Linear Programming and Future Landuse Scenarios: An Irrigated Catchment Case Study [1] [2]

Oliver Gyles [A] and Olive Montecillo [B]

Potential for change in the mix of irrigated enterprises was estimated for a catchment in the Shepparton irrigation region using linear programming. The model allocated resources to maximise net income in each of the next five decades as if the catchment were one farm. Change was driven by price trends and productivity and constrained by water resources, land capability and investment capital. On the basis of the assumptions implicit in the model and sensitivity testing carried out, it appears more likely that there will be a rapid decline in irrigated cropping and pasture based meat production in conjunction with a significant increase in irrigated dairying in the first two decades, followed by an interchange of resources between dairying and new horticulture with the catchment dominated by horticultural enterprises by year 50. A workshop has demonstrated the usefulness of the approach for assisting catchment management agencies and policy makers understanding the implications of different price, productivity and irrigation water allocation scenarios for sustainable economic growth and natural resource management. While improvement to the model is readily achievable, the marginal utility of complex sophistication is questionable.

Key Words: ***irrigation, enterprise, productivity, change, water allocation, policy, economic growth, natural resource management, linear programming, Shepparton Irrigation Region***

1. INTRODUCTION

The Murray-Darling Basin Commission (MDBC) has embraced the concept of sustainable natural resource management for irrigation regions and developed an Irrigation Management Strategy (IMS). A crucial component of the IMS is that irrigated production is made self funding while meeting resource protection standards. This microeconomic reform will impose additional costs on existing irrigated agricultural production and processing. However, large opportunities for increased efficiency will be stimulated through reduced constraints on resource location, adoption of new, more productive and appropriate production systems and by introducing more competition into the provision of essential services.

Implementation of Land and Water Management Plans (LWMPs) and reform in the water supply sector will secure the resource base of irrigated agriculture at a cost which will increase the pressure for structural adjustment. This increased pressure will provide the impetus for regional communities to actively pursue new markets and develop efficient, clean production technologies supported by world class processing, packaging and transport facilities and a highly trained regional workforce. This change will require strategic planning of profitable, coordinated long term private and public investment in:

- resource protection,
- water supply , processing, transport infrastructure,
- agricultural development,
- research and development of new technology,
- training and education.

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[A] Department of Natural Resources and Environment, Institute of Sustainable irrigated Agriculture, Tatura Victoria 3616

[B] Department of Natural resources and Environment, Echuca, Victoria 3564

The MDBC commissioned this project to provide a tool for catchment and regional communities to assess development scenarios using medium to long term world market demand forecasts and catchment based regional supply response estimates. Modeling the supply response to changes in prices and policies provides sensitivity testing of likely outcomes to market signals for those planning strategic investment in business development and regional growth. Knowledge of the likely changes in the patterns of production and of intensity of resource use will also assist those planning and managing regional infrastructure provision and natural resource protection programs.

To provide support for this decision making, changes in the enterprise profiles or landuse composition of a representative irrigated catchment over the next 50 years were modelled for a range of prices and resource inventory constraints.

1.1 Project Objectives

- Establish an industry validated, reviewable suite of medium to long term market demand forecasts for major irrigated commodity groups to enable long term resource allocation planning.
- Assemble and demonstrate a suitable methodology for examining future scenarios affecting agricultural development and natural resource management in irrigated catchments in the MDB.
- Under resource protection constraints, to estimate trends in enterprise mix and the resultant movement of production resources within farms, catchments and the MDB in response to the changing prices and volume demand of commodities.

2. MARKET DEMAND FORECASTS

Trends in commodity prices were forecast by consultants Gus Hooke and Associates using the Global Perspectives world demand model. The model specification and procedure followed for this component of the project are reported in Attachment 1[3]. The forecast price trends for particular products are shown in Table 1. The particular products were taken as indicators for generic commodity groupings.

Table 1: Forecast trends in changes of real prices for selected products.

	Rice	Wheat	Cheese	Beef	Apples	Linseed
Growth of demand (%)	**0.6**	**1.2**	**2.4**	**2.2**	**3.2**	**2.0**
Real Price Change (%)						
Absolute	**-1.5**	**-0.9**	**0.3**	**0.1**	**1.1**	**-0.1**
Compared to trend	**-0.5**	**0.1**	**1.3**	**1.1**	**2.1**	**0.9**

These long term trends for commodity groups relevant to the study catchment are shown as smooth curves in Figure 1. Short term fluctuations around long term trends will increase uncertainty for timing of investment or expansion of production for different commodity groups.

[3] Hooke A *et al* (1996) Long term world market outlook for selected farm products.

