4. Methodology

4.1 Introduction

This chapter provides details on the case study farm and the possible activities available. Data sources are provided, together with activity analysis which provides the input-output coefficients and objective function values used in the LP and MLP models. For activities requiring capital investment, development economic analysis is also presented.

Continued decline in the groundwater resource has prompted irrigators to consider significant changes in the activity structure of their existing farm businesses. The following alternative activities were included in the LP model:

- annual horticultural crops
- the use of subsurface drip irrigation (SDI) for traditional crops and horticultural alternatives
- table grapes
- redclaw crayfish.

Significant capital investment is needed in adopting irrigation technologies like SDI and alternatives such as horticultural crops and redclaw. These investments alter the resource supplies and demands of the farm business over several years. The MLP model was developed to determine the economic worth of these investments for the case study farm. Costs and returns over a number of years were incorporated in the model in order to consider:

- the timing of secondary development expenditure;
- consumption expenditure;
- financing arrangements; and
- tax implications.

4.2 Case study farm business

4.2.1 Land

The case study farm business is owned by Trevor and Lyn Stringer. The business comprises three properties:

- 'Vorelle' - Portions 23 and 24, Parish Koolingal, 126 ha
- 'Lenora' - Portion 91, Parish Prairie, 80 ha
- 'Conmurra' - Portion 43 and 44, Parish Scoria, 202 ha

In addition there are 122 ha of leased land in combination with the 'Conmurra' property.

There are 189 ha of irrigable land on 'Vorelle' and 'Lenora'. A 50 ML dam takes up 5 ha, and there is 12 ha of land subject to waterlogging and planted to Bambatsii panic. 'Conmurra' is used for grazing cattle, with 178 ha planted to Gatton panic and 24 ha to the browse shrub leucaena.

4.2.2 Water and irrigation

'Vorelle' is located in Section 10A of the alluvium and has a nominal irrigation allocation of 466 ML. 'Lenora' is located in Section 7 of the alluvium with a nominal allocation of 450 ML. Since 1990-91 the announced allocations each year have been 80 per cent of nominal allocation in both these sections (see Table 2.1).

Spray irrigation has traditionally been used with rolling sprayline and handshift systems. Currently there are 30 ha of SDI installed on 'Vorelle'. A total of 80 ha of irrigable land can be developed to SDI.

4.2.3 Activity pattern

Traditionally 50 ha of lucerne and 24 ha of navy beans were grown under irrigation. Irrigated forage oats for finishing yearling heifers bred on 'Conmurra' was grown on 20 ha. Raingrown crops of mungbeans, millets or wheat were grown on 50 ha on 'Lenora', and 45 ha of raingrown wheat on 'Vorelle' (sometimes supplementary irrigated). 'Conmurra' is used to run 65 breeding cattle for the production of Jap Ox steers.

Lucerne is generally grown for two and a half years. It is ploughed out in mid-summer in the final year, and planted to a grain or annual horticultural crop before replanting to lucerne. The current limitation to lucerne is 60 ha from July to December, and 40 ha from January and June. This limitation is based on the available water supply.

In the last two years annual crops of cucurbits (cucumbers, pumpkins and watermelons) have been grown together with a 2 ha area of table grapes. The owner-operators consider a maximum area of 60 ha of annual horticultural crops can be grown. This limitation is based upon the perceived risk associated with growing these crops.

4.2.4 Labour

The current permanent labour supply consists of the owner operators (3120 hours p.a. for Trevor and 1560 hours p.a. for Lyn) and two employees (a total of 4910 hours p.a.). The second employee has only been necessary since intensification of the cropping program. All grain crops are harvested using contractors. Casual labour is used for harvesting of horticultural crops and not considered a limitation to future cropping.

4.2.5 Overhead costs

Overhead costs for the farm business are summarised in Table 4.1.

Table 4.1: Overhead costs for case study farm

Expense	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Total
Living costs	$6000	$6000	$6000	$6000	$24,000
Rates	$2000	$0	$0	$0	$2,000
Wages	$13000	$13000	$13000	$13000	$52,000
Repairs & Maintenance	$6000	$6000	$6000	$6000	$24,000
Motor Vehicle	$1500	$1500	$1500	$1500	$6,000
Sundry	$3000	$3000	$3000	$3000	$12,000
Total	$31,500	$29,500	$29,500	$29,500	$120,000

4.2.6 Capital

Traditionally the business has operated without the use of an overdraft facility. Currently there is an overdraft facility of $100 000 in place. Interest on the overdraft is charged at 13 percent. Interest on term loans is 12 percent and deposits earn interest at 5 percent.

4.3 Data sources

4.3.1 Crops

A range of data sources were used in drawing up the input-output coefficients and objective function values (gross margins) in the LP and MLP models. Crop yield estimates were supplied by the case study farm owner-operators. Crop price estimates were obtained from the owner-operators and supplemented with market information supplied by Market Information Services and ABARE.

Input costs were obtained from local suppliers (Primac and Cottco Ag Sales). Estimates of irrigation costs were based upon information supplied by Queensland Water Resources and Agricultural Requirements (suppliers of irrigation equipment within Biloela). Machinery operating costs were calculated using information supplied by the owner-operators and Bruce Rhoades Machinery, Rockhampton.

Estimates of labour requirements for cropping activities were based upon work rate estimates provided by the co-operators for machinery and irrigation operations, and the harvesting of annual horticultural crops. Crop water use estimates were provided by the co-operators for crops with which they were familiar.

4.3.2 SDI

The estimated cost of installation and operation of SDI systems was based upon information supplied by Agricultural Requirements and the co-operators. Agricultural Requirements provided design details for alternative irrigations systems and estimates of equipment costs. The co-operators provided estimates of labour requirements in the use of alternative irrigation systems. On-farm monitoring of SDI lucerne over the past two years and reference to the literature provided estimates of water use and crop yield changes associated with drip irrigation systems (Ayer et al, 1984; Bucks et al, 1983;Bui and Osgood, 1990; Caswell and Zilbermann, 1985; Feinermann and Yaron, 1990; Jadhav et al 1990; Sanders et al, 1988; Saggu and Kaushal, 1991; Smith et al, 1991).

4.3.3 Redclaw

The potential for commercial production of redclaw crayfish was first considered in the late 1980s. There has been significant research into its commercialisation by the

Queensland Department of Primary Industries (Jones and Curtis 1994), and some of the research information was used in assessing the profitability of redclaw production.

In addition, considerable information was obtained through the experience of commercial redclaw crayfish operations. Paul and Leah Van Itallie of Central Queensland Crayfish, Biloela provided much of the information used in evaluating redclaw crayfish production within the Callide Valley. They operate a redclaw crayfish operation which currently farms five hectares of crayfish ponds. Information on establishment costs was also obtained from Cameron Milne, Rockhampton who has recently established a eight pond redclaw operation at Wowan to the north of Biloela.

4.4 Data analysis

4.4.1 Resource use

The resource of greatest interest in this study is water. The savings in irrigation water associated with SDI are dependent upon the irrigation system with which it is compared. The literature indicates potential water savings ranging from zero to 50 percent, with yield increases within a similar range (Ayer et al, 1984; Bucks et al, 1983; Bui and Osgood, 1990; Caswell and Zilberman, 1985; Feinermann and Yaron, 1990; Jadhav et al 1990; Sanders et al, 1988; Saggu and Kaushal, 1991; Smith et al, 1991).

It was assumed that a saving of 10 percent in water use compared with spray irrigation was possible for annual winter field crops grown with SDI. A saving of 20 percent was assumed with summer field crops, and 15 percent for lucerne. No irrigation savings were assumed for annual horticultural crops grown with SDI compared with the traditional system of surface laid drip irrigation.

Water use by the redclaw activity was based upon average monthly Class A Pan evaporation data for Biloela and pan coefficients for water storages (A Baker 1996, pers. comm.). Total water requirement was estimated to be 20.86 ML/ha. Reuse of water from redclaw production for irrigation was estimated to be 6 ML/ha annually (P Van Itallie 1996, pers. comm.). The net water use for this activity is therefore 14.86 ML/ha.

4.4.2 Development economics

4.4.2.1 Capital Investment

Investment in associated equipment is necessary for inclusion of the alternative activities within the farming business. A summary of this equipment and its cost is given in Table 4.2.

Table 4.2: Equipment requirements and cost for alternative activities

Equipment	Annual Horticulture	Table Grapes	Redclaw
Packing shed	$12 000	$12 000	$12 000
Forklift	$3200	$3200	$3200
Coolroom	$25 000	$25 000	
Harvesting equipment	$6500	$1500	$11 630
Other equipment		$4000	$5875
TOTAL	$46 700	$45 700	$32 705

Some equipment can be used by one or more of the proposed activities as indicated. The equipment listed in Table 4.2 is required irrespective of the scale of inclusion of the associated activities within the farm plan. It is adequate for the development of up to 10 ha of grapes and 4 ha of redclaw ponds. In addition, activities such as grapes or redclaw require significant capital investment which is proportional to the scale of operation considered. Capital investment in SDI technology is also required in order to grow SDI annual field and horticultural crops.

4.4.2.2 SDI

In comparison with alternative irrigation systems, SDI has a high development cost (see Appendix 6). Costs of establishment have ranged from $1625 to $3250/ha (S. Pratt 1996, pers. comm.) dependent upon

- the shape and fall of the block to be irrigated
- bore capacity and reliability
- water quality
- lateral spacings.

However, operating costs are generally lower than for other systems (see Appendix 7). In this study the cost of installation of SDI was assumed to be $1966/ha. This covers the cost of SDI equipment including laterals placed at 1.5m spacings, submains, filters and trenchdigging. The cost of mainline and pumps was not included as this equipment is already in place with the existing irrigation systems.

4.4.2.3 Table Grapes

Table grapes are a perennial activity requiring significant capital investment in their establishment. The cost of establishment includes land preparation, planting, trellising and the installation of drip irrigation. The cost is $16 462/ha with vines planted at 1440 vines/ha. Production of grapes commences in the second year after planting with vines yielding 1.5 kg/each. By the fourth year vines have reached their potential production of 6 kg/vine.

