

**BUREAU OF SUGAR EXPERIMENT STATIONS  
QUEENSLAND, AUSTRALIA**

**TECHNICAL REPORT**

**APSIM BASED DETERMINATION OF IRRIGATION  
ATTRIBUTES AND BEST USE OF LIMITED WATER  
IN SUPPLEMENTARY IRRIGATION AREAS  
OF THE AUSTRALIAN SUGAR INDUSTRY**

**by  
Marcus Hardie**

**TE00001**

**Principal Investigator: M A Hardie  
Research Officer  
Bureau of Sugar Experiment Stations  
PO Box 305  
Proserpine Q 4800**

**BSES Publication  
Technical Report TE00001**

**March 2000**

**Copyright © 2003 by Bureau of Sugar Experiment Stations**

*All rights reserved.* No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior permission of BSES.

**Warning:** Our tests, inspections and recommendations should not be relied on without further, independent inquiries. They may not be accurate, complete or applicable for your particular needs for many reasons, including (for example) BSES being unaware of other matters relevant to individual crops, the analysis of unrepresentative samples or the influence of environmental, managerial or other factors on production.

**Disclaimer:** Except as required by law and only to the extent so required, none of BSES, its directors, officers or agents makes any representation or warranty, express or implied, as to, or shall in any way be liable (including liability in negligence) directly or indirectly for any loss, damages, costs, expenses or reliance arising out of or in connection with, the accuracy, currency, completeness or balance of (or otherwise), or any errors in or omissions from, any test results, recommendations statements or other information provided to you.

## TABLE OF CONTENTS

	Page No.
<b>EXECUTIVE SUMMARY</b>	
<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>2.0 METHODS AND APSIM CONFIGURATIONS.....</b>	<b>1</b>
<b>2.1 Configuration of irrigation simulations .....</b>	<b>2</b>
<b>3.0 RESULTS.....</b>	<b>4</b>
<b>3.1 Comparison of irrigation attributes between districts.....</b>	<b>4</b>
<b>3.2 Long-term simulation results for the Mackay area .....</b>	<b>7</b>
<b>3.3 Long-term simulation results for the Proserpine area .....</b>	<b>8</b>
<b>3.4 Long-term simulation results for the Sarina area.....</b>	<b>9</b>
<b>3.5 Long-term simulation results for the Mareeba area.....</b>	<b>10</b>
<b>3.6 Long-term simulation results for the Bundaberg area .....</b>	<b>11</b>
<b>3.7 Long-term simulation results for the Childers area .....</b>	<b>12</b>
<b>4.0 CONCLUSION.....</b>	<b>13</b>
<b>5.0 ACKNOWLEDGMENTS .....</b>	<b>14</b>
<b>6.0 REFERENCES .....</b>	<b>14</b>

## LIST OF TABLES

<b>Table 1</b>	<b>APSIM setup criteria and configuration requirements.....</b>	<b>2</b>
<b>Table 2</b>	<b>Setup criteria for the limited strategy I simulations .....</b>	<b>3</b>
<b>Table 3</b>	<b>Setup criteria for limited strategy II simulations.....</b>	<b>3</b>

## LIST OF FIGURES

Page  
No.

<b>Figure 1</b>	<b>Average rainfall and rainfed effective rainfall for each district 1960-1992. ....</b>	<b>4</b>
<b>Figure 2</b>	<b>Estimated crop yield (365 day crop) under rainfed and unlimited irrigation conditions. ....</b>	<b>5</b>
<b>Figure 3</b>	<b>Comparison of the current allocation and unlimited irrigation requirement for each district. ....</b>	<b>6</b>
<b>Figure 4</b>	<b>APSIM based analysis of irrigation strategies in the Mackay Area: (a) Variation in effective rainfall; (b) ..... Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d)..... Water use efficiency.....</b>	<b>7</b>
<b>Figure 5</b>	<b>APSIM based analysis of irrigation strategies in the Proserpine area: (a) Variation in effective rainfall; (b) .....Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) ..... Water use efficiency.....</b>	<b>8</b>
<b>Figure 6</b>	<b>APSIM based analysis of irrigation strategies in the Sarina area: (a) Variation in effective rainfall; (b) .....Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.....</b>	<b>9</b>
<b>Figure 7</b>	<b>APSIM based analysis of irrigation strategies in the Mareeba area: (a) Variation in effective rainfall; (b) .....Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.....</b>	<b>10</b>
<b>Figure 8</b>	<b>APSIM based analysis of irrigation strategies in the Bundaberg area: (a) Variation in effective rainfall; (b) .....Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) ..... Water use efficiency.....</b>	<b>11</b>
<b>Figure 9</b>	<b>APSIM based analysis of irrigation strategies in the Childers area: (a) Variation in effective rainfall; (b) .....Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.....</b>	<b>12</b>

## **EXECUTIVE SUMMARY**

Identifying irrigation attributes and strategies for the best use of limited irrigation is difficult with short term field trials. The crop simulation model APSIM was employed to determine the rainfed yield, effective rainfall, crop response to irrigation, potential yield, and irrigation requirement for six supplementary irrigation areas in the Australian sugar industry. This information was used to determine potential gains from irrigation and assess the adequacy of current allocations in the Proserpine, Mackay, Sarina, Bundaberg, Mareeba and Childers areas. Additional simulations were conducted to identify possible strategies for the best use of limited allocation in each of the six areas.

Results demonstrated that the average rainfed effective rainfall varied from 573 mm/yr in Mareeba to 885 mm/yr in Mackay. Effective rainfall was significantly related to rainfed yield, which varied from 29 t/ha in Mareeba to 84 t/ha in the Mackay and Sarina. The potential yield determined by unlimited allocation simulations, varied from 120 t/ha in Childers to 154 t/ha in Proserpine. The potential gain from irrigation measured by the difference between the rainfed and the potential yield, indicated that Mareeba with the lowest effective rainfall, had the greatest potential gain from irrigation.

Crop response to irrigation varied depending on location, soil type, and irrigation strategy. Values for the unlimited allocation simulation demonstrated that Mackay (10.9 t/ML) had the lowest crop response to irrigation (CRI) and Bundaberg (12.6 t/ML) the highest. Irrigation requirement also determined by unlimited allocation simulations varied between districts from 10.3 ML/ha in Mareeba to 4.8 ML/ha in Childers. Sarina observed the largest difference between the irrigation requirement (unlimited simulations) and the current allocation.

Although based on a limited number of simulations, analysis indicated that in most years crop production would increase from greater allocation, particularly in the Sarina, Proserpine and Bundaberg areas.

In the Mackay and Sarina areas, limited irrigation strategies were found to be advantageous, however further simulations were required in all areas to determine strategies for the best use of limited irrigation.

## 1.0 INTRODUCTION

The current industry focus on improving irrigation efficiency has identified the need for a better understanding of the potential gains from irrigation and use of irrigation resources in many sugar producing regions. This paper was conducted as a component of project BS183S, *Statewide adoption of best irrigation practices for supplementary and full irrigation districts*, to determine a range of irrigation attributes and irrigation strategies for the use of limited allocation in supplementary irrigation areas.

