6. MLP Model

6.1 Introduction

The static LP model showed the potential for improved profitability of the case study farm with the use of SDI, annual horticultural crops and redclaw. Inclusion of the activities identified by the static LP model as having potential for improving operating profit requires capital investment. This capital is provided from cash surpluses generated from within the farm business from preceding years and borrowings. The planning problem is one of determining the most appropriate activity mix and investment decisions in order to maximise the objective function in the long run.

MLP is an appropriate planning tool in dealing with this planning problem, given the mix of possible activities and investment decisions available to the case study farm managers.

This chapter presents the structure of the MLP model and discusses the results obtained in the base run. It explores the effects of changes in critical variables such as water allocation, credit availability and casual labour constraints upon the optimal farm plan and operating profit.

6.2 Model Specification

6.2.1 The objective function

The objective function for the model is the maximisation of operating profit for the farming business as a whole over the planning period. It was intended to examine the optimal farm plan and associated activity mix and investment decisions over a 10 year time period. However, the size of the model and the limitation of What's*Best!* to 16 000 numeric cells restricted the planning horizon to five years.

6.2.2 Activities

From the static LP model results, the following activities were identified as likely to enter the optimal farm plan where the announced allocation was 80 percent of the nominal allocation, with no limit to the hiring of casual labour:

- SDI lucerne
- SDI navy beans
- raingrown mungbeans
- breeding cattle
- traditional and SDI cucumbers
- table grapes
- redclaw crayfish

In the pre-intensification situation the optimal farm plan included some of these activities, together with spray irrigated lucerne and navy beans. Where the hiring of labour was considered a constraint, traditional and SDI zucchinis, and SDI sweet corn also entered the optimal plan. On reflection, the co-operator felt that sweet corn could not be considered a practical option owing to its high insecticide use and the need to purchase harvesting equipment specific to this crop.

This information was used to reduce the list of possible activities so that reasonable size MLP model could be formulated. The spray irrigated lucerne activities were combined to produce two activities - a spray irrigated lucerne activity combining equal areas of first, second and third year lucerne, followed by either traditional cucumbers in autumn or spray irrigated navy beans. For SDI lucerne, there were two possible activities in the third year, either cucumbers or navy beans after the lucerne was ploughed out in December. The establishment phase in SDI lucerne was combined with first year SDI lucerne.

The breeding cattle activity on 'Conmurra' is unaffected by other changes within the farm business - there are always 65 cows in this activity which contributes $22 490 to the annual working capital. This activity was included within the MLP model via this contribution to annual working capital.

The grape and redclaw activities can begin in any year within the model. The yields of these activities increase over time until full production is achieved. This occurs in the fourth year after establishment (see Tables 4.4 and 4.12 respectively). This significantly adds to the size of the model. For example, in Year 5 there are five possible grape activities, those established in any of the preceding years plus the current one. Table 6.1 shows the activities and their codes used in the formulation of the MLP model.

Table 6.1: Activity list for MLP model

CODE	Detail
LucSI123TradCuc,n[a]	Spray irrigated lucerne (3 years with cucumbers following third year lucerne)
LucSI123NavSI,n	Spray irrigated lucerne (3 years with cucumbers following third year lucerne)
NavSI,n	Spray irrigated navy beans
SDINav,n	SDI navy beans
MunRG	Raingrown mungbeans
TradCuc,n	Traditional cucumbers
SDICuc,n	SDI cucumbers
SDILy[b],n	SDI lucerne
SDILy,Cuc,n	SDI Lucerne followed by cucumbers within the same year
SDILy,Nav,n	SDI Lucerne followed by navy beans within the same year
Grapesy,n	Grapes
RClawy,n	Redclaw
InvSDI,n	Investment in SDI installation
InvShed/Flift,n	Investment in shed and forklift
InvCroom,n	Investment in coolroom
InvAnnHEq,n	Investment in annual horticultural equipment
InvGrpFC,n	Investment in grape fixed costs
InvGrpEst,n	Investment in grape establishment
InvRclawFC,n	Investment in Redclaw fixed costs
InvRclawEst,n	Investment in Redclaw establishment
BWCap,n	Borrowing of working capital
BInvCap,n	Borrowing of investment capital
XFERWC,IC,n	Transfer of working capital to investment capital
HLab,n	Hiring labour
InvXWCap,n	Investment of excess working capital
PTI,n	Pre-tax income
CS,n	Cash surplus (after tax)
INW	Increase in Net Worth

[a] n is the year number

[b] y is the age of perennial investment since first installed

There are several investment activities available to the case study farm. Their implementation is necessary before certain production activities can be undertaken. The details of these investments and associated production activities are presented in Table 6.2.

Table 6.2: Details of investment activities incorporated in the MLP

Code	Details	Cost	Activities
InvShed/Flift	Packing shed, forklift	$15 200	Annual horticulture Table grapes Redclaw[a]
InvCroom	Coolroom	$25 000	Annual horticulture Table grapes
InvAnnHEq	Melon trailer, washer and table	$6500	Annual horticulture
InvGrpFC	Mister, crates and sundries	$5500	Table grapes
InvRclawFC	Feedblower, testing equipment, harvesting equipment, other costs	$17 505	Redclaw
InvSDI	SDI Installation	$1966/ha	All SDI activities
InvGrpEst	Grape establishment	$16 462/ha	Table grapes
InvRclawEst	Redclaw establishment	$58 945/10 ponds	Redclaw

[a] For the MLP model it was decided to include the shed and forklift as requirements for the redclaw activity - in the DCF analysis presented in Appendix 10 these have not been included in the capital cost

The first five investment activities in Table 6.2 were specified as binary integers, as they are necessary for their associated activities to enter the optimal solution. One of the problems in specifying some activities as taking only integer values in the solution, is that the dual values cannot be meaningfully interpreted.

The capital related activities included:

- the borrowing of working capital (BWCap) which was limited by an overdraft facility of $100 000. The annual interest cost was 13 percent.
- the borrowing of investment capital (BInvCap) with an annual interest cost of 12 percent.
- an activity for the transfer of excess working capital (XFERWC) to the investment capital activity.
- an investment activity for excess working capital (invXWCap) which allowed it to earn 5 percent interest p.a.

The coefficients entered into the BInvCap column were based on the approach outlined by Dent et al (1986, p. 183-7). In Year 1, the interest component was entered as 0.12 in the Pre-tax income tie row, and the principal component of the payment was found by subtracting 0.12 from the amortisation factor 0.27741 (it was assumed that money borrowed for investment has a term of 5 years). The coefficient for principal payments was thus 0.15741 in the first year of a loan, and was entered in the Income allocation row.

The hiring of casual labour to supplement permanent labour was a further activity included within the model. The final two activities were pre-tax income (PTI) and an after-tax cash surplus (CS).

6.2.3 Constraints

The constraints used are summarised in Table 6.3. The constraints are largely self-explanatory. The initial RHS level for the working capital constraint of $22 490 is the annual working capital provided to the farm business by the 65 breeding cows stocked on 'Conmurra'. The scale of the breeding activity always remains at the same level as it is the only activity which uses non-arable land.

A series of investment permission constraints were required in order for SDI, annual horticultural crops, table grapes and redclaw crayfish activities to be undertaken. The overdraft limit was $100 000 each year. The announced water allocation was set at 80 percent of the nominal allocation in each year of the model. Permanent labour available for activity related purposes was set at 8760 hours annually. Hired labour available was set at 100 000 hours annually so there was no constraint on the optimal plan. Annual fixed costs of $96 000 were paid from the pre-tax income. A marginal rate of tax of 29 cents in the dollar was used to convert the pre-tax income to a cash surplus for transfer from year to year, after allowance for $24 000 in annual living costs.

As with the static LP model, there were limitations on the maximum allowable areas of SDI, annual horticultural crops, table grapes and redclaw crayfish activities. The final constraint was for profit accumulation over the MLP. This allowed for the increase in net worth of the optimal farm plan over the time period of the MLP model.

Table 6.3: Constraint list for MLP model

Constraint	Code		Initial Level	Unit
Capital investment in year n	CapInv,n	≤	$0	$
Working capital in year n	WCap,n	≤	$22490	$
Maximum borrowing allowed in year n	MaxBorrow,n	≤	$0	$
Cultivatable land in year n	CLand,n	≤	189	ha
Permission to grow 2nd year SDI lucerne in year n after 1st year SDI lucerne in previous year	Perm1SDILuc2,n	≤	0	ha
Permission to grow 3rd year SDI lucerne and SDI cucumbers or SDI navy beans in year n after 2nd year SDI lucerne in previous year	Perm2SDILuc3CucNav,n	≤	0	ha
Permission to grow SDI lucerne, SDI cucumbers or SDI navy beans in year n following investment in SDI in this or earlier years	Perm1SDILuc1CucNav,n	≤	0	ha
Permission to grow cucumbers after investment in shed & forklift	Perm1Cuc,n	≤	0	ha
Permission to grow cucumbers after investment in coolroom	Perm2Cuc,n	≤	0	ha
Permission to grow cucumbers after investment in annual horticultural equipment	Perm3Cuc,n	≤	0	ha
Permission to grow 1st year grapes following investment in shed & forklift	Perm1Grapes1,n	≤	0	ha
Permission to grow 1st year grapes following investment in coolroom	Perm2Grapes1,n	≤	0	ha
Permission to grow 1st year grapes following investment in grape fixed costs	Perm3Grapes1,n	≤	0	ha
Permission to grow 1st grapes following investment in grape establishment costs	Perm4Grapes1,n	≤	0	ha
Permission to grow 2nd year grapes in year n following 1st year grapes in the previous year	Perm5Grapes2,n	≤	0	ha
Permission to grow 3rd year grapes in year n following 2nd year grapes in the previous year	Perm6Grapes3,n	≤	0	ha
Permission to grow 4th year grapes in year n following 3rd year grapes in the previous year	Perm7Grapes4,n	≤	0	ha
Permission to grow 5th year grapes in year n following 4th year grapes in the previous year	Perm8Grapes5,n	≤	0	ha
Permission to grow 1st year redclaw in year n following investment in shed & forklift	Perm1Redclaw1,n	≤	0	ha
Permission to grow 1st year redclaw in year n following investment in fixed costs for redclaw	Perm1Redclaw1,n	≤	0	ha
Permission to grow 1st year redclaw in year n following investment in redclaw establishment costs	Perm1Redclaw1,n	≤	0	ha
Permission to grow 2nd year lucerne in year n following 1st year lucerne in previous year	Perm1Redclaw2,n	≤	0	ha
Permission to grow 3rd year lucerne in year n following 2nd year lucerne in previous year	Perm1Redclaw3,n	≤	0	ha
Permission to grow 4th year lucerne in year n following 3rd year lucerne in previous year	Perm1Redclaw4,n	≤	0	ha
Permission to grow 5th year lucerne in year n following 4th year lucerne in previous year	Perm1Redclaw5,n	≤	0	ha

Table 6.3 cont.