A preliminary economic evaluation of the investment in table grapes was made using the partial discounted cash flow analysis approach outlined by Makeham and Malcolm (1993, p.330-6). In addition to establishment capital, table grapes also require investment in the equipment listed in Table 4.2. As some of this equipment can be shared with other activities, their cost was apportioned on the basis of likely use. Thus 20 percent of the shed cost and 50 percent of the coolroom cost was allocated to the table grape activity.

A budgeted net cash flow for the development of 2 ha of table grapes on 'Vorelle' was developed and is presented in Appendix 8. The development of 2 ha of grapes on 'Vorelle' has a positive NPV using a 10 percent after-tax discount rate given the assumptions used in drawing the budget up. The IRR is 14.64 percent after tax. It takes seven years for the investment in grapes to breakeven.

4.4.2.4 Redclaw

Redclaw production also requires significant capital investment in its establishment. For the development of 10 x 1000 square metre ponds the capital cost is $58 945. When coupled with the equipment costs in Table 4.2, the overall investment in a 1 ha redclaw activity is $76 450.

The production of redclaw takes four years to stabilise at 3.5 kg per square metre of pond area. This delay is a function of the time needed for management expertise to be acquired and required biological aging of the ponds.

The budgeted net cash flow for the development of 10 x 1000 square metre ponds on 'Vorelle' was developed and is presented in Appendix 9. The development has a positive NPV at all discount rates up to 20 percent given the assumptions in drawing up the budget. The IRR is 30.75 percent after tax. The breakeven for this investment occurs in Year 5.

4.4.3 Activity analysis

4.4.3.1 Activity options

The possible activities available for the case study farm were identified in consultation with the co-operator. These included several traditional irrigated and raingrown field crop activities as well as cattle related ones. Annual horticultural crops that had been grown within the last two years were also considered. In addition there were several annual horticultural crops that had not previously been grown but considered worthy of investigation for possible inclusion in the farm plan. Redclaw crayfish and table grape production were included in the list of possible future activities. The complete list is presented in Table 4.3

Of these, the annual cucurbit crops (butternuts, cucumbers, Jarrahdale pumpkins, watermelons and zucchinis) can all be grown twice a year (a spring and an autumn crop). Broccoli and sweet corn can only be grown during autumn. SDI can be used to grow all horticultural crops, and for lucerne and navy beans. At 1.5m spacings it is not considered suitable for the traditional broadacre grain crops (wheat, barley, millet and mungbeans).

Gross margins were drawn up for all possible activities in a set of linked Excel V5 workbooks. This enables updating of the gross margins through changes in the key variables and input costs. The structure of these linked workbooks is provided in Appendix 10. The associated files can be found on the enclosed 3.5" disks.

Table 4.3: Existing and potential activities for case study farm business

Existing Activities			Potential Activities	
Traditional		Horticulture	Annual	Perennial
Raingrown	Irrigated			
Barley	Barley	Butternuts	Broccoli	Redclaw crayfish
Millet	Forage oats	Cucumbers	Sweet corn	Table grapes
Mungbean	Lucerne	Jarrahdale pumpkins	Zucchini	
Wheat	Millet	Watermelons		
Breeding cattle	Navy beans			
	Wheat			

4.4.3.2 Assumptions

The assumptions for yield, price and water use for these activities is presented in Tables 4.4 to 4.6. The variable costs included within the gross margins are:

- fuel, oil, repairs and maintenance for machinery used for land preparation, crop protection and harvesting
- seed
- fertiliser
- crop protection inputs (herbicides, insecticides and fungicides)
- the water charge for irrigation water used
- electricity, repairs and maintenance of irrigation equipment
- harvesting costs

For traditional horticultural crops grown with short-term drip irrigation, the cost of the temporary drip system was included in the variable costs. Its life is estimated to be two seasons so half the costs was allocated to each traditionally grown horticultural crop.

The price for lucerne in its second year is higher than that in the first of third years. This is due to better quality in the second year, as there is less weed contamination.

Casual labour requirements were identified but not included within the gross margins to avoid double counting when specifying the LP and MLP models.

Table 4.4: Yield assumptions used in drawing up activity gross margins

Activity	Raingrown	Irrigated		
		Spray	Drip (traditional & SDI)	
			Yield change as a % of spray irrigation	Yield (t/ha)
Field crops				
Barley	1.85 t/ha	2.5 t/ha		
Lucerne (Year 1)		15.0 t/ha	25%	18.75 t/ha
Lucerne (Year 2)		20.0 t/ha	25%	25 t/ha
Lucerne (Year 3)		10.0 t/ha	25%	12.5 t/ha
Millet	1.08 t/ha	2.0 t/ha		
Mungbean	1.25 t/ha			
Navy bean		2.0 t/ha	20%	2.4 t/ha
Forage oats		2.39 head/ha		
Wheat	1.85 t/ha	2.5 t/ha		
Horticultural crops				
Broccoli				800 40L icepacks/ha
Butternuts				850 36L cartons/ha
Cucumbers				2500 18L cartons/ha
Grapes (Year 1)				0 kg/vine
Grapes (Year 2)				1.5 kg/vine
Grapes (Year 3)				3 kg/vine
Grapes (Year 4)				6 kg/vine
Jarrahdale pumpkins				20 t/ha
Sweet corn				850 18L cartons/ha
Water melons				30 t/ha
Zucchinis				1000 18L cartons/ha
Livestock				
Redclaw crayfish (Year 1)				1 kg/sq metre
Redclaw crayfish (Year 2)				2 kg/sq metre
Redclaw crayfish (Year 3)				3 kg/sq metre
Redclaw crayfish (Year 4)				3.5 kg/sq metre

Table 4.5: Price assumptions used in drawing up activity gross margins

Activity Commodity	Marketing imes	Market Price	On-farm Price
Field crops			
Barley	Nov	$155/t	$145.51/t
Lucerne (Year 1)	Jul-Jun	N/A	$200/t
Lucerne (Year 2)	Jul-Jun	N/A	$220/t
Lucerne (Year 3)	Jul-Jun	N/A	$200/t
Millet	May	$190/t	$180.18/t
Mungbean	Apr	$490/t	$387/t
Navy bean	May	$850/t	$761.90/t
Forage oats	Aug	N/A	N/A
Wheat	Nov	$160/t	$147.42/t
Horticultural crops			
Broccoli	May	$12/40L icepack	$8.53/40L icepack
Butternuts	Nov-Dec & May-Jun	$10/36L carton	$8.01/36L carton
Cucumbers	Oct-Nov & Apr-May	$8/18L carton	$6.30/18L carton
Grapes (Year 1)			
Grapes (Year 2)	late-Nov & Dec	$20/18L carton	$16.33/18L carton
Grapes (Year 3)	late-Nov & Dec	$20/18L carton	$16.33/18L carton
Grapes (Year 4)	late-Nov & Dec	$20/18L carton	$16.33/18L carton
Jarrahdale pumpkins	Nov-Dec & May-Jun	$200/t bulk bin	$139/t bulk bin
Sweet corn	May	$9/18L carton	$7.03/18L carton
Water melons	Nov & Ma	$200/t bulk bin	$138.15/t bulk bin
Zucchinis	Sep-Nov & Mar-May	$10/18L carton	$8.03/18L carton
Livestock			
Jap Ox	Aug	220 c/kg DW	
Cull cows	Aug	150 c/kg DW	
Cull bulls	Aug	120 c/kg LW	
Weaner heifers	May	100 c/kg LW	
Yearling heifers	Aug	105 c/kg LW	
Redclaw crayfish			
Juveniles <30g	Nov, Mar-Apr	N/A	25c each
Crayfish 30-50g	Nov, Mar-Apr	N/A	$12/kg
Crayfish 50-70g	Nov, Mar-Apr	N/A	$12/kg
Crayfish 70-90g	Nov, Mar-Apr	N/A	$12/kg
Crayfish >90g	Nov, Mar-Apr	N/A	$15/kg

Table 4.6: Water use (ML/ha) assumptions used in drawing up activity gross margins

Activity	Spray	Drip (traditional & SDI)	
		Water Use change as a % of spray irrigation	Water Use (ML/ha)
Field crops			
Barley	0.75		
Lucerne (Establishment)	2.0		2.0 (Spray)
Lucerne (Year 1)	0.0	-15%	8.5
Lucerne (Year 2)	2.0	-15%	10.2
Lucerne (Year 3)	6.0	-15%	5.1
Millet	2.5		
Navy bean	4.0	-20%	3.2
Forage oats	0.75		
Wheat	0.75		
Horticultural crops			
Broccoli			3.0
Butternuts			2.18
Cucumbers			2.0
Grapes			4.61
Jarrahdale pumpkins			2.18
Sweet corn			3.0
Water melons			2.18
Zucchinis			2.0
Livestock			
Redclaw crayfish			14.86

With each activity the farm manager was asked to rate a number of other considerations in undertaking the activity. This rating is a measure of the managers perception of the risks associated with each activity (see Tables 4.7 to 4.12).

