Adopting systems approaches to water and nutrient management for future cane production in the Burdekin

Peter Thorburn[1], Steve Attard[2], Toni Anderson[3], Marian Davis[3], Joseph Kemei[4], Evan Shanon[3], Rob Milla[5], Martijn van Greiken[4], Aaron Davis[6], Jon Brodie[6]

[1]CSIRO Sustainable Ecosystems, Brisbane
[2] CSIRO Sustainable Ecosystems, c/o BSES Ltd, Brandon
[3]BSES Ltd, Brandon
[4]CSIRO Land and Water, Townsville
[5]DPI&F, Townsville
[6]ACTFR, Townsville

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Final Report

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Project Leader: Dr Peter Thorburn
CSIRO Sustainable Ecosystems
Queensland Bioscience Precinct
306 Carmody Rd
St. Lucia Qld 4067
Peter.Thorburn@csiro.au

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Executive Summary

There is concern about environmental impacts of cropping in catchments of Australia's Great Barrier Reef, especially losses of nitrogen (N) and herbicides from cropping systems. Sugarcane production in the Burdekin region in the dry tropics stands out from other crops/regions because, (1) it is fully irrigated, which may enhance the losses of any chemicals from farms, and (2) it has the highest N fertiliser application rates of any sugarcane producing region in Australia. There are few measurements of N and/or herbicide losses from sugarcane production, especially fully irrigated production. More complete information is needed to evaluate, develop and underpin the adoption of management practices to reduce environmental impacts of sugarcane production. Four streams of work were undertaken to provide this information:

1. Monitoring water quality leaving sugarcane farms.
2. Demonstrating water quality and productivity benefits of farm management practices.
3. Harnessing the information from these two components to describe and classify management practice **systems** typical of past, current and future 'best practice', and estimate the water quality, productivity and economic benefits of these systems.
4. Communicating results of these activities widely within and beyond the region.

Water, N and herbicide losses were measured at three sites in different parts of the Burdekin region, covering a range of soil types and irrigation managements. The experimental data were then used to parameterise the APSIM-Sugarcane cropping systems model, and then used to infill missing data and develop complete water and N balances for each of the three crops measured at the sites. N losses in runoff were relatively small, being less than 10 kg N ha^{-1} $crop^{-1}$. Herbicide losses were similar to those measured previously. More N was lost via deep drainage than runoff at all sites, even those with slowly permeable soils. The results were consistent with the known ground water nitrate contamination issues in the region.

Water quality and productivity benefits of various farm management practices were demonstrated on nine farms, established in or near the regions of the monitoring sites. These activities resulted in a wide range in production and environmental benefits, with the practices demonstrated at the sites subsequently adopted by the farmers. At one site for example, the farmer trialled minimum tillage, fertilising with a stool splitter and increased irrigation inflow rates (to reduce deep drainage). Yields increased by ~25% under the changed practice and these new practices were adopted across the whole farm. In other cases, concerns about nutrient concentrations in irrigation tail water were investigated and practices to minimise nutrient losses identified.

To assess water quality and economic benefits of different farm management practices, relevant practices were grouped into Classes from A to E, following the 'A to D' framework adopted in the GBR-wide water quality planning processes. This grouping was undertaken within a series of participative workshop involving farmers, extension staff and a range of other stakeholders in the region. Long term simulations of each management class were used to provide a quantitative evaluation of their effectiveness for delivering water quality benefits in the region. These predictions were used to examine the relationship between adoption of the different management classes in the region, and resulting regional N loads. The information provided by this process was used in collaboration with the regional natural resource management group (NQ Dry Tropics) to determine targets for the adoption of the different practices to meet regional water quality objectives in the Burdekin Water Quality Improvement Plan.

Results of the project were communicated at dedicate field days, meetings within the Burdekin Cane Productivity Initiative throughout the project, in relevant regional training workshops, and in other regions of the sugarcane industry.

Evaluation of the project's impact found that it was the best known of the different water quality-related activities conducted in the region, with most farmers surveyed believing that the project had enabled them to learn new practices to help them farm sustainably and profitably, and become aware of new practices to reduce environmental impacts. The project also had a substantial impact on the Burdekin Water Quality Improvement Plan, with information from the project on management classes and associated N loads used as the basis of target-setting for water quality improvement in the Plan. The project also provided a contemporary, improved information base for extension activities, and improved the knowledge of extension officers.

