# Investment in Water Saving Technology on Horticultural Farms*

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A long run programming model for analysing investment behaviour on perennial crop farms is formulated and applied to citrus and wine grape producing farms in the Murrumbidgee Irrigation Area. Prices and technological parameters are defined exogenously, while the optimal replanting pattern of the crops and the optimal mix of irrigation techniques are determined endogenously.

The model is used to examine likely investment in water-saving irrigation technology at different crop prices and input costs. The results indicate that such investment is a profitable option at current water charges, particularly for those farmers with access to off-farm employment. However, the adoption decision will be highly sensitive to potential cost savings. Water-saving technology could become more attractive under higher water charges, but only if the preferred option of farm expansion were not available.

The modelling framework, which allows for control over many factors influencing perennial crop investment decisions, has applications in the analysis of the long term consequences of many policy options affecting farm yields or prices.

## 1. Introduction

Throughout Australian irrigation regions farmers are facing increases in water charges as water supply authorities move toward complete cost recovery. This is happening at a time when many farmers are encountering narrowing profit margins caused by escalating production costs and declining real commodity prices. Farmers would be expected to react by adjusting their operations to gain productivity improvements and cost savings. These adjustments may take various forms, ranging from rationalising input use to crop diversification. In horticulture, substantial change in the enterprise mix can be slow and complex because of the perennial nature of the horticultural tree and vine crops. Shifting farm technology toward better water management strategies could improve farm productivity without substantial changes to the enterprise mix.

A multiperiod mathematical programming model is developed to examine the investment behaviour on horticultural farms. The model is used to analyse the influences of input and output prices and technology on the investment patterns that would be expected in horticultural farms in the Murrumbidgee Irrigation Area (MIA) in New South Wales. The aims of the analysis are (a) to analyse the constraints on the adoption of water-saving technology; (b) to examine the likely effects of citrus, wine grapes (the two major horticultural crops in the MIA) and water prices on investment behaviour; and (c) to examine the likely effects of deregulation of farm size and price changes on horticultural farmers' incomes.

The water-saving technology investigated in this paper involves a shift from the high water consuming conventional furrow irrigation system to a drip irrigation system, where water is delivered to the plant at its root system at a given rate over a given duration based on soil, climatic and crop characteristics.

Estimates are prepared of the effects of prices on land use and crop plantings. Included are the magnitudes of the likely effects of output prices and water prices on adoption paths, and the sensitivity of the most profitable resource combinations to the policy assumptions chosen.

This analysis is conducted with a model of a representative farm based on information from the Australian Bureau of Agricultural and Resource Economic's (ABARE) Australian Horticultural Indus-

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try Survey (AHIS) sample for the MIA. However, the results may be applicable to other areas where similar irrigation practices are followed.

## 2. Background

### 2.1 Policy setting

The Murray-Darling Basin covers a major part of eastern Australia and produces 60 per cent of the gross value of rural production (Alouze and Fitzpatrick 1989). It includes all the major temperate irrigation areas in Australia. These areas produce much of Australia's wine and multipurpose grapes, citrus and canning fruit as well as dairy products, prime lambs and irrigated crops, particularly rice. A major irrigation area within the Murray-Darling Basin is the MIA centred around Griffith.

Irrigation water charges in the MIA have recently been increased but still do not meet the running costs of supplying the water, and certainly not the capital costs (Verdich and Amos 1984; Department of Water Resources 1992). However, the Department of Water Resources continues to pursue a commercial approach to its activities. In the past, the cost of irrigation water has been subsidised, and water use has been encouraged beyond the level which would be economically optimal in the absence of a subsidy.

Open-furrow irrigation systems are still the principal means of water application in horticultural farms in the MIA. While this practice is not efficient in terms of water use, it may also contribute to problems associated with rising ground water in the Basin[1]. Farmers have generally been indifferent toward investment in water-saving technology (Sinclair and McLachlan 1989).

Horticultural farms have in the past been strictly regulated as to size and, in some areas, ownership. Land use has been restricted by statutory regulations governing area expansion and industry controls restricting cropping extents, as well as by the agronomic potential of the soils. The institutional restrictions have reduced the scope for autonomous adjustment and hence may have reduced the long run efficiency of the industry. The present structure of the industry could therefore be viewed as a result of heavy subsidisation of a vital input and legal impediments to autonomous adjustment.

These impediments were strongly criticised by the Industries Assistance Commission (IAC 1987) and steps are being taken by state governments to reduce them. For example, in the irrigation areas of New South Wales the legal maximum for a Home Maintenance Area[2] for horticultural farms has recently been increased from 45.33 ha to 100 ha (Department of Water Resources 1992).

