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MOST PROFITABLE USE OF IRRIGATION SUPPLIES: A CASE STUDY OF A BUNDABERG CANE FARM

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Abstract

A range of biophysical and financial factors, including the crop response to available water and the cost of irrigation, significantly impact on the economic benefits from using irrigation. Research tools have been developed in a multi-disciplinary environment to allow for the assessment of the economic benefits associated with using irrigation. This paper adopts the 1996-1997 season in Bundaberg as a case study and develops arguments for best use of limited water based on current economic and biophysical modelling capability. A selection of irrigation 'options' were chosen for investigation based on combinations of soil type, allocation, critical fraction of available soil water (FASW) to irrigate, irrigation amount, and age of crop for irrigation commencement. The influence of these options on cane production is explored in a farm-level linear programming model. There appears to be a sound economic argument for further biophysical research into the crop response to irrigation, based on the sensitivity of farm incomes to choice of irrigation strategy.

Introduction

The high cost of irrigation means that growers need to make well-informed decisions about the best way to use this resource. A range of biophysical and financial factors, such as the crop response to applied water and the cost of irrigation, significantly impact on the economic benefits from using irrigation. Where water supplies are limited and/or costly, and there are a variety of irrigation application possibilities, there is a critical lack of information to help farmers decide the likely pay-off from irrigation, what proportion of water to apply to crops on different soil types, whether to favour plant over ratoons, whether to apply small amounts of water frequently or whether to apply more water in less frequent irrigations.

In a multi-disciplinary research environment, the crop growth simulation model, APSIM, coupled with an economic linear programming model offers good opportunities to address these questions by providing an insight into the response of cane production to varying amounts of irrigation water applied under different strategies. Linear programming is an appropriate method of economic analysis to assess the most profitable irrigation strategies through optimisation. It is an analytically robust modelling technique which has been available in other agricultural industries for many decades and has now been developed for application to the sugar industry.

The irrigation supply system in Bundaberg is in what Randall (1981) termed a ‘mature’ stage of development, as opposed to an ‘expansionary’ phase. The mature phase is characterised by sharply rising incremental costs of water supply and greater competition for water among different users. Growers therefore need to strive for efficiency in the management of existing water supplies, particularly because the district has faced water shortages in recent years. Bundaberg growers in the Bundaberg irrigation area are currently limited to about 2.9 ML/assigned ha allocation of irrigation water. However, the deficit between crop demand and effective rainfall for cane crops in Bundaberg has been calculated to be 7.8 ML/ha (at 85% irrigation application efficiency) (Willcox *et al*., 1997). For these reasons the district was chosen as a case study to demonstrate the modelling capability described above.

Method

Biophysical modelling

Biophysical simulations were performed using the APSIM systems model (Agricultural Production Systems Simulator; McCown *et al*., 1996). APSIM simulates agricultural production systems by combining modules describing the specific processes within the system under investigation. In this study, the sugar crop module APSIM-Sugarcane (Keating *et al.*, 1998) was linked with the soil water module SOILWAT (Probert *et al.*, 1997), the soil nitrogen module SOILN (Probert *et al.*, 1997), and the surface residue module RESIDUE (Probert *et al.*, 1997) to investigate yield responses to applied irrigation across a range of irrigation options in the Bundaberg district.

APSIM-Sugarcane was configured to simulate continuous cropping of the variety Q124 with a cycle consisting of one plant crop followed by four ratoon crops. The simulation runs were conducted over a period leading up to and including 1997 without re-initialising soil water, residue and nitrogen related parameters. This enabled the capture of simulated carry-over effects from one season to the next, such as the effects of residue retention and the pre-planting fallow period on soil moisture levels. Subsequent analysis of responses to varying irrigation strategies were centred on the 1996-97 season, on the basis that it is was a relatively dry year within recent memory.