Identifying strategies for the best use of limited irrigation resources is difficult with short term field trials. Crop simulation modelling enables these strategies and a range of irrigation attributes to be determined on a long-term basis wherever climatic and soils data is available. APSIM (McCown *et al.* 1996, Keating *et al.* 1999) was employed to determine rainfed yield, effective rainfall, crop response to irrigation, potential yield, and irrigation requirement using 'synthetic' climatic data (Hardie and Mallet 2000) for six supplementary irrigation areas of the Australian sugar industry. This information was used to assess current and potential gains from irrigation, identify strategies for the best use of limited allocation, and raise questions about the current level of allocation and irrigation infrastructure in the Proserpine, Sarina, Mackay, Bundaberg, Mareeba and Childers areas.

## 2.0 METHODS AND APSIM CONFIGURATIONS

Simulations were conducted to investigate crop response to irrigation and to identify possible strategies for the best use of limited irrigation in the Mackay, Sarina, Proserpine, Atherton, Mareeba, Childers and Bundaberg areas. APSIM (McCown *et al.* 1996, Keating *et al.* 1999) was configured to conduct crop simulations over a 32 year period between 1960 and 1992. Simulations were conducted on a 365 day crop cycle ie plant cane and ratoons were planted and harvested on the same day each year. This avoided complications arising from analysis of differential crop lengths. As such APSIM based estimates of crop yield are different to yields produced in the field under a typical plantcane - ratoon crop cycle. Yield differences may also result from a number of sources that APSIM does not take into account, including losses associated with pests, disease, weed competition, lodging and unusual climatic events. Furthermore, unless otherwise programmed above-ground irrigation efficiency was always 100% efficient.

In each district, simulations were configured to represent the local environment and cropping practices. Information on each area was obtained from interviews with local irrigation extension staff and focus group meetings conducted as part of project BS183 (Table 1). As some of this information is speculative, the setup criteria on which the simulations were based represents a 'best guess' of actual practices and conditions. All simulations were conducted with a starting soil moisture of 65% and total nitrogen of 13kgN/ha as NO<sub>3</sub>, and 7 kgN/ha as NH<sub>4</sub>. Simulations were conducted using three soil types that represented soils in each of the cropping districts. Results from the different soil types have been combined to present the average response for each location.

**Table 1** APSIM setup criteria and configuration requirements

	<b>Mackay</b>	<b>Proserpine</b>	<b>Sarina</b>	<b>Mareeba</b>	<b>Bundaberg</b>	<b>Childers</b>
Climate file	Te-Kowai	Upriver	Sarina PO	Mareeba	Bundaberg Aero Club	Childers PO
Location	149.12 -21.16	148.5 -20.33	149.22 -21.43	145.25 -17.00	152.32 -24.91	152.28 -25.24
Soil type 1	Clay 84 mm	Silt 90 mm	Silt 60 mm	Silt 90 mm	Yellow Dermosol	Isis Red Dermosol
Soil type 2	H. Clay 126 mm	Clay 126 mm	Silt 114 mm	Clay 126 mm	Aeric Podsol	Yellow Dermosol
Soil type 3	Silt 90 mm	H. Clay 126 mm	Clay 126 mm	X	Silt 90 mm	Red Ferrosol
Variety	Q124	Q124	Q124	Q124	Q124	Q124
Sow/harvest date	20 Aug	1 Sept	5 Aug	10 May	10 Sept	1 Oct
No of ratoons	4	4	4	3	3	3
Fertilised plant cane (kgN)	140	190	150	200	190	136
Fertilised ratoons (kgN)	200	200	180	240	190	130
Allocation (ML/ha)	3	4	1.5	8.0	3.5	4
Dryoff period (days)	110	60	60	56	60	100
Irrigation cycle (days)	20	14	21	10	15	14

X 3<sup>rd</sup> soil type not simulated for the Mareeba area

## 2.1 Configuration of irrigation simulations

In all districts, **Rainfed** simulations were conducted to determine the average rainfed yield. Simulations with **Unlimited** allocation were employed to estimate the potential crop yield and irrigation requirement at 100% irrigation application efficiency. Unlimited simulations were programmed to return the soil to a full profile once 65% of the total PAWC had been depleted to a depth of 900 mm. Unlimited simulations were conducted regardless of cycle time between irrigations or the amount of available irrigation. Simulations with the **Runout Strategy** allowed irrigations to occur until all the nominated allocation was used (or had runout) or the dryoff period had been reached. The runout strategy represents typical irrigation practices better than the unlimited simulations, as allocation and cycle time restrict irrigations. Runout strategies were conducted with 1.0, 0.5, and 1.5 times the current allocation for most districts. All runout strategies were programmed to irrigate with a specified amount of allocation, when the soil moisture fell to 65% of the PAWC to a depth of 600 mm. In some areas such as Bundaberg, additional simulations were run with a quarter of the allocation to test crop response under severe allocation restrictions.

**Limited Strategy** simulations were conducted to investigate the effect of applying limited amounts of irrigation at different soil moisture deficits and times of year. These strategies were employed to investigate possible strategies suggested by local industry advisers for the best use of limited water. Limited Strategy I simulations involved a brief planting/ratoon period in which a single irrigation occurred to ensure germination within 10 days of sowing or harvest. The second irrigation period, allowed multiple irrigations at different combinations of irrigation quantity, and soil moisture deficit (Table 2).

**Table 2 Setup criteria for the Limited Strategy I simulations**

	<b>Mackay</b>	<b>Proserpine</b>	<b>Sarina</b>	<b>Mareeba</b>	<b>Bundaber g</b>	<b>Childers</b>
Start of period	20 Aug	1 Sept	5 Aug	10 May	10 Sept	1 Oct

First Period Sowing / Ratooning	Irrigation amount	30 mm	30 mm	40 mm	30 mm	30 mm	30 mm
	Soil moisture deficit	0.35	0.35	0.35	0.35	0.35	0.65
	Depth of PAWC	300 mm	300 mm	300 mm	600 mm	300 mm	600 mm
	End of period	30 Aug	11 Sept	15 Aug	21 May	22 Sept	15 Oct
Second Period	Start second period	1 Sept	1 Jan	17 Aug	1 Nov	15 Dec	16 Oct
	Irrigation amount	60 mm	80 mm	50 mm	50 mm	50 mm	50 mm
	Soil moisture deficit	0.20	0.35	0.20	0.5	0.2	0.2
	Depth of PAWC	900 mm	900 mm	1500 mm	600 mm	900 mm	900 mm
	Start of dryoff	12 May	3 July	6 June	15 Mar	12 July	23 June

**Limited strategy II** simulations included the same sowing/ratooning period as the first strategy, then two separate periods in which different amounts of irrigation and soil moisture deficits could be employed. This strategy was employed to represent different growing conditions corresponding to three different time periods.