Diversification of crop enterprises is limited by agronomic factors, including the influence of soil type. Soil type generally varies across the Basin depending on the relationship of the soil to the prior stream systems. The general sequence of soil types ranges from the sandy soils of the prior streams, which make up about 10 per cent of the MIA, through red-brown earth and transitional red-brown earth, to grey and brown earths of heavy texture. The last two soil categories are almost equally distributed throughout the MIA (Woodlands and Penman 1981). Generally, the type of soil in each location determines the possible land use. Rice cannot be produced on light soils, nor can tree crops be grown on impermeable soils. Thus, for example, any adjustment out of rice will be into other broadacre crops or pasture, either irrigated or dryland, while expansion of horticulture is likely to be into new areas rather than into existing broadacre irrigation land.

Removal of the impediments to adjustment, and phasing out of the subsidy on the price of irrigation water, can be expected to have large effects on the structure, technology and income earning capacity of horticultural farms. The directions of farm growth and diversification will be largely governed by the investment behaviour of the farms, which inher-

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[1] Many horticultural farms in the MIA have tiled drains installed from which water is pumped into surface drains. In this way, horticultural farmers themselves avoid rising water tables but may still contribute to the rise of water tables in the region by charging the aquifer system with drainage water.

[2] This is the farm size defined in the New South Wales *Crown Land Consolidation Act 1913*, as 'an area which, when used for the purpose for which it is reasonably fitted, would be sufficient for the maintenance in average season and circumstances of an average family' (Woodlands and Penman 1981).

ently involves decisions over a long period. The likely effects of some of these policy changes are analysed in this paper.

### 2.2 Investment decisions and supply response

Investment decisions involve choices between consumption of current funds and access to future income flows. In perennial crop situations, these choices are complicated by the reinvestment problem — the need to allocate investment funds in future time periods to maintain the productivity of the perennial asset. Optimal investment decisions, under conditions of certainty as to the returns from any investment, can be defined as those that maximise the firm's net present value (Hirshleifer 1958). In this simplified view, investment decisions are based solely on the earning power of the alternatives and the prevailing interest rate in an assumed perfect financial market, and do not depend on the decision maker's utility function.

In the real world, however, a host of other factors influence investment. On the farm, the choice of technology, for example, may be influenced by the farm size, the nature of the farm enterprise, the existing resource complement (including both machinery and productive stock), and of course the cost of investment and the availability of capital funds. Though annual cash flow is determined by commodity prices, yields, farm operating expenses and tax obligations, returns to equity are influenced by the farm's leverage position and the cost of funds. On the management side, the farmer's attitude toward risk, technology preferences, access to investment information and perception of public policy directions are equally important.

Although relatively little is known about the effects on the investment behaviour of horticultural farmers with different characteristics (such as farm size and ownership) and price parameters, significant public policy initiatives affecting those variables are apparent over recent years, particularly in relation to irrigation water management (Watson 1990).

Perennial crop producers tend to respond slowly to price signals because of the relative fixity of their investments, and are therefore relatively unresponsive to short term price fluctuations. (Faced with short term low prices, they may decide not to harvest, or to harvest only partially, but this possibility can be neglected in the present context.) Under good husbandry, reliable yield levels can be maintained for horticultural crops over a long period. Significant changes to yield levels may be brought about by changes to planting stock. Given their long term price expectations and yields, the investment behaviour of farmers can be affected by public policy if it alters the relative profitability of investment alternatives. An example is the special taxation provisions for capital costs of conserving or conveying water. Section 75B of the *Income Tax Assessment Act 1936* (as revised) provides for primary producers to claim deductions for capital expenditures on water storage and farm reticulation systems over three years, one-third of the expenditure being deductible in the income year in which it is incurred and one-third in each of the subsequent two years (CCH Australia 1990).

Technological innovations can improve the physical productivity of capital assets, thus influencing potential production capacity and the optimum stock of capital. Drip irrigation technology and improved planting stocks are the two such innovations considered in the present analysis.

## 3. Method

The economic problem studied here involves decisions about farm redevelopment and subsequent operation under conditions of certainty. The analysis employs a multiperiod investment programming model (MIPMOD) specified with a 20-year time horizon. The model is designed to represent horticultural farms in the MIA based on data from ABARE's AHIS (ABARE 1990, pp. 25–7) and to be able to analyse the investment decisions involved in switching between citrus and wine grapes and between furrow and drip irrigation. Farms can borrow or invest off-farm, and can invest in farm expansion by purchasing and developing new farm land. (The farm expansion option was omitted in certain simulations to demonstrate the effects of the competing nature of the investments of central interest in this study.) The basic structure of MIPMOD is described below, followed by a description of the representative farm and the mechanism used to simulate structural adjustment.