Background

The intensification of farming systems increases the likelihood of detrimental environmental impacts in agricultural regions, including changes to flows and chemical concentrations of surface and ground waters. In Australia, there are particular concerns about these impacts in catchments along the north eastern coastline because of the unique aquatic ecosystems of the Great Barrier Reef World Heritage Area. The Great Barrier Reef (GBR) is internationally recognised for its environmental and social values (Furnas, 2003), and also has considerable economic value (Access Economics, 2007). Recent research has raised concerns about the impact of land based pollutants on the health of the GBR (Mitchell *et al.*, 2001; Bramley and Roth, 2002; Mitchell *et al.*, 2005, 2007; Fabricius *et al.*, 2005; Rasiah *et al.*, 2005, DeVanter *et al.*, 2006; Ham, 2007a,b; Hunter and Walton, 2008; Brodie and Bainbridge, 2008). As well as concerns over the GBR, there are other important environmental issues in these catchments, such as the quality of ground water, which supplies drinking water in many places, or water quality of coastal wetlands supporting freshwater ecosystems (Thorburn *et al.*, 2003; Rayment, 2003).

The GBR receives runoff from 35 river and creek catchments with a combined area of ~423,000 km^2 (Furnas, 2003). Land use in catchments draining into the GBR lagoon is dominated by agriculture; mainly grazing, sugarcane and tropical horticulture. While grazing occupies the greatest area, sugarcane (*Saccharum* spp.) is the most significant crop grown on GBR catchments. Its production systems are intensive, relying on large inputs of fertilisers and pesticides, and tend to be located on the coastal floodplains adjacent to the GBR (Furnas, 2003). The Burdekin is Australia's largest sugarcane producing region with over 70,000 ha of sugarcane harvested annually, yielding ~8 Mt of cane or ~22% of Australia's total production. In common with other sugarcane producing regions, nitrate and herbicide are one of the priority water quality contaminants originating from sugarcane cultivation in the region (Mitchell *et al.*, 2007, Brodie and Bainbridge, 2008). Sugarcane production in the Burdekin region stands out from other crops/regions in the GBR because; (1) it is fully irrigated, and the irrigation may enhance the losses of pollutants from farms, and (2) it has the highest average N fertiliser application rates (~220 kg ha^{-1}) of any sugarcane producing region. Despite these concerns there have been few measurements of the quality of water leaving sugarcane farms in the region. This is especially true for N loads (kg ha^{-1}), which are the driver of aquatic and marine ecological processes and the primary pollutant of concern from the region (Brodie and Bainbridge, 2008).

In response to concerns over the health of the GBR, the Federal and State Governments in Australia developed the Reef Water Quality Protection Plan (Anon 2003). The Plan requires industries in catchments draining into the GBR lagoon to specify and meet water quality targets. These targets will be specified in Water Quality Improvement Plans (WQIP) developed for all GBR catchments. As well as water quality targets, management actions that will improve water quality to meet these targets are also specified in the WQIP. Clearly, lack of information on quality of water leaving sugarcane farms in the Burdekin region is a serious impediment to the development of sound and realistic management actions in the WQIP that will underpin a sustainable and prosperous sugarcane industry in the Burdekin region.

Objectives

The main objectives of the project were to:

- Develop of a range of proven farm management options for improved water, nutrient and crop management that will maintain or increase profitability, whilst improving off-farm water quality;
- Carry out assessments of the economic feasibility of the proven farm management options;
- Establish industry reference sites with grower participation to provide robust benchmarks and to assist in the dissemination of project learnings;
- Broaden and strengthen industry-led innovation and change processes to promote best management practice in irrigation;
- Synthesise and package project results and learnings to extend improved water and nutrient management options to other districts.

These objectives were achieved.

Methodology

There were four main components to this project. In summary they were:

1. Monitoring water quality leaving sugarcane blocks on three farms that cover a range of soils and management conditions in the region, that also complement previous research.
2. Working with a broad range of farmers to demonstrate water quality and productivity benefits of a range of specific farm management options available to them.
3. Harnessing the information from these two components to describe and classify management practice **systems** typical of past, current and future ‘best practice’, and estimate the water quality, productivity and economic benefits of these systems.
4. Communicate results of the project widely within the regions, to other sugarcane areas and other relevant stakeholders, and evaluation of the project’s regional impact.

Further details of the method employed follow.