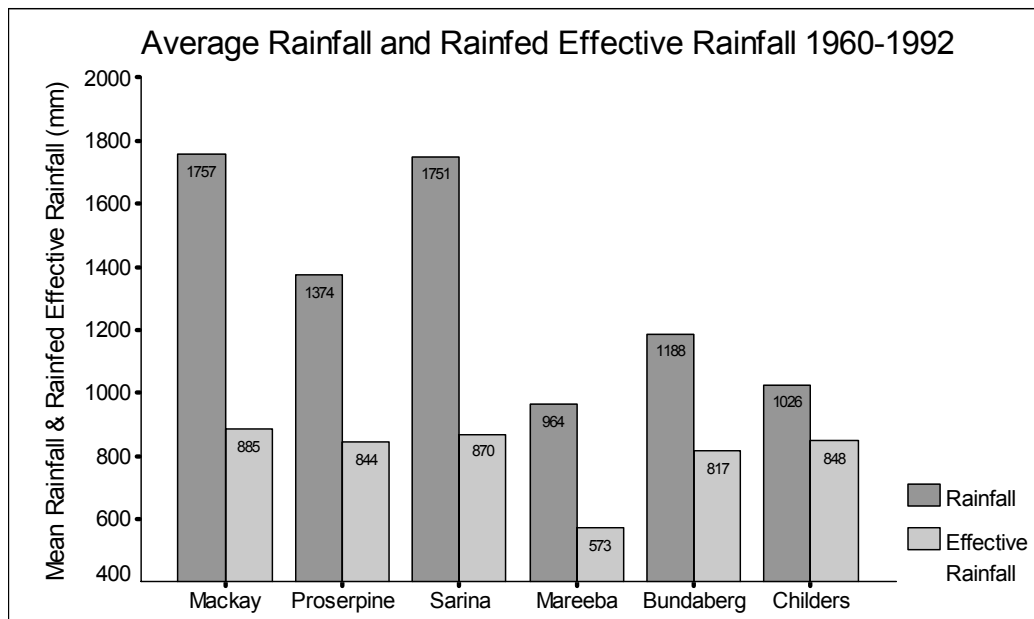
**Table 3 Setup criteria for Limited Strategy II simulations**

		<b>Mackay</b>	<b>Proserpine</b>	<b>Sarina</b>	<b>Mareeba</b>	<b>Bundaberg</b>	<b>Childers</b>
First period (sowing/ ratooning)	Start of period	20 Aug	1 Sept	5 Aug	10 may	10 Sept	1 Oct
	Irrigation amount	30 mm	30 mm	40 mm	40 mm	30 mm	30 mm
	Soil moisture deficit	0.35	0.35	0.35	0.35	0.85	0.65
	Depth of PAWC	300 mm	300 mm	300 mm	600 mm	600 mm	600 mm
	End of period	31 Aug	12 Sept	15 Aug	21 May	22 Sept	15 Oct
Second period	Start of period	1 Sept	13 Sept	16 Aug	22 May	26 Sept	16 Oct
	Irrigation amount	60 mm	80 mm	50 mm	50 mm	40 mm	X
	Soil moisture deficit	0.20	0.15	0.05	0.1	0.2	X
	Depth of PAWC	900 mm	900 mm	1500 mm	900 mm	900 mm	X
	End of second period	20 Dec	20 Dec	25 May	15 Dec	1 Dec	14 Jan
Third period	Start of third period	21 Dec	21 Dec	26 May	16 Dec	2 Dec	15 Jan
	Irrigation amount	60 mm	80 mm	50 mm	50 mm	50 mm	50 mm
	Soil moisture deficit	0.35	0.35	0.35	0.35	0.50	0.50
	Depth of PAWC	900 mm	900 mm	900 mm	600 mm	900 mm	900 mm
	Start of dryoff	12 May	3 July	6 June	15 Mar	12 July	23 June



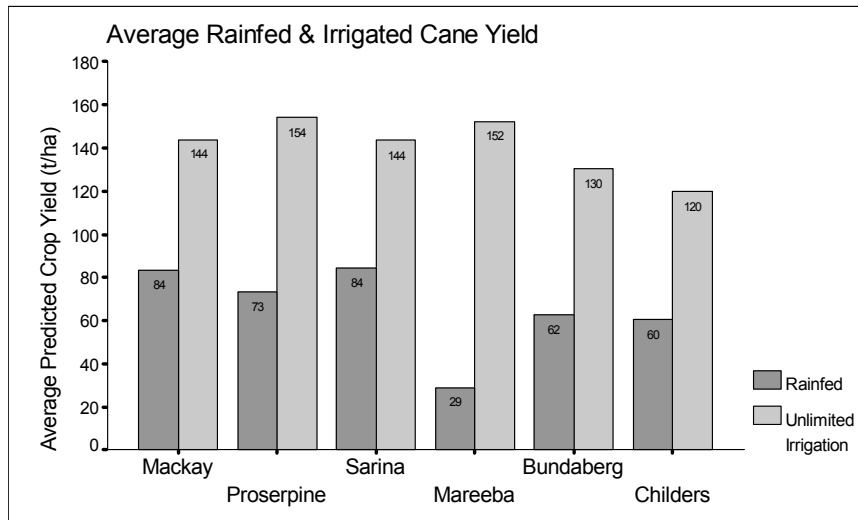
### 3.0 RESULTS

#### 3.1 Comparison of irrigation attributes between districts



**Figure 1 Average rainfall and rainfed effective rainfall for each district 1960-1992**

Effective rainfall was calculated on a 365 day crop cycle under rainfed (Figure 1) and irrigated conditions (Figures 4a - 9a). Both rainfall and effective rainfall varied between districts (Figure 1) with the effective rainfall ranging between 573 mm/yr in Mareeba to 885 mm/yr in Mackay. Effective rainfall was consistent with values presented by Robertson and Muchow (1997).

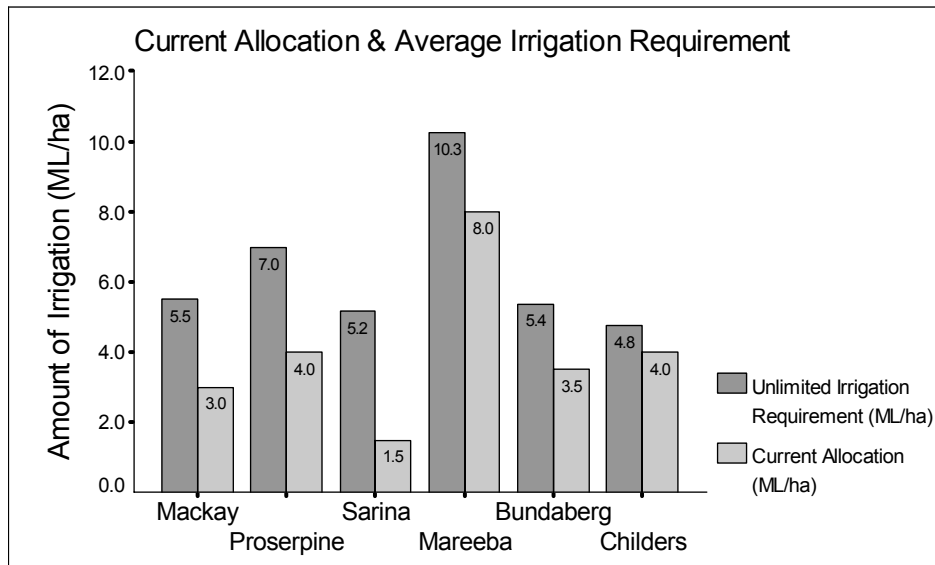


**Figure 2 Estimated crop yield (365 day crop) under rainfed and unlimited irrigation conditions**

The average rainfed yield varied from 29 t/ha in Mareeba to 84 t/ha in the Mackay and Sarina areas (Figure 2). Crop failures resulting from a lack of germination within 40 days of sowing, were not included in the analysis of average rainfed yield. Linear regression demonstrated that rainfed yield was significantly ( $p < 0.05$ ,  $df = 621$ ) related to effective rainfall.