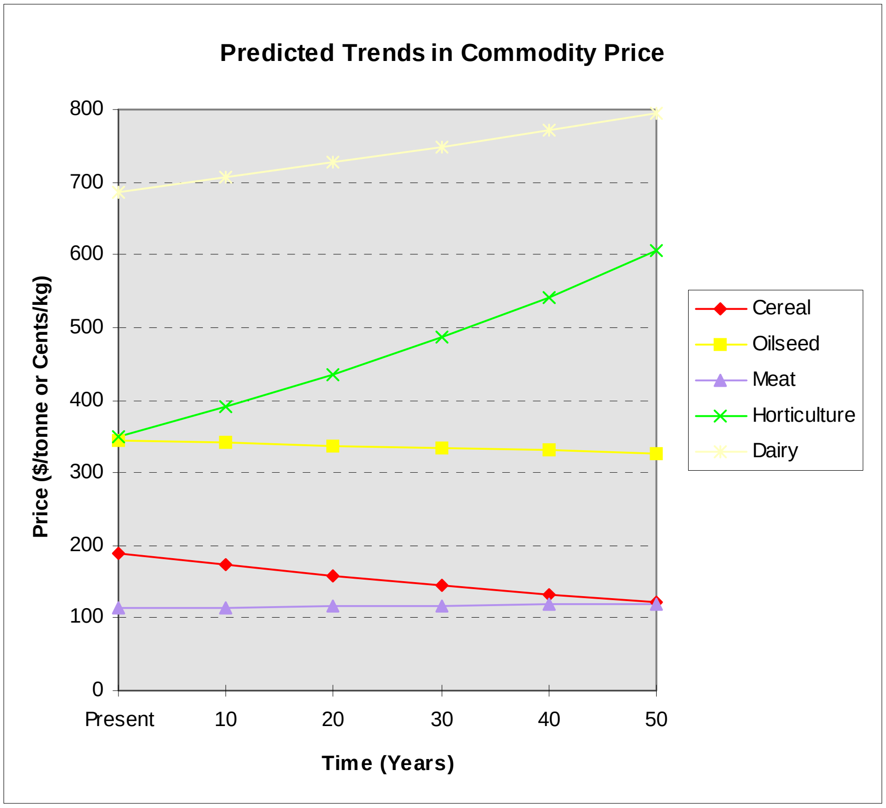

Figure 1: Impact of forecast trends on assumed commodity prices.

3. SUPPLY RESPONSE MODELING

3.1 Data collection

Data were collected from secondary sources such as project reports, annual reports and briefing papers.

A project data base was set up and collated the following information:

- The resource inventory of the pilot catchment including details of the current land use, crop suitability, watertable level, aquifer salinity, water supply characteristics and constraints
- Production technology, including crop yield and production functions
- Costs of production, overhead, depreciation, operator's allowance, investment requirement for new enterprises including cost of resource protection
- Trends in commodity price from Gus Hooke's report on "Long Term World Market Outlook for Selected Farm Products"

3.2 Modeling

The future profile of the pilot area was defined by estimating the production responses of farm enterprises to market price signals under the resource management constraints necessary for sustainability. Cereal, oilseed, meat and horticulture were modeled as wheat, canola, beef and apple enterprises.

The catchment enterprise mix and resulting resource use allocation under appropriate prices and resource constraints were modeled using *What'sBest!,* linear programming software.

The LP model is specified in matrix form. The activities (enterprises) are specified in the columns and the constraints are specified in the rows.

Linear programming (LP) as an operational research planning tool can be used in solving a wide range of business and operational problems (Dent, Harrison and Woodford, 1986). Its use in agriculture includes determining the most profitable enterprise selection and/or identifying the least cost alternative of producing crops and livestock. It can be used to introduce the students to economic principles in farm management (Dent, Harrison and Woodford, 1986).

Generally, it can be used in solving problems that are characterised by the following (Dent, Harrison and Woodford, 1986):

- farmers or managers can make a choice over a range of activities
- activities are constrained to prevent free selection
- the objective is quantifiable (e.g. profit maximisation, cost minimisation or both)

As the name implies, an LP model assumes that the relationships among the activities and variables are linear. It also assumes that the stated activities are infinitely divisible, risk neutral and have a fixed number of planning horizons. Marshall *et al* (1997) describe and demonstrate the use of the distribution method to account for tactical adjustment to outcomes of risk. They show that ignoring opportunities for tactical adjustment may lead to under estimation of net benefits from investment in operating infrastructure. Given the magnitude of errors in model specification and price forecasts and the limited resources for the project, sensitivity analysis was used to explore the range of likely outcomes. However individual managers may find it worthwhile to use the distribution method for appraisal of investments conferring tactical advantages.

The improper use of the technique and lack of adequate data for farm planning purposes are two of the seven factors identified by Dent, Harrison and Woodford (1986) that limit the use of linear programming as a technique in farm planning. The problem of scarcity of data, however, is not unique to linear programming. These limitations can be overcome by creating a number of scenarios over a period of time. With the advent of improved computer technology, sensitivity testing of variables is quick and simple.

3.2.1 Objective Function

The objective is to identify a combination of areas of the different enterprises in the Rodney sub-catchment that will maximise its net income from farming. It is shown in the following formula:

Maximise $Z = C_p X W$

Subject to:

$A X \leq B; \; X \geq 0$

whereby:

Z = catchment income (Gross income less variable and overhead costs, operator's allowance, depreciation and annualised investment cost for new enterprises)

C_p = income per megalitre of total water use (net of variable cost, overhead cost, depreciation, annualised investment for new enterprises and operator's allowance) of the enterprise

X = area of each enterprise

W = total water use

A = the matrix of input-output coefficients representing resource-to-product relationships

B = the column vector of constant terms representing resource and institutional constraints

A and B are known and constant in solving the problem.

3.2.2 Constraints

The production of the seven commodities is constrained by water allocation (water right + sales water); area under different crop suitability groupings and salinity scenarios; and investment for new dairy and horticultural enterprises.

1. Irrigation Water

The available irrigation water consists of the catchment's total water right plus sales as percentage of water right. The Goulburn Murray Water supply authority announces the water allocation in the catchments at the start of each irrigation season.

2. Crop Suitability Grouping (CSG) and Salinity Scenarios

There are six crop suitability groupings and six salinity scenarios:-

Crop suitability groupings

CSG 1 - Very good soils, if given careful irrigation, for all horticultural crops, vegetables and tomatoes. Summer fodder crops, cereals, lucerne and perennial and annual pastures can also be grown successfully.

CSG 2 - Good soils for horticultural crops (except citrus), pumpkins, peas, beans, tomatoes, summer fodder crops, cereals, lucerne and perennial and annual pastures.

CSG 3 - Good soils for apricots, apples, pears, plums and summer fodder crops, cereals and perennial and annual pastures; fair soils for peaches, tomatoes, peas, beans and lucerne.

CSG 4 - Fair soils for pears and plums; good soils for summer fodder crops, cereals and perennial and annual pastures.

CSG 5 - Pears, plums and perennial pastures can only be grown if well drained; summer fodder crops, cereals and annual pastures can be grown.

CSG 6- Soils not recommended for irrigation because of swampiness or uneven surface features making layout for irrigation impractical.