Monitoring water quality

Water, N and herbicide losses were monitored over three years on three commercial sugarcane farms in the Burdekin region (Table 1, Figure 1). One site, Delta-f, was in the Delta region (Airdmillan district) where soils have relatively coarser textured sub-soils and both ground and surface water is used for irrigation. The soil at this site had a comparatively fine textured A-horizon which contrasted the coarser textured A-horizon of a site (referred to as Delta-c in this study) in the region where N losses below the root zone had previously been monitored (Stewart *et al.*, 2006). The other two sites were located in the Mona Park and Mulgrave districts of the Burdekin-Haughton Water Supply Scheme (BHWSS) region, a more recently developed surface irrigation area with water supplied from the Burdekin Falls dam in which very little information relevant to water quality was available.

Figure 1. Approximate location of the three study sites (shown in yellow). A fourth site used in analyses within the project is shown in orange.

Measurements were made at one field (area ranging between 3 and 12 ha) on each farm, starting in 2004 with the commencement (planting or rationing) of the crop. The Delta-f and Mulgrave sites were instrumented to measure runoff, providing the first such measurements in either of these regions. The Mona Park site was instrumented to measure deep drainage to provide information for comparison with previous measurements of deep drainage in the Delta region (Stewart *et al.*, 2006) and because the ends of the irrigation furrows at this site had been blocked by the farmer to minimise loss of runoff irrigation water. At all sites irrigation water applied, rainfall, crop yields and the N concentration in the above ground crop biomass were measured. As well, the volume of water, and N and herbicide concentrations were measured in either runoff or deep drainage, depending on the site. During the study sugarcane was the only crop grown, the fields were furrow irrigated and all management operations were performed and recorded by collaborating farmers.

To obtain complete water and N balances at all sites, the experimental data were used to parameterise the APSIM-Sugarcane cropping systems model (Thorburn *et al.*, 2005) for each site. There was good agreement between predicted and measured water and N balance terms (Attachment 1). The model was then used to predict 'missing data'. These data included deep drainage volume and N leached at the Delta-f and Mulgrave sites, runoff occurring during heavy rainfall at the Mona Park site, and data not captured due to equipment malfunction.

Full details of the methods employed in this component of the project are given in Attachment 1.

Demonstrating water quality and productivity benefits

Nine sites were established on commercial farms, in or near the regions of the monitoring sites (Appendix 1). One of these sites had centre pivot irrigation, an irrigation system with the potential to deliver much greater application precision than the furrow systems almost exclusively used for irrigation in the region. Farmers at each of these sites had concerns over the possible environmental and productivity performance of their management system. The possible cause of, and potential solutions to these problems were identified. The solutions were implemented by the farmers and project staff and the results monitored.

As well as demonstrating the outcomes of practice change to collaborating farmers, they contributed significantly to the regional communication process within the project (described below).

Classifying and estimating benefits of different management practice systems

Collation of farming operations and management practices affecting water quality
This component of the project was undertaken in collaboration with the regional natural resource management group, NQ Dry Tropics as part of their development of the Burdekin region WQIP. The possible operations required for growing sugarcane in the Burdekin region were collated at a series of workshops held with farmers and local natural resource management extension staff. The aim of the workshops was to document local growers' perceptions of what constituted desirable or 'best practice' farm management for their particular situations. Discussions focussed on the main drivers of water quality, namely;

- Irrigation practices,
- Nutrient and fertilizer management,
- Herbicide/pesticide management, and
- Sediment management.

Discussion were structured around the different stages of a typical cane production cycle; beginning at farm design and layout, fallow management, planting, crop husbandry, harvesting, ratoon crop management and crop destruction. Rather than a strongly prescriptive specification of 'best management practices', the intent of this process was to produce information with some level of flexibility to allow different components to be integrated into practical farming systems relevant to the diversity of farming systems, environmental and production issues and constraints facing various farmers across the Burdekin.

Classifying management practices with respect to water quality
To link the collection of 'best practices' with the Burdekin WQIP, relevant practices were grouped into classes from E to A, following the 'A to D' framework developed for and adopted in the GBR-wide water quality planning processes (Higham *et al.*, 2008). Classes E to C are commonly practiced in the region, while Class B is similar to the currently promoted and industry supported 'best practice', with Class A being possible future best practice currently under experimental investigation.

Prediction of nitrogen loads from different management practice classes
Given the importance of N in water quality concerns in the region (Brodie and Bainbridge, 2008), the long term losses of N from each of these management classes was predicted to provide a quantitative evaluation of their effectiveness for delivering water quality benefits in the region. Long term simulations of each management class was undertaken for four soil types in the region, those at the three experimental sites in this study and a site in the Delta region (named Delta-c) with a coarser textured soil than the Delta-f site that had been previously studied. These soils were chosen as they generally represented the range of soils in the region and the modelling capability had been demonstrated using them.