4.4.3.3 Gross margins

The gross margins for each possible activity are summarised in Tables 4.7 to 4.12. Table 4.7 shows the gross margins for traditional field crops. The raingrown crop gross margins range from $179 to $291/ha. Raingrown mungbeans have the highest gross margin compared with wheat and barley. However, the former is considered to have higher production risk and requires greater management skills compared with the later

Table 4.7: Traditional field crop activity gross margin comparison

ACTIVITY	Raingrown Barley	Irrigated Barley	Spray Irrigated Forage Oats	Spray Irrigated Lucerne Est	Spray Irrigated Lucerne Year 1	Spray Irrigated Lucerne Year 2	Spray Irrigated Lucerne Year 3	Raingrown Millet	Spray Irrigated Millet	Raingrown Mungbean	Spray Irrigated Navy Bean	Raingrown Wheat	Irrigated Wheat
CODE	**BarRG**	**BarSpIrr**	**OatSpIrr**	**LucSpIrrEst**	**LucSpIrr1**	**LucSpIrr2**	**LucSpIrr3**	**MillRG**	**MillSpIrr**	**MunRG**	**NavSpIrr**	**WheRG**	**WheSpIrr**
Gross income													
On-farm price ($/t)	$146	$146		$200	$200	$220	$200	$180	$180	$387	$762	$147	$147
Yield (t/ha)	1.85	2.50		0.00	15.00	20.00	10.00	1.08	2.00	1.25	2.00	1.85	2.50
Gross income ($/ha)	$269	$364	$843	$0	$3,000	$4,400	$2,000	$195	$360	$484	$1,524	$273	$369
Variable costs													
Machinery operations	$28	$28	$28	$36	$5	$4	$0	$28	$28	$34	$51	$28	$28
Seed	$26	$26	$41	$102				$9	$13	$62	$130	$14	$15
Inoculant				$3						$1			
Fertiliser	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1	$85	$0	$0
Herbicide	$0	$0	$0	$0	$27	$0	$0	$0	$0	$13	$105	$0	$0
Insecticide	$0	$0		$11	$6	$6	$0	$0	$0	$33	$57	$0	$0
Defoliant										$0	$0		
Scouting										$0	$0		
Fungicide				$0	$0	$0	$0			$0	$0		
Contract spraying	$0	$0						$0	$0	$0	$0	$0	$0
Irrigation		$30	$25	$66	$329	$394	$197		$101		$131		$30
Casual labour	$0	$0		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Harvesting	$36	$58			$225	$276	$138	$36	$58	$49	$109	$36	$58
Stock transfers			$613										
Stock costs			$0										
Total variable costs	$91	$143	$707	$218	$592	$680	$335	$73	$200	$192	$670	$78	$132
Gross margin ($/ha)	$179	$221	$135	($218)	$2,408	$3,720	$1,665	$121	$160	$291	$854	$194	$236
Gross margin ($/ML)	N/A	$295	$180	($109)	$241	$310	$277	N/A	$64	N/A	$213	N/A	$315
Other considerations													
Production risk	low	low	low	med	med	med	med	med	med	high	high	low	low
Price fluctuations	low	low	med	med	med	med	med	high	high	med	low	low	low
Cash cost of growing	med	med	med	high	high	high	high	low	low	med	high	med	med
Capital investment	low	low	low	high	high	high	high	low	low	low	med	low	low
Harvest timeliness	med	med	N/A	high	high	high	high	high	high	high	high	med	med
Management skills	med	med	med	high	high	high	high	med	med	high	high	med	med
Irrigation required	low	low	med	high	high	high	high	low	med	low	med	low	low

Table 4.8: SDI field crop activ ty gross margin comparison

ACTIVITY	SDI Lucerne Est	SDI Lucerne Year 1	SDI Lucerne Year 2	SDI Lucerne Year 3	SDI Navy Bean
CODE	SDILucEst	SDILuc1	SDILuc2	SDILuc3	SDINav
Gross income					
On-farm price ($/t)	$200	$200	$220	$200	$762
Yield (t/ha)	$0	18.75	25.00	12.50	2.40
Gross income ($/ha)	$0	$3,750	$5,500	$2,500	$1,829
Variable costs					
Machinery operations	$36	$5	$4	$0	$51
Seed	$102				$130
Inoculant	$3				
Fertiliser	$0	$0	$0	$0	$85
Herbicide	$11	$27	$0	$0	$105
Insecticide	$0	$6	$6	$0	$57
Defoliant					$0
Scouting					$0
Fungicide	$0	$0	$0	$0	$0
Contract spraying					$0
Irrigation	$66	$281	$338	$169	$106
Casual labour	$0	$0	$0	$0	$0
Harvesting		$266	$328	$170	$109
Total variable costs	$218	$586	$675	$338	$644
Gross margin ($/ha)	($218)	$3,164	$4,825	$2,162	$1,184
Gross margin ($/ML)	($109)	$372	$473	$424	$370
Other considerations					
Production risk	med	ned	med	med	high
Price fluctuations	med	ned	med	med	low
Cash cost of growing	high	high	high	high	high
Capital investment	high	high	high	high	med
Harvest timeliness	high	high	high	high	high
Management skills	high	high	high	high	high
Irrigation required	high	high	high	high	med

crops. Price fluctuations are greater for mungbeans, as is the emphasis on harvest timeliness.

Amongst the irrigated traditional field crops, lucerne has the greatest gross margin on an area basis with the gross margin ranging from $1665/ha for third year lucerne to $3720/ha for second year lucerne (the lower gross margin in the third year results from only a six month cropping interval as lucerne is cultivated out at the end of December). Lucerne also has a high gross margin per ML of irrigation water, with gross margins ranging from $241/ML to $310/ML. Wheat and barley have a higher gross margin per ML, but a much greater area of these is needed to produce a similar return to that possible from lucerne.

Table 4.8 shows the gross margins for SDI lucerne and navy beans. SDI significantly increases the gross margins for these crops. The SDI lucerne gross margin ranges from $2162 to $4825/ha (an increase of about 30 percent). The gross margin per ML increase is around 53 percent for SDI lucerne over spray irrigation. For navy beans, the relative gross margin increases per unit of land and water is 39 percent and 74 percent respectively with the use of SDI.

Table 4.9 shows the gross margins for the traditionally grown horticultural crops. Amongst the annual crops there is a large range in potential gross margins - from $861/ha for Jarrahdale pumpkins to $10 566/ha for cucumbers. The returns from these crops on an annual basis is potentially even higher than this given that two crops can be grown on the same area within a year. The return per ML has a similar range - from $359/ML for broccoli to $5283/ML for cucumbers. Within these crops there is also a range of risks related to production, price fluctuations and harvest timeliness as would be expected. The returns from these crops are generally greater than those from the traditional field crops, although lucerne is comparable with a number of crops (broccoli, Jarrahdale pumpkins, butternuts, sweet corn and watermelons for example). Table grapes as a perennial horticultural crop has a high gross margin ($9700/ha and $2105/ML) which is, however, lower than that for some annual crops, particularly when two crops a year are possible in the latter (cucumbers and zucchinis are examples).

As with the field crops, the use of SDI significantly increases gross margins. This can be seen in Table 4.10. The increase ranges from as low as 5 percent for cucumbers to 64 percent for Jarrahdale pumpkins. The increase range is a function of the cost of semi-permanent drip irrigation used in traditional horticultural crops as a proportion of total costs, together with gross returns. SDI provides savings in these costs for annual horticultural crops rather than yield increases and water savings that occurs with field crops grown with SDI compared to spray irrigation.

Table 4.11 summarises the gross margins for both cattle activities - breeding cattle for the production of Jap Ox and the fattening of yearling heifers on irrigated forage oats. The gross margin for breeding cattle is $346/cow. This activity uses 324 ha of non-

Table 4.9: Traditional horticultural crop activity gross margin comparison

ACTIVITY	Traditional Broccoli	Traditional Cucumbers Spring	Traditional Cucumbers Autumn	Grapes	Traditional Jarrahdale Pumpkins Spring	Traditional Jarrahdale Pumpkins Autumn	Traditional Butternuts Spring	Traditional Butternuts Autumn	Traditional Sweet corn	Traditional Watermelon Spring	Traditional Watermelon Autumn	Traditional Zucchini Spring	Traditional Zucchini Autumn
CODE	**TradBro**	**TradCucSp**	**TradCucAu**	**Grape**	**TradJarSp**	**TradJarAu**	**TradButSp**	**TradButAu**	**TradSCor**	**TradWatSp**	**TradWatAu**	**TradZucSp**	**TradZucAu**
Gross income													
On-farm price ($/unit)	$8.53	$6.30	$6.30	$16.33	$139	$139	$8.01	$8.01	$7.03	$138	$138	$8.03	$8.03
Yield (unit/ha)	800	2500	2500	864	20.0	20.0	850	850	850	30.0	30.0	1000	1000
Gross income ($/ha)	$6,828	$15,752	$15,752	$14,105	$2,780	$2,780	$6,809	$6,809	$5,972	$4,145	$4,145	$8,029	$8,029
Variable costs													
Machinery operations	$86	$86	$86	$133	$83	$83	$83	$83	$74	$86	$86	$86	$86
Seed	$1,575	$88	$88		$90	$90	$90	$90	$250	$330	$330	$270	$270
Inoculant													
Fertiliser	$412	$363	$363	$58	$282	$282	$267	$267	$280	$300	$300	$300	$300
Nematode control		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Weed control	$12	$32	$32	$38	$32	$32	$48	$48	$37	$32	$32	$32	$32
Insect control	$134	$103	$103	$13	$109	$109	$156	$156	$341	$156	$156	$156	$156
Defoliant													
Scouting													
Disease control	$26	$246	$246	$259	$179	$179	$179	$179	$0	$179	$179	$179	$179
Bird control				$2,304									
Growth regulants				$135									
Contract spraying									$133				
Irrigation	$607	$574	$574	$152	$580	$580	$580	$580	$607	$580	$580	$574	$574
Casual labour	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Harvesting	$2,898	$3,695	$3,695	$1,312	$564	$564	$2,380	$2,380	$1,406	$800	$800	$1,490	$1,490
Total variable costs	$5,749	$5,186	$5,186	$4,405	$1,919	$1,919	$3,783	$3,783	$3,128	$2,462	$2,462	$3,086	$3,086
Gross margin ($/ha)	$1,078	$10,566	$10,566	$9,700	$861	$861	$3,026	$3,026	$2,845	$1,682	$1,682	$4,942	$4,942
Gross margin ($/ML)	$359	$5,283	$5,283	$2,105	$395	$395	$1,388	$1,388	$948	$772	$772	$2,471	$2,471
Other considerations													
Production risk	med	med	med	high	low	low	low	low	med	low	low	high	high
Price fluctuations	high	high	high	high	med	med	med	med	high	high	high	high	high
Cash cost of growing	high	med	med	high	low	low	low	low	high	low	low	med	med
Capital investment	med	med	med	high	low	low	low	low	high	low	low	high	high
Harvest timeliness	high	high	high	high	med	low	med	low	high	high	high	high	high
Management skills	med	med	med	high	low	low	low	low	med	low	low	med	med
Irrigation required	med	med	med	med	med	med	med	med	med	med	med	med	med