A representative cropping sequence for Bundaberg was used, with each cycle commencing on day 244 (September 1) with planting to a depth of 15 cm. This plant crop was harvested on day 263 (September 20). Subsequent ratoon crops were harvested on days 248 (September 5), 232 (August 20), 213 (August 1) and 186 (July 5). This ‘plough-out / replant’ cycle allowed approximately two months between cycles for harvesting and ground preparation activities. Given that APSIM is a paddock scale model, it was necessary to conduct a series of five separate runs, each offset by one year in order to simulate the response of each crop class in the 1996-97 season. A green cane trash blanket system was employed in the simulation with pre- and post- harvest residues retained in the system. At the end of the crop cycle, all residues were incorporated to a depth of 40 cm. Stalk density for both plant and ratoon crops was set to 10 stalks per m^2.

Actual average cane fresh weights reported for the 1996/97 season in Bundaberg district ranged from 44 t/ha to 118 t/ha for applied irrigation amounts between 0-7 ML/ha (June 1996-June 1997)(Bundaberg Cane Productivity Committee, 1997). The largest reported yields were about 150 t/ha. This compares with maximum simulated yields in the vicinity of 190t/ha. Simulated yields exceed the industry averages because they do not take into account losses associated with pests, disease, weed competition, unusual climatic events and they are based on uniform soil characteristics. Furthermore, irrigation is assumed to be 100% efficient.

Nitrogen fertiliser application rates were set to non-limiting levels of 250 kg N ha^{-1} for both plant and ratoon crops. This rate was based on a potential cane fresh weight yield of 200 t ha^{-1} and rule of thumb applications of 1.4 kg N t^{-1} for the first 100 t of crop and 1.0 kg N t^{-1} for each tonne above that (Keating *et al*., 1997).

A selection of irrigation ‘options’ were chosen for investigation based on combinations of soil type, allocation, critical fraction of available soil water (FASW) to irrigate, irrigation amount, and age of crop for irrigation commencement. The elements of these options are specified in Table 1. The irrigation amount was based on the quantity required to refill the profile to the drained upper limit from the soil water content corresponding to the largest critical FASW. The two soil types used in the simulation were selected to represent profiles with sharply contrasting plant extractable soil water contents (PESW). The sand has a PESW of 63 mm to a depth of 150 cm, and the clay soil, a PESW of 146 mm to 120 cm. A pre-harvest drying-off (irrigation free) period of 30 days duration was incorporated into each element of the crop cycle.

Table 1- Elements of the irrigation options used in the APSIM simulations.

Soil	Allocation (ML/ha)	FASW	Irrigation (mm)	Delay (days)
Sand	0, 2, 4, 6, 8, 10	0.2, 0.5	30	0, 90, 180
Clay	0, 2, 4, 6, 8, 10	0.2, 0.5, 0.8	32	0, 90, 180

Rainfall, temperature and solar radiation data used for the simulation were based on calibrated weather station data (March 1996 – December 1997) recorded at the Bundaberg Sugar Fairymead Mill. Data prior to this period was sourced from a QDNR climate file for the Bundaberg Sugar Research station.

Cane fresh weight by applied irrigation response functions generated from these model runs were used as inputs to the economic model framework described below. Simulated applied irrigation and cane fresh weights for the various irrigation options appear in Appendices 1 and 2.

Economic modelling

A farm-level linear programming (LP) model was developed to estimate the changes to optimum irrigation strategies under varying levels of water availability and water charge assumptions based on gross margins, for a single season. The model also provides information about how canegrowers should tactically adjust their irrigation strategies in response to changed water charges and water availability.

The LP model represents the production system of a 'typical' Bundaberg cane farm with existing irrigation equipment and the option of either irrigated or dryland cane production (Table 1). The representative cane farm in this study is 58 ha with fixed production areas of plant cane (14 ha) and 4 ratoon cane crops each of 11 ha. Each crop class has exactly half of its area under the sand and clay soils described above. For example, 7 ha of the plant crop is grown on sand and the other 7ha of plant crop is on the clay soil. Other physical and financial assumptions for the LP model are listed in Appendix 3.

The LP model allocates available water between various irrigation 'options' for each crop class by soil type combination to maximise farm gross margin. It selects the most profitable combination of irrigation options subject to various constraints such as water availability, and fixed areas of each crop class on each soil type.