Estimation of regional nitrogen loads
These predictions were used to examine the relationship between adoption of the different management classes, and resulting regional N loads and regional water quality targets for N. The hydraulic connections in the region are simple, with transport of water and chemicals to the river and creeks rapid so processes such as in-stream denitrification negligible. Reflecting this simplicity, a regional N load 'calculator' was developed for combining predicted loads for each soils type and the area of the soil with different sub-regional patterns of management class adoption. The 'calculator' was used with local farmers and extension officers in a facilitated workshop run for the Burdekin region WQIP to determine targets for the adoption of the different practices to meet regional water quality objectives.

Economic analysis of different management practice classes
Detailed information on costs of the range of potential management operations carried out on Burdekin farms was obtained through in-depth interviews with collaborating farmers. These data were cross-reference with data in the DPI&F economic modelling tool to ensure their accuracy, and then used to calculate gross margins for each of the management classes (E to A) on each soil type. Gross margin was defined as the value of the crop produced minus variable input costs of the management operations (i.e. labour, machinery and irrigation) associated with each management class.

Communication and evaluation of project results

Situating monitoring and demonstration sites on commercial farms provided an inherent platform for communication of project results within the Burdekin. So too did the extensive consultation process employed in the development and analysis of management practice classes. As well as these activities, project results were regularly highlighted at Burdekin Cane Productivity Initiative meetings and regional field days. Results were communicated outside the region through internal BSES extension processes, presentation at industry conferences and the publications that resulted from these activities. Communication with other relevant stakeholders was ensured through active collaboration with NQ Dry Tropics (the regional natural resource management group) and partners in their WQIP development process.

The project impact on local farmers was evaluated from surveys of their understanding, knowledge, attitudes, skills and aspirations in regard to water and nutrient management. Farmers mainly came from the districts where project activities were centred (i.e. Mona Park, Mulgrave and Airdmillan), but farmers from two outlying districts (Kilrie and Leichhardt) that had less direct exposure to the project through field activities were also included. Surveys were conducted at the start of the project (mid 2004) with a total of 34 farmers surveyed. In February 2008, as many as possible (28) of these original farmers were resurveyed to determine changes in practice or attitudes over the life of the project. Surveys were undertaken one-on-one with BSES Ltd Extension Officers and individual growers. Details of the surveys are given in Attachment 2.

Outputs

Monitoring water quality

Water and N fertiliser inputs
The number of irrigations applied to the crops at the sites varied from nine for the final two crops at Mona Park to 23 for the first crop at the Mulgrave site (Table 1), equivalent to ~865 mm of irrigation water per crop for the Mona Park crops and 1,642 mm for the first Mulgrave crop. The amount of irrigation applied at the sites was in the range reported by (Raine and Bakker, 1996, Charlesworth *et al.*, 2002, Klok *et al.*, 2003, Stewart *et al.*, 2006), except for the first crop at the Mulgrave. Here, irrigation was high because the farmer had access to irrigation from both the surface water scheme and stored runoff, and the climate during the season necessitated that the crop was irrigated frequently. The average amount of water applied during each irrigation was ~100, 95 and 70 mm for the Delta-f, Mona Park and Mulgrave sites, respectively.

Irrigation decreased markedly in the second and third crops at the Mona Park and Mulgrave sites (Table 1) due to higher rainfall and, more significantly, an attempt by the farmers to reduce irrigation in response to the results from the first crop. At the Delta-f site, more irrigation was applied to the second crop as the farmer was disappointed with the yield of the first crop (a plant crop, usually the highest yield crop in a crop cycle) which he suspected had been limited by water stress from under-irrigation. Irrigation was reduced in the third crop at this site in response to rainfall.

Nitrogen fertiliser applications averaged 230 kg ha^{-1} across all the ratoon crops, with 144 kg ha^{-1} applied to the plant crop at the Delta-f site (Table 1). These applications are consistent with recommendations in the region (Calcino, 1994) at the time of the study.

Whole-crop water balances

The majority of water lost from each site was estimated to be through evapotranspiration (Table 1), which was correlated to cane yield as expected. However, evapotranspiration (ET) was higher relative to yield at the Mona Park site than at the other two sites, especially for the first and third crops. It is uncertain whether the prevention of runoff from irrigation (through blocking furrows) at this site would have contributed to the higher ET.