Table 4.10: SDI horticultural crop activity gross margin comparison

ACTIVITY	SDI Broccoli	SDI Cucumbers Spring	SDI Cucumbers Autumn	SDI Jarrahdale Pumpkins Spring	SDI Jarrahdale Pumpkins Autumn	SDI Butternuts Spring	SDI Butternuts Autumn	SDI Sweet corn	SDI Watermelon Spring	SDI Watermelon Autumn	SDI Zucchini Spring	SDI Zucchini Autumn
CODE	**SDIBro**	**SDICucSp**	**SDICucAu**	**SDIJarSp**	**SDIJarAu**	**SDIButSp**	**SDIButAu**	**SDISCor**	**SDIWatSp**	**SDIWatAu**	**SDIZucSp**	**SDIZucAu**
Gross income												
On-farm price ($/unit)	$8.53	$6.30	$6.30	$139	$139	$8.01	$8.01	$7.03	$138	$138	$8.03	$8.03
Yield (unit/ha)	800	2500	2500	20.0	20.0	850	850	850	30.0	30.0	1000	1000
Gross income ($/ha)	$6,828	$15,752	$15,752	$2,780	$2,780	$6,809	$6,809	$5,972	$4,145	$4,145	$8,029	$8,029
Variable costs												
Machinery operations	$83	$83	$83	$80	$80	$80	$80	$71	$85	$85	$83	$83
Seed	$1,575	$88	$88	$90	$90	$90	$90	$250	$330	$330	$270	$270
Inoculant												
Fertiliser	$412	$363	$363	$246	$246	$267	$267	$280	$300	$300	$300	$300
Nematode control	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Weed control	$12	$32	$32	$32	$32	$48	$48	$37	$32	$32	$32	$32
Insect control	$134	$103	$103	$109	$109	$156	$156	$341	$156	$156	$156	$156
Defoliant												
Scouting												
Disease control	$26	$246	$246	$179	$179	$179	$179	$0	$179	$179	$179	$179
Bird control												
Growth regulants												
Contract spraying								$133				
Irrigation	$99	$66	$66	$72	$72	$72	$72	$99	$72	$72	$66	$66
Casual labour	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Harvesting	$2,898	$3,695	$3,695	$564	$564	$2,380	$2,380	$1,406	$800	$800	$1,490	$1,490
Total variable costs	$5,239	$4,675	$4,675	$1,373	$1,373	$3,272	$3,272	$2,617	$1,954	$1,954	$2,576	$2,576
Gross margin ($/ha)	$1,589	$11,077	$11,077	$1,407	$1,407	$3,537	$3,537	$3,355	$2,190	$2,190	$5,453	$5,453
Gross margin ($/ML)	$530	$5,538	$5,538	$646	$646	$1,622	$1,622	$1,118	$1,005	$1,005	$2,726	$2,726
Other considerations												
Production risk	med	med	med	low	low	low	low	med	low	low	high	high
Price fluctuations	high	high	high	med	med	med	med	high	high	high	high	high
Cash cost of growing	high	med	med	low	low	low	low	high	low	low	med	med
Capital investment	med	med	med	low	low	low	low	high	low	low	high	high
Harvest timeliness	high	high	high	med	low	med	low	high	high	high	high	high
Management skills	med	med	med	low	low	low	low	med	low	low	med	med
Irrigation required	med	med	med	med	med	med	med	med	med	med	med	med

Table 4.11: Cattle activity gross margins

ACTIVITY	Breeding Cattle (per cow)	Fattening Heifers (per ha)
CODE	**BCattle**	**OatSpIrr**
Gross income		
Stock sales	$321	$907
Stock transfers	$112	
less sale costs	$8	$64
Gross income ($/unit)	$425	$843
Costs		
Stock purchases	$48	
Stock transfers		$613
Drenching	$0	$0
Vaccination	$2	$0
Tick control	$3	
Buffalo fly control	$0	
Supplements	$25	
Forage crop		$94
Other	$2	$0
Casual labour	$0	$0
Variable costs ($/unit)	$79	$707
Gross margin ($/unit)	$346	$135
Gross margin ($/ML)	N/A	$180
Other considerations		
Production risk	low	med
Price fluctuations	med	med
Cash cost of production	low	low
Capital investment	med	low
Harvest timeliness	low	med
Management skills	med	med
Irrigation required	N/A	low

arable grazing land, on which 65 breeders are run. The total gross margin is thus $22490. There are no alternative uses for this land. The gross margin for the fattening of yearling heifers on irrigated forage oats is $135/ha or $180/ML. This activity has a lower gross margin than most other traditional field crops (other than raingrown millet). In fact, raingrown wheat and barley have higher gross margins than this activity, without the use of irrigation.

Table 4.12 summarises the annual gross margin for redclaw crayfish production form Year 1 to Year 4 (when yields stabilise). This activity has a very high gross margin per unit area (increasing form $9299/ha in Year 1 to $38 214/ha in Year 4). It also has one

of the highest gross margins per ML of all activities (from $621 in Year 1 to $2572/ML in Year 4). The only activities with higher gross margins per ML are traditionally grown and SDI cucumbers, and SDI zucchinis.

Table 4.12: Redclaw crayfish activity gross margins

ACTIVITY	Redclaw Year 1 (per ha)	Redclaw Year 2 (per ha)	Redclaw Year 3 (per ha)	Redclaw Year 4 (per ha)
CODE	**Rclaw1**	**Rclaw2**	**Rclaw3**	**Rclaw4**
Gross income				
On-farm price ($/kg)	$12.91	$13.22	$13.22	$13.22
Yield (kg/ha)	1000	2000	3000	3500
Gross income ($/unit)	$12,915	$26,445	$39,668	$46,279
Costs				
Machinery operations	$135	$135	$135	$135
Feed	$2,574	$5,148	$5,148	$5,148
Fertiliser	$0	$0	$0	$0
Water	$488	$488	$488	$488
Casual labour	$0	$0	$0	$0
Harvesting	$488	$1,311	$1,966	$2,293
Variable costs ($/unit)	$3,686	$7,082	$7,737	$8,065
Gross margin ($/unit)	$9,229	$19,363	$31,930	$38,214
Gross margin ($/ML)	$621	$1,303	$2,149	$2,572
Other considerations				
Production risk	high	high	high	high
Price fluctuations	med	med	med	med
Cash cost of production	low	low	low	low
Capital investment	high	high	high	high
Harvest timeliness	med	med	med	med
Management skills	high	high	high	high
Irrigation required	high	high	high	high

4.5 Summary

In this chapter the details of the case study farm and possible alternative activities were outlined. A range of data sources were used to ascertain the input-output coefficients and objective function values used in the specification of the LP and MLP models presented in the following chapters. Development economics was undertaken to ascertain the capital investment necessary for the inclusion of the following activities within the farm plan:

- SDI
- table grapes

- redclaw crayfish.

The gross margins for all possible activities were drawn up using data supplied by the co-operator and estimates for activities where no existing experience existed. Best estimates were extensively used for SDI horticultural and navy bean gross margins. The co-operator also provided their own perception of the risks associated with the alternative activities.

5. Static LP Model

5.1 Introduction

This chapter outlines the development and solution of the static LP model aimed at identifying the long run optimal m x of activities for the case study farm. It assumes there is not constraint on the ava lability of capital for investment in infrastructure necessary for the full range of possible activities to enter the optimal solution.

Details on the specification of the model - the objective function, activities and constraints are given. A brief description of the LP matrix and its implementation to produce the initial optimal solution is covered. The initial optimal solution is examined in detail, and compared with that if intensification is not undertaken.

The shadow prices for all constraints are given, together with a brief summary of the most important ones. A sensitivity analysis was undertaken to examine the impact of changes in key parameters upon the optimal farm plan. The key parameters examined were:

- the announced water allocations
- the maximum allowable area of lucerne
- the maximum permissible area of annual horticultural crops
- the availability of casual labour.

5.2 Specification

A static LP model was specified wi h the aim of determining which activities should be included within the MLP model developed to test the hypotheses.

5.2.1 The objective function

The objective function in the model is the maximisation of annual operating profit for the farming business as a whole. The gross margin for each activity is included as a function of yield, on-farm price and associated variable costs:

$$GM_j = P_j Y_j - VC_j \quad (5.1)$$

where

GM_j = represents the gross margin for the activity j

P_j = the price for the commodity produced by activity j

Y_j = the quantity of commodity produced by activity j

VC_j = the variable costs associated with activity j

$j = 1,2,...,m$

5.2.2 Activities

In specifying the model, the resources of the three farms managed by the co-operators were combined within a single model. The available activities and their appropriate coefficients were all entered. There were 13 traditional field crop activities, including four lucerne activities (for the establishment phase, Year 1, Year 2 and Year 3 spray irrigated lucerne). There were 12 traditional horticultural activities. With SDI, there were 17 activities, five field crop (four for lucerne as before) and the remainder for annual horticultural crops. The breeding cattle, redclaw and grapes completed the list of available activities. The redclaw and grape activity were included at final production levels (Year 4 levels for both activities). In all there were 45 possible production activities within the model. The complete list of activities and associated codes within the model are given in Table 5.1.

In addition to the possible production activities there are also activities for the hire of labour and borrowing of working capital for each quarter within the year. In addition there are transfer activities for the transfer of surplus working capital from one quarter to the next.

5.2.3 Constraints

The constraints used are summarised in Table 5.2. The constraints are specified on a time period basis within the year. This enables a practical annual farm plan to be found. Non-arable land is only used for the breeding cattle activity and totals 324 ha. For cultivable land the year was divided into 5 periods in order to model within-year land use. The total area of cultivable land is 189 ha.