Salinity scenarios

SCEN 1 - Areas without salinity problem
SCEN 2 - Areas where no salinity control is possible
SCEN 3 - Areas without pumpable aquifers, but there is vertical leakage out
SCEN 4 - The area is under pumping but no leakage out.
SCEN 5 - The area is under pumping and there is leakage out.
SCEN 6 - The area is under pumping and there is leakage in.

The productivity of enterprises varies between crop suitability groupings and salinity scenarios.

3. Investment for New Dairy and Horticultural Enterprises

It was assumed that there is already existing farm infrastructure to support new entrants in the grains, oilseeds and meat industries. The investment outlay is needed only for new dairy and horticultural enterprises because of huge capital requirement for these enterprises such as new dairy, farm relayout, irrigation system and sub-surface and surface drainage systems.

4. Other Constraints

The total area with canola cannot exceed the area with wheat because of the crop rotation requirements. Any additional land for dairying and apple growing is considered new dairy and new apple enterprises.

3.2.3 The Matrix

The pilot sub-catchment is modeled as one entire farm producing five irrigated agricultural commodity groups: grains (wheat); dairy and new dairy; meat (beef cattle); oilseeds (canola); and horticulture (apple and new apple).

The matrix consists of 250 columns and 58 rows. The activities (enterprises) are wheat, dairy, “new” dairy, beef cattle, canola, apples and “new” apples.

3.2.4 Running the Model

Dialogue boxes to enter price, productivity, water availability and adjust trend data are provided on the input sheet of the model. The assumptions used to simulate the 1996 situation are shown in Table 2. Sensitivity testing includes changing the water allocation (100% and 200%), increasing the water price, changing the prices of commodities (butterfat price and apple prices are independently increased by 20% and reduced by 20%) and increasing the productivity per cow in "old" dairy farms by 20%. These variables were tested individually.

Table 2: **Assumptions to simulate 1996 situation and adoption of new technology.**

	Price	Production
Cereal	$200 per tonne	3.3 t/ha
Oilseed	$350 per tonne	2.4 t/ha
Meat	$1.54 per kg LW	360 kg LW /ha
Horticulture	$350 per tonne	34 t/ha
Dairy	$6.85 per kg	28.6 kg Fat/ML TWU
New Horticulture		54 t /ha
New Dairy		34.3 kg Fat/ML TWU
Water	$27.00 per ML	140% WR

3.3 Limitations of the Study

The results of the runs for each decade are not linked and should be looked at independently. For example, the area with “new” apple in Year 10 will not be added to the 1996 area to become "old" apple in Year 20.

The model also assumes that the levels of inputs to these enterprises remain constant regardless of the productivity under the different crop suitability and salinity scenarios.

The level of productivity under the different salinity scenarios was based mainly on the response of pasture to waterlogging and salinity. As such, this may cause an under or over estimation of the effect of waterlogging and salinity on crops and horticulture.

The social implications of the model output are not covered in the study.

3.4 The Study Area

The Shepparton Irrigation Region covers about 500,000 hectares, of which some 427,000 hectares are suitable for irrigation. The area irrigated is about 280,000 hectares.

In 1993/94, agriculture posted a gross output of about A$816 M, about 19% of the region's total gross output (EconSearch P/L & FarmStats Australia P/L). It employed 9,200 people (22% of the total regional employment) of which 74% are in the livestock industry (dairy, beef cattle and sheep) and 17% in the horticulture industry (Table 3).

Table 3: Gross output and employment in agriculture, Shepparton Irrigation Region, 1993/94

Sector	Gross Output ($Millions)	Employment
Dairy	354	5,400
Animal industries	194	1,500
Horticulture	186	1,570
Other Agriculture	54	550
Cereals	28	230
Total	816	9250

Source: EconSearch P/L & FarmStats, 1996.

The processing of these agricultural commodities also dominates the regional economy. Food processing is valued at $1.420 million employing about 4,200 people (Table 4).

Table 4: Gross value of and employment in processing sector, Shepparton Irrigation Region, 1993/94

Sector	Gross Output ($Millions)	Employment
Dairy	660	1,300
Horticulture	440	2,000
Other food processing	320	900
Total	1,420	4,200

Source: EconSearch P/L & FarmStats, 1996.

3.4.1 The Study Catchment

The Rodney catchment was selected as the pilot catchment because of the availability of data generated from a structural adjustment project (NRMS I 6040). The catchment covers about 16,500 hectares of agricultural land. In 1996, approximately 57% of agricultural land have dairy cattle; 28% has beef cattle and sheep; 8% has wheat; 4% has canola and 4% has fruit trees (Table 5).

Table 5: Land use, Rodney catchment, 1996

Enterprise	Area (ha)
Cereal	1,305
Dairy	9,365
Meat	4,566
Oilseed	652
Horticulture	645
Total	16,533

Source: Kularatne, 1996.

4. RESULTS

4.1 Calibration

Initial runs of the model using gross margin as the objective function showed a negative income before interest and tax. This means that although the catchment's total gross margin is maximised, agricultural production is not viable and sustainable because there is insufficient surplus to cover overhead expenses, depreciation and operator's allowance. Using the operating income as the objective function also gave a negative income before interest and tax. Part of this income deficiency may also be made good by surplus farm labour sourcing off farm income. This off farm income makes unprofitable farm businesses viable in the short term as the assets underpinning the current production system are run down. Small adjustments to productivity and starting price estimates were necessary to make the model simulate current catchment landuse on a purely agricultural income basis.

4.2 Unchanged technology

Investment in new dairy and new horticulture was restricted while assumed prices were increased until the model output closely simulated catchment landuse statistics. This scenario approximates likely the enterprise mixes expected under forecast price trends with no productivity increases through increased adoption of best management practices or investment in new technology, and no changes in water availability.