### 3.1 Model description

The model is designed to enable identification of the long run equilibrium solution to the optimisation problem which comprises the choice of optimal scale and mix of possible investment streams.[3] The planning horizon chosen consists of 20 single year time periods which are grouped into a ten-year farm development phase followed by a ten-year stabilisation phase.

The capital developments are undertaken during the first ten years, and during the following ten years all the resulting activities are brought to full maturity. This stabilisation phase allows the maximum sustainable yields of all crop enterprises to be reached. This procedure is supported by the suggestion of Tisdell and de Silva (1986) that consideration of maximum sustainable yields provides a basis for identifying correct replacement patterns for perennial crops.

### 3.2 The model specification and the objective function

*Assumptions*

It is assumed that farmers' investment decisions are secondary to meeting their immediate family living commitments. The model therefore provides for after-tax drawings of $15 100 a year as living expenses based on the pastoral award wage. Farmers may also wish to attain various non-essential family goals — termed discretionary consumption in this analysis. This is comparable to 'basic' and 'luxury' consumption expenditure in the specification used in Ockwell (1979).

In the allocation of post-tax surpluses, the balance between discretionary consumption and investment is a problem of capital rationing, which will depend on a variety of factors of which the family wealth, stage of development of the farm enterprise in relation to desired goals and current income are major determinants.

Arndt and Cameron (1957) suggested that there was a tendency of farmers not to adjust their current consumption expenditure in response to short term fluctuations in their incomes. Also, Freebairn (1977) concluded that estimates of annual marginal propensity to consume of Australian households ranged from 0.4 to 0.6, for the time period 1948-49 to 1974-75. A ratio of 2:3 between discretionary consumption and investment of post-tax post-living surpluses was assumed in this analysis. This represents a marginal propensity to consume of 0.4.

The farm has an initial investible capital endowment of $12 000. This was based on the liquid asset position of the surveyed farms. Sensitivity of the model results to changes in the level of this parameter is also investigated. Farm borrowings are allowed as ten year term loans during the development phase. The total commitments cannot exceed a predefined ceiling which is 80 per cent of the asset value of the farm. Farm overhead expenditures are assumed to be $10 000 for the first seven years, $12 000 for years 8–13, $15 000 for years 14–16 and $17 000 for years 17–20, based on survey data.

Where crop yields are declining because of vine or tree age, replanting with material of better quality and at higher densities will allow greater productivity. The technological improvements in water delivery systems could also improve farm performance by reducing input costs (through water and labour saving), improving quality of output and increasing crop yields. They are also likely to improve the capital value of the farm, at least in the short term. However, the analysis does not consider any capital appreciations as the delivery systems are assumed to fully depreciate over a period of 20 years, which is the planning horizon used in the analysis.

Incorporation of these options allows the model to evaluate various circumstances under which farmers could afford a shift towards capital-intensive drip irrigation systems.

Since replanting disrupts any drip irrigation system already in place, and since new drip irrigation systems require heavy capital investment and af-

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[3] The concept of a long run equilibrium solution to the optimisation problem is well defined only if it can be assumed that the expected values of the exogenous variables do not change (Nerlove 1979).

fect intertemporal cash flows and labour use, such investment is allowed only for plantings not earmarked for clearing. Plantings to be cleared become available for conversion to the drip system upon replanting with either citrus or grapes. The model allows the testing of replanting and modernisation of irrigation systems together as well as separately, in order to reveal the maximum benefits obtainable from complementary relationships in resource use among activities.

*The objective function*

It is assumed that the farmers wish to maximise profits from their income generating activities. Production and consumption are two concurrent activities in a farm business and are somewhat difficult to separate out. Therefore profits were considered to include both consumption and capital accumulation in the model. This follows the interpretation of profits as 'consumption plus capital accumulation' offered by Hicks (1946) and that the optimal rate of investment is closely related to the rate of profit retention. The entrepreneur resorts to financing new investment by means of retained profits and borrowings. This is consistent with Steigum (1983) and closely resembles a flexible accelerator model of investment and the general consideration given for taxation purposes.

The objective function is designed to maximise the net cash surplus at the planning horizon, subject to annual operator drawings and discretionary consumption of annual post-tax surpluses. All income-generating activities (ie. farm income and off-farm income from investments and off-farm work[4]) in each year contribute to a single row in the linear program from which all the farm operating expenditure is deducted. The residual therefore represents 'gross profit before tax' from all farm and non-farm operations. After allowing for capital depreciation, 'taxable income' for each period is obtained. This is channelled through a submatrix which simulates the progressive income tax system[5] to calculate the tax liability and post-tax surpluses. This post-tax income is then available for discretionary consumption and investment in the following year after compulsory annual operator drawings are allowed. Investments may be made on-farm and/or off-farm during the first ten years of the planning horizon but are limited to off-farm investments only during the last ten years. This fund flow is repeated in each year until the 20th year, which is the end of the planning horizon (Table 1).