Table 5.1: Activity list for LP model

Activity	Code	Unit	Activity	Code	Unit
Raingrown Barley	BarRG	(1 ha)	SDI Lucerne (Est)	SDILucEst	(1 ha)
Spray Irrigated Barley	BarSpIrr	(1 ha)	SDI Lucerne (Year 1)	SDILuc1	(1 ha)
Spray Irrigated Oats	OatSpIrr	(1 ha)	SDI Lucerne (Year 2)	SDILuc2	(1 ha)
Raingrown Wheat	WheRG	(1 ha)	SDI Lucerne (Year 3)	SDILuc3	(1 ha)
Spray Irrigated Wheat	WheSpIrr	(1 ha)	SDI Navy Beans	SDINav	(1 ha)
Spray Irrigated Lucerne (Est)	LucSpIrrEst	(1 ha)	SDI Broccoli	SDIBro	(1 ha)
Spray Irrigated Lucerne (Year 1)	LucSpIrr1	(1 ha)	SDI Cucumbers (Spring)	SDICucSp	(1 ha)
Spray Irrigated Lucerne (Year 2)	LucSpIrr2	(1 ha)	SDI Cucumbers (Autumn)	SDICucAu	(1 ha)
Spray Irrigated Lucerne (Year 3)	LucSpIrr3	(1 ha)	SDI Jarrahdale Pumpkins (Spring)	SDIJarSp	(1 ha)
Raingrown Millet	MillRG	(1 ha)	SDI Jarrahdale Pumpkins (Autumn)	SDIJarAu	(1 ha)
Spray Irrigated Millet	MillSpIrr	(1 ha)	SDI Butternuts (Spring)	SDIButSp	(1 ha)
Raingrown Mungbean	MunRG	(1 ha)	SDI Butternuts (Autumn)	SDIButAu	(1 ha)
Spray Irrigated Navy Beans	NavSpIrr	(1 ha)	SDI Sweet Corn	SDISCor	(1 ha)
Breeding Cattle	BCattle	(1 cow)	SDI Watermelons (Spring)	SDIWatSp	(1 ha)
Traditional Broccoli	TradBro	(1 ha)	SDI Watermelons (Autumn)	SDIWatAu	(1 ha)
Traditional Cucumbers (Spring)	TradCucSp	(1 ha)	SDI Zucchinis (Spring)	SDIZucSp	(1 ha)
Traditional Cucumbers (Autumn)	TradCucAu	(1 ha)	SDI Zucchinis (Autumn)	SDIZucAu	(1 ha)
Traditional Jarrahdale Pumpkins (Spring)	TradJarSp	(1 ha)	Working Capital Transfers	Jul/Sep to Oct/Dec	($1)
Traditional Jarrahdale Pumpkins (Autumn)	TradJarAu	(1 ha)	Working Capital Transfers	Oct/Dec to Jan/Mar	($1)
Traditional Butternuts (Spring)	TradButSp	(1 ha)	Working Capital Transfers	Jan/Mar to Apr/Jun	($1)
Traditional Butternuts (Autumn)	TradButAu	(1 ha)	Borrowing Working Capital	BorrowWCJul/Sep	($1)
Traditional Sweet Corn	TradSCor	(1 ha)	Borrowing Working Capital	BorrowWCOct/Dec	($1)
Traditional Watermelons (Spring)	TradWatSp	(1 ha)	Borrowing Working Capital	BorrowWCJan/Mar	($1)
Traditional Watermelons (Autumn)	TradWatAu	(1 ha)	Borrowing Working Capital	BorrowWCApr/Jun	($1)
Traditional Zucchinis (Spring)	TradZucSp	(1 ha)	Hire of Labour	HireLabourJul/Sep	(1 hour)
Traditional Zucchinis (Autumn)	TradZucAu	(1 ha)	Hire of Labour	HireLabourOct/Dec	(1 hour)
Grapes	Grapes	(1 ha)	Hire of Labour	HireLabourJan/Mar	(1 hour)
Redclaw crayfish	RClaw4	(1 ha)	Hire of Labour	HireLabourApr/Jun	(1 hour)

For the lucerne activities, crop sequencing linkages were needed to ensure that the area of lucerne of a particular age was equal to or less than that in the previous year. Thus, the area of Year 3 Lucerne was less than or equal to the Year 2 Lucerne, which in turn was less than the Year 1 Lucerne. The area of Year 1 lucerne has to be less than or equal to the establishment phase lucerne. The maximum area of lucerne from June to December is 60 ha, with 40 ha the maximum area from January to May (this is due to the need to plough out Year 3 lucerne during this period).

Owing to the risks associated with growing annual horticultural crops and their high variable costs, the co-operator placed a limit of 60 ha on the area of these crops grown within a year. As two annual horticultural crops can be grown on the same area of land this constraint is equivalent to placing a 30 ha limit on the area of annual horticultural crops that can be grown within each season (July to December and January to June).

Licensing restrictions on the scale of a redclaw activity limits the maximum area of redclaw ponds to 4 ha (40 x 1000 square metre ponds). The maximum area of grapes is 10 ha, the largest area the co-operator is prepared to plant owing to the risk associated with this activity. The minimum area of grapes is set at 2 ha - this is the area currently established on 'Vorelle'.

The maximum area of SDI that can be established is 80 ha. The fixed costs for each quarter are deducted from the RHS of the working capital constraints. There is an overdraft limit in each quarter of $100 000. The announced allocation of water is determined annually as a percentage of the nominal allocation for 'Vorelle' and 'Lenora'. Water from the 50 ML dam on 'Vorelle' is also included within this constraint in the model - the level available is set at the same percentage as that used for the announced allocation. For both 'Vorelle' and 'Lenora' the announced allocation since 1990-91 has been 80 percent of the nominal allocation (see Table 2.1) - this figure was used to set the initial level at 772.8 ML.

Table 5.2: Constraint list for I P model

Constraint	Code		Initial Level	Unit
Non-arable land	NonALandC	≤	324	ha
Cultivable land July/Sep	CLandJul/Sep	≤	189	ha
Cultivable land Oct/Dec	CLandOct/Dec	≤	189	ha
Cultivable land Jan/Mar	CLandJan/Mar	≤	189	ha
Cultivable land Apr/May	CLandApr/May	≤	189	ha
Cultivable land June	CLandJun	≤	189	ha
Spray Irrigated Lucerne				
Year 1/Establishment tie	LucSpIrrYr1/LucSpIrrEst tie	≤	0	ha
Year 2/Year 1 tie	LucSpIrrYr2/LucSpIrrYr1 tie	≤	0	ha
Year 3/Year 2 tie	LucSpIrrYr3/LucSpIrrYr2 tie	≤	0	ha
SDI Lucerne				
Year 1/Establishment tie	SDILucYr1/SDILucEst tie	≤	0	ha
Year 2/Year 1 tie	SDILucYr2/SDILucYr1 tie	≤	0	ha
Year 3/Year 2 tie	SDILucYr3/SDILucYr2 tie	≤	0	ha
Maximum lucerne area Jul/Dec	MaxLucJul/Dec	≤	60	ha
Maximum lucerne area Jan/May	MaxLucJan/May	≤	40	ha
Maximum lucerne area June	MaxLucJun	≤	60	ha
Maximum annual horticultural crops Jul/Dec	MaxHortiCropsJul/Dec	≤	30	ha
Maximum annual horticultural crops Jan/May	MaxHortiCropsJan/May	≤	30	ha
Maximum annual horticultural crops June	MaxHortiCropsJun	≤	30	ha
Maximum redclaw area	MaxRClaw	≤	4	ha
Maximum grape area	MaxGrapeArea	≤	10	ha
Maximum SDI area Jul/Sep	MaxSDIAreaJul/Sep	≤	80	ha
Maximum SDI area Oct/Dec	MaxSDIAreaOct/Dec	≤	80	ha
Maximum SDI area Jan/Mar	MaxSDIAreaJan/Mar	≤	80	ha
Maximum SDI area Apr/May	MaxSDIAreaApr/May	≤	80	ha
Maximum SDI area Jun	MaxSDIAreaJun	≤	80	ha
Working capital Jul/Sep	WCapJul/Sep	≤	-$31 500	
Working capital Oct/Dec	WCapOct/Dec	≤	-$29 500	
Working capital Jan/Mar	WCapJan/Mar	≤	-$29 500	
Working capital Apr/Jun	WCapApr/Jun	≤	-$29 500	
Overdraft limit Jul/Sep	OverdrftMaxJul/Sep	≤	$100 000	
Overdraft limit Oct/Dec	OverdrftMaxOct/Dec	≤	$100 000	
Overdraft limit Jan/Mar	OverdrftMaxJan/Mar	≤	$100 000	
Overdraft limit Apr/Jun	OverdrftMaxApr/Jun	≤	$100 000	
Announced allocation of water	Water	≤	772.8	ML
Available labour Jul/Sep	LabourJul/Sep	≤	2190	hrs
Available labour Oct/Dec	LabourOct/Dec	≤	2190	hrs
Available labour Jan/Mar	LabourJan/Mar	≤	2190	hrs
Available labour Apr/Jun	LabourApr/Jun	≤	2190	hrs
Casual labour	HireLabour	≤	5475	hrs
Harvest limit on casual labour	LimHireLabHarv	≤	0	hrs
Minimum grape area	MinGrapeArea	≥	2	ha
Traditional horticulture Spring/Autumn tie	TradHorSpAu tie	=	0	ha

The total amount of permanent labour available is 9590 hours annually. Of this, it was assumed that overhead labour demand (labour required for maintenance that is not directly related to specific activities) is equal to one person for 2 days per week at 8 hours per day (832 hours annually) Thus the permanent labour available for activities is 8758 hours. It was assumed in the model that this labour was equally divided between each quarter - resulting in approximately 2190 hours per quarter of permanent labour being available for use in act vities.

The co-operator believes that casual labour supply is currently unlimited with his existing cropping system. Currently two or three people are employed at a time for 4 to 5 hours for harvesting of annual horticultural crops. This casual labour is assumed to be available all year. This is equivalent to 5475 hours which was the initial level used for the RHS for the casual labour constraint in the LP model. A constraint was included to limit the use of casual labour to the harvest of horticultural crops and redclaw, and pruning and thinning in grapes.

The final constraint within the model is a crop sequence linkage which ensures that if an area of traditional annual horticultural crop is grown in spring, then this area is reused in autumn for a similar crop. This ensures that semi-permanent drip irrigation tape is used for two consecutive crops before being discarded.

5.2.4 The LP Matrix

The LP matrix is detailed in Appendix 11. Coefficients with a negative sign represent a receipt of the row resource, positive signs represent resource use. The working capital generated within a quarter by each activity was found by subtracting the receipts for that quarter from the costs incurred within the quarter. This required determination of the timing of all receipts and expenditures for each activity.

The labour required for each activity within a quarter was estimated from work rates for machinery and irrigation operations, and harvest rates for horticultural crops. This labour demand was allocated to the appropriate quarters. The HireLabour constraint and HireLabour activities for each quarter enables casual labour to be employed to add to the quarterly labour pool. This casual labour was limited to use in the harvest of

horticultural crops and redclaw, and in pruning and thinning of grapes by estimating these requirements and entering them as negative coefficients within the matrix for each activity in which they can be employed.