The future catchment profile under this scenario is shown illustrated in Figure 2. As dairy and horticulture are fixed, the only change is an increase in meat production as cereal and oilseed become less profitable. The area of dryland increases as water use intensity is greater on pastures used for meat production than for irrigated cropping.

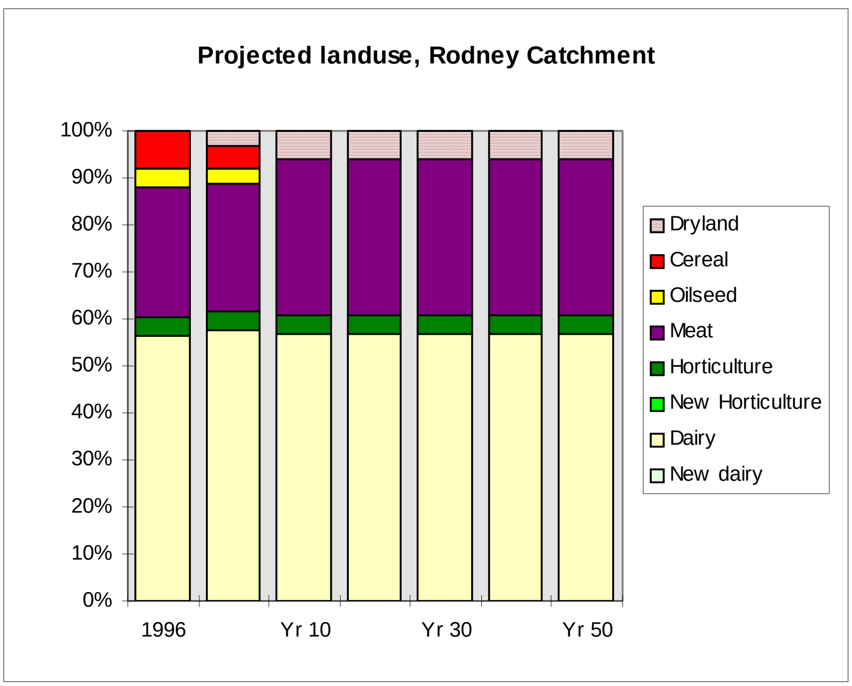

Figure 2: Continuation of current practice and no investment in new dairy or new horticulture

4.3 Adoption of new technology

The annualised cost of investment in higher water use efficiency was estimated at $30/ML Total Water Use (TWU) for dairy and $600/ML TWU for horticulture. With a catchment budget of $ 10 million p.a. for investment in adoption of new technology, new dairy replaces meat production in years 10 and 20. Thereafter the model allocates resources away from dairy to horticulture in years 30, 40 and 50. The percentage landuse by each commodity is shown in Table 6 and the transition between enterprises illustrated in Figure 3.

Table 6: Land use and enterprise mix with investment in new technology

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		3	24	24	15	13	12
Cereal	8	5					
Oilseed	4	3					
Meat	28	27					
Horticulture	4	4	4	4	4	4	4
New horticulture					48	58	68
Dairy	57	57	57	57	33	24	8
New Dairy			16	16			9

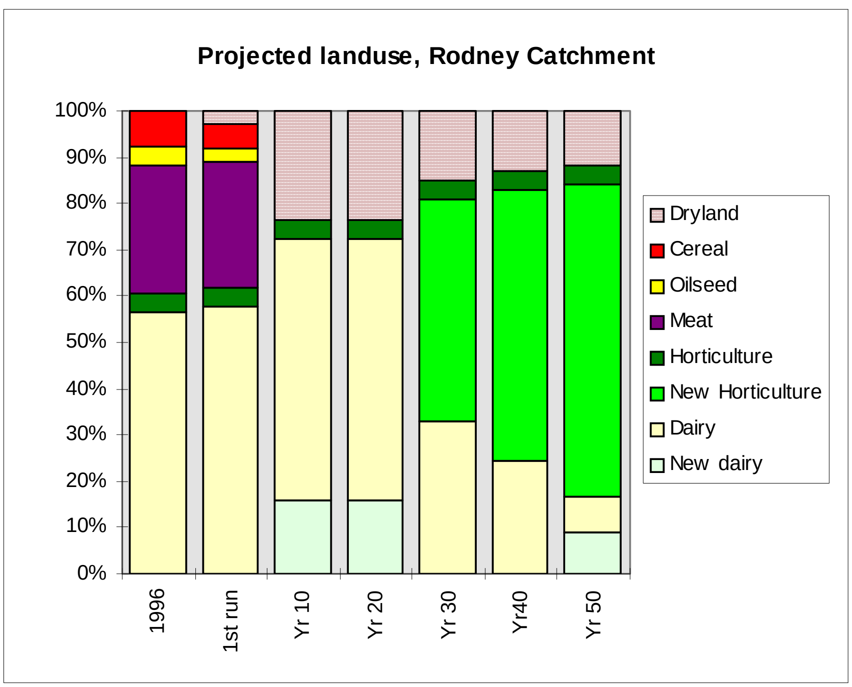

Figure 3: Adoption of new technology

This implies that at the assumed present productivity, cost and price structures new horticulture is only competitive with the financial performance of new dairy from year 20 onwards, occupying about 68% of the land in Year 50. The area of dairy decreases from 73% as resources move to horticulture with some dairy replaced by new dairy in the fifth decade. The area under irrigation increases because of the lower water use intensity of horticulture and dryland falls from 24% down to 12% by Year 50.
The average water use efficiency of cropping and pasture based meat production enterprises would need to increase substantially to enable them to remain competitive with dairying and horticulture.

4.4 Sensitivity testing of price and productivity assumptions

4.4.1 Water Price

If the price of water is increased $20 to bring irrigation and drainage charges to $47/ML, the enterprise mix and area of land use does not change. This indicates that a $20/ML fall in irrigation gross margin does not change the relative profitability of enterprises. However catchment gross margin falls by $1.8 million and the pressure for structural adjustment is increased. More investment in productivity increasing technology or increasing scale of business operation to reduce overheads per unit of gross margin is necessary to maintain business viability.