Constraint	Code		Initial Level	Unit
Overdraft limit in year n	OverdrftMax,n	≤	$100000	$
Announced water allocation in year n	Water,n	≤	772.8	ML
Labour in year n	Labour,n	≤	8760	hrs
Hired labour in year n	HireLabour,n	≤	100000	hrs
Pre-tax income tie in year n	Pre-tax Inc,n tie	=	-$96000	$
Income allocation in year n	Income allocation,n	=	-$24000	$
Maximum area of SDI that can be installed	MaxSDIArea	≤	80	ha
Maximum area of annual horticultural crops permitted by investment in shed and forklift	MaxHortiCropsShed/Flift	≤	1	ha
Maximum area of annual horticultural crops permitted by investment in coolroom	MaxHortiCropsCroom	≤	1	ha
Maximum area of annual horticultural crops permitted by investment in annual horticultural equipment	MaxHortiCropsFC	≤	1	ha
Maximum area of grapes permitted by investment in grape fixed costs	MaxGrapeAreaFC	≤	1	ha
Maximum area of grapes permitted by investment in grape establishment costs	MaxGrapeAreaEst	≤	10	ha
Maximum area of redclaw permitted by investment in redclaw fixed costs	MaxRClawFC	≤	1	ha
Maximum area of redclaw permitted by investment in redclaw establishment costs	MaxRClawEst	≤	4	ha
Profit accumulation at the MLP period	Profit accumulation	=	$0	$

[a] n is the year number

6.2.4 The LP Matrix

A five year MLP model was developed using the activities and constraints specified. Although a longer period was preferred, this was not possible owing to the limitations of the What'sBest! software. The maximum allowable numeric cells (which includes zero values) is 16 000. With 156 activities and 141 constraints in the five year model there were 21 996 numeric cells in the model. The Omit command in the What'sBest! package was used to exclude four ranges of zero numeric cells which reduced the numeric cell number to 14 519 and enabled a five year model to be specified and solved.

The model has a block diagonal structure of the form represented in Figure 6.1. The coefficient details within the submatrix are presented for Year 5 in Appendix 12.

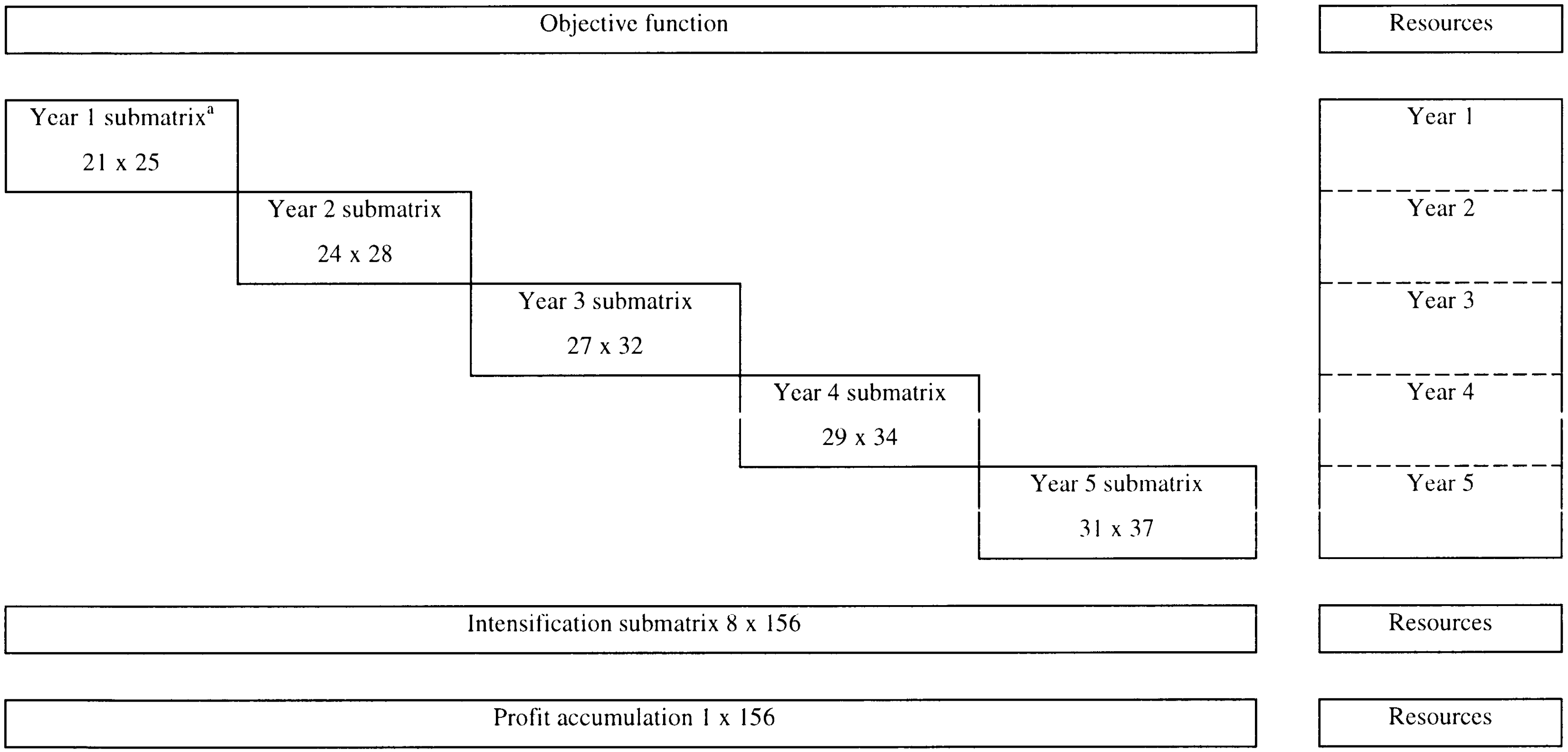
6.3 Solution

The original optimal farm plan using 1996 prices and a zero discount rate is given in Table 6.4. Here the initial plan is the pre-intensification plan presented in Table 5.6.

In Year 1 there was an investment in 18.5 ha of SDI, which was planted to lucerne as there was insufficient capital to invest in the necessary horticultural equipment to allow annual horticultural crops to be grown. The area of spray irrigated lucerne fell to 51.1 ha, with a total lucerne area of 69.6 ha. The area withdrawn from lucerne production was planted to raingrown mungbeans, resulting in an increase to 119.4 ha. 'Conmurra' was used to run 65 breeding cows in all years. The overdraft facility was utilised fully, but no hired labour was necessary. The annual operating profit fell to $55 984 compared with the initial farm plan level of $250 260.

In Year 2, sufficient funds existed for the investment in the equipment necessary for annual horticultural crops to be grown - the shed, coolroom, forklift, melon trailer, washer and table. An area of 8.4 ha of cucumbers was grown using an area of SDI lucerne from Year 1, resulting in a reduction in the area of SDI lucerne to 10.1 ha. The area of the spray irrigated lucerne and navy beans rotation was increased to 56.1 ha.

Figure 6.1: Diagrammatic layout of overall model



[a] the submatrix size represents constraints x activities

Table 6.4: The original optimal farm plan

Activities	Units	Initial plan	Year 1	Year 2	Year 3	Year 4	Year 5
Crops and livestock							
Spray irrigated lucerne	ha	77.3					
Spray irrigated lucerne/navy beans	ha		51.1	56.1	54.9	48.8	47.0
Traditional cucumbers	ha					25.3	30.3
SDI lucerne/cucumbers	ha		18.5	10.1	10.1		
SDI cucumbers	ha			8.4	19.6	29.7	29.7
Raingrown mungbeans	ha	11.7	119.4		104.3	85.1	82.0
Breeding cattle	cows	65	65	65	65	65	65
Investments							
SDI	ha		18.5		11.2		
Shed & forklift	units			1			
Coolroom	units			1			
Annual horticultural equipment	units			1			
Grape fixed costs	units						
Grape establishment	ha						
Redclaw crayfish fixed costs	units						
Redclaw establishment	ponds						
Other							
Borrowing working capital	$	$0	$100 000	$100 000	$100 000	$100 000	$100 000
Casual labour	hours	0	0	0	14 117	39 668	43 834
Annual operating profit (after tax)	$	$250 260	$55 984	$143 424	$275 550	$457 526	$598 535

Raingrown mungbeans were excluded from the farm plan. Permanent labour was capable of operating the existing farm plan without the need for casual labour to be hired. The annual operating profit increased to $143 424, still below that of the pre-intensification farm plan. The cumulative operating profit was $199 408.