The model was run to calculate the most profitable quantity of water to apply under the following situations:

- Water charges (including pumping cost) ranging from \$0/ML to \$350/ML.
- Whole farm irrigation allocation of 0, 116, 232, 348, 464 and 580 ML corresponding to per hectare irrigation allocations of 0, 2, 4, 6, 8 and 10 ML respectively.

Two of these whole-farm allocations, 116 ML and 464 ML, and three of the water charges, \$0, 100 and 300/ML were then examined in closer detail to show how the available water should be applied to the farm to maximise profits. This also serves to demonstrate the sensitivity of the most profitable set of irrigation options, and gross margins, to changes in water availability and water charge, and the consequences of making a sub-optimal choice from the range of irrigation options.

Results of economic modelling

Economically optimum demand for water

Demand for irrigation water was determined by varying the water charge from $0 to $350 per megalitre for whole-farm water allocations ranging from 116ML to 580ML (Fig. 1)[1].

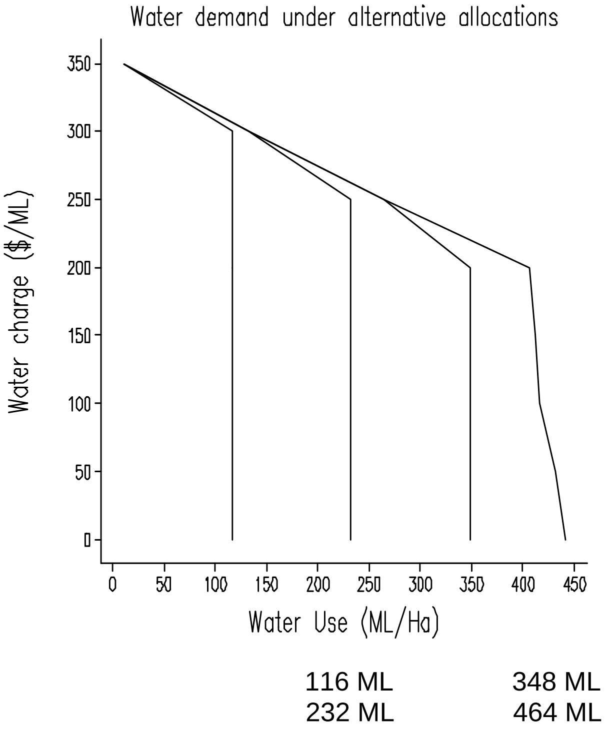

Fig. 1. Derived demand for water for four whole-farm irrigation allocations.

The shadow price output or marginal value of water represents the amount by which the gross margin would increase if one additional megalitre of water was made available for irrigation and is shown in Table 2. For the allocations of 116 and 232 ML, and to a lesser extent for the 348 ML allocation, the economic demand for water by canefarmers appears to be relatively ‘inelastic’ or stable over the simulated range. In these cases, water is limiting yields and the positive marginal values indicate that the returns from applying an extra unit of water exceed the cost of applying the water. However, increasing water

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[1] Demand curve for 580ML allocation as for 464 ML but omitted from Fig. 1 for clarity of presentation.

charge eventually erodes these returns, as shown by the falling marginal value of water. When the total farm allocation is increased beyond 464 ML, the demand for water is more ‘elastic’ and decreases as the water charge is increased, and not all the available water is used. When the water charge increases, the cost of applying an extra unit of water is not compensated by a sufficient yield response to generate additional profits, hence the marginal value of water is 0. The gross margin would actually fall if all of the available water was used.

Table 2- Response to irrigation management under varying water charges and water availabilities: Economically optimum quantity of water (ML).

Water	**0 ML**		**116 ML***		**232 ML**		**348 ML**		**464 ML**		**580 ML**	
Charge ($)	**Quant. (ML)**	**MV** ($)**	**Quant. (ML)**	**MV ($)**	**Quant. (ML)**	**MV ($)**	**Quant. (ML)**	**MV ($)**	**Quant. (ML)**	**MV ($)**	**Quant. (ML)**	**MV ($)**
0	0	358	116	301	232	265	348	200	441.2	0	441.2	0
50	0	308	116	251	232	215	348	150	432	0	432	0
100	0	258	116	201	232	165	348	100	416.2	0	416.2	0
150	0	208	116	151	232	115	348	50	411.3	0	411.3	0
200	0	158	116	101	232	65	348	0	406	0	406	0
250	0	108	116	51	232	15	264.7	0	264.8	0	264.8	0
300	0	58	116	1.7	131.6	0	131.6	0	131.6	0	131.6	0
350	0	8.4	10.6	0	10.6	0	10.6	0	10.6	0	10.6	0

* Whole-farm allocation; ** Marginal value of one additional ML of water.