The overdraft facility can be used to provide working capital within each quarter, up to a limit of $100 000. The cost of this overdraft facility is 13 percent, which is entered within the matrix as a quarterly cost of $1.0325 for each dollar borrowed.

5.3 Implementation

The model was developed within an Excel V5 spreadsheet. It was initially intended to use the Solver add-in within Excel V5 solve the LP model. However, it was found that Solver was unable to produce consistent results so the What's*Best!* add-in was used instead. The reason for inconsistent results with Solver is unknown, but could be related to size of the model developed. What's*Best!* had no difficulties with solution of the model.

Other dedicated LP software packages could have been used to solve the model (for example LINDO or GAMS). However, it was hoped that the approach used in this study could be adapted for use at the farm level to aid future planning and decision making under conditions of declining water supplies. This process would be aided by development and solution of the model in Excel, owing to its wide availability and use within the farming community (see Harris, 1996). The use of specific LP packages would hinder this owing to their unavailability at the farm level.

5.4 Solution

5.4.1 Initial Optimal Plan

The initial optimal farm plan is summarised in Table 5.3. It can be compared with the optimal farm plan pre-intensification (where there were no horticultural crops, SDI, grapes or redclaw activities available).

The maximum allowable area of lucerne is grown in both farm plans. Spray irrigated navy beans are grown in both plans with a greater area pre-intensification. The area of SDI navy beans is 10 ha following intensification. The available cultivable land which cannot be irrigated is planted to raingrown mungbeans in both plans - at approximately 105.8 ha in the pre-intensification situation and 93 ha where intensification is possible.

Table 5.3: Comparison of optimal farm plans pre-intensification and post-intensification

Activity	Unit	Pre-intensification	Post-intensification
Spray Irrigated Lucerne	ha	60	
Raingrown mungbeans	ha	105.8	93
Breeding cattle	cows	65	65
SDI Lucerne	ha		60
Spray irrigated navy beans	ha	43.2	6.0
SDI navy beans	ha		10
Grapes	ha		2.0
Traditional Zucchinis (Spring)	ha		20
SDI Cucumbers (Spring)	ha		0.4
SDI Sweet corn	ha		12.1
SDI Zucchinis (Spring)	ha		9.6
SDI Zucchinis (Autumn)	ha		17.9
Redclaw	pounds		40
Working capital Jul/Sep to Oct/Dec	$	$74 825	$59 073
Working capital Oct/Dec to Jan/Mar	$	$62 786	$0
Working capital Jan/Mar to Apr/Jun	$	$37 058	$0
Borrowing Working capital Jul/Sep	$	$0	$0
Borrowing Working capital Oct/Dec	$	$0	$64 296
Borrowing Working capital Jan/Mar	$	$0	$0
Borrowing Working capital Apr/Jun	$	$0	$0
Hire labour Jul/Sep	hours	0	150
Hire labour Oct/Dec	hours	0	3483
Hire labour Jan/Mar	hours	0	0
Hire labour Apr/Jun	hours	0	1842
Operating profit	$	$241 794	$676 737

Horticultural crops are a feature of the optimal farm plan following intensification. Spring zucchinis grown traditionally, together with SDI zucchinis and SDI cucumbers at the same time account for 30 ha of cultivable land in spring, with a further 30 ha planted

to SDI zucchinis and SDI sweet corn in autumn. Grapes are forced into the optimal farm plan at the minimum required level of two hectares.

The maximum allowable number of redclaw ponds are included in the optimal farm plan. Both plans have the same number of breeding cattle which is to be expected as this is the only activity which uses the non-arable land on 'Conmurra'.

Working capital transfers were required in each quarter to fund activities in the pre-intensification farm plan. In the optimal farm plan with intensification, the transfer of working capital from the July/September quarter to October/December amounted to $59 073, with $64 296 of overdraft capital required in the second quarter. No overdraft capital was necessary in the pre-intensification farm plan. Prior to intensification, there was no demand for hired labour. With intensification, casual labour is hired up to the limit of 5475 hours.

The improvement in operating profit with the inclusion of SDI, annual horticultural crops, grapes and redclaw is close to triple that where these activities are not available - from $241 794 to $676 737.

5.4.2 Shadow prices

The dual values or shadow prices for the constraints in the optimal farm plan are summarised in Table 5.4. The shadow price provides information on the effect on total operating profit by making a change in the constraint. The shadow price can also be viewed as the maximum additional price the manager would be willing to pay to obtain more of the resources to maximise profit subject to the resource constraints (Lee et al.1990,p. 136). The shadow price is a marginal value, so that the shadow price for non-arable land of $63.43/ha is the maximum additional amount the manager is willing to pay annually for additional non-arable land above its current annual cost in order to maximise profit.

The upper and lower range for each shadow price indicates the valid range for which the shadow price is relevant. The lower range refers to the decrease in use or availability of a resource (the RHS of a constraint) needed before the shadow price changes. The

upper range is the increase in use or availability of a resource, or RHS side of a constraint, needed before the shadow price changes. For example, the non-arable land

Table 5.4: Shadow prices for selected constraints within the initial optimal farm plan

Constraint	Unit	Demand		Supply	Shadow Price	Upper Range	Lower Range
NonALandC	ha	24.00	<=	324	63.43	953.50	324
CLandJul/Sep	ha	96.00	<=	189	0	∞	93
CLandOct/Dec	ha	89.00	<=	189	228.21	4.03	56.73
CLandJan/Mar	ha	85.02	<=	189	0	∞	3.98
CLandApr/May	ha	85.02	<=	189	0	∞	3.98
CLandJun	ha	66.00	<=	189	0	∞	123
MaxLucJul/Dec	ha	60.00	<=	60	419.37	0	1.82
MaxLucJan/May	ha	40.00	<=	40	0	∞	0
MaxLucJun	ha	60.00	<=	60	410.98	0	0
MaxHortiCropsJul/Dec	ha	30.00	<=	30	444.42	0.53	1.85
MaxHortiCropsJan/May	ha	30.00	<=	30	1522.78	1.96	8.02
MaxHortiCropsJun	ha	0.00	<=	30	0	∞	30
MaxRClaw	ha	4.00	<=	4	21877.42	0.36	0.86
MaxGrapeArea	ha	2.00	<=	10	0	∞	8
MaxSDIAreaJul/Sep	ha	70.00	<=	80	0	∞	10
MaxSDIAreaOct/Dec	ha	80.00	<=	80	521.24	10	9.63
MaxSDIAreaJan/Mar	ha	80.00	<=	80	0	∞	0
MaxSDIAreaApr/May	ha	80.00	<=	80	46.84	0	10
MaxSDIAreaJun	ha	60.00	<=	80	0	∞	20
WCapJul/Sep	$	-3 500.00	<=	-31500	0	∞	59072.99
WCapOct/Dec	$	-37 0419.35	<=	-29500	0	∞	340919.3
WCapJan/Mar	$	-2 9500.00	<=	-29500	0	36863.91	66386.09
WCApApr/Jun	$	-13 0594.74	<=	-29500	0	∞	101094.7
OverdrftMaxJul/Sep	$	0.00	<=	100000	0	∞	100000
OverdrftMaxOct/Dec	$	6 296.45	<=	100000	0	∞	35703.55
OverdrftMaxJan/Mar	$	0.00	<=	100000	0	∞	100000
OverdrftMaxApr/Jun	$	0.00	<=	100000	0	∞	100000
Water	ML	772.80	<=	772.8	159.34	16.94	25.61
LabourJul/Sep	hrs	2 90.00	<=	2190	22.48	128.41	97.55
LabourOct/Dec	hrs	2 90.00	<=	2190	22.48	894.41	97.55
LabourJan/Mar	hrs	2 90.00	<=	2190	14.87	60.11	551.09
LabourApr/Jun	hrs	2 90.00	<=	2190	22.48	894.49	97.55
HireLabour	hrs	5 475.00	<=	5475	12.48	894.49	97.55
LimHireLabHarv	hrs	-4537.22	<=	0	0	∞	4537.22
MinGrapeArea	ha	2.00	=>	2	255.03	0.24	1.32

shadow price of $63.43/ha remains the same over the range zero to 1278 ha, as the lower range is 324 ha and the upper range 954 ha.

Non-binding constraints have a zero shadow price. The amount of available cultivable land is only a constraint in the October to December period, where its shadow price is $228/ha (with a valid range of 132.2 to 193 ha). The maximum area of lucerne is a binding constraint in June, and from July until December (with shadow prices of $411/ha and $419/ha respectively). The maximum horticultural crop constraint is binding from July until May. The shadow price of $444/ha applies to the July to December maximum horticultural crop constraint over a narrow range (28.15 to 30.53

ha). The shadow price for the maximum horticultural area constraint from January to May is greater - $1523/ha over a range of 21.98 to 31.96 ha.

The maximum area of redclaw is a binding constraint with very high shadow price of $2188/pond, over a range of 31 to 44 ponds. The maximum area of SDI is a binding constraint during October to December, and April to May ($521/ha and $47/ha respectively).

Water has a shadow price of $159/ML (over a range of 747 to 790 ML). Permanent labour is a binding constraint in all quarters, with the shadow price ranging from $14.87 to $22.48/hour. The shadow price for hired labour is $12.48/hour over a range of 5377 to 6369 hours.

5.5 Sensitivity analysis

Sensitivity analysis is necessary to study changes in the key parameters within the LP model and the sensitivity of the initial optimal solution to these changes. These key parameters are the costs, prices, resource supplies and input-output coefficients which appear important in determining the optimal solution but there is uncertainty or variability about their true value (Dent et al. 1986, p. 136). Only one parameter is varied at a time in sensitivity analysis

5.5.1 Announced Water Allocation

The announced water allocation used within the model was increased to 100 percent and decreased to 60 percent of nominal allocation to ascertain the effect upon the optimal farm plan. The results of this analysis are presented in Table 5.5.