4.4.2 "Old" Dairy Productivity and starting dairy price

There is no significant difference between the total area of the catchment with dairy farms if the water use efficiency (WUE) is increased by 20% or if the starting price for butterfat is increased by 20%(Tables 7 and 8). With increased productivity, “old" dairy farms become more profitable and the transition to "new" dairy farms is delayed. However, a 20% increase in butterfat prices accelerates the transition to "new" dairy farm systems. Yet the price increase only slightly tempered the movement of catchment resources from dairy to horticulture. At both scenarios, the area with horticulture steadily increases starting in the third decade at 28% and rising to 68% by Year 50. The scenarios are shown in Figures 4 and 5.

Table 7: Land use and enterprise mix, WUE 34.3 kg Fat/ML TWU on existing farms

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		3	23	23	19	14	12
Cereal	8	5					
Oilseed	4	3					
Meat	28	27	3	1			
Horticulture	4	4	4	4	4	4	4
New horticulture					28	58	68
Dairy	57	57	57	57	49	25	16
New Dairy			14	15			

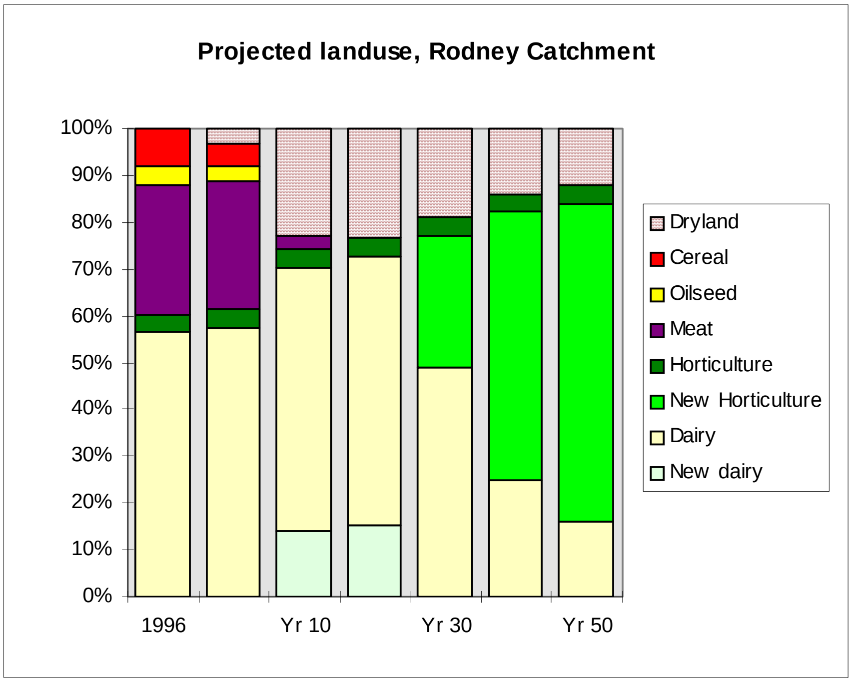

Figure 4: Old dairy productivity 34.3 kg fat/ML TWU

4.4.3 Butterfat price up 20%

Table 8: Land use and enterprise mix, $8.22/kg BF price

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		4	24	24	19	14	12
Cereal	8	5					
Oilseed	4	3					
Meat	28	27					
Horticulture	4	4	4	4	4	4	4
New horticulture					27	58	68
Dairy	57	57	5	6	4	6	
New Dairy			67	66	46	18	16

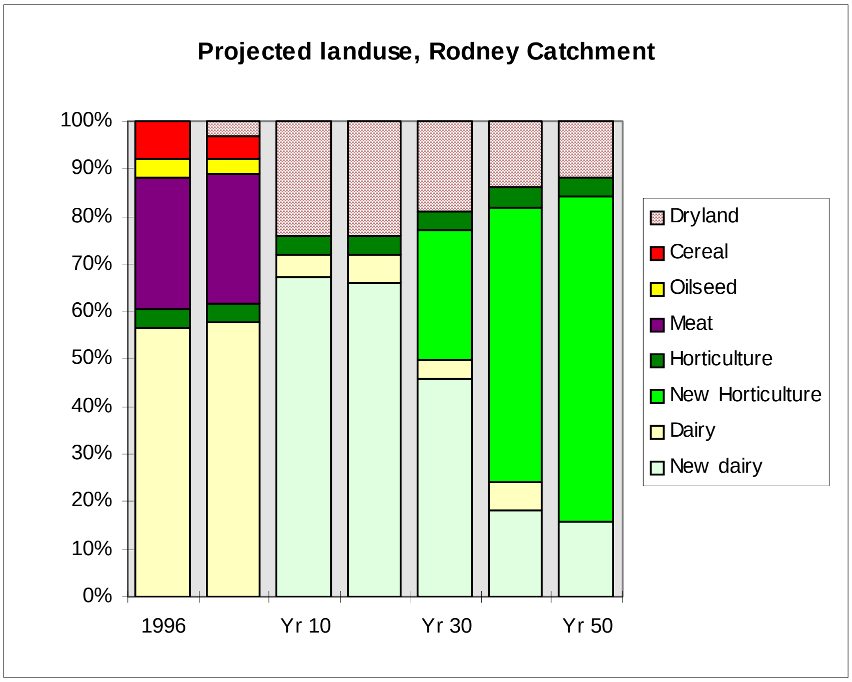

Figure 5: $8.22 starting price for dairy

4.4.4 Butterfat price down 20%

A 20% fall in the starting price for butterfat prices almost eliminates dairy production in the 1st run. The rising trend for dairy prices increases dairy area to 48% by the second decade after which it declines to 10-14%. (Table 9 and figure 6)

There is no investment in new dairy. Land and water resources used by dairy are diverted to increased pasture based meat production which rises to 77% of the catchment area in the 1st run and steadily declines to 5% by Year 50.
New horticulture starts in the second decade (1%) and rises rapidly to 50% by the third decade and reaches 68% by Year 50.
The area of dryland runs at 3-4% and then rises to 9% by Year 50.