In Year 3, there was further investment in SDI, with 11.2 ha installed. This increase together with that from Year 2 was used to grow SDI cucumbers. The area of SDI lucerne from Year 2 was carried forward into Year 3, followed by autumn cucumbers. There was a slight decrease in the area of the spray irrigated lucerne and navy beans rotation. Raingrown mungbeans were once again grown. The increased area of cucumbers required 14 117 hours of casual labour to be hired. The operating profit was increased to $275 550, which exceeded that for the initial pre-intensification plan. The cumulative operating profit was $474 958.

In Year 4, the entire area of SDI was used for the production of cucumbers, with 25.3 ha of traditionally grown cucumbers also grown. The area of the spray irrigated lucerne and navy beans rotation was reduced to 48.8 ha, with raingrown mungbeans down to 85.1 ha. The increased production of cucumbers required 39 668 hours of casual labour to be hired. The operating profit was $457 526, with the cumulative profit equalling $932 484.

In Year 5, the maximum allowable area of annual horticultural crops was reached, with 30.3 ha of traditionally grown cucumbers and 29.7 ha of SDI cucumbers. Lucerne remained a significant crop, with 47 ha of the spray irrigated lucerne and navy beans rotation. Raingrown mungbeans and cattle breeding completed the activity mix, which resulted in an annual operating profit of $598 535 (a cumulative profit of $1 531 019 over the five years of the MLP model). There were 43 834 hours of casual labour which had to be employed.

The key features for the five year optimal farm plan investigated are:

- the initial investment in installation of 13.5 ha of SDI in Year 1, followed by further investment in this technology in Year 3 (bringing the total area of SDI to 29.7 ha, below the maximum allowable area of 80 ha).
- investment in capital equipment required by annual horticultural crops in Year 2.
- expansion in the area of annual horticultural crops from zero to the maximum allowable area of 60 ha in Year 5 (with around half grown traditionally and half using SDI).
- a significant component of lucerne grown in all years (although declining from 69.6 ha in Year 1 to 47 ha in Year 5), principally using spray irrigation.
- full use of the available overdraft facility in all years.
- a significant increase in the use of casual labour with increasing use of annual horticultural crops (from zero hours in Year 2 to 43 834 hours in Year 5).
- a significant increase in the annual operating profit beyond Year 3 compared with the initial plan. The cumulative operating profit at the end of Year 5 was $1 531 019, compared with an estimated cumulative operating profit for the initial plan at the same time of $1 251 300 - an increase of 22 percent.

6.4 Sensitivity analysis

6.4.1 Announced Water Allocation

The announced water allocation for all years 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 6.5.

With the announced allocation at 100 percent of the nominal allocation, there was a greater area of spray irrigated lucerne and navy beans grown in all years, and a greater area of SDI installed (to around 60 ha) compared with the other water allocations. As with the original optimal plan, SDI lucerne was initially grown and investment in capital equipment necessary for annual horticultural crops was made in Year 2. In the third year cucumbers were grown on the SDI lucerne area in autumn after it was ploughed out (15.9 ha). In addition, SDI cucumbers were grown in Years 2 to 5, with the maximum allowable area of 60 ha in the final two years.

In Year 2, the area of raingrown mungbeans fell substantially at 100 and 80 percent nominal allocations. In both situations, not all cultivable land was used. In all other years the full 189 ha was used for cropping. This coincided with the investment in horticultural equipment which limited the available funds for the variable costs associated with raingrown mungbean production in that year.

When the announced allocation was reduced to 60 percent, the area used for spray irrigated lucerne and navy beans was reduced to 50 ha in Year 1. By Year 5 it fell to 30 ha. Capital was initially invested in horticultural equipment in Year 1, enabling 3.3 ha of traditional cucumbers to be grown. In Years 2 and 3, investment in SDI was made, resulting in a total area of 22.2 ha which was used to produce cucumbers in Year 3, 4 and 5. In this plan, raingrown mungbeans were excluded in Year 1, resulting in only 53.3 ha of cultivatable land being used. The full 189 ha of cultivable land was used from Year 3 onwards.

In all years and at all levels of water allocation the overdraft facility was fully used. At all water levels the use of casual labour commenced in Year 3. The amount hired was greatest at the highest water levels, and increased until Year 5. This increase resulted from the expansion in the area of cucumbers (both SDI and traditional) beyond Year 3.

With the existing assumptions of unlimited labour, but no capital borrowing, neither table grapes nor redclaw crayfish activities entered the optimal farm plan in the first five years. This is of interest given the presence of the redclaw activity at is maximum allowable level in the static optimal plan at all levels of announced allocation from 60 to 100 percent. The table grape activity entered the static farm plan when there was unlimited casual labour available (see Table 5.8).

The annual operating profit for the optimal farm plan prior to intensification (see Table 5.6) was extrapolated to five years and compared with that produced by the MLP model. The aim was to examine the effect of intensification and differing water availability on the cumulative operating profit. The results of this are presented in Figure 6.2.

Figure 6.2: The impact of differing water availability pre- and post-intensification upon cumulative operating profit

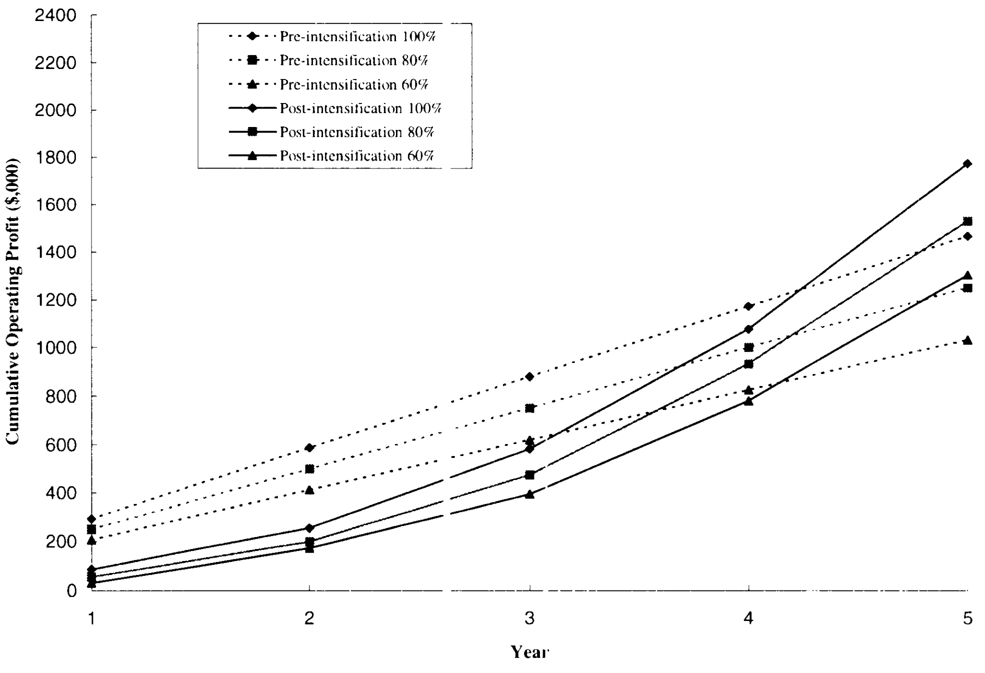


Table 6.5: The impact of changes in the announced water allocation upon the the optimal farm plan

Activities	Units	Announced allocation 100% of nominal					Announced allocation 80% of nominal					Announced allocation 60% of nominal				
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
Crops & livestock																
Spray irrigated lucerne	ha															
Spray irrigated lucerne/navy beans	ha	70.5	68.2	67.8	64.1	64.1	51.1	56.1	54.9	48.8	47.0	50.0	48.2	43.3	34.4	30.0
Spray irrigated oats	ha															
Traditional cucumbers	ha									25.3	30.3	3.3			25.2	37.8
SDI lucerne/cucumbers	ha	15.9	15.9	15.9			18.5	10.1	10.1							
SDI cucumbers	ha		7.7	21.2	60	60		8.4	19.6	29.7	29.7		8.4	22.2	22.2	22.2
Raingrown mungbeans	ha	102.6	45.4	84.1	64.9	64.9	119.4		104.3	85.1	82.0		91.9	123.5	107.2	99.0
Breeding cattle	cows	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Investments																
SDI	ha	15.9	7.7	13.4	22.9		18.5		11.2				8.4	13.8		
Shed & forklift	units		1					1				1				
Coolroom	units		1					1				1				
Annual horticultural equipment	units		1					1				1				
Grape fixed costs	units															
Grape establishment	ha															
Redclaw crayfish fixed costs	units															
Redclaw establishment	ha															
Other																
Borrowing working capital	$	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
Casual labour	hours	0	0	18199	44194	44194	0	0	14117	39668	43834	0	0	11722	32895	43451
Annual operating profit (after tax)	$	87517	166379	327775	495628	696403	55984	143424	275550	457526	598535	30592	141628	223751	384840	524694

The impact of falling water supplies is clearly evident in both the pre- and post-intensification scenarios. With adoption of SDI and annual horticultural crops, the cumulative operating profit takes five years to exceed that of the pre-intensification scenarios at all levels of announced allocation. Beyond this period, the annual operating profit is higher as a result of the greater gross margins for annual horticultural crops grown with SDI.

6.4.2 Availability of borrowed capital

The effect of available borrowed capital on the optimal farm plan was examined using borrowing limits of \$100 000, \$200 000 and \$300 000 in Year 1. The results of this analysis are presented in Table 6.6.