When the announced allocation is 100 percent of the nominal allocation, 60 ha of SDI lucerne is grown from June to December. At the same time spring grown cucumbers (3.2 ha) and zucchinis (16.8 ha) are grown on the remaining 20 ha of SDI. There is also 10 ha of traditionally grown zucchinis (bringing the total area of annual horticultural crops up to the maximum allowable of 30 ha). From January to May, the area of SDI lucerne is reduced to 40 ha (as Year 3 lucerne has been ploughed out). This enables the

SDI area to be used for sweet corn (22.5 ha) and zucchinis (7.5 ha). There are 10 ha of SDI not utilised during this period. There are 59.7 ha of spray irrigated navy beans and 53.3 ha of raingrown mungbeans grown. The maximum

Table 5.5: The impact of changes in the announced water allocation upon the optimal farm plan

		Announced allocation (as % of nominal)		
Activity	Unit	100	80	60
SDI Lucerne	ha	60	60	40.9
Spray irrigated navy beans	ha	59.7	6.0	0
SDI navy beans	ha	0	10.0	9.1
Raingrown mungbeans	ha	53.3	93	112.1
Cattle	cows	65	65	65
SDI Cucumbers (Spring)	ha	3.2	0.4	0.7
SDI Sweet corn	ha	22.5	12.1	9.9
Traditional Zucchinis (Spring)	ha	10	20	0
SDI Zucchinis (Spring)	ha	16.8	9.6	29.3
SDI Zucchinis (Autumn)	ha	7.5	17.9	20.1
Grapes	ha	2.0	2.0	2.0
Redclaw	ponds	40	40	40
Operating profit	$	$697 991	$676 737	$629 476
Shadow prices				
Water	$/ML	$105	$159	$314
MaxLucJul/Dec	ha	$0	$419	$0
MaxLucJan/May	ha	$0	$0	$0
MaxLucJun	ha	$1409	$411	$0
MaxHorticropsJul/Dec	$/ha	$787	$444	$612
MaxHorticropsJan/May	$/ha	$1511	$1522	$1081
MaxSDIAreaJul/Sep	$/ha	$0	$0	$0
MaxSDIAreaOct/Dec	$/ha	$518	$521	$53
MaxSDIAreaJan/Mar	$/ha	$0	$0	$0
MaxSDIAreaApr/May	$/ha	$0	$47	$0
MaxSDIAreaJun	$/ha	$0	$0	$0
MaxRclaw	$/ha	$22 912	$21 877	$18 955
MaxGrapeArea	$/ha	$0	$0	$0
HireLabour	$/hour	$12.48	$12.48	$12.48

allowable number of redclaw ponds enter the plan (40 ponds), as well as the minimum area of grapes (2 ha). A cattle breeding activity of 65 cows is undertaken on 'Conmurra'. The operating profit is estimated to be $697 991.

With a nominal allocation at 80 percent, the area of SDI lucerne remains at 60 ha in July to December, and 40 ha from January to May. In spring, there is a fall in the area of SDI zucchinis (9.6 ha) and cucumbers (0.4 ha) - 10 ha of SDI are not utilised. Traditional zucchinis increase to 20 ha in spring. From January to May there is a large reduction in the area of spray irrigated navy beans to 6.0 ha, and SDI navy beans enters at 10 ha. The area of SDI sweet corn falls to 12.1 ha, with SDI zucchinis increasing to 17.9 ha. The area of raingrown mungbeans increases to 93 ha. There is no change in the breeding cattle activity, or the scale of the redclaw and grape activities. The operating profit decreases to $676 737, a fall of around three percent.

A further fall in the announced allocation (to 60 percent) results in a decline in the area of SDI lucerne to 40.9 ha (with an area of 27.3 ha from January to May). There is a slight increase in the area of SDI cucumbers in spring (to 0.7 ha), but a large increase in the area of SDI zucchinis (to 29.3 ha). Around 9 ha of SDI is not utilised during July to December. Traditional zucchinis are no longer grown. From January to May, the area of SDI sweet corn falls to 9.9 ha and SDI zucchinis increase to 20.1 ha. The area of raingrown mungbeans increases further to 112.1 ha. The cattle breeding, redclaw and grape activities continue at the same level. The operating profit is $629 476, a fall of nearly 10 percent compared to a 100 percent announced allocation.

The shadow price of water increases with the decline in availability - from $105/ML to $314/ML. The shadow prices for the maximum horticultural crop area, maximum redclaw area and hired labour suggest that a higher operating profit at all levels of available water is possible if these constraints were relaxed. At the higher levels of available water, the lucerne area limitation may also be restricting operating profit. The maximum SDI area available also limits operating profit during the October to December quarter (for 100 and 80 percent announced allocations, the shadow prices are

$518/ha and $521/ha respectively). The shadow price for this constraint falls significantly when the announced allocation falls to 60 percent (to $53/ha).

5.5.2 Maximum lucerne area

The impact of relaxing the maximum lucerne area constraint was investigated under declining groundwater supplies in both pre- and post-intensification situations. The results of this are presented in Table 5.6.

Spray irrigated lucerne is a significant component of the optimal farm plan in the pre-intensification situation. As the level of available groundwater declines so too does the area of lucerne grown, from 51 percent of the cultivable area to 36 percent. At the same time, the area of raingrown mungbeans expands. The fattening of weaner heifers on irrigated oats only enters the optimal farm plan when the available water is at its lowest. The operating profit falls from $293 406 to $206 538 with a fall in the announced allocation from 100 to 60 percent of the nominal allocation (a fall of 30 percent).

The shadow price for water in the pre-intensification situation increases from $223/ML at an announced allocation of 100 and 80 percent to $230/ML with a fall to 60 percent of the nominal allocation. The high shadow prices for horticultural crops, redclaw and grapes indicates the potential increase in operating profit possible if these activities were to enter the optimal farm plan. The increase is evident in the post-intensification situation in Table 5.6.

The maximum allowable area of SDI is installed and used for the production of lucerne, with sweet corn and zucchinis planted in autumn following the third year of lucerne. Lucerne is a significant crop in the optimal farm plan, but declines as the available water supply falls (a decline of 53 percent from 87.9 ha to 40.9 ha with a fall in the announced allocation to 60 percent of the nominal level). At an 80 percent announced allocation, a small area of SDI watermelons enters the plan together with 18.3 ha of spring grown SDI zucchinis. The traditionally grown zucchinis falls to 11.1 ha. There is an increase in autumn grown SDI zucchinis to 19.8 ha.

Table 5.6: The impact of changes in the announced water allocation upon the optimal farm plan with all activities possible and no limit on lucerne

		Pre-intensification			Post-intensification		
		Announced allocation (as % of nominal)			Announced allocation (as % of nominal)		
Activity	Unit	100	80	60	100	80	60
Spray irrigated lucerne	ha	96.6	77.3	56.6	7.9		
SDI lucerne	ha				80.0	61.1	40.9
Spray irrigated oats	ha			17.9			
SDI navy beans	ha						9.1
Raingrown mungbeans	ha	92.4	111.7	132.4	65.1	91.9	112.1
Cattle	cows	65	65	65	65	65	65
SDI cucumbers (Spring)	ha						0.7
SDI sweet corn	ha				10.2	10.2	9.9
Traditional watermelons (Spring)	ha				2.5		
SDI watermelons (Spring)	ha					0.6	
Traditional zucchinis (Spring)	ha				27.5	11.1	
Traditional zucchinis (Autumn)	ha				3.3		
SDI zucchinis (Spring)	ha					18.3	29.3
SDI zucchinis (Autumn)	ha				16.5	19.8	20.1
Grapes	ha				2.0	2.0	2.0
Redclaw	ponds				40	40	40
Operating profit	$	$293 406	$250 260	$206 538	$724 371	$683 315	$629 476
Shadow prices							
Water	$/ML	$223	$223	$230	$184	$241	$314
MaxHorticropsJul/Dec	$/ha	$9826	$9826	$10 847	$325	$210	$612
MaxHorticropsJan/May	$/ha	$10 117	$10 117	$10 049	$958	$1069	$1081
MaxSDIAreaJul/Sep	$/ha	$0	$731	$0	$0	$0	$0
MaxSDIAreaOct/Dec	$/ha	$1744	$0	$0	$814	$521	$53
MaxSDIAreaJan/Mar	$/ha	$511	$0	$0	$0	$223	$0
MaxSDIAreaApr/May	$/ha	$0	$511	$3092	$517	$0	$0
MaxSDIAreaJun	$/ha	$0	$27	$0	$11	$0	$0
MaxRclaw	$/ha	$34 595	$34 595	$35 874	$21 339	$20 239	$18 955
MaxGrapeArea	$/ha	$8383	$8383	$8812	$0	$0	$0
HireLabour	$/hr	$0	$0	$0	$12.90	$12.90	$12.48

At 60 percent announced allocation the area formerly planted to SDI lucerne is replaced with spring grown SDI cucumbers (0.7 ha) and SDI zucchinis (29.3 ha). In autumn, SDI sweet corn (9.9 ha), SDI zucchinis (20.1 ha) and 9.9 ha of SDI navy beans are grown. As in the pre-intensification situation the area of raingrown mungbeans grown increases as the water resource declines. Grapes are forced into the plan at 2.0 ha owing to the minimum area of grapes constraint Redclaw enter the optimal farm plan at all water levels at the maximum allowable level of 40 ponds.

The operating profit level ranges from $724 371 to $629 476 with a fall in the announced allocation from 100 to 60 percent, a two to three-fold increase over the pre-intensification situation.

The water shadow price rises from $223/ML to $230/ML as water availability falls in the pre-intensification situation. For the post-intensification situation, the shadow price increase is greater, from $184 to $314/ML. The shadow prices for the maximum horticultural and redclaw areas, and the hiring of labour, suggest increases in operating profit are possible with relaxation in these constraints.

5.5.3 Maximum annual horticultural area

Table 5.7 presents the results of relaxing the constraint limiting the area of annual horticultural crops. The impact of this is a significant reduction in the area of lucerne within the optimal farm plan, and the exclusion of raingrown mungbeans and spray irrigated navy beans. The maximum area of SDI is used for Spring grown watermelons and lucerne from July to December, with traditionally grown watermelons (26.6 ha) and zucchinis (9 ha) also grown. In the January to May period 72.6 ha of SDI watermelons and 103 ha of traditional watermelons. Grapes are once again in the optimal plan at the lowest possible level of 2 ha, and redclaw crayfish at the maximum of 40 ponds.