Table 9: Land use and enterprise mix, $5.48/kg BF price

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		4	3	3	3	4	9
Cereal	8	5					
Oilseed	4	3					
Meat	28	77	68	45	33	18	5
Horticulture	4	4	4	4	4	4	4
New horticulture				1	50	60	68
Dairy	57	7	26	48	10	14	14
New Dairy							

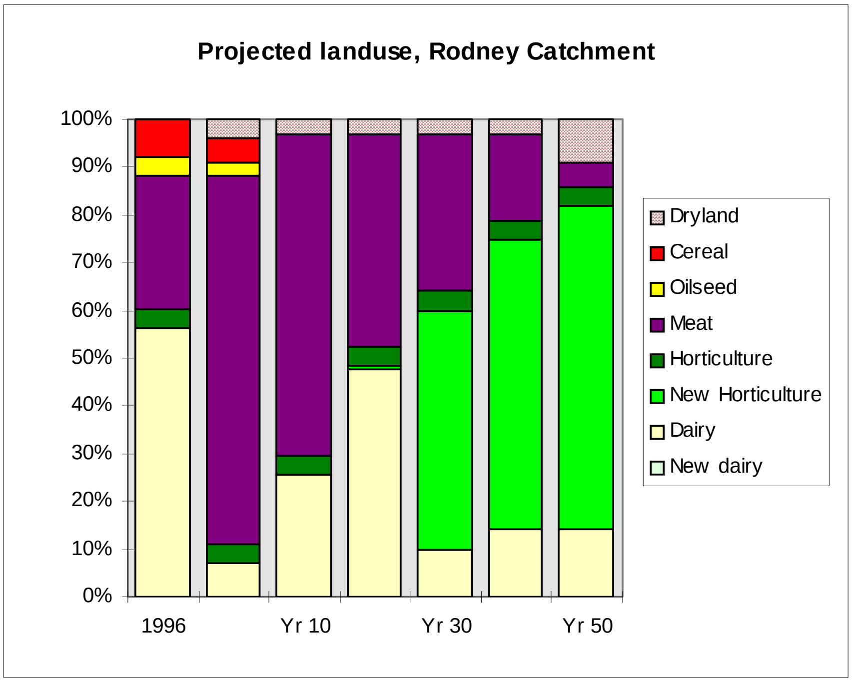

Figure 6: Starting dairy price $5.48

4.4.5 Horticulture price down 20%

If the price of horticulture is reduced by 20% to $280 per tonne, even old horticulture with sunk development costs becomes uncompetitive with meat and dairy. All investments in Year 10 are allocated to new dairy, with 76% of the total area used for dairy. The remaining 24% of the catchment becomes dryland (Table 10 and figure 7).

Starting from $280 per tonne, the rising relative price trend of horticulture does not make "old" horticulture systems profitable until the second decade. This implies some adjustment out of old horticulture will occur if a $280 per tonne based price trend prevailed. Investment in "new" horticulture does not become competitive until year 50 using 26% of the land in the catchment.

Table 10: Land use and enterprise mix, $280/tonne price of horticulture

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		3	24	24	24	24	19
Cereal	8	5					
Oilseed	4	3					
Meat	28	33					
Horticulture	4			4	4	4	4
New horticulture							26
Dairy	57	57	57	57	24	24	17
New Dairy			19	16	48	48	33

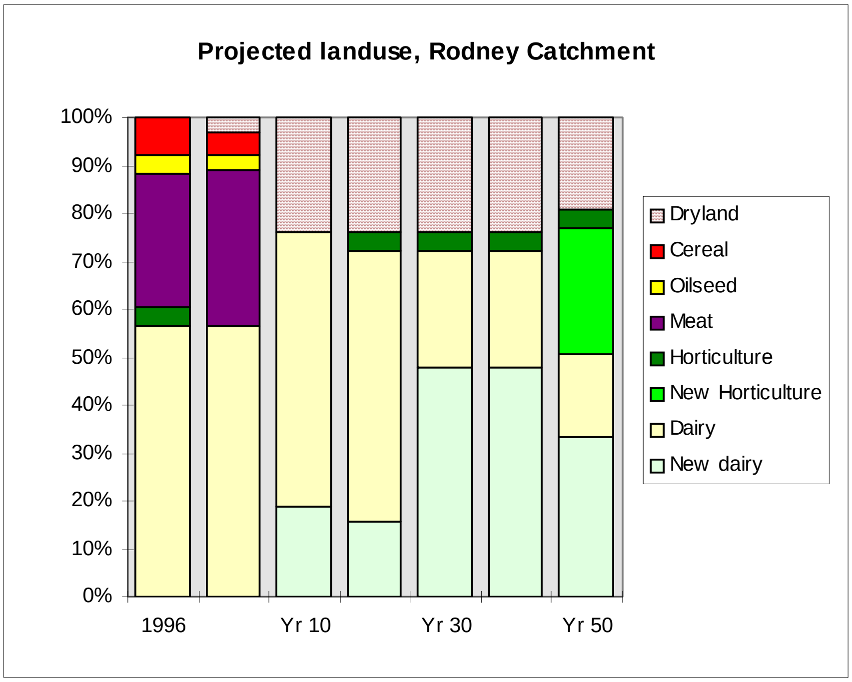

Figure 7: $280/ tonne starting price for horticulture

4.4.6 Horticulture price up 20%

If the base price for horticulture is increased by 20% new horticulture starts in the first decade (11%), rising to 74% by Year 50. Only a small area of new dairy occurs in the first and fifth decades and dairying declines from 64% of the catchment area in Year 10 down to 11% by year 50. (Table 11 and figure 8)