$$\text{Rainfed yield (t/ha)} = 0.16 \times \text{Effective Rainfall (mm)} - 59.86 \quad R^2 = 0.83$$

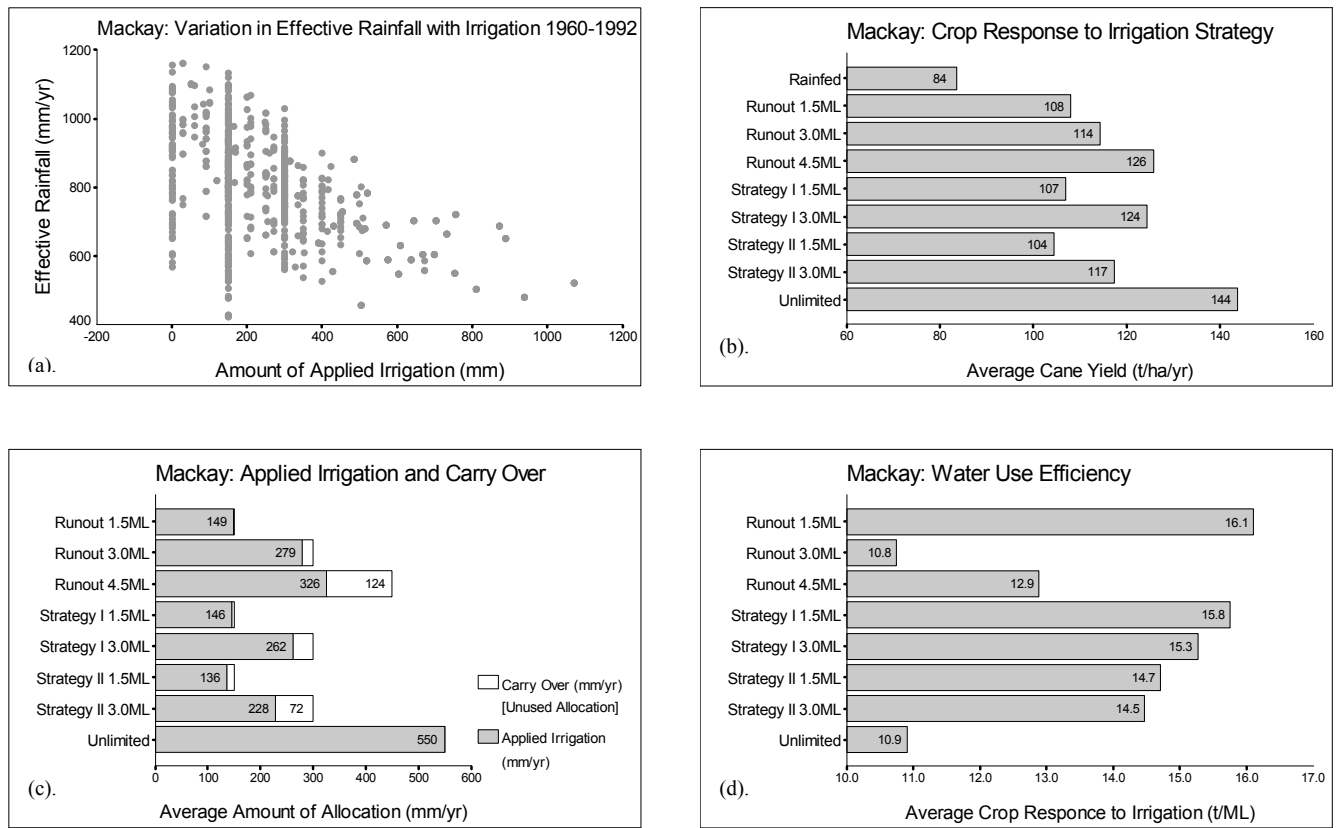
The unlimited irrigation strategy demonstrates the potential yield averaged over the three soil types for each district. Despite differences in the duration of the dryoff period, Figure 2 demonstrated that Childers (120 t/ha) had the lowest potential yield and Proserpine (154 t/ha) the highest. The difference between the rainfed yield and the potential yield, indicated that Mareeba with the lowest effective rainfall (Figures 1 and 2) had the greatest potential gain from irrigation.



**Figure 3 Comparison of the current allocation and unlimited irrigation requirement for each district**

The average irrigation requirement for each district was estimated by determining the amount of irrigation used by the crop under unlimited allocation conditions (Figure 3). Figure 3 demonstrates that the irrigation requirement varied between districts from 10.3 ML/ha in Mareeba to 4.8 ML/ha in Childers. Sarina observed the largest difference between the unlimited irrigation requirement and the current allocation. Given that unlimited allocation simulations apply irrigation without losses from runoff or deep drainage the actual amount of allocation required by irrigators to fully irrigate their sugarcane may be higher than the values presented in this analysis. However this strategy does not account for cycle time limitations, inundation following irrigation or the presence of watertables which may reduce actual crop yields. As such the unlimited allocation strategy is prone to overestimation of actual crop yield and irrigation requirement.

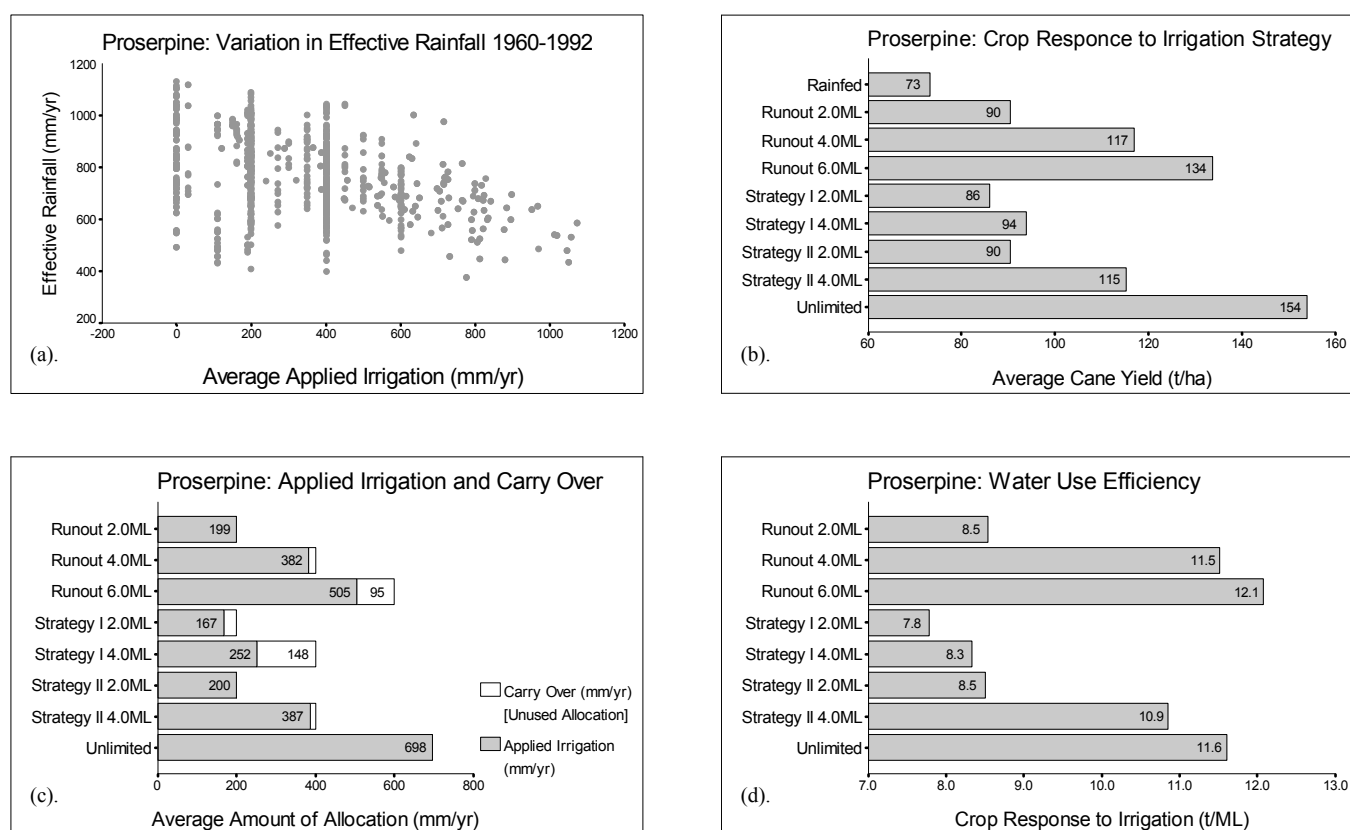
### 3.2 Long-term simulation results for the Mackay area