Most profitable irrigation strategies

Two of these whole-farm allocations, 116 ML and 464 ML, and three of the water charges, $0, 100 and 300 /ML, are highlighted in Table 2. These cases were examined in closer detail to show the gross margins that corresponded with the optimum quantity of water and the combination of irrigation options that should be applied to the farm to maximise profits (Table 3). The gross margins presented in Table 3 represent the highest possible income obtainable under the particular set of market factors. The gross margin falls substantially as the water charge is increased. For the “costless” water charge, the gross margin for the 464 ML allocation is almost 3 times higher than the 116 ML allocation. For the $300/ML water charge, the gross margin for the 464ML allocation is lower than for the 116ML allocation. This is because a $5 levy per ML of nominal allocation (incurred in addition to the variable water charge) is charged on every ML of the 464Ml allocation, regardless of the quantity used, and this is having the effect of lowering these gross margins. The irrigation options which were selected by the model to produce the optimum gross margin are also listed in Table 3.

Table 3- Optimal irrigation strategies for the whole farm for 2 whole-farm allocations and 3 water charges, gross margins, and optimum quantity of water applied to the whole-farm.

Water	Whole farm allocation 116 ML						Whole farm allocation 464 ML					
Charge ($)	class	soil	ha	ML/ha	fasw	delay (days)	class	soil	ha	ML/ha	fasw	delay (days)
0	P	Sand	3.2	1.92	0.5	90	P	Sand	7	7.36	0.5	0
		Sand	3.8	6.72	0.5	90		Clay	7	7.2	0.8	0
		Clay	7	1.8	0.8	0						
	R1	Sand	5.5	1.92	0.2	90	R1	Sand	5.5	7.04	0.5	0
		Clay	5.5	1.8	0.8	90		Clay	5.5	6	0.5	90
	R2	Sand	5.5	1.92	0.5	90	R2	Sand	5.5	8.32	0.5	0
		Clay	5.5	1.8	0.8	90		Clay	5.5	7.8	0.8	0
	R3	Sand	5.5	1.92	0.2	90	R3	Sand	5.5	8.32	0.5	0
		Clay	5.5	0	0.2	0		Clay	5.5	8.4	0.8	0
	R4	Sand	5.5	1.92	0.2	90	R4	Sand	5.5	8	0.5	0
		Clay	5.5	1.8	0.2	0		Clay	5.5	7.8	0.8	0
	Gross margin = $42 631						**Gross margin = $116 718**					
	Optimum quantity applied = 116ML						**Optimum quantity applied = 441.2 ML**					
100	As above						P	Sand	7	6.72	0.5	90
								Clay	7	7.2	0.8	0
							R1	Sand	5.5	7.04	0.5	0
								Clay	5.5	6	0.5	90
							R2	Sand	5.5	6.72	0.5	90
								Clay	5.5	7.2	0.8	90
							R3	Sand	5.5	8.32	0.5	0
								Clay	5.5	7.2	0.5	0
							R4	Sand	5.5	7.68	0.5	0
								Clay	5.5	7.8	0.8	0
	Gross margin = $31 031						**Gross margin = $73 530**					
	Optimum quantity applied = 116ML						**Optimum quantity applied = 416.2 ML**					
300	As above						P	Sand		6.72	0.5	90
								Clay		1.8	0.8	90
							R1	Sand	5.5	1.92	0.2	90
								Clay	5.5	1.8	0.8	90
							R2	Sand	5.5	1.92	0.5	90
								Clay	5.5	1.8	0.8	90
							R3	Sand	5.5	1.92	0.2	90
								Clay	5.5	0	0.2	0
							R4	Sand	5.5	1.92	0.2	90
								Clay	5.5	1.8	0.2	0
	Gross margin = $7 831						**Gross margin $6 118**					
	Optimum quantity applied = 116ML						**Optimum quantity applied = 131.6 ML**					

For the 116ML whole-farm allocation, the profit-maximising set of irrigation strategies does not change for the range of water prices. The highest possible gross margin is achieved by applying water at low intensity across all crop classes on both soil types. Part of the plant crop on the sand soil is irrigated intensively, however, there are insufficient supplies to profitably irrigate all of the plant crop at this rate.