Runoff losses were lowest at the Mona Park site (where irrigation furrows were blocked) and highest at the Mulgrave site (Table 1). Runoff at the Mona Park site was caused by large rainfall events that exceeded the capacity of the field to pond water. At the Delta-f and Mulgrave sites irrigation runoff was 19 and 34 mm per irrigation, respectively, averaged across all three crops. This is equivalent to ~20 and 50% of irrigation applied at these sites, respectively.

Deep drainage was variable across both sites and crops (Table 1). The between-crop variability was greatest at the Delta-f site and least at the Mona Park site. The amount of deep drainage that occurs is obviously caused by the interactions between the amount and timing of rainfall and irrigation, together with patterns of crop water use. Despite this complexity, the amount of deep drainage relative to irrigation plus rainfall was generally greater at the Delta-f site (21% averaged over the three crops) than the other two sites (14%), and this difference corresponds to the coarser textures sub-soils at the Delta-f site.

Whole-crop N balances

Nitrogen removed in the crop (through harvested cane and burnt crop residues) was related to crop yield, as expected (Table 1). However, given the yields (> 130 t ha^{-1}), less N was removed in the first two crops at the Mona Park site than in crops at the other sites.

The amount of N lost through runoff was 1-10 kg ha^{-1} at the Delta-f and Mulgrave sites (Table 1). These losses equate to 0.4 to 4% of fertiliser N applications, except at the first crop at the Delta-f site (7%) which was a plant crop preceded by a cover crop. No N was predicted to be lost in runoff (caused by large rainfall events) at the Mona Park site (Table 1).

N lost through deep drainage was considerably lower at the Mulgrave and Mona Park sites, averaging 10 and 20 kg ha^{-1}, respectively, but much higher at the at the Delta-f site, especially in the second crop (Table 1). In this crop, depletion of soil mineral N (200 kg ha^{-1}) that had been high during the first crop due to mineralisation of N from the previous cover crop, accounted for much of the 214 kg ha^{-1} of N lost in deep drainage. Even accounting for substantial changes in soil mineral N, N lost through deep drainage was substantially higher than estimated at another site in the Delta district (Stewart *et al.*, 2006) or a site in the Australian wet tropics (Reghenzani *et al.*, 1996). The N inputs from the cover crop and management factors, such as higher irrigation and N fertiliser applications, may explain the higher losses from this site than found in the other studies.

The amount of N lost via denitrification varied considerably (20-160 kg ha^{-1}) across the sites (Table 1). At the Mulgrave and Mona park sites denitrification was the biggest environmental loss pathway, equivalent of > 50% of fertiliser applications. The losses are greater than the few measurements previously undertaken in sugarcane crops in Australia (Weier *et al.*, 1996, 1998). These previous measurements were only made over short times (i.e. 2-6 weeks after fertiliser application) at sites receiving little or no irrigation and only 160 kg ha^{-1} of N fertiliser (compared to

~230 kg ha^{-1} at the Mona Park and Mulgrave sites, Table 1). These short term measurements may considerably underestimate whole-crop denitrification. The high N losses through denitrification are plausible considering the soil conditions (clay sub-soils and relatively high concentrations of organic C), the high frequency with which the soils are wet by irrigation (Table 1), and the high applications of N fertiliser applied at the sites.

Table 1. Whole-crop water and nitrogen balances and cane and sugar yields for each of the three crops monitored at the three study sites (simulated values in italics).

Harvest year	Delta			Mona Park			Mulgrave		
	2005	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Ratoon number	Plant	1	2	1	2	3	2	3	4
Harvest date	12 Jun	30 Jun	29 Jul	28 Sep	31 Oct	26 Nov	8 Oct	23 Oct	7 Dec
Number of irrigations	13	14	12	16	9	9	23	15	16
Total irrigation (mm)	1300	1536	1144	1461	855	873	1642	1137	1104
Rainfall (mm)	682	863	965	608	864	804	639	799	835
Irrigation + rainfall (mm)	1982	2399	2109	2069	1719	1677	2281	1936	1939
N fertiliser applied (kg ha^{-1})	144	219	227	237	247	220	234	234	234
Cane yield (t ha^{-1})	139	144	136	139	131	91	114	88	85
Sugar yield (t ha^{-1})	18	20	20	24	22	15	15	13	13
Evapotranspiration (mm)	1467	1487	1434	1717	1444	1291	1277	1065	1008
Runoff (mm)	238	240	253	180	93	89	730	542	562
Deep drainage (mm)	297	672	401	207	189	285	182	329	368
Crop N removed (kg ha^{-1})	96	112	95	71	72	57	80	66	49
N in Runoff (kg ha^{-1})	10	2	9	0	0	0	5	2	1
N in Deep drainage (kg ha^{-1})	109	241	68	19	27	20	2	9	19
Denitrification (kg ha^{-1})	24	24	18	147	185	150	94	145	140
Change in soil N (kg ha^{-1})	-32	-200	14	-12	-44	-5	19	-19	9