**Figure 4 APSIM based analysis of irrigation strategies in the Mackay area: (a) Variation in effective rainfall; (b) Crop response to irrigation strategy (c) Applied irrigation and carry over; (d) Water use efficiency.**

The rainfed yield for the Mackay area averaged 84 t/ha, from an average effective rainfall of 885 mm/yr (Figure 4a and b). At an allocation of 3 ML/ha, the runout strategy produced an average yield of 114 t/ha, a 30 t/ha increase from the rainfed yield (CRI 10.6 t/ha) (Figure 4b,c and d). This crop response was still 30 t/ha lower than the potential yield determined by the unlimited allocation simulation for the Mackay area (144 t/ha). At half the current allocation (1.5 ML/ha), the estimated crop yield was 108 t/ha (CRI 16.1 t/ML), a decrease of only 6 t/ha from the current 3 ML/ha allocation (Figure 4b). Of the three 3 ML/ha strategies, the first limited strategy required 17 mm less irrigation and was 10 t/ha more productive, than the runout strategy. This suggests that growers in the Mackay area with an annual allocation of 3 ML/ha are better off irrigating, firstly to ensure germination/ratoon success, then at a lower soil moisture deficit (0.2) (higher moisture stress) than the single time period runout strategy with a soil moisture deficit of 0.35.

### 3.3 Long-term simulation results for the Proserpine area



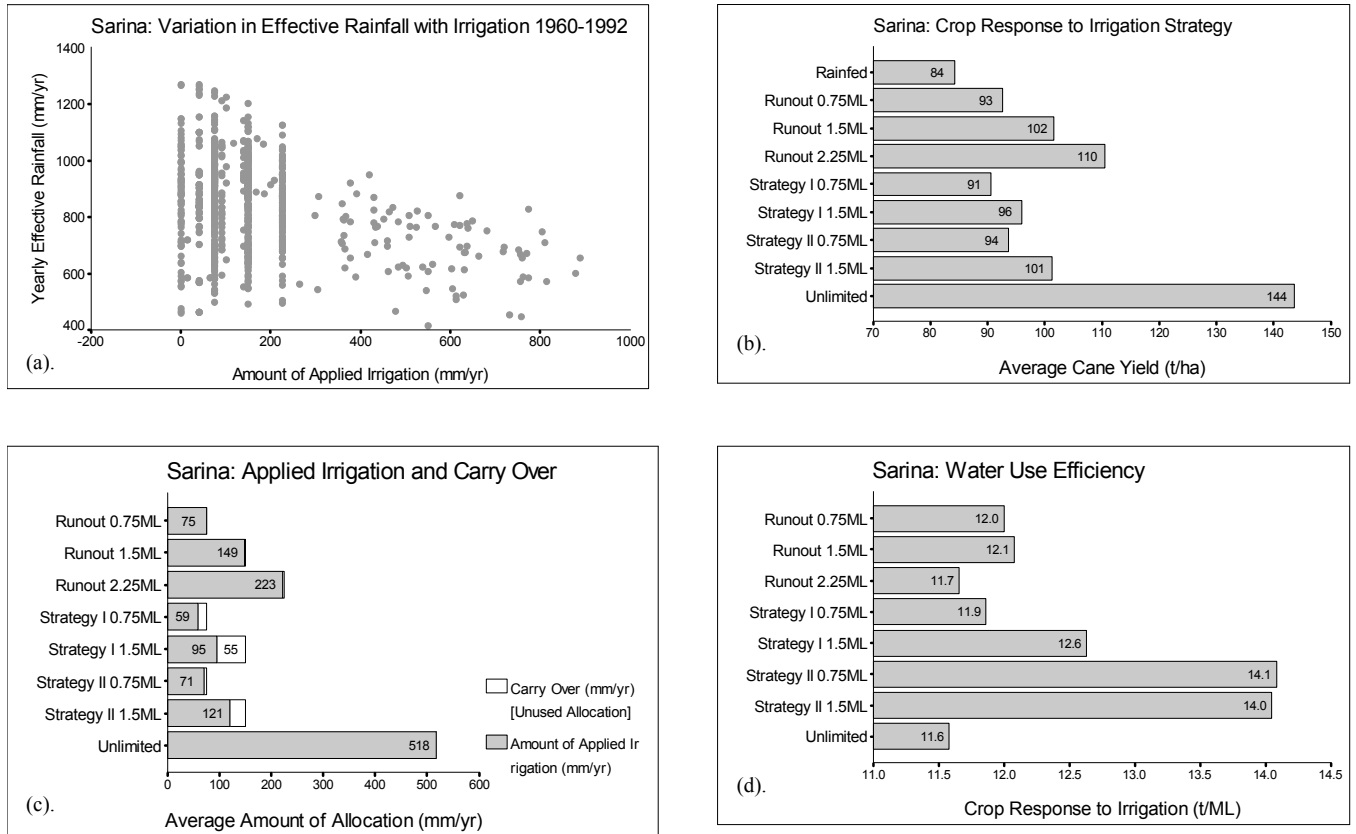
**Figure 5 APSIM based analysis of irrigation strategies in the Proserpine area: (a) Variation in effective rainfall; (b) Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.**

In the Proserpine area the rainfed effective rainfall ranged from 493 mm to 1134 mm. Irrigation reduced the effective rainfall from a rainfed average of 844 mm to 681 mm under the unlimited irrigation strategy (Figure 5a). The 4 ML/ha runout strategy produced an average yield of 117 t/ha and the largest crop response to irrigation (CRI 11.5 t/ML) for that allocation. This represents a 44 t/ha increase in crop yield from the rainfed simulation (73 t/ha) (Figure 5b and d). However the 4 ML/ha runout strategy yielded 37 t/ha less cane than the potential yield (unlimited allocation simulations) for the Proserpine area of 154 t/ha (Figure 5b). At 1.5 times the average allocation, the 6 ML/ha runout strategy produced an estimated crop yield of 134 t/ha (CRI 12.1) from an average of 5.0 ML/ha irrigation. This represents an increase in both yield (17 t/ha) and water use efficiency (0.6 t/ML) (Figure 5b, c and d). Analysis indicated that the current 4 ML/ha allocation was likely to be limiting production in most years. The small number of simulations conducted in this analysis suggested an appropriate allocation for the Proserpine area was in the order of 6.0 to 6.5 ML/ha. Simulations conducted using climate data from the Proserpine Post Office (higher rainfall area) (Hardie *et al.* 2000), also indicated the irrigation requirement for the Proserpine area was in the order of 4 to 6 ML/ha.