An increase in the borrowing limit from zero (see Table 6.5, announced allocation at 80 percent of nominal) to \$100 000 resulted in an increase in the area of SDI installed in Year 1 from 18.5 ha to 27.1 ha. By the end of Year 4 the area of SDI installed was 38.1 ha. This compares with 29.7 ha installed where borrowing was not available.

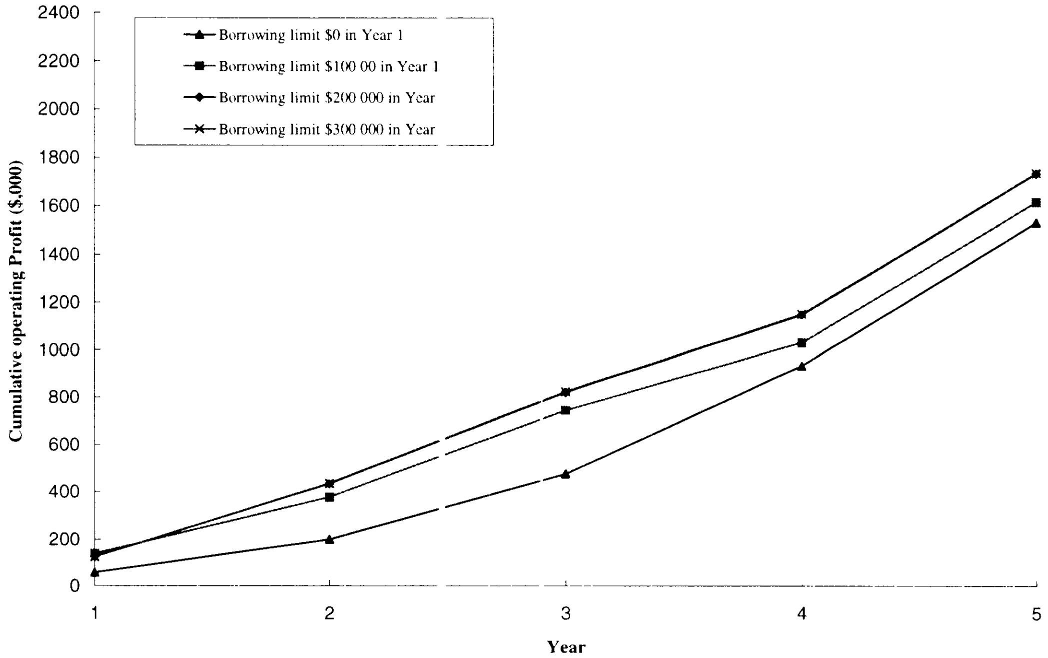
The investment in capital items required for annual horticultural crops took place a year earlier, resulting in an earlier expansion in the area of cucumbers grown to fully utilise the area of SDI installed. There remained a significant area of spray irrigated lucerne and navy beans in all years.

An increase in the borrowing limit in Year 1 to \$200 000, resulted in quicker installation of SDI, with 77.9 ha installed in Year 1. This was greater than the area installed at the \$100 000 borrowing limit, and resulted in a larger area of SDI lucerne being grown compared with the former. The area of SDI was gradually used for annual horticultural crops with spray irrigated lucerne and navy beans increasing to 47 ha in Year 5 when the maximum possible area of cucumbers was grown on 60 ha of SDI. A further increase in the borrowing limit in Year 1 to \$300 000 had little impact on the optimal farm plan.

Table 6.6: The impact of changes in the limit on borrowing in Year 1 upon the optimal farm plan

		Borrowing limit $100 000					Borrowing limit $200 000					Borrowing limit $300 000				
Activities	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
Crops & livestock																
Spray irrigated lucerne	ha															
Spray irrigated lucerne/navy beans	ha	47.2	43.9	35.8	44.8	47.0				9.0	47.0				7.1	47.0
Spray irrigated oats	ha															
Traditional cucumbers	ha			24.2		21.9		9.0	26.6				7.0	24.8		
SDI lucerne/cucumbers	ha	19.9	19.9	18.2	18.2		70.9	68.6	54.5	57.7		70.9	68.5	54.4	59.7	
SDI cucumbers	ha	7.2	18.1	19.9	19.9	38.1	7.0	9.4	23.5	20.2	60.0	7.0	11.5	25.6	20.2	60.0
Raingrown mungbeans	ha		107.1	91.0	106.1	82.0		102.1	84.4	102.0	82.0		102.0	84.2	101.9	82.0
Breeding cattle	cows	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Investments																
SDI	ha	27.1	11.0				77.9					80.0				
Shed & forklift	units	1					1					1				
Coolroom	units	1					1					1				
Annual horticultural equipment	units	1					1					1				
Grape fixed costs	units															
Grape establishment	ha															
Redclaw crayfish fixed costs	units															
Redclaw establishment	ha															
Other																
Borrowing working capital	$	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
Borrowed capital	$	100000					200000					203980				
Casual labour	hours	0	8522	30427	10000	43825	0	8351	35410	10000	43803	0	8445	35653	10000	43803
Annual operating profit (after tax)	$	139181	236909	367905	286933	584039	124546	308394	386607	328100	584671	123579	310072	389313	327512	583701

Figure 6.3: The impact of changes in the borrowing limit upon cumulative operating profit



Neither the table grapes or redclaw crayfish activity entered the optimal farm plan in the five years examined, despite increased borrowing in Year 1. The impact of increased borrowing in on whole farm profitability is demonstrated in Figure 6.3.

Allowing borrowing up to $100 000 in Year 1 results in an increase in the cumulative operating profit in all years. By the end of Year 5, the cumulative operating profit for this scenario is $1 614 967 compared to $1 531 018 where no borrowing was available (an increase of 5 percent). Increasing the available borrowing to $200 000 in Year 1 results in a cumulative operating profit of $1 732 317 at the end of Year 5, an improvement of 13 percent. There is no significant impact of increasing the allowable borrowing beyond $200 000 upon the cumulative operating profit.

6.4.3 Starting capital

The effect of increasing the capital available for investment in Year 1 upon the optimal farm plan was examined. The results are presented in Table 6.7.

With $100 000 of capital initially available, investment in annual horticultural equipment and 27.1 ha of SDI took place. Investment continued in SDI until 60 ha were installed. The SDI was initially used for 19.9 ha of lucerne, and the balance

Table 6.7: The impact of changes in available investment capital in Year 1 upon the optimal farm plan

		Available capital $100 000					Available capital $200 000					Available capital $300 000				
Activities	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
Crops & livestock																
Spray irrigated lucerne	ha															
Spray irrigated lucerne/navy beans	ha	47.2	43.1	41.8	47.0	47.0			23.1	30.8	47.0			20.1	27.3	45.3
Spray irrigated oats	ha															
Traditional cucumbers	ha							12.0	11.6				7.8	10.5		
SDI lucerne/cucumbers	ha	19.9	19.9	19.9			70.9	66.6	29.5	18.0		69.2	64.8	30.5	20	
SDI cucumbers	ha	7.2	20.4	39.4	60.0	60.0	7.0	11.4	48.4	60.0	60.0	6.6	15.2	49.5	60.0	60.0
Raingrown mungbeans	ha		105.6	87.9	82.0	82.0		99.0	76.3	80.2	82.0		100.0	77.0	80.4	82.4
Redclaw	ha											1.3	1.3	1.3	1.3	1.3
Breeding cattle	cows	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Investments																
SDI	ha	27.1	13.2	19.0	0.7		77.9					80				
Shed & forklift	units	1					1					1				
Coolroom	units	1					1					1				
Annual horticultural equipment	units	1					1					1				
Grape fixed costs	units															
Grape establishment	ha															
Redclaw crayfish fixed costs	units											1				
Redclaw establishment	ha											1.3				
Other																
Borrowing working capital	$	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
Casual labour	hours	0	10390	34802	43803	43803	0	12615	48590	43658	43803	0	13034	49002	44489	44651
Annual operating profit (after tax)	$	163442	271463	423483	526629	646855	173068	383582	551770	567383	657179	172248	387713	566637	594119	677706

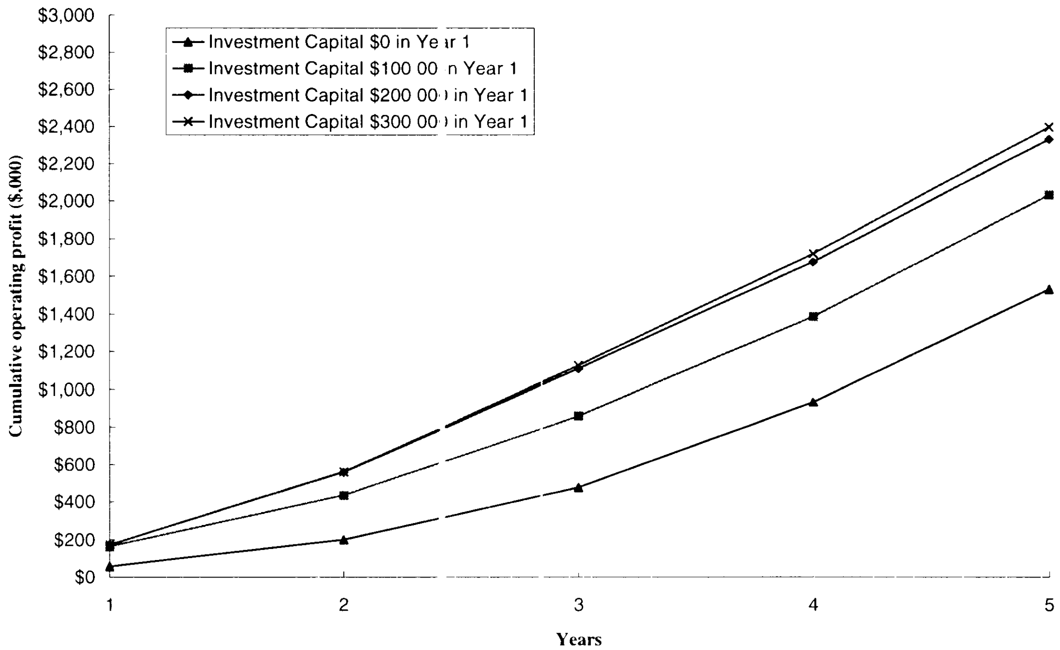
planted to cucumbers. In Year 4 the whole SDI area was planted to cucumbers. In all years a significant area of spray irrigated lucerne and navy beans were grown.