Table 11: Land use and enterprise mix, $420/tonne price of horticulture

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		4	22	17	13	13	11
Cereal	8	5					
Oilseed	4	3					
Meat	28	27					
Horticulture	4	4	4	4	4	4	4
New horticulture			11	40	60	60	74
Dairy	57	57	57	39	22	22	2
New Dairy			7				9

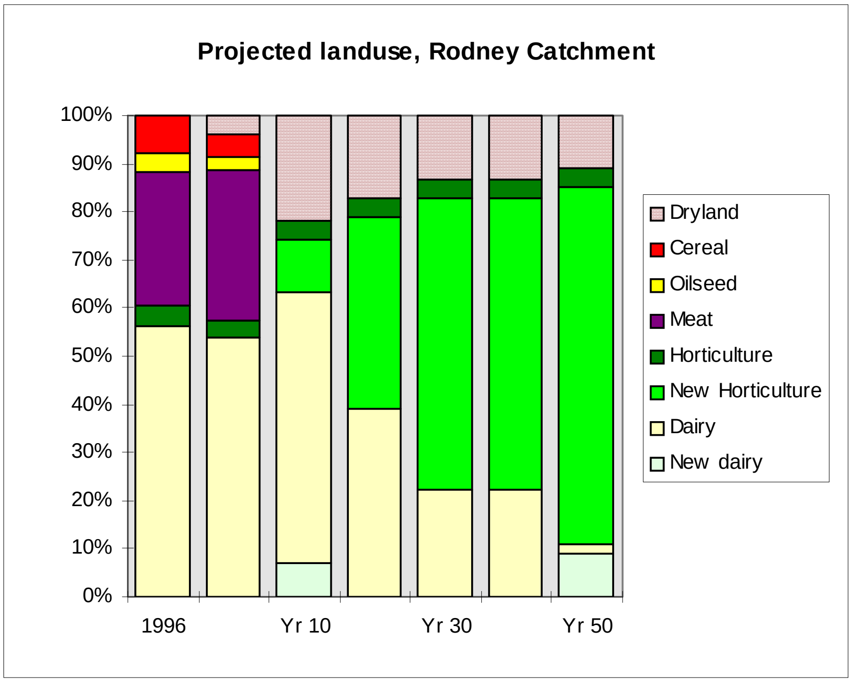

Figure 8: Horticulture starting price $420 per tonne

4.4.7 Irrigation water availability Water Right only

Reduction of the long term water allocation to 100% of water right had a large effect on catchment land use and enterprise mix (Table 12). Irrigated cropping and pasture based meat production cease in Year 1 and all water resources are used by existing horticulture and dairy. Almost half (45%) of the previously irrigated catchment area becomes dryland. The area of dryland declines to 34% by Year 50. New horticulture is established at 48% of catchment area in the third decade, rising to 62% by Year 50. Dairy occupied 51% of the catchment in the first run using all water resources after existing horticultural demand was met. Some new dairy replaces less efficient old dairy as total dairy area remains steady at 1% until the third decade when new horticulture becomes competitive. Dairy area then rapidly declines and production ceases after Year 40. This scenario is shown in Figure 9.

Table 12: Land use and enterprise mix, 100% water allocation

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		45	45	45	37	35	34
Cereal	8						
Oilseed	4						
Meat	28						
Horticulture	4	4	4	4	4	4	4
New horticulture					48	58	62
Dairy	57	51	44	44	11	3	
New Dairy			7	7			

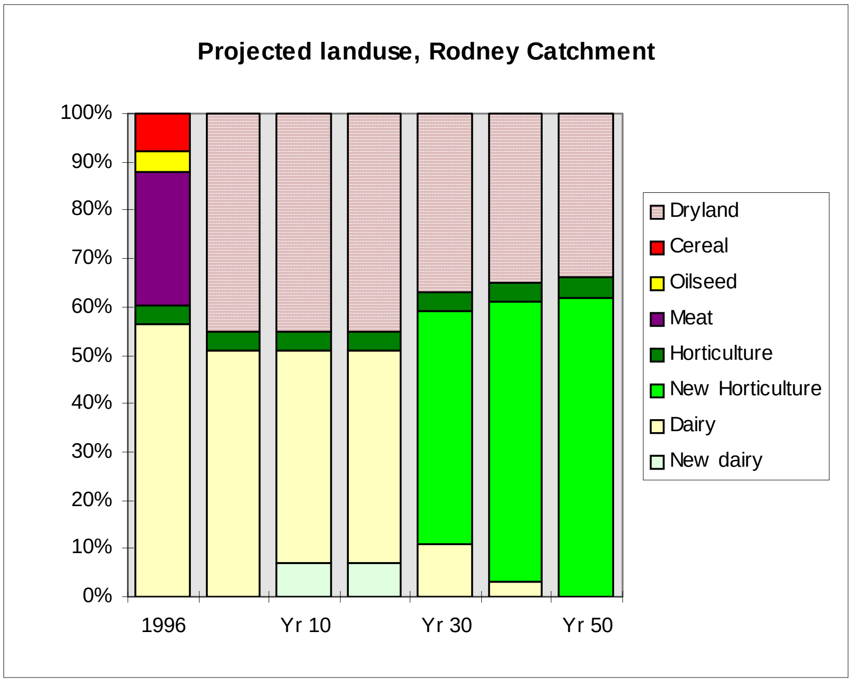

Figure 9: Water right only

4.4.8 Irrigation water availability Water Right plus 100% sales allocation

At 200% long term water allocation, there is sufficient water for some land use by "old" dairy systems in Years 20 to 40 and only 3% of the catchment is dryland (Table 13 and figure 10). The dryland is mainly areas under salinity scenario 3 - areas without pumpable aquifers where productivity is negligible.