For the 464ML whole-farm allocation, the optimal set of irrigation strategies changes considerably with increasing water charge. Water was applied at considerably lower intensities across the farm as the water charge increased. It was not only the intensity of irrigation which varied for the range of water charges - the timing of irrigation and soil moisture status at irrigation were also adjusted to achieve highest possible gross margins. With increasing water charge, optimum irrigation strategies involved delaying the commencement of irrigation, and soil water was also allowed to run down further before the next irrigation. Both management factors are water saving measures which become economically important when water charges become costly. Water is applied 'luxuriously' with shorter delays for the commencement of irrigation, and less soil water depletion, when water is plentiful and inexpensive.

The cost of choosing a sub-optimal strategy

For each crop class on the sand and clay soils there were 5 and 7 alternative combinations of FASW and delay after planting (or harvest), respectively, which could have been selected. The linear programming model generates information revealing the sensitivity of gross margin to choosing one of these alternative options instead of the optimum. An example of this is shown in Table 4 where the costs associated with implementing an alternative strategy are explored. Given the large amount of information to present for all crop classes, only the plant crop is examined in the table.

The highlighted section of Table 3 shows that the optimum irrigation strategy for the plant cane is where 6.72 ML/ha is applied to the full 7 ha of the sand soil starting 90 days after planting when the soil water fraction is 0.5. Note that the precise quantity applied is not listed in the table because this varied for each irrigation option. However, the amount applied can be summarised as an upper, per hectare, rate limit which was used in the APSIM runs. Whole farm allocations were not used in APSIM because it is a block-level model. On the clay soil, 7.2 ML/ha is applied to the full 7 ha with no delay after planting and a soil water fraction of 0.8. The negative values in Table 4 represent the amount by which the total farm gross margin would fall when just one hectare of these optimum options is replaced by one hectare of any of these alternative options on both soil types. The biggest gross margin losses occur when the low-intensity irrigation options are selected. For example, replacing one hectare of the plant crop on sand, irrigated according to the optimum option, with one hectare of non-irrigated cane reduces gross margin by $1 377. In this example, increasing the delay from planting to irrigation appears to reduce gross margin.

Table 4- Impact of implementing alternative plant crop irrigation options on whole farm gross margin for the 464 ML whole-farm allocation and 100 $/ML water charge.

Marginal revenue		**Delay (days) - Sand**			**Delay (days)- Clay**		
Fasw	**Upper limit ML applied to ha**	**0**	**90**	**180**	**0**	**90**	**180**
0	**0**	-1377	-1377	-1377	-1302	-1302	-1302
0.2	**2**	-1038	-982	-1087	-1022	-1302	-991
	4	-667	-690	-904	-775	-1022	-817
	6	-480	-607	-904	-775	-775	-817
	8	-480	-607	-904	-775	-775	-817
	10	-480	-607	-904	-775	-775	-817
0.5	**2**	-1013	-968	-1082	-951	-951	-1043
	4	-624	-705	-761	-601	-601	-652
	6	-353	-422	-759	-301	-301	-652
	8	-13	Optimal	-759	-157	-157	-652
	10	-13	<1	-759	-157	-157	-652
0.8	**2**	Not applicable			-922	-922	-1027
	4				-551	-551	-672
	6				249	-249	-577
	8				Optimal	-2	-577
	10				-2	-2	-577

