More from irrigated dairy farms: by computer

D A. Morrison

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by computer

Most farmers aim to get the best possible profit from their operations without overtaxing their land and improvements.

To do this, they draw on observation, experience, information from other farmers, information from the Department of Agriculture and 'gut feeling'.

By putting all this together to make whole-farm decisions and forecasts, they are using 'models' of their farms which already exist in their minds.

Could a computer do the job more effectively using a model prepared from all the relevant information?

Economist D. A. Morrison, of the Department of Agriculture's Marketing and Economics Branch believes it can.

He has reached the final stages of perfecting a model for an irrigated dairy farm to the extent of 'asking it questions' about how Harvey farmers should deal with water restrictions.

He compared its answers with the strategies some of the local farmers have decided on. The results of the comparison are contained in this article.

The problem

It is not easy for the farmer to work out how to maximise profits on an irrigated dairy farm. It is much easier to continue with traditional practices.

However, in the last few years irrigation scheme water supplies have become more expensive and restrictions have been applied.

Water prices have increased from $3.80 per 1 000 cubic metres in 1976/77 to $8.45 per 1 000 cubic metres for the 1980/81 season, and 1979/80 was the fourth consecutive year in which Harvey farmers received less than their allocation. These factors have made it even more important for farmers to make the most profitable use of irrigation water supplies.

To maximise profits the farmer needs to take account of many different factors at the same time. For example, in deciding how often to water his pasture for profit maximisation the irrigation farmer should consider:

- How much does the water cost?
- How much pasture will be produced from further waterings?
- What quality will the extra pasture be?
- By how much will milk or beef production increase with this additional pasture?
- What is the value of the milk or beef produced?
- What is the price and quality of feed which may substitute for irrigation pasture?
- Does he have the time to water more often?
- How expensive is labour or how highly does the farmer value his leisure time?
- If he is able to cut back his irrigation area, how profitable is the dryland use of this area?

Irrigation water is not cheap. Users seek the best possible value from it.
These are only some of the questions to be answered before the profit maximising solution can be found. Irrigation decision making is complex and it should only be dealt with in the context of the whole farm.

**Whole-farm modelling**

To decide on an irrigation strategy the farmer considers at least some of the above questions. In effect he has, stored in his mind, a model of the farm which he uses to predict whole-farm effects of management changes. He is most likely to be concerned with the effect of management change on farm profits, as well as the amount of work he has to do.

Through years of observation and experience, farmers have an intimate knowledge of their land, so their models are usually very good. But, wherever there are many factors to be considered and much of the information is in the form of experimental results and measurements, computer modelling has more to offer because the computer easily 'crunches' the numbers to solve the problem. Just as a farmer chooses between many feasible management alternatives to maximise profits, so a computerised linear programming (L.P.) technique can select the profit maximising strategy from many alternatives.

Linear programming can simultaneously take account of the physical, financial and labour limitations of the farm. With a big enough computer and suitable 'software', it is possible to model a whole farm in detail.

Whole-farm modelling should take all partial objectives into account. For example, an agronomist may see the major need to be to increase pasture yield, whereas the animal productionist may see it as increasing production per cow. A whole-farm L.P. solution aimed at maximising profits will seek those

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Top: Checking an irrigation outlet at Wokalup Research Station.

Below: Flooding a typical South West irrigated pasture.
yields for both pasture and milk which would give the best overall financial return.

The irrigation dairy farm model
Unlike the models stored in the mind, the computer model must be based on data—where possible, local measurement and experimental results.

Whole-farm modelling for irrigated dairy farming brings together the disciplines of soil science, agronomy and animal nutrition because it requires data about the soil, pasture and cow nutrition as well as economics.

Important soil measurements include infiltration rates, water holding capacity, capillary rise and run-off. The necessary pasture information includes evaporation and transpiration rates, the effective depth of the root zone and the relationship of pasture growth to transpiration. Necessary cow nutrition information includes the level of digestible energy, digestible crude protein, crude fibre, calcium and phosphorus in the pasture and the requirements for these nutrients in cow maintenance and milk production.

The costs and returns from different activities also are needed for the model.

Model building is then required to put together all the information in a form which represents the farm and can be solved by linear programming.

A wholefarm L.P. model has been designed for irrigated dairy farms in the South-West.

Because there is not enough local data relating water input to pasture production, a simulation model, based partly on theory and partly on local information was used to predict the response of pasture to additional water.

Also there is little local data relating the level of nutrients to milk yield, so standards derived elsewhere had to be used.

More local experimental information is needed to perfect the model so it is not ready to provide precise recommendations for farmers. Nevertheless, at this stage the computer model’s recommendations make interesting comparisons with what farmers are doing.

Farmer practices versus computer model solution
Many of the strategies selected in the computer model’s solution are the same as farmer practices. One of the first questions ‘asked’ the computer model was: How should Harvey farmers deal with water restrictions?

