resource use. Ratios greater than unity indicate that more resources could profitably be directed into the inputs concerned, and vice versa. Thus the results listed in Table 2 lead to recommendations for an increased allocation to the milking cows (X_4), irrigation water (X_6) and other cash expenses (X_8) input categories (in the first two, this implies a simultaneous increase in associated inputs), and a decreased allocation to the plant and machinery services (X_7) category; alternatively this may be interpreted as a diversion of resources from the latter to the other three categories.

Although these ratios may supply qualitative information, they say nothing of a quantitative nature in this respect. Two procedures have been adopted for this latter purpose: first, each input is examined separately, holding all others at their geometric means, and its optimum level is determined under conditions of unlimited capital; second, all production function inputs are examined simultaneously, and their optimum combinations are specified for various restrictive situations. Throughout, corresponding to the adjusted production function used, the specified input arrays are per 100 total acres.

The optima specified by the first of the above-mentioned procedures are listed in Table 3. It would appear from Table 2 that substantial increases in milking cows would be profitable, but the optimum of 380, listed in Table 3, is beyond all bounds of reasonable extrapolation, especially if one bears in mind that the constant elasticity restriction of the Cobb-Douglas model means that marginal productivities are likely to be over-estimated for observations well above the geometric means.

The first limit on the expansion of milking cows is set by the model itself, via the subsidiary equation for irrigation land. With irrigation water held at its geometric mean, milking cows may be raised to a limit of 113, at which point all of the total acreage is being irrigated. However, such a level of milking cows represents the outside limit for the expansion of this input on the group of farms studied. Although five farms had all of their acreage irrigated, this is not feasible on the majority of farms, varying proportions of their acreage being classified as unsuitable for irrigation. It would appear more meaningful then to recognize this fact, and investigate the profitability of smaller increases in milking cows. For example, an increase to 90, holding the other production function inputs at their geometric means, implies an increase to 85 per cent of the total acreage irrigated, and yields a marginal net return of £10·44 per milking cow.

The optimum level for irrigation water suggested by this method, viz. 160 acre feet, appears feasible, but is liable to the same type of over-estimation as discussed in relation to milking cows; at this level the model implies that 83 per cent of the total acreage is being irrigated at a rate just under two acre feet per annum.

Looking at each of the other two production function inputs separately, the results suggest that annual expenditure should be contracted to £600 in the case of the plant and machinery services category, and expanded to £1,200 in the case of other cash expenses.

The second of the procedures described above allows for the definition of optimum combinations of the production function inputs under various situations of resource fixity and total resource restrictions. A number of situations, varying in their degree of resource fixity and hence the length of run being considered (or time period for adjustment), may be distinguished and investigated for positions of optimum resource allocation.

The first is the long-run situation in which all production function inputs are considered variable. Table 5 indicates the least-cost combination of these inputs for the same total cost as the geometric mean farm combination, and Table 6, the associated inputs. As these tables indicate, such reallocation involves a diversion of resources from the irrigation water and plant and machinery services categories into the other inputs. This involves a change in the proportions of the production function inputs from 1·0 : 1·6 : 17·0 : 10·2 in the geometric mean combination, to 1·0 : 1·2 : 6·3 : 9·9 in the least-cost combination, for milking cows (number), irrigation water (acre feet), plant and machinery services (£), and other cash expenses (£), respectively. Since the Cobb-Douglas model specifies linear least-cost combinations, the production function inputs are increased in these latter proportions as extra resources become available for allocation. The limit to feasible expansion along this path is imposed by the model itself, when the proportion of the total acreage irrigated becomes 100 per cent. Thereafter, milking cows and irrigation water (and associated inputs) are held constant, and plant and machinery services and other cash expenses are expanded in their least-cost combination to the optimum point. Table 7 (column 4) lists the allocation of resources for such a situation, the production function inputs being in the ratio 1·0 : 1·2 : 9·5 : 15·0 for the order of inputs as described above.