Where there was $200 000 of investment capital initially available, most of the possible area of SDI was installed (77.9 ha) together with the annual horticultural equipment. Lucerne was planted on most of the SDI area, with a significant increase in the area of cucumbers in Year 3 (48.4 ha). In Years 4 and 5 the maximum allowable area of cucumbers was grown with a corresponding decrease in the area of SDI lucerne. The area of spray irrigated lucerne and navy beans increased in these later years.

With a further increase in initial investment capital to $300 000, a similar investment pattern to that above was followed. In addition, investment in a redclaw crayfish activity also entered the optimal plan. These investments resulted in 13 redclaw crayfish ponds being installed in Year 1.

The impact of available investment capital upon whole farm profitability is demonstrated in Figure 6.4.

Figure 6.4: The impact of intial investment capital upon cumulative operating profit



Increasing the available investment capital in Year 1 to $100 000 resulted in an increase in the cumulative operating profit in all years. By the end of Year 5, the cumulative operating profit for this scenario was $2 031 872 compared to $1 531 018 where no investment capital was available (an increase of 33 percent). An increase in the initial available capital to $200 000 in Year 1 resulted in a cumulative operating profit of $2 332 982 at the end of Year 5, an improvement of 52 percent. An increase in the available investment capital to $300 000 in Year 1 resulted in a further improvement in cumulative operating profit to $2 398 423, an increase of 56 percent over that where there was no initial investment capital available.

6.4.4 Casual labour

The optimal plans presented in Tables 6.5 to 6.7 indicate high demands for casual labour owing to the presence of large areas of annual horticultural crops present. The co-operators initially indicated that casual labour availability would not be a limiting constraint in implementing the optimal farm plan. However, in the initial LP model the use of casual labour was limited to 5475 hours annually. This constraint was imposed on the MLP model to determine its impact on the optimal farm plan. The results of this analysis are presented in Table 6.8.

With the availability of casual labour limited, development of SDI was restricted to 18.5 ha which was installed in Year 1 (compared with 29.7 ha). The impact of this constraint was to restrict the area of horticultural crops that can be grown to 14.3 ha of cucumbers in Year 5. At the same time the area of cucumbers grown where there was unlimited casual labour was 60 ha (around half traditionally grown and half using SDI). With limited labour available, there was a greater area of spray irrigated lucerne and navy beans grown, together with raingrown mungbeans.

The effect of this labour constraint on profitability was to restrict cumulative operating profit to $1 056 841, which is 69 percent of that where labour was readily available ($1 531 018).

Table 6.8: The impact of changes in the availability of casual labour upon the optimal farm plan

		Unlimited casual labour					Limited casual labour				
Activities	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
Crops & livestock											
Spray irrigated lucerne	ha										
Spray irrigated lucerne/navy beans	ha	51.1	56.1	54.9	48.8	47.0	51.1	56.1	54.8	59.4	63.2
Spray irrigated oats	ha										
Traditional cucumbers	ha				25.3	30.3			5.1		
SDI lucerne/cucumbers	ha	18.5	10.1	10.1			18.5	10.1	14.2	4.1	
SDI cucumbers	ha		8.4	19.6	29.7	29.7		8.4	4.2	14.4	14.3
Raingrown mungbeans	ha	119.4		104.3	85.1	82.0	119.4		110.7	111.1	111.6
Breeding cattle	cows	65	65	65	65	65	65	65	65	65	65
Investments											
SDI	ha	18.5		11.2			18.5				
Shed & forklift	units		1					1			
Coolroom	units		1					1			
Annual horticultural equipment	units		1					1			
Grape fixed costs	units										
Grape establishment	ha										
Redclaw crayfish fixed costs	units										
Redclaw establishment	ha										
Other											
Borrowing working capital	$	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
Casual labour	hours	0	0	14117	39668	43834	0	0	5475	5475	5475
Annual operating profit (after tax)	$	55984	143424	275550	457526	598535	55984	143424	231940	244763	380730

6.5 Summary

Given the assumptions used, the optimal farm plan involves the investment in SDI technology and capital equipment necessary for annual horticultural crops in the first and second years. SDI lucerne is initially grown and replaced by cucumbers. Traditional cucumbers are also grown, with the total area of annual horticultural crops in Year 5 limited to 60 ha. This limit results from co-operators perceptions of the greater risk associated with annual horticultural crop production compared with the more traditional crops.

In the optimal farm plan, lucerne and navy beans continue as significant activities under spray irrigation, together with raingrown mungbeans and the cattle breeding activity. In Year 5, the annual operating profit is \$598 535, more than twice that in the initial farm plan.

With a decline in the availability of irrigation water, there is earlier investment in the annual horticultural crop capital equipment and less SDI is installed. The maximum allowable area of cucumbers is grown, with all the SDI area used and the remainder grown traditionally. The impact of declining water availability to 60 percent of the nominal allocation, is a reduction in the cumulative operating profit of around 15 percent, compared to that where the announced allocation is 80 percent of the nominal allocation.

Where borrowing of \$200 000 is allowed in Year 1, there is rapid investment in SDI and annual horticultural equipment. The majority of the SDI is used initially for lucerne production, and in turn for horticultural crops by Year 5. This results in an improvement in cumulative operating profit over the five year planning period of 13 percent to \$1 732 317.

Where there is initial capital available for investment, the improvement in cumulative operating profit is even greater. Compared with nil initial capital the improvement is approximately 33, 52 and 57 percent for starting capital of \$100 000, \$200 000 and

$300 000 respectively. Entry of the redclaw crayfish activity into the optimal farm plan occurs when there was $300 000 of available starting capital. At this level, 13 redclaw ponds are installed in Year 1.

The importance of casual labour availability on the optimal farm plan was also examined. The reduction in casual labour to 5475 hours annually limits the investment in SDI and the area of cucumbers which can be grown. There is a resultant increase in the areas of raingrown mungbeans and the spray irrigated lucerne/navy bean rotation. There is a fall in the cumulative operating profit from $1 531 018 to $1 056 841, a reduction of around 31 percent.

7. Discussion

7.1 Introduction

This chapter examines the results of the static LP and MLP models. The implications for future management of the business are discussed, particularly with respect to its activity mix and future profitability. The impact of changes in the availability of groundwater, capital and labour is discussed. Finally, the importance of this research in the context of future adoption of management approaches by irrigators to the diminishing water resource is dealt with.

7.2 Static optimal farm plan

7.2.1 Activity mix

The key features of the static optimal farm plan were:

- the maximum allowable 60 ha of lucerne was grown using SDI
- there were 16 ha of navy beans grown (6 ha using SDI and the balance with spray irrigation)
- the maximum area of annual horticultural crops was grown, with half in spring and half in autumn. In spring, 10 ha were grown using SDI and the balance with traditional drip irrigation. The autumn crop was all grown using SDI as third year lucerne was ploughed out in December. Zucchinis dominated the annual horticultural crops grown in spring (29.6 ha) and autumn (17.9 ha), with cucumbers and sweet corn making up the balance in the respective seasons.
- the redclaw crayfish activity was present at the maximum allowable scale of 40 ponds.
- the table grape activity was present at its existing level of 2 ha, as was the cattle breeding activity on ‘Conmurra’ (65 breeders).
- the optimal plan was able to operate with the existing overdraft facility of $100 000.

This plan produced an annual operating profit of $676 737, which was nearly triple that of the optimal farm plan pre-intensification. This plan required the maximum allowable area of SDI to be installed (80 ha).

7.2.2 Announced water allocations

The optimal plan operates where the announced water allocation is set at 80 percent of the nominal allocation. This level has been applicable to both sections of the alluvium in which the case study farm is located (Sections 7 and 10A) since 1990-91 (see Table 2.1).

Of concern, however, is the likelihood that this situation could change in the future. Continued failure of recharge events to materialise increases the likelihood that further restrictions are likely. The model was used to test the impact of changes in water availability upon the optimal farm plan by altering the announced allocation downwards to 60 percent of the nominal allocation (579.6 ML), and also increasing it to 100 percent of the nominal allocation (966 ML). The water available from the 50 ML dam used to supplement irrigation was similarly adjusted.