### 3.3 Timing of evaluation and terminal wealth

Maximising terminal cash surplus is equivalent to maximising net present value of the income stream. While this simplifies the specification of the model, problems involved in evaluating terminal assets as well as that of choosing an appropriate discount rate are also minimised (Rae 1970).

The model screens out activities which generate rates of return less than a market opportunity rate, specified exogenously as the returns to off-farm investment of annual investible cash surpluses. Comparisons of activities are made on a post-tax basis, both among farm activities and between farm activities and the market opportunity rate. (A real interest rate of 6 per cent was used for investment, consistent with the real borrowing rate of 10 per cent used[6].) This also simulates a situation of automatic compounding, as any activity which enters the model in an earlier period is given preference over activities that enter the model in later periods (Candler 1960). This specification is an improvement on Candler's original suggestion, because off-farm investment is a parallel activity to the between-year capital transfer activity (which provides capital for on-farm investments in the following year). The two activities are set in competition for the use of post-tax surpluses from each year in the subsequent year, thus enabling filtering out of

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[4] The model specification also permits the operator to work off-farm for award wages.The base formulation of the model did not however have provisions for off farm work as availability of casual off-farm work is very limited in MIA. However, the effect of availability of off-farm work on the investment response of farmers is analysed in section 5.2.

[5] Farmers are eligible to use the income averaging provisions to reduce the adverse impacts of fluctuating income on tax liability. This model is deterministic and no income fluctuations are allowed. Incorporation of income averaging was not attempted as it is unlikely to change the pattern of investment due to the upward trending of incomes seen in the model.

[6] Average borrowing rate of interest for long term investments of 15.75 per cent and an inflation rate of 5.3 per cent during 1990-91, was the basis for the real borrowing rate of 10 per cent used in the analysis.

**Table 1: Layout of the Accounting Tableau**

| | Activity (j) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | | | | Selling | Farm investment | Off-farm investment | Profit transfer | Taxation | | | | | | Fund transfer |
| Row | $P_1$ | $P_2$ | $P_3$ | $P_n$ | $S_1 \ldots S_n$ | $I^{*(a)} I_1 \ldots I_n$ | $I_o$ | $T_p$ | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_n$ |
| OBJECT(Z) | | | | | | | | | | | | | | | 1 |
| $CASH_k$ | $x_1$ | $x_2$ | $x_3$ | $x_n$ | $-c_1 \ldots -c_n$ | $x^*$ | $-i_o$ | 1 | | | | | | | |
| $CASH_{k+1}$ | | | | | | | | | | | | | | | |
| $CPTL_k^{(b)}$ | | | | | | $X^* X_1 \ldots X_n$ | $X_o$ | | | | | | | | |
| $CPTL_{k+1}$ | | | | | | | $-X_o$ | | | | | | | | |
| Yields row | $-y_1$ | $-y_2$ | $-y_3$ | $-y_n$ | 1 | | | | | | | | | | |
| Gross profit | | | | | | | | -1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Taxation constraints | | | | | | | | | | | | | | | |
| TAXLIMA | | | | | | | | | 1 | | | | | | |
| TAXLIMB | | | | | | | | | | 1 | | | | | |
| TAXLIMC | | | | | | | | | | | 1 | | | | |
| TAXLIMD | | | | | | | | | | | | 1 | | | |
| TAXLIME | | | | | | | | | | | | | 1 | | |
| TAXLIMF | | | | | | | | | | | | | | 1 | |
| Taxation | | | | | | | | | 0 | -.21 | -.29 | -.39 | -.47 | -.48 | |
| $NPAT_k$ | | | | | | | | | -1 | -.79 | -.71 | -.61 | -.53 | -.52 | 1 |
| $NPAT_{k+1}$ | | | | | | $-dn$ | | | | | | | | | -1 |
| $NPAT_{k+2}$ | | | | | | $-dn$ | | | | | | | | | |
| $NPAT_{20}$ | | | | | | | | | | | | | | | 1 |

(a) I* is the investment activity on drip irrigation, for which deductions *dn* are allowed as credits on subsequent years net profit after tax (NPAT). (b) CPTL denotes capital expenditure.

activities which yield a return less than that of off-farm investment (an exogenously specified interest rate). This condition is equivalent to setting the 'marginal productive rate of return' at the market interest rate to obtain optimal investment decisions, as proposed by Fisher (Hirshleifer 1958). Enterprise combinations yielding the highest present value between time periods are therefore selected through this specification.