The second situation analysed is more short run in nature, in that reallocation is carried out on the assumption that the proportion of the total acreage irrigated cannot be varied from its geometric mean value of 73·1 per cent. The least-cost combination of production function inputs for which irrigation land becomes 73·1 acres is located, and holding milking cows and irrigation water constant at these values, plant and machinery services and other cash expenses are expanded in the least-cost combination to their optimum levels. Table 7 (column 1) lists the optimum allocation of resources for this situation, the ratio of the production function inputs being 1·0 : 1·2 : 9·3 : 14·6. Such reallocation yields an increase in output of 1,317 lb. of butterfat per annum for an extra cost of £49.

The third situation considers the case where milking cows and irrigation water (and hence also associated inputs) cannot be varied from their geometric mean levels, and reallocation is restricted to the adjustment of plant and machinery services and other cash expenses into their least-cost combination, and expansion along this path to their optimum levels. Table 8 shows that even in this very limited case of resource reallocation, output may be increased by 209 lb. of butterfat per annum, with an annual saving of £127; in this case the production function inputs exhibit the ratio 1·0 : 1·6 : 9·8 : 15·4.

The final situation to be distinguished is the restricted case in which only a single production function input may be varied, all other inputs being held at their geometric means. This is, of course, equivalent to the procedure outlined above. Due to the structure of the model, however, all the specified inputs cannot (computationally) be varied independently, e.g. changes in either milking cows or irrigation water are accompanied by changes in associated inputs. Thus this situation may only be analysed in respect of the plant and machinery services or other cash expenses categories. Considering each of these in turn, their optimum levels are £593 and £1,144 per annum respectively. The allocation of resources in each case is listed in Table 9, the ratios of production function inputs being 1·0 : 1·6 : 8·8 : 10·2 and 1·0 : 1·6 : 17·0 : 17·0.

The use, in the above analysis, of a model comprising a reduced production function and subsidiary equations takes recognition of the fact that farm survey data is characterised by factors of production correlated in such a way that their independent effects on production cannot be measured. Thus the inputs specified in the reduced production function are "joint", in the sense that they explain not only their own effects but also those of associated inputs. However, as Cozens and White have pointed out in their study, such correlations are statistical only;[12] they do not necessarily connote a causal or invariant relationship. Hence, it can neither be implied that changes in the main inputs are not possible without simultaneous changes in associated inputs, nor that changes in the associated inputs have any direct effect on production. Thus it would appear reasonable to take account of associated inputs (via their costs as expressed through the subsidiary equations) when considering non-marginal changes in the main inputs, as in the present study; but in the case of marginal changes, to take account of associated inputs only if they are considered to have a direct effect on production.

Conclusions

In terms of the geometric mean farm of the group, the conclusions may be summarized as follows.

1. In all situations examined, it would be profitable to increase expenditure on the milking cows input category. In terms of the group of farms investigated, such an increase would usually be accompanied by simultaneous increases in the utilization of the irrigation land, labour, and superphosphate input categories.

[12] Cozens and White, *op. cit.*, p. 34.

2. Recommendations regarding the optimum utilization of irrigation water vary with the situation being examined. Additional investment in irrigation water, over and above its geometric mean level, appears profitable when this input alone of the production function inputs is allowed to be varied; such a variation is accompanied, in the group of farms studied, by a change in the subsidiary inputs, irrigation land and labour. In the situation where all the production function inputs are increased along their least-cost combination expansion path, investment in irrigation water, over and above its geometric mean level, only becomes profitable when the proportion of the total farm acreage irrigated is in excess of some 90 per cent. In all other situations studied, including the more feasible of the short-run opportunities for improving resource allocation efficiency in which the proportion of the farm irrigated is held constant, the optimum use of irrigation water appears to be less than its actual geometric mean level.

3. The analysis indicates that the geometric mean farm of the group is overcaptitalized with respect to plant and machinery services for all situations investigated, and thus that the annual expenditure on this item should be substantially diminished.

4. It would appear profitable to substantially increase the annual expenditure on the other cash expenses category in all situations investigated, though it is not possible to indicate which specific components within this category should be expanded.