Table 13: Land use and enterprise mix 200% water allocation

Landuse	1996	1st run	Yr 10	Yr 20	Yr 30	Yr 40	Yr 50
Dryland		3	3	3	3	3	3
Cereal	8	5					
Oilseed	4	3					
Meat	28	27	1				
Horticulture	4	4	4	4	4	4	4
New horticulture					48	58	68
Dairy	57	57	57	57	46	35	17
New Dairy			36	37			9

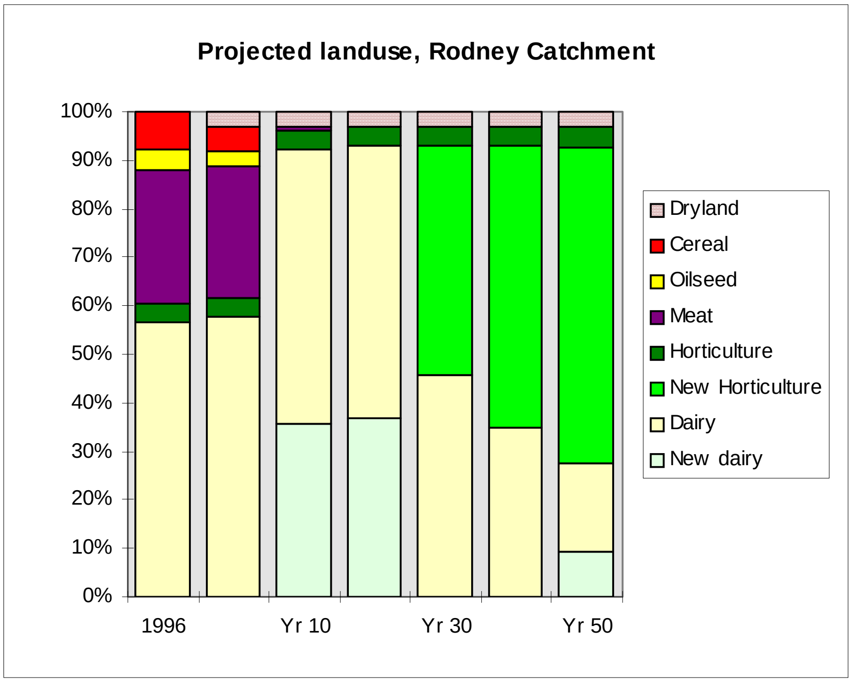

Figure 10: Water right plus 100% sales

4.5 QUALIFICATIONS OF MODEL OUTPUT

The output from runs of the model needs to be interpreted after considering a number of limitations in the methodology and also in the light of broader human and social issues.

The model allocates resources including investible cash surplus to enterprises as though the catchment is one farm where the management aim is profit maximisation. In reality, the catchment resources are mainly owned by family farm business establishments. As such, they have a wide and varied range of management aspirations and personal goals.

While the assumption of profit maximising management may be applicable to some farms in the catchment, some reduction in the rate of transition to "new" enterprises will occur due to use of prudent risk management strategies. Acquisition of catchment resources by more profitable businesses will be retarded by asset fixity on farms with "old" enterprises running down sunk capital and partially meeting family income needs from off-farm sources.

The model uses land capability as a proxy for land suitability. There will be cases where capable land is not suitable because land parcels are too small because of fragmentation caused by geographic, planning or ownership factors. Land suitability may be further constrained by proximity of incompatible uses and the cost of providing services such as increasing channel capacity.

It is also necessary to review assumptions regarding sustainability of natural resource management when the area of horticulture increases well beyond the estimates used in the Shepparton Irrigation Region Land and Water Salinity Management Plan (SIRLWSMP). The salt disposal allowances available to the region may limit the area of horticulture requiring deep drainage and disposal of high volumes of saline effluent without the option of conjunctive use on irrigated dairy pasture.

The sensitivity of catchment enterprises to horticulture prices and the lack of data on the elasticity of demand for horticultural produce calls for caution when estimating or promoting the rapid expansion of the horticultural industry.

The size and output of the dairy industry will not only depend on the area of irrigated pasture but also on the integration of other feed sources into a sustainable production system.

The seasonal variability in water availability, commodity prices and access to off farm income for farm families will continue to provide opportunities for "residual" water uses such as fodder production for beef, fat lamb and dairy enterprises and irrigated cropping.

These and other considerations reduce the rate and extent of expected changes in the composition of catchment enterprises.

5. USING THE MODEL IN REGIONAL DEVELOPMENT WORKSHOPS

Adam Smith (1976) recognised the usefulness of systems as a thinking aid:

“Systems in many respects resemble machines. A machine is a little system, created to perform, as well as connect together, in reality, those different movements and effects which the artist has occasion for. A system is an imaginary machine invented to connect together in the fancy those different movements and effects which are already in reality performed.”

The model has been run in an interactive workshop using role plays to simulate regional development forums. Evaluation of the workshop indicates interactive LP is useful for assisting a wide range of decision makers to quickly test the implications for their area of interest of a wide range of scenarios as described by Pannell (1996). Sensitivity testing within scenarios gives rapid understanding of the relative importance of decision variables, constraints and assumptions.

Feedback indicated that it would be useful to link the temporal stages of the model.

However further significant modification was not recommended as it was felt this would reduce the ability of participants to *“ connect together in the fancy those different movement and effects…”* and cloud the understanding of the working of the model. The group preferred an open framework to a “Black Box”.

6. CONCLUSION

The model predicts a shift in land use in the pilot study area from predominantly livestock farming to horticulture. This change has a significant social impact in the area where 17% of the population is directly employed in the livestock industry. The productivity of broad-acre farming (grazing and cropping) must improve to enable these enterprises to compete with dairying and horticulture and to remain viable. However they may remain as vertically or horizontally integrated components of the dairy industry with labour surplus engaged in earning off farm income.

Because of the necessary calibration adustments and the rational response to price and resource uncertainty, the predicted rates and extent of change should be viewed as an upper bound. Going on past experience, rates of change will be greatly tempered by the process of structural adjustment.

Use of the model in interactive workshops should facilitate the intertwined processes of business expansion, structural adjustment and regional development which comprise economic growth.

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