The MIPMOD specification has no mechanism to directly compute terminal wealth. This is being achieved through the inclusion of the last ten years of the planning horizon in which stabilisation takes place without any development activities. The off-farm investment activity is the only investment avenue during this phase. This endogenises the computation of terminal valuations based on the revenue generating potential of alternate investment activities originated in the development phase. This permits the selection of the final optimal mix of activities from among the different competing activities based on their revenue generating capacities over the planning horizon rather than being influenced by an exogenously determined terminal value of the perennial assets.

### 3.4 Intertemporal cash flows and taxation

The model activities are set in a hierarchical pattern where all the capital and current expenditure items are recorded as separate flows. Taxation has been included with a progressive tax structure based on linear segments. This method was preferred over the approach suggested by Vandeputte and Baker (1970) both for the ease of accounting for different income flows and because it avoids 'nonsense' combinations and sequences of activities appearing in response to oversimplified incentives.

Provision was made however for tax deductions allowable for capital investments on irrigation improvements (CCH Australia 1990). Reid, Wesley and Martin (1980) report a specification for handling investment tax credit in a multiperiod setting. That specification was not used because, unlike investment tax credit, the deduction of capital expenditure is not a dollar-for-dollar reduction in taxes but a reduction in taxable income, the benefit of which depends on the farm's marginal tax rate. A normative approach is followed in the specification used here: an allowable deduction is treated as a cash cost in the year of investment, and tax credits on after-tax profits are allowed at a selected marginal rate for the deductions in the relevant subsequent periods. (A rate of 29 cents in the dollar was used, based on the average rate of tax paid in the model over the first ten years, when the investments are allowed.) This avoids numerical difficulties in the computation and sufficiently captures the benefit of deductions. The farm is assumed to be owned and operated by a farm family, and a single taxpayer for the household is assumed in the formulation. (This assumption is relaxed at a later stage, when the response of a two-party partnership is briefly investigated.)

### 3.5 The representative farm and the resource base

Activities of a hypothetical farm representing average structures and management practices of the horticultural farms in the MIA are simulated in the model based on ABARE AHIS data. Supplementary data were also obtained from Sinclair and McLachlan (1989), Hansen, Cook and Oborne (1983) and through telephone discussions with experts in the field.

The model represents a mixed horticultural farm[7] growing citrus and wine grapes. A total cultivable area of 15.5 ha is used for these two crops. Out of 6.6 ha planted to citrus, 2.2 ha of the trees are young while 4.4 ha consists of aged trees earmarked for replanting at some time during the 10-year development phase. Similarly, the grape area (8.9 ha) is composed of 4.1 ha of young stands and 4.8 ha of aged vines which are to be replanted. The young plantings of both crops have been established over the previous ten years, and hence fall into ten yearly age categories.

Once planted, all crops are assumed to be under open furrow irrigation. The farm is owner operated, with contract labour hired for specialised tasks and occasional casual supplements. Except in the base simulation, it is assumed that the operator is able to find off-farm employment to supplement farm income during slack periods. After allowing for time spent by the farmer on routine farm and non-farm activities, 48 weeks of operator labour is available for farm operations and off-farm employment.

The crop prices used are net of harvesting and cartage costs. Seventy per cent of citrus output is earmarked for processing while the balance is sold for the fresh market. All the prices are in 1990-91 dollars and real interest rates are used.

## 4. Analysis

An initial optimal solution to the model was ob-

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[7] In the MIA about 90 per cent of horticultural farms are exclusively horticultural without any broadacre activities. Therefore the treatment of horticultural farms as separate entities in this analysis is not unrealistic.

**Table 2: Base Prices and Price Changes Used in Model Simulations**

| Variable | Unit | Base value | Test values | | | |
|---|---|---|---|---|---|---|
| Crop prices* | | | | | | |
| Oranges | $/t | 112.00 | 89.60 | 100.80 | 123.20 | 134.40 |
| Wine grapes | $/t | 268.00 | 214.40 | 241.20 | 294.80 | 321.60 |
| Irrigation costs | | | | | | |
| Water charge | $/ML | 24.37 | 12.00 | 18.27 | 30.46 | 36.56 |
| Pumping cost | $/ML | 8.50 | 10.63 | 12.75 | 22.40 | — |
| Farm size | ha | 15.50 | 31.00 | 46.50 | 62.00 | 124.00 |

*For crop prices only, the test values were set at -20%, -10%, +10% and +20%.

tained for the base formulation as described in the previous section. Then an appraisal of the irrigation development options and crop replanting strategies was undertaken in a series of experiments in which the model parameters were systematically altered. The crop prices were changed within a range of ±20 per cent around the base values.

In three of these experiments prices and costs were changed one at a time with the rest held at base levels to obtain policy responses over the price range. The prices and costs changed were those of water, grapes and citrus, and electricity (for driving water pumps to pressurise the drippers). Farm size was varied in a fourth experiment, with and without the option of farm expansion. The base values and those applied in the experiments are presented in Table 2. By examining net farm incomes and investment patterns in these experiments, differences in the optimal pattern of technology adoption in various situations can be examined and the impact of different government operating policies can be evaluated.