At half the current allocation (2.0 ML/ha), little difference existed between the predicted yield or water use efficiency of the different irrigation strategies. The 2 ML/ha runout strategy

produced an average crop yield of 90 t/ha (CRI 8.5), an increase of only 17 t/ha from the rainfed yield (Figure 5b). This indicates that reductions in the current allocation, are likely to result in considerable production losses. Further limited irrigation simulations are required to identify a more productive or efficient strategy for allocations of 2 ML/ha or less, in the Proserpine area.

### 3.4 Long-term simulation results for the Sarina area



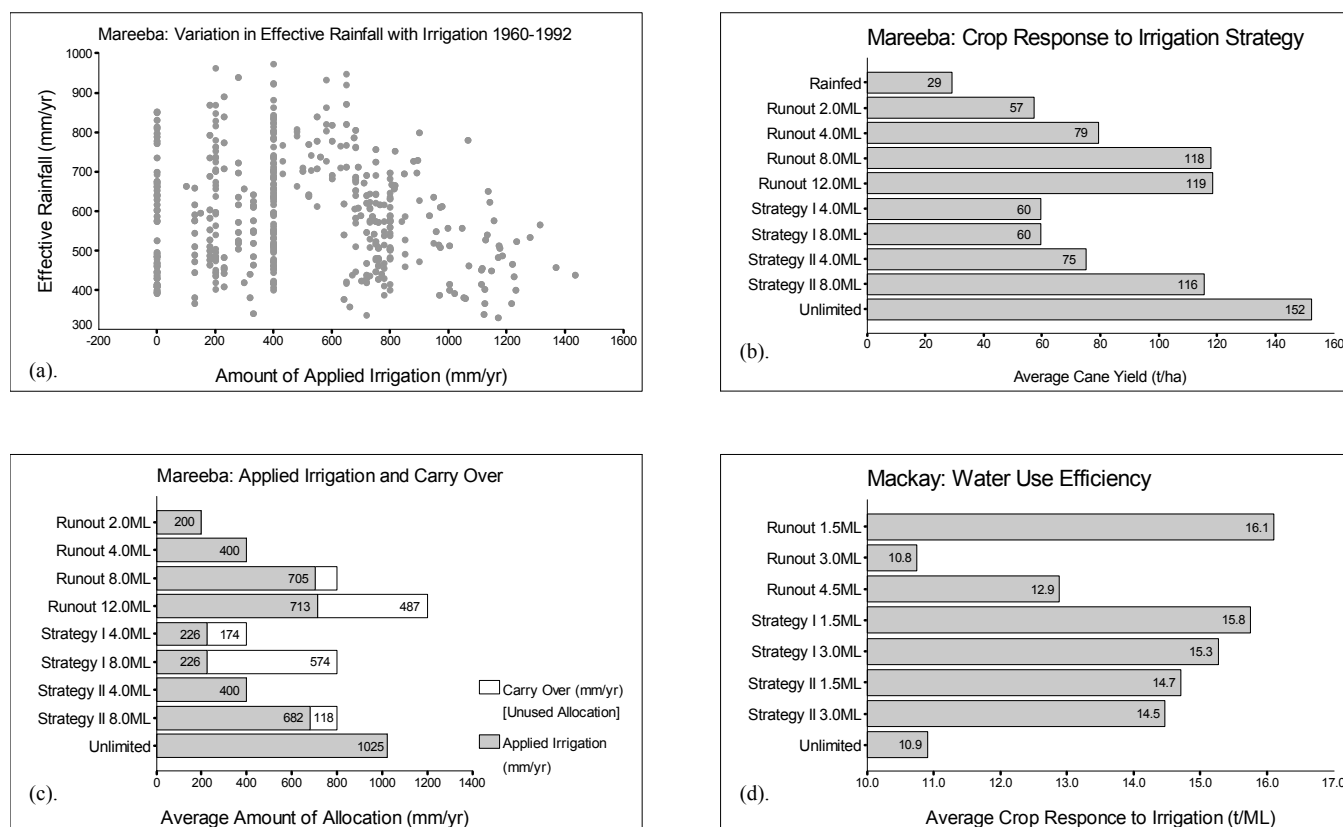
**Figure 6 APSIM based analysis of irrigation strategies in the Sarina area: (a) Variation in effective rainfall; (b) Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.**

In the Sarina area an average rainfed yield of 84 t/ha was produced from a rainfed effective rainfall which ranged from 462 mm to 1270 mm (Figure 6a and b). The current 1.5 ML/ha allocation produced an estimated crop yield of 102 t/ha (CRI 12.1), a moderate 18 t/ha increase from the rainfed yield of 84 t/ha (Figure 6b). The 1.5 ML/ha runout strategy produced 42 t/ha less cane than the potential crop yield of 144 t/ha. A number of indicators suggest that the current 1.5 ML/ha allocation is likely to be limiting production in the Sarina area. These include, the increased yield at higher allocations, and the difference between the applied irrigation for the 1.5 ML/ha runout strategy and the unlimited allocation simulation (5.2 ML/ha) (Figure 6b and c). The limited number of simulations conducted in this analysis suggest an appropriate allocation for the Sarina area would be in the order of 4.0 to 5.0 ML/ha. However, more simulations are required to confirm these values under a broader range of conditions.

The 1.5 ML/ha second limited irrigation strategy produced similar cane yield (101 t/ha) to the runout strategies (102 t/ha) while requiring 28 mm (19%) less irrigation (Figure 6a, b and c). At half the allocation (0.75 ML) the differences between the second limited irrigation strategy and the runout strategy were minimal, despite the second strategy observing the highest crop

response to irrigation of 14.1 t/ML (Figure 6b and c). Under the current limited allocation, growers should adopt an irrigation strategy to hold back allocation until the winter period by only allowing irrigations when 95% of the PAWC had been extracted (ie only irrigate to keep the cane alive over winter).