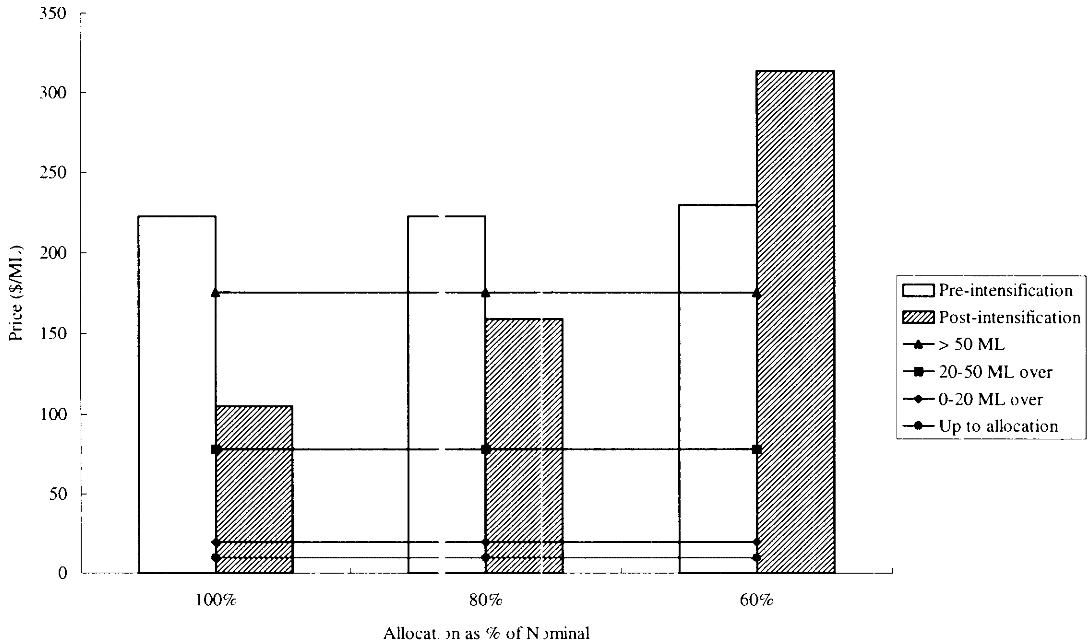
The impact of these adjustments was shown in Table 5.5. The key features of the optimal farm plan with these changes were:

- lucerne remained a significant component of the farm plan at all levels, with the area falling by around one-third when the announced allocation was reduced to 60 percent.
- the total area of annual horticultural crops grown remained at 60 ha, the upper limit imposed by the co-operator. It was the mix of annual horticultural crops within this total area that adjusted with changes in available water.
- a fall in the area of navy beans and sweet corn with decreasing water allocation.
- an increase in the area of zucchinis and raingrown mungbeans with lowering water levels.

The pricing of water is an important issue in the adoption of new irrigation technologies such as drip irrigation (Caswell and Zilberman 1985; Chewings and Pascoe 1988; Dinar and Yaron 1990; Dinar and Zilberman 1991; Mallawaarachchi et al. 1992; p.200-1;

Poulter et al. 1993, p. 18-9; Yaron and Regev 1989). This has implications for the adoption of SDI by Callide Valley irrigators. The shadow price of water for the case study farm and the current groundwater price are presented in Figure 7.1.

Figure 7.1: Comparison of water shadow prices for pre- and post-intensification (bars), and existing groundwater charges (lines)



The current market price for allocation water is $9.75/ML (see the lowest horizontal line in Figure 7.1). Price penalties are in place as a means of limiting excess water use. These are shown by the upper three horizontal lines. They represent charges of:

- $19.50/ML for for water up to 20 ML in excess of the announced allocation;
- $78.00/ML for water from 20 to 50 ML in excessof announced allocations; and
- $175.50/ML for water in excess of 50 ML above the announced allocation.

Prior to intensification the shadow price for water was $223/ML (over a range from 663 to 1890 ML when the announced allocation was 80% of the nominal allocation), with a slight increase in the shadow price caused by a fall to 60 percent, and no change with an increase to 100 percent of the nominal allocation.

A different situation arises where intensification is possible. At full allocation, the shadow price is $105/ML. With decreasing availability the shadow price rises to

$314/ML when the announced allocation is 60 percent. The elasticity of the shadow price is -1.36 with an increase in allocation from 80 to 100 percent (a 1.36 percent decrease in the shadow price for each percent increase in the nominal allocation). For the fall in allocation from 80 to 60 percent, the elasticity of the shadow price is -3.90 (a 3.90 percent increase in the shadow price for each percentage fall in the nominal allocation).

The operating cost of using groundwater ranges from $35.07/ML for SDI to $45.93/ML for rolling sprayline systems (see Appendix 7). This includes the water charge for allocation water of $9.75/ML. In Figure 7.1 it can be seen that the shadow prices in all situations exceeds the current market price for allocation water. In the pre-intensification situation, the shadow price exceeds the market price for all water, inlcuding that used in excess of allocation. With intensification, the shadow price at full and 80 percent of announced allocations is below that for water used in excess of 50 ML above allocation.

An important implication of these results is that the existing excess allocation charges (listed in Appendix 5) do not by themselves discourage the excess use of the groundwater resource. This is due to the potential returns from using excess water (as shown by the shadow price) exceeding its cost. Only in recent years has the charge for water in excess of 50 ML of announced allocation more closely aligned the cost of water with its true economic value. Irrigators who use water in excess of allocation more than twice can be prosecuted. This threat is more likely to limit excess use.

The impact upon profitability of changing allocations is evident in Table 5.5, where an increase in the announced allocation from 80 to 100 percent increased profitability by $21 254, an increase of around three percent (an elasticity of 0.126). With a fall in the allocation to 60 percent, the loss in operating profit was $47 261 which is around 7 percent (an elasticity of 0.279).

7.2.3 Activity level constraints

7.2.3.1 Maximum lucerne area

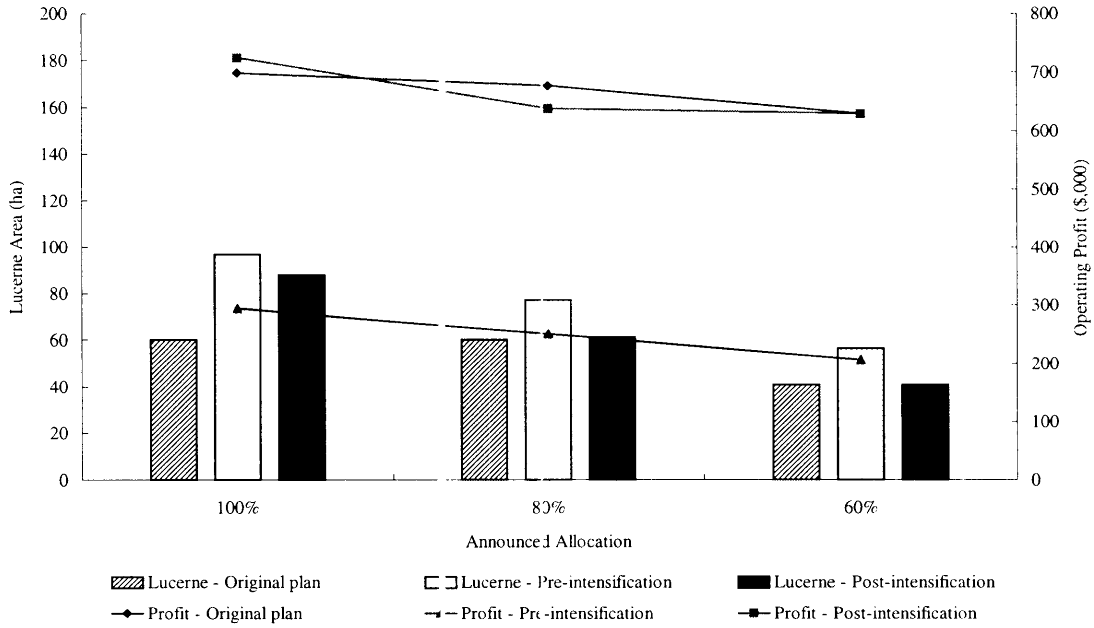
The constraints imposed on the levels of some activities impact upon the optimal farm plans and their profitability. When the maximum area of lucerne is unrestricted the effect is clearly seen in Figure 7.2.

Prior to intensification, the optimal area of spray irrigated lucerne was 96.6 ha at a 100 percent allocation, and fell to 56.6 ha when the allocation dropped to 60 percent. This is just below the 60 ha imposed as a constraint in the base model. Where intensification was possible, the area of lucerne grown exceeded 60 ha when a 100 percent allocation was available, but fell to similar levels to those in the original optimal plan at both 80 and 60 percent allocations.

The operating profit falls as the level of available water is restricted. There is generally little impact on operating profit by removing the constraint limiting the maximum area of lucerne grown. An increase in operating profit at 100 percent allocation becomes a decrease at 80 percent, and a similar level at 60 percent allocation (see Figure 7.2).

These results demonstrate the importance of retaining lucerne in the activity mix used by irrigators. Staff of the Department of Natural Resources have indicated their desire for the area of lucerne within the Callide Valley to decline as a means of reducing the volume of water used (A Baker 1996, pers. comm.). This is based upon the high water use attributed to lucerne (see Appendix 2). This, however, would decrease profitability of the optimal farm plan because of the high gross margins for both spray irrigated (Table 4.7) or SDI (Table 4.8) lucerne. These activities provide the necessary cashflow to allow investment in SDI and annual horticultural crop production..

Figure 7.2: The impact of removing the lucerne area restriction upon the lucerne area (bars) and profitability (lines) of the pre- and post-intensification optimal farm plan, as affected by water



7.2.3.2 Maximum annual horticultural area

The lifting of the constraint limiting annual horticultural crops to 60 ha results in significant changes in the optimal farm plan (see Table 5.7). Here the area of lucerne is significantly reduced (down to 11.0 ha from 60 ha). At the same time the mix of annual horticultural crops grown adjusts, with a dominance of watermelons within the plan. July/September working capital, the July/September overdraft limit and available casual labour become significant constraints limiting the maximisation of the objective function (with shadow prices of $0.25, $0.25 and $26.18/hour respectively).