## 5. Results and Discussion

It is indicated from the results of the study that investment behaviour of horticultural farmers will be sensitive to their pre-development farm size, to their opportunities for farm expansion and off-farm employment, and to changes in irrigation water charges and the cost of electricity for pumping. Relative changes in crop prices will affect only the choice of crops for replanting. Under the specified technological and policy constraints, conversion to drip irrigation will generally be an optimal investment but only when farmers do not have the option of expanding their farm area. Possible increases in water charges above current levels should make such investments more profitable. The model responses are sensitive to the availability of off-peak electricity tariff rates for irrigation pumping.

Summary results from solutions under some of the experimental specifications are given in Table 3, followed by a brief discussion on selected aspects of individual experiments.

### 5.1 Farm expansion as an investment option

In the model, investment pattern varies with farm size, as the latter directly influences the pre-development farm income and hence the choice between farm expansion and technological innovation. Investment in farm expansion receives priority in allocation of capital among small farms while improvements in farm productivity are the preferred options on large farms. This is because of the relative scarcity of capital in small farms and of labour in the larger farms. In the absence of a land buying option, holders of larger farms will put a higher proportion of the farm under drip irrigation than will those of small farms — the influencing factors being available cash flow, which also limits the borrowing capacity of the farms, and the increasing marginal benefits from the tax deductions

**Table 3: Summary of Experimental Results**

| Experiment | Objective value (net surplus at year 20) | Investment pattern |
|---|---|---|
| Baseline model with farm expansion option | $190 332 | No investment on drip irrigation; farm area expanded with borrowed funds to more than twice the original size. |
| Baseline model with no farm expansion option | $69 995 | A large area (86%) of farm under drip irrigation; no off-farm investment during development phase, low borrowings. |
| Higher water charges, with no farm expansion option | $62 544 at $30.46/ML | Shift in the area under drip irrigation with increasing water charges; full conversion to drip at $27/ML. |
| Depressed citrus prices— (a) $89.60/t, (b) $100.80/t— with farm expansion option and grape price at base level ($268/t) | (a) $178 595<br>(b) $184 396 | Reduction in area expansion with decreasing crop prices; in new plantings, substitution toward high priced crops; gradual increase in unpaid debt. |

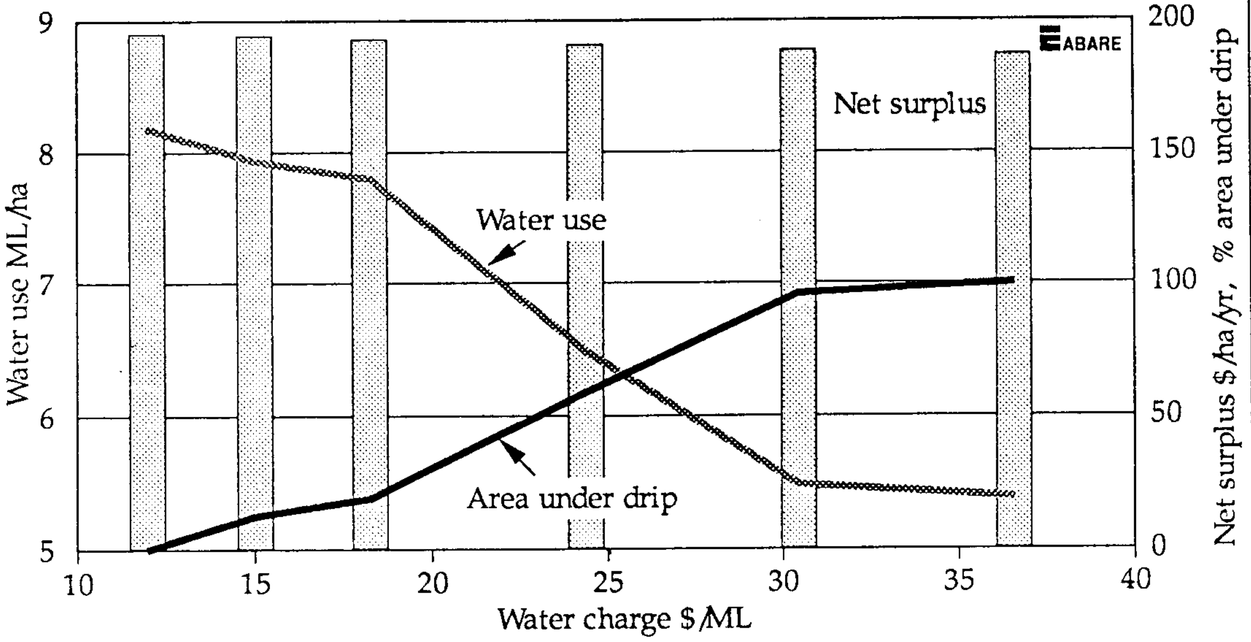
for drip investment as income reaches higher tax brackets. As was observed by French, King and Minami (1985), expected future production from existing plantings has a significant effect on planting decisions.