### 3.5 Long-term simulation results for the Mareeba area



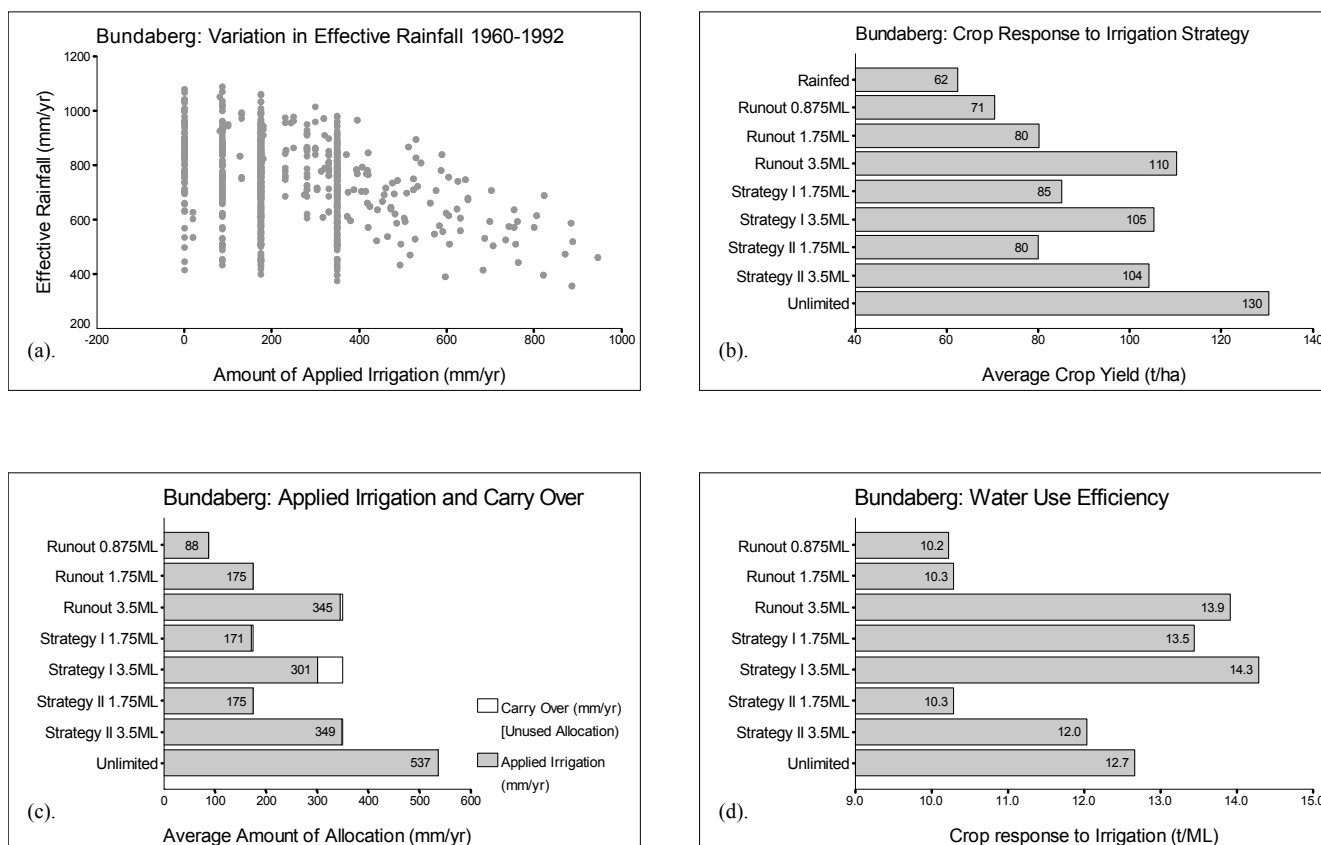
**Figure 7 APSIM based analysis of irrigation strategies in the Mareeba area: (a) Variation in effective rainfall; (b) Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.**

The average effective rainfall for the Mareeba area (573 mm/yr) produced an estimated rainfed yield of only 29 t/ha (Figure 7b). At the current 8 ML/ha allocation, the runout strategy produced an average yield of 118 t/ha (CRI 12.6 t/ML), an increase in crop yield from the rainfed strategy of 89 t/ha. An additional 4 ML/ha allocation however only increased the average yield by 1 t/ha, 487 mm of the 12 ML/ha allocation remained unused (Figure 7b, c and d). This suggests that under the current irrigation cycle time and a soil moisture deficit (0.35) the current 8 ML/ha allocation is appropriate for the Mareeba area. The 34 t/ha difference in crop yield and 3.2 ML/ha difference in irrigation requirement between the 8 ML/ha runout strategy and the unlimited strategy suggests that potential still exists for increased crop production in the area under different soil deficits and cycle time.

At half (4 ML/ha) and quarter (2 ML/ha) of the current allocation, the estimated crop yields were only 79 t/ha (CRI 12.5 t/ML) and 57 t/ha (CRI 14.0) respectively (Figure 7b and d). This indicates that any reduction in the current allocation would result in considerable production losses in the Mareeba area. At the current 8 ML/ha allocation, the second limited irrigation strategy was marginally more efficient (CRI = 12.8) at producing cane than the runout strategy (CRI = 12.6) (Figure 7d). At half the current allocation (4 ML/ha) the runout strategy produced 4 t/ha more cane than the second limited irrigation strategy without additional irrigation. Under allocation restrictions growers are encouraged to irrigate on

demand until all the allocation is consumed as the limited irrigation strategies were only marginally more efficient than the runout strategies.

### 3.6 Long-term simulation results for the Bundaberg area



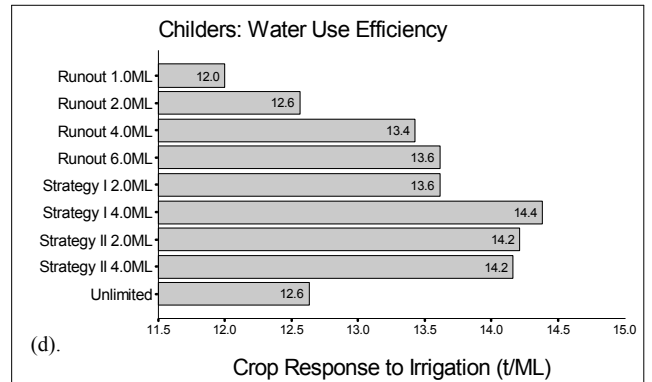
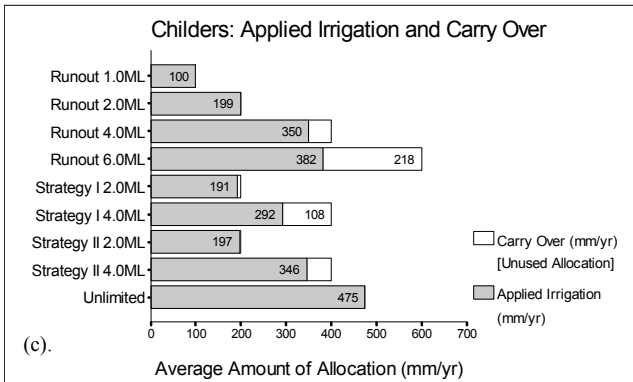
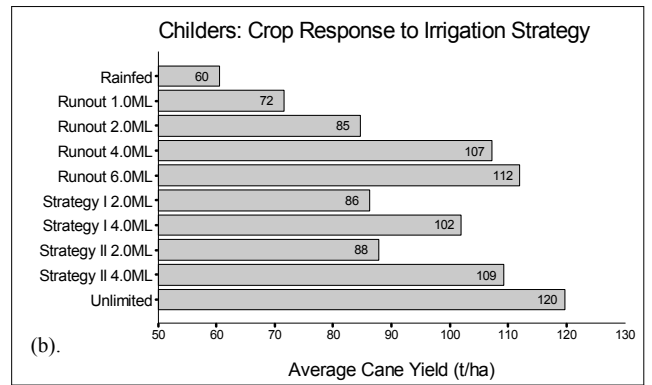
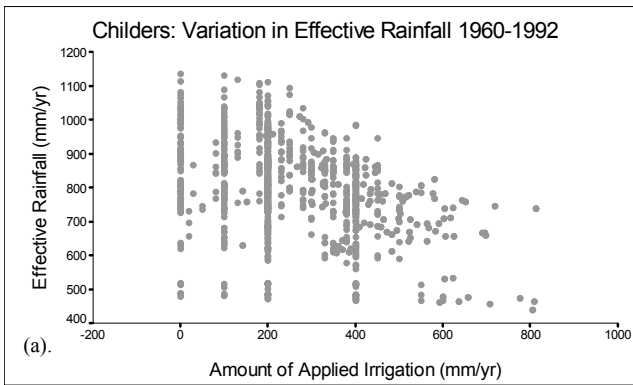
**Figure 8 APSIM based analysis of irrigation strategies in the Bundaberg area: (a) Variation in effective rainfall; (b) Crop response to irrigation strategy; (c) Applied irrigation and carry over; (d) Water use efficiency.**