The operating profit is $748 036, an increase of 11 percent over the operating profit where the maximum annual horticultural crop area constraint is enforced. Also, the farm business utilises the overdraft facility during the July/September quarter - due to

Table 5.7: The impact on the optimal farm plan of relaxing the constraint on the maximum area of annual horticultural crops

Activity	Unit	Limited horticulture	Unlimited horticulture
Raingrown mungbeans	ha	93	
Breeding cattle	cows	65	65
SDI lucerne	ha	60	11.0
Spray irrigated navy beans	ha	6.0	
Grapes	ha	2.0	2.0
Traditional watermelons (Spring)	ha		26.6
Traditional watermelons (Autumn)	ha		103
Traditional zucchinis (Spring)	ha	20	9.0
SDI cucumbers (Spring)	ha	0.4	
SDI sweet corn	ha	12.1	
SDI watermelons (Spring)	ha		69.0
SDI watermelons (Autumn)	ha		72.6
SDI zucchinis (Spring)	ha	9.6	
SDI zucchinis (Autumn)	ha	17.9	
Redclaw	pounds	40	40
Working capital Jul/Sep to Oct/Dec	$	$59 073	$0
Working capital Oct/Dec to Jan/Mar	$	$0	$143 580
Working capital Jan/Mar to Apr/Jun	$	$0	$0
Borrowing Working capital Jul/Sep	$	$0	$100 000
Borrowing Working capital Oct/Dec	$	$64 296	$0
Borrowing Working capital Jan/Mar	$	$0	$0
Borrowing Working capital Apr/Jun	$	$0	$0
Hire labour Jul/Sep	hours	150	0
Hire labour Oct/Dec	hours	3483	2652
Hire labour Jan/Mar	hours	0	0
Hire labour Apr/Jun	hours	1842	2823
Shadow prices			
Water	$/ML	$159	$228
MaxSDIAreaJul/Dec	$/ha	$0	$0
MaxSDIAreaOct/Dec	$/ha	$521	$645
MaxSDIAreaJan/Mar	$/ha	$0	$0
MaxSDIAreaApr/May	$/ha	$47	$517
MaxSDIAreaJun	$/ha	$0	$0
WCapJul/Sep	$/$	$0	$0.25
OverdrftMaxJul/Sep	$/$	$0	$0.25
HireLabour	$/hr	$12.48	$26.18
Operating profit	$	$676 737	$748 036

the loss of income from the reduction in lucerne area and high cost of such a large increase in the area of horticultural crops which have high variable costs.

The shadow price for water increases to $228/ML. The shadow price for July/September working capital and overdraft is $0.25/dollar required. For the overdraft, this suggests that it would be profitable to pay an annual interest charge up to 38 percent to obtain additional financing at this time. The shadow price for hired labour has also increased significantly, from $12.48 to $26.18/hour over the range from 4517 to

6666 hours). With casual labour costing $10/hour, a significant increase in operating profit is likely if more casual labour can be employed.

5.5.4 Casual labour

The co-operator initially indicated that casual labour availability was not a constraint to the existing farm plan. Given the possibility of a significant horticultural component in the optimal plan, it was decided to investigate the effect of removing it as a constraint. This was achieved by increasing the limit on hired labour to 100000 hours, while still retaining the constraint which limited hired labour use to the harvest operations in horticultural and redclaw activities, and pruning, thinning and harvest operations in grapes. The results of this analysis are presented in Table 5.8, in comparison with the optimal farm plan at 80 percent announced allocation.

With the hiring of labour no longer a constraint, there is a significant increase in the area of cucumbers within the optimal farm plan (an increase to 60 ha comprising 19.8 ha of traditional cucumbers and 10.2 ha SDI cucumbers in Spring, and 30 ha of SDI cucumbers in Autumn). This is at the expense of sweet corn and zucchinis which were in the original optimal plan as they had low labour requirements compared to cucumbers. The area of grapes increases to the maximum allowable area of 10 ha. These activities have a high labour demand which is reflected in the increase in its use to 26404 hours (with 14 371 hours in the October/December quarter and 12 033 hours in the April/June quarter). Permanent labour is also fully utilised during these periods.

The operating profit increases to $397 782, an increase of 33 percent over that for the optimal farm plan where only limited casual labour is available. The shadow price for water is $208/ML, with those for the maximum area of horticultural crops increasing to very high levels ($5693 and $6480/ha for the Jul/Dec and Jan/May period). There is also a significant increase in the shadow price for the redclaw activity (to $31 188/ha or $3119/pond).

Table 5.8: The impact on the optimal farm plan of relaxing the hired labour constraint

Activity	Unit	Limited labour	Unlimited labour
SDI lucerne	ha	60	60
Spray irrigated navy beans	ha	6.0	
SDI navy beans	ha	10.0	9.8
Raingrown mungbeans	ha	93	85
Breeding cattle	cows	65	65
Grapes	ha	2.0	10.0
Traditional cucumbers (Spring)	ha		19.8
SDI cucumbers (Spring)	ha	0.4	10.2
SDI cucumbers (Autumn)	ha		30.0
SDI Sweet corn	ha	12.1	
Traditional zucchinis (Spring)	ha	20.0	
SDI zucchinis (Spring)	ha	9.6	
SDI zucchinis (Autumn)	ha	17.9	
Redclaw	pounds	40	40
Working capital Jul/Sep to Oct/Dec	$	$59 073	$0
Working capital Oct/Dec to Jan/Mar	$	$0	$0
Working capital Jan/Mar to Apr/Jun	$	$0	$46 469
Borrowing Working capital Jul/Sep	$	$0	$13 409
Borrowing Working capital Oct/Dec	$	$64 296	$0
Borrowing Working capital Jan/Mar	$	$0	$0
Borrowing Working capital Apr/Jun	$	$0	$0
LabourJul/Sep	hours	2190	1454
LabourOct/Dec	hours	2190	2190
LabourJan/Mar	hours	2190	1380
LabourApr/Jun	hours	2190	2190
Hire labour Jul/Sep	hours	150	0
Hire labour Oct/Dec	hours	3483	14 371
Hire labour Jan/Mar	hours	0	0
Hire labour Apr/Jun	hours	1842	12 033
Shadow prices			
Water	$/ML	$159	$208
MaxHortiCropsJul/Dec	ha	$444	$5693
MaxHortiCropsJan/May	ha	$1523	$6480
MaxSDIAreaJul/Dec	$/ha	$0	$0
MaxSDIAreaOct/Dec	$/ha	$521	$511
MaxSDIAreaJan/Mar	$/ha	$0	$0
MaxSDIAreaApr/May	$/ha	$47	$0
MaxSDIAreaJun	$/ha	$0	$0
MaxRclaw	pounds	$21 877	$31 188
MaxGrapeArea	ha	$0	$4928
LabourJul/Sep	hours	$22.48	$0
LabourOct/Dec	hours	$22.48	$10
LabourJan/Mar	hours	$14.87	$0
LabourApr/Jun	hours	$22.48	$10
HireLabour	$/hr	$12.48	$0
Operating profit	$	$676 737	$897 782

5.6 Summary

The LP model demonstrated the potential for intensification of the farm plan to significantly increase the operating profit of the farm business under existing water allocations. There was a threefold increase in operating profit.

With intensification, the optimal farm plan results in 80 ha of SDI being installed. Of this, 60 ha is planted to lucerne, and the balance to annual horticultural crops. The maximum allowable area of annual horticultural crops are grown, with half in spring (20 ha of traditional zucchinis, 9.6 ha of SDI zucchinis and the remaining 0.4 ha to cucumbers). The remaining 30 ha of horticultural crops is planted to SDI zucchinis and SDI sweet corn in autumn. The maximum possible number of redclaw ponds also enters the farm plan. Only the minimum area of grapes enters the farm plan. Navy beans are the only spray irrigated crop within the plan. There remains a significant area of raingrown mungbeans, and there is no change in the scale of the breeding cattle activity.

Intensification of the farm requires the use of an overdraft facility during the October/December quarter, and the maximum allowable quantity of casual labour is hired for the harvest horticultural crops and redclaw crayfish. It is also used by the table grape activity for pruning and thinning.

A further decline in the announced allocation to 60 percent of the nominal results in a loss in the area of SDI lucerne grown (a reduction of 32 percent to 40.9 ha). The area of annual horticultural crops remains at 60 ha. However, there is an increase in the area of SDI zucchinis in both spring and autumn. Traditionally grown horticultural crops exit the optimal plan, but there is no change in the scale of the table grape or redclaw activity. Spray irrigated crops are no longer included.

If the amount of available water were to increase through recharge, the optimal farm plan contains the maximum allowable area of SDI lucerne and annual horticultural crops. The scale of the redclaw crayfish, table grape and breeding cattle activities remains the same. There is a significant increase in the area of navybeans grown, and a

consequent reduction in the area of raingrown mungbeans. There is only a 3 percent increase in the operating profit over that where the announced allocation is 80 percent of the nominal allocation.

The shadow price for water increases from $105/ML to $314/ML with the decline in its availability. When compared with the current charge for allocation water of $9.75/ML (see Appendix 5), it suggests that the resource is currently undervalued. The current excess water charges of $175.50/ML for use exceeding 50 ML above the announced allocation more closely aligns with these shadow prices. Current water pricing is likely to be an inadequate incentive in the adoption of SDI and activity intensification. It has been the reduction in the resource availability which has prompted this adoption in recent years.

The impact of relaxing the maximum lucerne and maximum annual horticultural area constraints demonstrated the importance of these activities in maximising operating profit. Where the area of lucerne is unrestricted, and there is a full allocation of water, lucerne is grown on 87.9 ha (80 ha using SDI). With the nominal allocation at 80 percent it was of interest to see the optimal area of lucerne fall to a level close to the 60 ha imposed as a constraint by the co-operator in the original model formulation. Where the area of annual horticultural crops is unrestricted, there is a significant increase in the area of horticultural crops grown (from 60 ha to 280 ha), with the less labour intensive horticultural crops (for example watermelons) replacing crops like zucchinis. The resultant increase in operating profit is 11 percent, but no allowance for the change in risk is included in this.

The availability of casual labour also impacts upon the optimal farm plan and its profitability. Where it is no longer a constraint, there is a large increase in the area of cucumbers (a labour intensive crop from 12.5 to 60 ha, and table grapes expand to the maximum allowable area of 10 ha.

The results of the LP solution and sensitivity testing were used to select the activities and constraints included within the MLP model outlined in Chapter 6.