The horticultural crops are generally considered risky in comparison with more traditional crops (see Table 4.9). Watermelons for example, are considered to have high price fluctuations and harvest timeliness is critical. This is the reason for the limit placed on the area of annual horticultural crops. Considering the risks involved, the large scale replacement of the lucerne area with annual horticultural crops is not a preferred option by the co-operator.

7.2.3.3 Casual labour

The hiring of casual labour has a significant impact on the optimal farm plan (see Table 5.8). Where it is unlimited there is potentially a 33 percent increase in operating profit. The level of hired casual labour used increases from 5475 hours to 26 404 hours. This is nearly a five-fold increase and the likelihood of this level of labour being available needs to be considered by the co-operator. It does, however, highlight the importance of casual labour in the intensification of activities. Increases in labour availability results in an increase in the more labour demanding, but higher returning, annual horticultural crops such as cucumbers being grown as alternatives to zucchinis.

The other impact of removing the hired labour constraint is to allow the area of table grapes to increase to the maximum permissible area of 10 ha.

7.3 MLP optimal farm plan

7.3.1 Activity mix and investment decisions

The optimal farm plan over the five year planning period is presented in Table 6.4. The optimal plan involves initial investment in SDI on 18.5 ha with lucerne planted on this area. In Year 2, investment in annual horticultural crop equipment takes place. This enables 8.4 ha of SDI to be planted to cucumbers and the area of SDI lucerne reduced to 10.1 ha. In Year 3 a further 11.2 ha of SDI are installed, and planted to cucumbers. By the end of the planning period the total area of SDI is 29.7 ha, and it is used for cucumber production. The balance of the annual horticultural area constraint is planted to traditionally grown cucumbers. Spray irrigated lucerne and navy beans remain a significant component of the farm plan throughout the planning period.

In the MLP model, there was no limit on the availability of casual labour. Despite this, neither the redclaw crayfish or table grape activity entered the optimal plan within the planning period. This is despite their presence at the maximum permissible level in the optimal plan in the static LP model (where labour was unlimited - see Table 5.8).

The optimal plan involves a significant component of hired labour for harvesting annual horticultural crops. It is required for the cucumber activities undertaken from Year 3 onwards. The demand increases to 43 834 hours by Year 5.

The annual operating profit falls relative to that of the pre-intensification plan for the first two years of development. By the end of the planning period the cumulative operating profit has improved by 22 percent over that for the pre-intensification situation (from $1 251 300 to $1 53 019).

7.3.2 Announced water allocations

The impact of different announced water allocations throughout the planning period was summarised in Table 6.5. At the higher allocation, there was a greater area of spray irrigated lucerne and navy beans grown, which in turn allowed for a greater area of SDI to be installed. By the end of the five years there were 60 ha of SDI installed where the announced allocation was 100 percent of the nominal level. The elasticity of investment in SDI with respect to an increase in the allocation from 80 to 100 percent is 4.07 (there is a 4.07 percent increase in the final area of SDI installed for each percentage increase in the announced allocation - see Table 7.1).

Table 7.1 Elasticities of selected variables with respect to the water resource[a]

Variable	Water Allocation Increase	Water Allocation Decrease
SDI Investment area	4.07	1.01
SDI Annual horticultural crop area	4.08	1.01
Traditional annual horticultural crop area	-4.0	-0.99
Spray irrigated lucerne area	1.46	1.45
SDI lucerne area	0	0

[a] estimated for the total period for investments and Year 5 for activity areas

This 60 ha is used for the production of cucumbers by Years 4 and 5. The SDI area initially installed is planted to lucerne which is retained for three years. In Year 2 investment in annual horticultural crop equipment enables these crops to enter the optimal plan. The elasticity for SDI annual horticultural crops of 4.08 indicates an increase of 4.08 percent in the area of these crops for each percentage increase in the water allocation from 80 to 100 percent.

The impact of declining allocations is to restrict the extent of final investment in SDI, but bring forward the investment in the annual horticultural crop equipment. The elasticity of investment in SDI is 1.01 (there is a 1.01 percent decrease in the final area of SDI installed for each percentage decline in the announced allocation from 80 to 60 percent). At all allocations, the maximum allowable area of annual horticultural crops are grown. With greater water restrictions a greater proportion are grown using traditional drip irrigation as opposed to SDI - this can be seen in the lower elasticities for SDI and Traditional annual horticultural crop areas where the allocation is decreased compared to where it is increased (see Table 7.1).

The change in allocation from 80 to 100 percent increases the area of spray irrigated lucerne by 1.46 percent for each percentage increase, and the fall from 80 to 60 reduces the area of spray irrigated lucerne similarly (a 1.45 percent decrease for each percentage decrease in the available allocation)

The impact of changing allocations upon the cumulative operating profit are clearly evident in Figure 6.2. By Year 5, the cumulative operating profit is greater at all three allocation levels compared with that were intensification had not occurred.

7.3.3 Capital considerations

Allowing capital to be borrowed at the start of the planning period results in investment in annual horticultural equipment a year earlier (see Table 6.6 compared with the nil borrowing which produced the optimal farm plan in Table 6.4). Where $100 000 can be borrowed, there is also an increase in the final area of SDI installed (from 29.7 ha to 38.1 ha). The second stage of SDI installation also occurs one year earlier. An increase in the borrowing limit to $200 000 results in 77.9 ha of SDI being installed, all in the initial investment year. Where the limit is raised to $300 000, an amount of $203 980 is borrowed and the maximum permissible 80 ha of SDI is installed.

The impact of the associated investments resulting from increased borrowing capacity were:

- increased area of the SDI lucerne/cucumber rotation
- the earlier production of cucumbers
- the operating profit increased for borrowing limits of $100 000 and $200 000 over that for the initial optimal plan (see Figure 6.3). There was, however, no benefit from increasing the borrowing limit to $300 000.

Increased starting capital available for investment had similar effect as increased borrowing capacity. However, the area of SDI installed where $100 000 of starting capital was available was greater than where a similar amount was available through borrowing. The area of SDI installed was 60 ha, equivalent to the maximum permissible area of annual horticultural crops. The expansion in annual horticultural crop production was more rapid with increased starting capital - by Year 4, 60 ha of SDI was used to grow cucumbers.

A redclaw crayfish activity was a feature of the optimal static farm plan (see Table 5.5). This activity only entered the five year planning period of the MLP model where the available capital for investment in Year 1 was $300 000. Here, investment in the associated fixed costs of the redclaw activity and construction of 13 ponds was made.

The availability of starting capital significantly increases the operating profit of the optimal farm plan (see Figure 6.4). However, the inclusion of the redclaw activity within the optimal plan where starting capital is $300 000 is not much greater than where the starting capital is $200 000 (within the 5 year planning period of the current MLP model).

7.3.4 Casual labour availability

Within the MLP model the impact of labour availability on the optimal farm plan is clearly demonstrated in Table 6.8. When restricted to the original 5475 hours, there is a limit on the area of SDI installed. This occurs as the area of cucumbers which can be grown is limited to 14.3 ha owing to this crops high labour demand at harvest. In turn, the revenue generated from this activity is reduced and less funds are available for investment. There is an increase in the area of the spray irrigated lucerne and navy bean rotation in Year 5 as a result.

The impact upon the operating profit is clearly seen in Table 6.8 where the cumulative profit as a result of restricting labour is 69 percent of that where casual labour is readily available.

The availability of labour is clearly an important consideration in the future development of the case study farm business. In the longer term, its availability needs to be addressed in order to optimise the future farm plan.

7.4 Adoption of drip irrigation technology

The study has shown the potential for SDI and the use of annual horticultural crops to increase operating profits for the case study farm. The increase in profit occurs at all groundwater levels tested.

Research has identified the following factors which impact upon the rate of adoption of drip irrigation technology:

- improved profitability through yield increases and cost savings as a result of more efficient water use with drip irrigation (Caswell and Zilberman 1985; Feinerman and Yaron 1990; Mallawaarachchi et al 1992).
- water pricing policies (Caswell and Zilberman 1985; Dinar and Yaron 1990; Mallawaarachchi et al 1992).
- size of irrigation farms. Larger farms were more likely to adopt new irrigation technology and at a faster rate (Caswell and Zilberman 1985).
- source of irrigation water. Farms sourcing irrigation from groundwater were more likely to adopt drip irrigation then those using surface water (Caswell and Zilberman 1985).
- the quantity and quality of the available water resource (Dinar and Yaron 1990; Dinar and Zilberman 1991).
- human capital factors such as age, and experience with existing irrigation systems and drip irrigation (Dinar and Yaron 1990; Feinerman and Yaron 1991).

The slow adoption of new technology and management practices aimed at conserving the existing water resource has been attributed to a number of factors. These include:

- the need for improved availability of information on the economic and environmental benefits of best management practices such as irrigation scheduling (Feather and Amacher 1994).
- the "common-pool" problem in which the groundwater resource is commonly owned by a large number of producers. Farehed Shah et al (1993, p. 497) suggest that this results in over exploitation of the resource from a social point of view, and low rates of adoption of resource-conserving technologies such as drip irrigation.
- the low market price of water which prevents the adoption of irrigation scheduling and the use of new irrigation management technologies (Meyer 1992).

This study demonstrated the need for a link between the installation of SDI and shift to the production of annual horticultural crops in order for such investment to be profitable. This is a similar result to that found by cost-benefit analysis of the transition from a traditional to a modern irrigation project in the Jordan Valley, Israel (Dinar et al. 1992; Regev et al 1990; Yaron and Regev 1989). The chief findings of this study were:

1. investment in modernisation of an irrigation project incorporating drip systems and high-value cash crops achieves a high internal rate of return;
2. investment in modernisation of an irrigation project incorporating drip systems is not economically justified where a traditional crop mix is retained;
3. where capital resources are scarce, partial modernisation systems may still be profitable at a reasonable level.