The average rainfed yield for the Bundaberg region was estimated to be 62 t/ha, this was produced from an average effective rainfall of 816 mm/yr (Figure 8a and b). At an allocation of 3.5 ML/ha, the runout strategy produced an average crop yield of 110 t/ha (CRI 13.9 t/ML), 48 t/ha higher than the rainfed strategy (62 t/ha) from 345 mm/yr irrigation. The potential crop yield for the Bundaberg area was estimated to be 130 t/ha, 20 t/ha higher and requiring 192 mm/yr more irrigation than the 3.5 ML/ha runout strategy (Figure 8a, b, c and d). Given the small amount of unused allocation associated with all three runout strategies, and the 1.9 ML/ha difference between irrigation requirement and the unrestricted allocation, it would appear that greater allocation is required in the Bundaberg area to meet crop requirements and increase crop yields.

Under allocation restrictions of 1.75 ML/ha and 0.875 ML/ha the runout strategies exhibited a decrease in crop yield of 30 t/ha and 39 t/ha respectively, compared to the 3.5 ML/ha runout strategy. This reduction in estimated yield indicates that allocation restrictions have the potential to considerably reduce crop yield in the Bundaberg area. At 3.5 ML/ha allocation, no advantage was observed with the limited irrigation strategies, however at 1.75 ML/ha allocation the first limited strategy produced 3.2 t/ML more cane than the runout strategy (Figure 8b). More simulations using different combinations of soil moisture stress and irrigation timing are required to identify limited irrigation strategies for the Bundaberg area.

### 3.7 Long-term simulation results for the Childers area





**Figure 9 APSIM based analysis of irrigation strategies in the Childers area:**  
**(a) Variation in effective rainfall; (b) Crop response to irrigation strategy;**  
**(c) Applied irrigation and carry over; (d) Water use efficiency.**

Rainfed production in the Childers area produced an average cane yield of only 60 t/ha despite a relatively high effective rainfall of 848 mm/yr (Figure 6a and b). The potential crop yield for the Childers area was estimated by unlimited allocation simulation to be 120 t/ha, the lowest potential yield for any of the areas presented in this paper. The current allocation for the Childers area of 4 ML/ha produced an average cane yield of 107 t/ha, (CRI 12.6 t/ha) from 350 mm irrigation, and a yearly unused allocation 0.5 ML/ha (Figure 6b, c and d). The addition of another 2 ML/ha increased cane yield by only 5 t/ha resulting in an average yearly unused allocation of 2.2 ML/ha (Figure 6b and d). This analysis indicates that for most years a 4 ML/ha allocation is suitable for the Childers area, as additional allocation only resulted in greater carry-over and limited gains in crop yield.

At the 4 ML/ha allocation, little gain was achieved through the use of the limited irrigation strategies, the second limited irrigation strategy produced marginally higher yield of 2 t/ha, using 4 mm/yr less irrigation than the runout strategy (Figure 6b and c). At half the current allocation (2 ML/ha) the second limited irrigation strategy also produced marginally higher cane yield, 3 t/ha, with 2 mm/yr less irrigation (Figure 6b and c). More limited simulations are required to identify improved strategies for the use of limited irrigation in the Mareeba area.

#### **4.0 CONCLUSION**

This study has demonstrated that APSIM is capable of determining a range of irrigation attributes including long term averages of effective rainfall, response to irrigation, irrigation requirement, water use efficiency and rainfed yield. APSIM has also demonstrated the ability to identify strategies for the use of limited allocation in supplementary irrigation areas.

The limited number of simulations conducted in this report indicated that the current allocation was sufficient to meet crop demand in most years for the Mackay, Mareeba and Childers areas. However in the Proserpine, Sarina, and Bundaberg areas, simulations indicated that the current allocation was not sufficient to meet expected crop demand in most years. The limited number of simulations conducted in this report indicate the allocation required to meet crop demand in the Proserpine area would be in the order of 6.0 - 6.5 ML/ha, 4.0 - 5.0 ML/ha for the Sarina area and 4.5 - 5.0 ML/ha for the Bundaberg area. It should however be noted that APSIM is not capable of taking into effect the occurrence of shallow water tables or inundation following irrigation. As such the increased allocation suggested in this report may have unaccounted detrimental effects in some conditions or locations.

Simulated allocation restrictions reduced crop yields in all districts. Analysis of the runout strategies indicated a 50% reduction in allocation was likely to result in a range of production losses from of 6 t/ha in Mackay to 39 t/ha in Mareeba (yearly average).

In all areas, further simulations are required to identify possible strategies for the best use of limited irrigation. In the Childers, Proserpine, Bundaberg and Mareeba areas the limited irrigation strategies suggested by local advisory staff were of no or marginal benefit to cane production or water use efficiency. However in the Mackay and Sarina areas APSIM was capable of identifying such strategies.

This study supports the use of crop simulation tools for estimating a range of irrigation attributes including the best use of limited water in supplementary irrigation areas. Due to the limited number of simulations conducted in this study (approximately 27 per location) further simulations are recommended to identify strategies for the best use of limited allocation in supplementary irrigation areas. These strategies should form the basis of treatments in field trials to verify the APSIM based outputs.

## 5.0 ACKNOWLEDGMENTS

I would like to acknowledge the assistance offered by Shaun Lisson with the use of APSIM and editing of the text. I would also like to acknowledge the efforts made by Stuart Brown, APRSU Toowoomba, who modified the APSIM user interface APSFront~Sugar. Without the modifications made by Stuart the limited irrigation strategies would not have been able to be simulated. I would also like to thank Bill Webb and Mandy Adams for assistance with the text.

## 6.0 REFERENCES

- Keating, B.A., Robertson M.J., Muchow R.C., and Huth N.I. (1999). Modeling sugarcane production systems 1. Development and performance of the sugarcane module. *Field Crops Res.*, **61**:253-271.
- McCown, R.L., Hammer, G.I., Hargreaves, J.N.G., Holzworth, D.P. and Freebairn, D.M. (1996). APSIM: A novel software system for model development, model testing, and simulation in agricultural systems research. *Agric. Syst.* **50**. 255-271
- Robertson, M.J., and Muchow, R.C. (1997). Variation in the effectiveness of rainfall meeting crop water requirements in the Australian sugar industry. *Proc. Aust. Soc. Sugar Cane Technol.*, **19**: 229-236.
- Hardie, M.A. and Mallet, Y. (2000) Drilled climate data? Interpolated climate data for crop simulation modelling, *Proc. Aust. Soc. Sugar Cane Technol.*, Poster paper. *In press*.