Conclusion

In a production environment characterised by volatile sugar prices, increasing costs and increasing competition for water supplies it is critical to use water efficiently. The research outlined in this paper highlights the importance of an improved understanding of the crop response to varying quantities of irrigation water applied under different biophysical circumstances. Based on the sensitivity of farm incomes to choice of irrigation strategy, there appears to be a solid economic argument for further biophysical research into the crop response to irrigation, not just in terms of quantity applied but also with respect to understanding how profitability of irrigation strategies are influenced by soil type and manipulation of the timing of application of water. It should be stressed, however, that the analysis presented in this paper is based on simulated potential yield data and there is an element of uncertainty about the outcomes presented. Therefore, the results should not form the basis of industry recommendations on best use of limited water supplies in the Bundaberg district. Until the model is run with actual yield data, the results should be seen as only indicative of the relationship between irrigation strategies and farm profitability.

The coupling of crop growth simulation models with economic optimisation models has provided a powerful capacity to explore these issues by also providing information about how canegrowers should tactically respond to changed water charges, and what irrigation strategy to select under changed market factors. The linear programming model represents a significant improvement over traditional spreadsheet-based economic tools available to the industry. This is because of its ability to calculate optimum solutions from large numbers of irrigation options for various combinations of water allocation and market factors, and its ability to generate information about how farm incomes would change if non-optimal irrigation options were implemented.

This multi-disciplinary, multi-party research was initiated by a small group of bio-physical scientists and an economist in the CRC for Sustainable Sugar Production with a genuine interest in improving the effectiveness of irrigation research. Both the economist and the bio-physical scientists agreed that the CRC environment has provided an interactive opportunity to improve their understanding of each other's disciplines and make the 'language' and theory of the scientific and economic disciplines more accessible to each other. The bio-physical scientists involved in irrigation research have a strong desire to make their research relevant and have changed the emphasis and design of future irrigation field experiments with knowledge gained from economic sensitivity of the results. The emphasis has shifted from trying to maximise responses per megalitre of irrigation to exploring incremental responses to achieve maximum profitability.

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Appendix 1: Simulated cane fresh weight (C, t/ha) and applied irrigation (I, mm) for the range of irrigation options on the sand soil.

				Plant		Rtn. 1		Rtn. 2		Rtn. 3		Rtn. 4	
Soil	FASW	Delay	Allocation	I	C	I	C	I	C	I	C	I	C
Sand	Rainfed			0	46	0	53	0	54	0	54	0	52
	0.2	0	2	192	75	192	85	192	82	192	83	192	79
			4	384	106	384	110	384	110	384	109	384	111
			6	448	120	448	123	480	128	544	136	512	125
			8	448	120	448	123	480	128	544	136	512	125
			10	448	120	448	123	480	128	544	136	512	125
		90	2	192	78	192	92	192	88	192	89	192	89
			4	384	105	384	111	384	109	384	110	384	112
			6	416	111	448	124	448	122	448	122	416	112
			8	416	111	448	124	448	122	448	122	416	112
			10	416	111	448	124	448	122	448	122	416	112
		180	2	192	72	192	80	192	79	192	81	192	78
			4	256	86	192	81	224	85	224	87	256	82
			6	256	86	192	81	224	85	224	87	256	82
			8	256	86	192	81	224	85	224	87	256	82
			10	256	86	192	81	224	85	224	87	256	82
	0.5	0	2	192	76	192	85	192	73	192	75	192	76
			4	384	109	384	114	384	110	384	112	384	112
			6	576	134	576	140	576	130	576	133	576	142
			8	736	162	704	158	768	154	768	156	768	164
			10	736	162	704	158	832	165	832	168	800	164
		90	2	192	79	192	91	192	91	192	86	192	83
			4	384	104	384	115	384	117	384	115	384	112
			6	576	130	576	140	576	139	576	139	576	134
			8	672	159	640	152	672	156	704	153	704	150
			10	672	159	640	152	672	156	704	153	704	150
		180	2	192	73	192	72	192	75	192	78	192	77
			4	384	101	256	85	352	95	320	93	320	92
			6	384	101	256	85	352	95	320	93	320	93
			8	384	101	256	85	352	95	320	93	320	93
			10	384	101	256	85	352	95	320	93	320	93

Appendix 2: Simulated cane fresh weight (C, t/ha) and applied irrigation (I, mm) for the range of irrigation options on the clay soil.