## 5.2 Adoption of new technology

Zilberman (1984) argued that the effective marginal adoption cost of a technological change declines with farm size, and that in consequence there is a critical farm size where profits are equal under both technologies. At a given set of prices and costs, farms smaller than the critical size do not adopt the new technology, while those above do so at a rate which increases with size. The rate of adoption will be influenced by the cost of water, the cost of pumping, the price of crops and the extent of water saving achieved by the new technology. In the present study the water saving associated with a move from furrow to drip irrigation was assumed to be 40 per cent as supported by some field observations in the MIA. However, it could vary considerably depending on a variety of factors, such as crop age, soil type, planting density and frequency of irrigation. The model responses for different values of the cost of water, cost of pumping and price of crops are discussed in turn below. These experiments were performed while the other variables were left at their base levels in each case (unless otherwise stated) and without the farm expansion option.

The sensitivity of the model to changes in interest costs were analysed by changing the level of interest, both on the off-farm investment option and on term borrowings, as well as altering the interest rate differential — the gap between investment and borrowing rates. Reduction in interest rates in general favoured investment in drip irrigation by reducing the interest costs associated with development. The higher interest rates diverted investment

Figure 1: Effect of changing water charges on investment, farm income and water use.



from farm to off-farm due to higher returns associated with off-farm investments and also due to the effect of a high compounding rate associated with a high interest rate regime. This phenomenon was particularly evident when the interest rate differential was widened in the experiment, to simulate the observed behaviour of the financial markets over recent times with the relaxation of monetary policy.

The availability of off-farm work in the MIA is rather limited. The ABARE survey indicates that 25 per cent of the households have some off-farm income, most of which in turn are derived from off-farm investments. The few households who derive any income from off-farm work are mainly engaged in permanent or casual paid work in a regular basis. Therefore the base model did not allow off-farm work but the sensitivity of the model response to the availability of off-farm work was investigated in a subsequent simulation.

Availability of off-farm work proved to be an incentive for farmers to invest in water saving technology and other farm developments as supplementary income available through off-farm work enhanced their capacity to pay for the investments. Under this provision the model completed the farm investments much faster than the base level assumptions as the labour released from the farm due to the adoption of improved technologies had an opportunity cost equivalent to the off-farm wage rate.

### 5.3 Effects of water charges

The effects of the irrigation water charge on investment in irrigation technology, farm income and water use are shown in Figure 1. Changes in water charges have a more pronounced influence on adoption of drip irrigation as a water saving technology and on water use than on farm income. From the results shown, the elasticity of demand for water (estimated through a double log function) was -0.34.

Net surplus per hectare declines as water charges increase, but only slowly. (Per-hectare measures are used in this case because results from the range of farm sizes are combined.) However, at water charges of $18/ML or above, the farm household cannot afford any discretionary consumption during the early development phase as developments are funded through borrowed capital during that stage. The forgone consumption opportunities are to a large extent compensated by increased availability of profit after-tax during the stabilisation phase. As a result, the average discretionary consumption over the 20-year period under higher water charges is only slightly lower than that in the base case.

Thus, the current water price of $24.37/ML, and likely future increases in water charges would make farmers better off in adopting water saving technologies in the long term, although they would have to postpone their discretionary consumption activities over the short term.

### 5.4 Effects of costs of electricity for pumping

The effects of variations in variable irrigation costs for drip irrigated areas — specifically, of four different electricity prices — are shown in Table 4 for the case where water costs $24.37/ML. As the pumping cost rises from $8.50/ML (the base) to $22.40/ML, the optimal area under drip irrigation drops from 86 per cent to zero. The base pumping charge reflects the electricity costs for off-peak operations which prevailed in 1990-91; $22.40/ML is based on regular electricity charges during normal operations. Results clearly indicate that investment in drip irrigation is sensitive to the price differential between water and electricity charges. At current water charges, pumping cost (based on off-peak electricity charges) is not a limiting factor on investment in drip irrigation.

### 5.5 Effects of crop prices

The results for investment behaviour at different crop prices over a price range of ±20 per cent, with the other variables held constant at the base level, are presented in Table 5. Changing the relative prices of the crops affected only the substitution pattern of crops for replanting, so the price of each crop was varied by the same percentage during the experiments. The analysis was undertaken at a water price of $24.37 at which price 86 per cent conversion to drip irrigation takes place under base crop price assumptions. When farm expansion is allowed, there is no adoption of water saving irrigation technology within the simulated range of crop prices. Results are therefore reported only for the case where farm expansion is not an option.