The strategy specified was:

- Feed cows heavily with barley, lupins and hay to substitute for the reduction in irrigation pasture.
- Milk fewer cows but feed enough grain to boost production per cow. (Because of its high digestible energy content, grain complements irrigation pasture and promotes higher production per cow).
- Cope with the reduced water allocation mainly by reducing the area watered, in order to maintain the frequency of irrigation.

A recent survey (Market Milk Survey, 1980) has shown that most farmers adapted to the water shortage in this way, although they preferred oats to barley.

(Results from the model put oats close behind barley, although this finding was very sensitive to the price of grain.)

The model’s results are in accord with the experience of Harvey farmer Colin Rigg: “While I do not wish to detract from the seriousness of water restrictions, it is not difficult to maintain or even increase milk production over the summer period with a few managerial changes, though not without cost,” he said.

The model proved very sensitive to pasture quality, which can be determined at the Department’s dairy laboratories.
"I found that once water allocation fell below three thousand cubic metres per cow milked the need for heavy grain feeding became evident. The compatibility of grain feeding and irrigation with additional hay is quite astonishing.

"Milk production on my property from January to June this year has been higher than ever before this period, despite the reduced area of pasture"

However, in some instances the model's recommendations differed from common farmer practice. This was especially so for irrigation frequency.

The model selected more frequent irrigation for December, January, February and March than is practised at present (Table 1). Unlike traditional practice the model recommended higher irrigation frequencies for the hotter months of January and February.

This traditional practice has persisted from the time when irrigation frequency was fixed by the Public Works Department at one watering every 16 days. Not all farmers have retained this watering frequency but it does suggest that some farmers water about twice a month simply because they have always done so.

The answer from the model was not straightforward. Sensitivity analysis showed that the number of waterings selected was sensitive to:

- The price put on the farmer's labour. If labour was valued at more than $6 per hour, then irrigation frequency was reduced.
- The change in pasture quality which results from more frequent irrigation.

**What holds back irrigation profits most?**

The L.P. Model also gives a second sort of information. It indicates what holds back profits most and by how much profits are being held back.

Not surprisingly, irrigation farmers would make bigger profits if they had more land or bigger market milk quotas or more water.

The model predicted that extra dryland would be worth only $535 per ha for a farmer with a big land holding, but $1 203 per ha for a small farmer who found it difficult to meet his market milk quota.

The value of water also was found to vary greatly from farm to farm. It varied with market milk quota size and water allocation. Each extra 1 000 cubic metres (TCM) of water was found to be worth about $12 to the farmer in a year of normal supplies, but up to double this with restrictions at Harvey's 1979/80 level.

The model identified some less obvious limitations on profit. In all cases, even in summer and autumn months, the level of digestible energy in the cow's diet is limiting, however digestible crude protein, calcium and crude fibre are not.

Extra digestible energy is more valuable in February, March and April, than early summer. Digestible energy seems so much more important than other nutrients that the irrigation dairy farmer should think in terms of producing digestible energy rather than kilograms of pasture.

Results from the model indicate that over the summer months profits are held back by the cows' low voluntary feed intake. It follows that feeds of low digestibility take up valuable stomach space without meeting energy requirements.

Based on the overseas phosphate standards used in the model, the level of phosphate in the cows' diet was also shown to limit profits.

**Table 1. Watering frequency selected by the model, versus farmer practices**

<table>
<thead>
<tr>
<th>Number of waterings for profit maximisation</th>
<th>Model selects</th>
<th>Traditional farmer practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>0-1</td>
<td>0-1</td>
</tr>
<tr>
<td>November</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>December</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>January</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>February</td>
<td>3-4</td>
<td>2</td>
</tr>
<tr>
<td>March</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>April</td>
<td>—</td>
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</tr>
</tbody>
</table>

**Further development of the model**

The model can be improved by replacing the data based on work elsewhere or based on estimates, with results from local measurement and experimentation.

The exercise of improving the model has brought together a small team of researchers with expertise in soil science, agronomy, nutrition and economics. Instead of such experts solving partial problems, whole-farm modelling brings them together with a common purpose—to maximise farm profits.

In this context researchers can not be concerned with improving pasture yield or improving milk production per cow, each as an end in itself, but because it adds to farm profits. The model can be used to predict by how much these changes will affect farm profits.

Eventually the model will be used to provide farmers with advice on how to maximise their profits, and especially how to manage their scarce water supplies for this purpose.

This multidisciplinary modelling exercise is the first of its kind in Western Australia. If it proves worthwhile, other farming enterprises may be modelled in a similar way.

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1. In this case 'software' is the programmed instruction to the computer on how to solve a L.P. problem.
2. The passage of water through the plant.
3. Both the L.P. and simulation models were developed by the author as part of his work on a Ph.D thesis, with assistance from Jonathan Nelson of the Farm Management Service Laboratory and support from the Public Works Department.