				Plant		Rtn. 1		Rtn. 2		Rtn. 3		Rtn. 4	
Soil	FASW	Delay	Allocation	I	C	I	C	I	C	I	C	I	C
Clay	Rainfed			0	83	0	79	0	78	0	82	0	87
	0.2	0	2	180	109	180	107	180	104	180	106	180	118
			4	300	129	390	136	390	136	390	139	390	140
			6	300	129	540	158	540	162	570	164	570	164
			8	300	129	540	158	540	162	660	176	630	173
			10	300	129	540	158	540	162	660	176	630	173
		90	2	180	109	180	109	180	105	180	104	180	109
			4	300	129	390	136	390	134	390	134	390	135
			6	300	129	540	158	570	160	570	162	570	164
			8	300	129	540	158	600	165	570	162	600	166
			10	300	129	540	158	600	165	570	162	600	166
		180	2	180	110	180	103	180	102	180	99	180	101
			4	270	125	270	117	300	120	360	126	360	124
			6	270	125	270	117	300	120	360	126	360	124
			8	270	125	270	117	300	120	360	126	360	124
			10	270	125	270	117	300	120	360	126	360	124
	0.5	0	2	180	113	180	106	180	104	180	108	180	114
			4	390	144	390	135	390	140	390	142	390	140
			6	570	170	570	165	570	165	570	168	570	165
			8	630	182	570	165	690	182	720	185	720	187
			10	630	182	570	165	690	182	720	185	720	187
		90	2	180	113	180	109	180	108	180	107	180	108
			4	390	144	390	141	390	139	390	138	390	139
			6	570	170	570	166	570	164	570	164	570	164
			8	630	182	600	170	660	177	660	172	720	180
			10	630	182	600	170	660	177	660	172	720	180
		180	2	180	108	180	104	180	103	180	100	180	102
			4	390	141	300	122	360	127	390	127	390	129
			6	390	141	300	122	360	127	390	127	390	129
			8	390	141	300	122	360	127	390	127	390	129
			10	390	141	300	122	360	127	390	127	390	129
	0.8	0	2	180	114	180	107	180	101	180	101	180	110
			4	390	146	390	137	390	135	390	133	390	136
			6	570	173	570	161	570	158	570	161	570	165
			8	720	195	570	162	780	186	780	186	780	191
			10	720	195	570	162	780	186	840	187	780	191
		90	2	180	114	180	110	180	108	180	106	180	109
			4	390	146	390	139	390	140	390	139	390	138
			6	570	173	570	162	570	167	570	166	570	164
			8	720	195	600	164	720	184	720	176	750	189
			10	720	195	600	164	720	184	720	176	750	189
		180	2	180	108	180	104	180	104	180	100	180	102
			4	390	140	360	129	390	131	390	129	390	133
			6	450	148	360	129	390	132	450	130	420	136
			8	450	148	360	129	390	132	450	130	420	136
			10	450	148	360	129	390	132	450	130	420	136

Appendix 3: LP Model assumptions

Other model assumptions for the LP model, based on data obtained from Canegrowers (1996) and ABARE (1996) survey data.

- Crop labour requirements were: fallow 8 hrs/ha, plant 50 hrs/ha, ratoon 20 hrs/ha. The family labour available totalled 3200 hours per year. Casual labour was available to supplement on-farm labour depending on crop activity labour requirements. The additional labour could be purchased at $20 per hour. This price included wages and on-costs.
- The plant and ratoon crops had cultivation requirements of 11 and 5 hrs/ha respectively, and the total tractor hours available were 5000 hours.
- The ccs was set to12.
- Farm cash costs, excluding harvesting, hired labour and water charges were $1000 /ha. This figure includes maintenance costs for the irrigation system.
- Sugar price set to $330/t
- Harvesting and levies was $5.70/t
- An annual allocation charge of $5/ML of nominal allocation water payable regardless of the quantity of water used from the whole-farm allocation.
- As only the farm gross margin is calculated in the model, the fixed costs associated with investment in irrigation equipment and other capital items were not considered.