### 5.6 Effects of taxation arrangements

In the model, taxation provisions concerning irrigation improvements have a significant influence on the investment decisions, particularly on larger farms where heavy tax commitments are involved. Two alternative tax regimes were modelled. One of these involved a depreciation schedule as generally applicable to capital investments according to the current taxation provisions. Under this regime, conversion to drip irrigation was not as sensitive to water charges as under the alternate specification where the special provisions for the deduction of capital costs of conserving or conveying water were incorporated.

These cost deductibility provisions under Section 75B of the *Income Tax Assessment Act 1936* (as revised) act as a capital supplement thus encouraging investment. However, the benefits of these tax

**Table 4: Model Response to Change in Pumping Costs (a)**

| Pumping cost | Area under drip | Water saving(b) |
|---|---|---|
| $/ML | % | ML/y |
| 8.50 | 86 | 32 |
| 10.63 | 80 | 30 |
| 12.75 | 57 | 18 |
| 22.40 | none | none |

(a) Water charge $24.37/ML. (b) Average over 20 years.

**Table 5: Model Response to Changes in Crop Prices [a]**

| Variation in crop price | Area under drip | Average discretionary consumption [b] | Average net farm surplus [c] | Remarks |
|---|---|---|---|---|
| % | % | $/year | $/year | |
| -20 | 0 | 12 137 | 2 029 | Replantings financed through borrowings; no off-farm investment during the development phase. |
| -10 | 41 | 17 258 | 2 610 | Increased borrowings than the base level. |
| 0 | 86 | 17 387 | 2 956 | Base level scenario. |
| +10 | 100 | 21 997 | 3 422 | Full conversion to drip during latter part of investment phase; low borrowings; no off-farm investment during the development phase. |
| +20 | 100 | 26 392 | 4 104 | Faster rate of investment on both replanting and drip, borrowings restricted to first five years; high off-farm investment. |

[a] Water charges $24.37/ML. [b] Average over the 20-year period. [c] Final surplus divided by 20.

provisions depends on the farms' marginal tax rate, where those farms at a higher marginal tax rate receive larger benefits.The welfare implications of such programs deserve further analysis (Stoneman and David 1986).

The analyses presented above were conducted on the basis of a single tax return for the farm. An alternative taxation regime was also modelled for a two-party partnership arrangement which reduces tax liabilities. Under that assumption, the entire farm area is converted to drip irrigation at base prices for both crops and water, as more after-tax funds are available for investment.

## 6. Implications and Conclusions

The analytical framework employed in this study, allowing for control over many factors affecting investment decisions, appears to capture the important features of investment behaviour of perennial crop farmers. Model simulations of this kind could be used to inform farmers about the likely long term consequences of investment decisions; they also provide a tool for analysing farmers' decision processes, and for testing likely investment responses to policy changes. The model can be used to similarly examine other farm management options affecting farm yields or prices, by adding appropriate coefficients to the model skeleton. The length of the planning horizon can be easily altered to suit the problem under investigation. However, the model has some limitations.

The model is based on survey data and reflects average farm management conditions. It does not show variability among farm enterprises. However, this can easily be addressed by conducting sensitivity analysis on critical variables. The latest version of MIPMOD is based on a GAMS (Brooke, Kendrick and Meeraus 1988) formulation and inclusion of a wider range of investment options and variation of the time periods covered can be made easily. However, handling stochasticity and nonlinear technological and utility relationships are currently beyond the scope of the model.

While achieving the exploratory objectives relating to the modelling techniques, the results of the study in relation to investment behaviour are also of .interest in themselves. They provide insights into factors limiting the growth of investment in modern irrigation technology, and confirm the importance, stressed by Caswell and Zilberman (1985), of economic considerations for decisions on the adoption of such technologies. They also demonstrate the need to consider the structural characteristics of individual farms and the actual farm accounting framework in micro-level analyses of farmers' investment behaviour.

The analysis presented does not include a detailed investigation of the effects of farmers' leverage positions, farm ownership arrangements and type of tenure, but these too may have a significant bearing on the investment pattern.

Though the limited availability of data, and the use of a representative farm with a narrow range of variants do not permit generalisation of the findings over a large domain of horticultural farmers, the model framework provides a useful means for testing policy options which may affect investment behaviour. The analysis demonstrates that water price policies and tax incentives are important determinants of the adoption of water-saving technologies and that a faster adoption rate could be expected if alternate employment opportunities could be found for underemployed farm labour. Further analysis incorporating a choice between diversification, technological and marketing options and perhaps leisure as a competing option for farm labour would provide useful information for policy analysis.

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