In these studies, the modernisation of the irrigation project was only feasible when higher valued horticultural crops could be grown. One of the concerns expressed by the authors was the limited market demand for these high income crops. This in turn would limit the development of modern capital intensive irrigation projects. They pointed out that this is not a problem at the single farm level, but at a national policy level there is a need to develop profitable farming systems, which incorporated horticultural crops with the more traditional crop and livestock activities.

The foregoing discussion and evidence from the case study farm is sufficient to warrant further investigation of the use of SDI and alternative activities for irrigation farms within the Callide Valley. The potential for improved profitability with possible future changes in the groundwater supply supports this suggestion.

7.5 Summary

The profitability of the case study farm within the five year planning period can be maximised through the installation of SDI and investment in annual horticultural crop equipment. This enables annual horticultural crops to be grown up to the limit imposed by the manager's perception of their associated risk. The choice of annual horticultural crops to grow will be determined by their potential returns and the availability of adequate casual labour.

In the longer term, a redclaw crayfish activity can be included within the farm plan. This will further improve profitability. Consideration needs to be given to how best to finance this intensification of the existing farm plan. The availability of finance or investment capital will increase the speed of intensification. However, the associated risk may be more than the manager is willing to accept.

For the case study farm, intensification is a profitable alternative to the traditional activities irrespective of groundwater supplies (within the range examined). Many factors will determine the wider applicability of SDI installation and activity intensification, and the rate of adoption of these approaches. Further research is necessary to examine these with other farm businesses within the Callide Valley.

8. Summary and Conclusions

8.1 Intoduction

This chapter presents a summary of the study. Each of the hypotheses postulated in the Introduction is re-examined in light of the study findings, and either supported or rejected. The major findings of the study and its limitations are presented, together with suggested future scientific and economic research. Finally, the achievements of the study are detailed in the Conclusion

8.2 Hypotheses

No formal statistical hypothesis tests are applied in this study, rather, the LP and MLP models developed, and the associated sensitivity analysis, provide the basis upon which the four guiding hypotheses outlined in the Introduction are either accepted or rejected.

8.2.1 Hypothesis 1

'The inclusion of horticultural crops in exiting farm activities will improve profitability as water resources decline'.

Allowing horticultural crops to enter the base LP model increased operating profit by 180 percent (from $241 794 to $676 737). This increase was caused by both traditionally grown and SDI grown annual horticultural crops entering the optimal plan. Although the optimal mix of crops changed and profitability adjusted in line with increased or decreased groundwater supply, the maximum permissible area (60 ha) of annual horticultural crops was grown at all levels of announced allocation tested. The proposed hypothesis is therefore accepted on the basis of the available evidence for the case study farm.

8.2.2 Hypothesis 2

'Subsurface drip irrigation is a profitable alternative to existing irrigation system use in growing traditional irrigation crops under conditions of declining water supplies'.

The gross margin comparisons between traditionally grown irrigated crops and SDI crops indicated the potential improvement in annual returns possible from the use of SDI for the case study farm. At all allocations investigated, the maximum possible area of SDI was used in the optimal LP farm plan.

In the MLP model, the area of traditionally grown irrigation crops (spray irrigated lucerne and navy beans) fell with declining groundwater allocations. The area of SDI installed also declined as less funds were generated for investment in this technology. Within the five year planning period examined, the area of SDI was initially used for lucerne production. Once the necessary investment in horticultural crop facilities had been made, the SDI area was then used for annual horticultural crops.

The evidence from the models support the stated hypothesis for the case study farm business.

8.2.3 Hypothesis 3

'The inclusion of a redclaw crayfish enterprise into existing farm systems will improve their profitability as water resources decline.'

In the static LP model, the redclaw crayfish activity entered the optimal farm plan at the maximum permissible scale at all water allocations investigated. The MLP model brings into question the feasibility of undertaking a redclaw activity within the five year planning period. Investment in the redclaw activity was absent from all optimal farm plans where the announced allocation changed from 100 to 60 percent. This activity only entered the optimal plan for the case study farm when the available investment capital at the start of Year 1 was $300 000.

For the case study farm in question, the models indicate that a redclaw crayfish activity should be included in the overall farm plan in the long term. However achieving this within the planning period considered is unlikely.

The hypothesis proposed cannot be accepted on the basis of the evidence provided by the models.

8.2.4 Hypothesis 4

'Given the resource constraints existing it is possible to develop a more profitable farm model using horticultural crops, subsurface drip irrigation and/or redclaw production than exists with current farm design and operations.'

The evidence provided by the models supports this hypothesis. A more profitable optimal farm plan is possible through investment in SDI and the necessary capital equipment to enable diversification into annual horticultural crops. Over the five year planning period the cumulative operating profit for the optimal farm plan using SDI and annual horticultural crops was $1 531 019, an improvement of 22 percent over that estimated for the initial farm plan prior to intensification.

With the existing resource constraints, neither redclaw crayfish nor table grapes entered the optimal plan. Redclaw were included only where $300 000 of investment capital was available in Year 1.

8.3 Major findings

The study has demonstrated the potential improvement in profitability possible through the use of SDI and annual horticultural crops for a case study farm within the Callide Valley. Redclaw crayfish entered the optimal plan in the longterm, although not within the five year planning period examined in the MLP model.

The importance of water, capital and labour in determining the optimal plan were examined using sensitivity analysis of the models. The use of SDI and annual horticultural crops improve profitability at all levels of water allocation from 100 to 60 percent. The availability of capital through borrowing or initial investment capital hastened the investment in SDI and annual horticultural crop infrastructure, which in turn increased profitability over the planning period examined.

The availability of casual labour was an important constraint affecting the mix of horticultural crops undertaken in the static plan, and the scale of the table grape activity. In the MLP model, the impact of reducing the available supply of casual labour was to restrict the area of annual horticultural crops that could be grown. This in turn limited the investment in SDI. The result over the planning period was a 31 percent reduction in the cumulative profit.

An observation not initially considered in the study objectives was the importance of a lucerne activity to overall farm profitability and future development. This enterprise remained significant at all levels of announced allocations. In the absence of alternative activities, it fell from 51 percent to 30 percent of the cropping area with a reduction in the announced allocation to 60 percent. Where alternative activities were possible, the area of lucerne fell from 40 to 18 percent of the cropping area with the decline in groundwater allocation.

The current market prices for water were lower than the shadow prices for this resource. Therefore, current water prices provide no incentive towards the adoption of more efficient water use.

8.4 Study limitations

There are a number of limitations with the existing study. Firstly, only a single case study farm has been used. The general applicability of the study findings to other farms within the Callide Valley is only possible if the case study farm is representative of the greater proportion of farms present. It is not possible to claim this as there is no detailed information on the characteristics of irrigation farms within the study area. The advantage of using the single case study farm was the depth of detail which could be obtained and used in model development. This was particularly important as the farm in question was the first to use SDI in lucerne within Australia. It had also begun intensification through the use of annual horticultural crops and table grapes. It was thus ideal for the collection of data necessary in the development of the models.

A second limitation was the neglect of risk within the model. The co-operators perceptions of the risks associated with the range of activities were obtained, but not specifically used within the model development. These perceptions did however aid in the interpretation of the model output in the context of on farm decisions about the activity mix and investment in new technologies and activities.

Thirdly, limitations of the software restricted the planning horizon to five years. This is a short planning period in terms of the investment decisions about the inclusion of redclaw crayfish and table grape activities within the overall farm plan. However, it was sufficient to provide guidelines on the investments in SDI and annual horticultural crops.

Finally, there was no discounting of the objective function within the MLP model. This simplified model development, but should be included in future versions of the model.

8.5 Future research

The foregoing limitations of this study provide opportunities for future scientific and economic research. Further scientific research is required into:

- the quantification of water savings and yield improvements attributable to the use of SDI with a range of field and horticultural crops;
- the technology of redclaw crayfish production aimed at increased growth rates and overall productivity; and
- the technology of table grapes production aimed at earlier productivity increases.

Future economic research could include:

- analysis of SDI technology and the results obtained from scientific research into its use;
- analysis of commercial redclaw crayfish production and current research into this activity;
- a survey of the characteristics of existing farms within the different sections of the alluvium. The data collected can be used to test the generality of the MLP results within this study;
- extension of the MLP model to incorporate a longer planning period;
- greater detail of the labour requirements for the activities available; and

- analysis into other alternative activities such as herb production and floriculture currently being undertaken.

Economic and scientific research is needed to determine the most profitable application of new technology and activities in a range of situations encountered by Callide Valley irrigators. This will provide information that irrigators can use in making better plans for the future given the existing groundwater supply limitations.

Further research should also aid in policy decisions that impact upon the use of the groundwater resource - in particular, water pricing and announced allocations. These and other policy decisions can be used to bring about adoption of more profitable and sustainable irrigation technologies and activity mixes.

8.6 Conclusions

This study has shown that the use of SDI and annual horticultural crops is a profitable approach for the case study farm in dealing with diminishing groundwater supplies. This approach is profitable across the range of groundwater supply situations examined. It has also demonstrated the importance of lucerne production within the overall farm plan in maintaining profitability, and generating funds for future farm development.

Other achievements of this study include:

- development of annual gross margins for traditional and alternative cropping and livestock activities;
- detailed estimates of the establishment and operating costs for a range of irrigation systems, including the new SDI technology;
- production of discounted cash flow analyses for table grapes and redclaw crayfish activities; and,
- development of LP and MLP models which can be used with data from other farms to evaluate alternative approaches to maintaining profitability with declining groundwater supplies.