Herbicides lost in runoff

The amount of diuron lost in runoff varied between 0.1 and 1.8 % of that applied, with maximum concentrations of ~100 µg L^{-1} (Table 2). For atrazine, losses were between 0.3 and 3.2%, with maximum concentrations of 545 µg L^{-1}. For both chemicals, losses (mass and concentration) were greatest in the first runoff event following application. Losses were higher at the Mulgrave site than the Delta-f site, consistent with the greater runoff from the former site. One year after application of these herbicides concentrations in runoff water were negligible.

If the average mass lost across all the events monitored is representative of losses from the whole region, annual losses would be 120 and 800 kg of diuron and atrazine, respectively. These results compare with estimates of 155 and 230 kg derived from concentration measurement in the main surface creek and river systems draining the sugarcane growing areas in the region (Mitchell *et al.*, 2007, Brodie and Bainbridge, 2008). The agreement between these different loads estimates is reasonable, for diuron, given the uncertainties inherent in scaling the measurements to annual loads.

Table 2. Application rates and losses of the herbicides Diuron and Atrazine at the Delta and Mulgrave study sites. (nd – not detected.)

Date	Application (g a.i. ha^{-1})	Peak concentration (µg L^{-1})	Mass lost (g a.i. ha^{-1})	Total loss (% of applied)
Delta-f				
Diuron appl. 1				
18-Nov-05	244			
21-Nov-05		93	0.8	0.3
Atrazine appl. 1				
10-Oct-05	1530			
13-Oct-05		157	4.1	
3-Nov-05		6	0.1	
21-Nov-05		3	0.1	0.3
Mulgrave				
Diuron appl. 1				
30-Oct-04	225			
2-Nov-04		120	3.9	
13-Oct-05		nd	nd	1.8
Diuron appl. 2				
17-Dec-06	375			
20-Dec-06		10	0.1	
29-Dec-06		6	0.3	0.1
Atrazine appl. 1				
30-Oct-04	580			
2-Nov-04		545	17.9	
13-Oct-05		10	0.4	
1-Nov-06		< 1	< 0.1	
20-Dec-06		5	< 0.1	
29-Dec-06		1	0.1	3.2

Demonstrating water quality and productivity benefits

Activities at the nine demonstration sites resulted in a wide range of production and environmental benefits (summarised in Appendix 1), with the practices demonstrated at the sites subsequently adopted by the farmer. For example, at a demonstration site in the Mona Park area (referred to as Site 3, Appendix 1) the farmer trialled minimum tillage, fertilising with a stool splitter and increased irrigation inflow rates (to reduce deep drainage). The result was that yields increased from 114 t ha^{-1} in the 1^{st} ratoon crop to 143 t ha^{-1} in the 2^{nd} ratoon under the changed practice. Due to this success, these practices were adopted across the whole farm. At another site (Site 4, Appendix 1) in the Airdmillan area, the farmer wanted to adopt trash blanketing. So a new strategy for irrigation application was devised that resulted in good lateral soakage of irrigation water into the stool. Subsequent benefits of adopting trash blanketing were increased numbers of beneficial nematodes, lower weed pressure and hence weed control costs, and 10-20% increased yield in comparison blocks.

In other cases (Sites 5 and 9, Appendix 1), concerns about nutrient concentrations in irrigation tail water were investigated. At these sites, nutrient concentrations in runoff were generally low, with highest concentrations in the first irrigation following nutrient application. This tail water could be captured in recycle pits on farms that had them and re-applied to the block when water in the recycle pit was subsequently used for irrigation.

Classifying and predicting water quality benefits of different management practice systems

Collation of farming operations and management practices affecting water quality
The workshops and subsequent analyses of farming practice identified there are four goals that need to be met to minimise the water quality impacts. The goals relate to:

- *Water management:* Minimise water excess; that is the difference between water received (irrigation and rainfall) by the crop and lost through crop evapotranspiration.
- *Nitrogen management:* Minimise N surplus; that is the difference between N applied to the crop and lost through harvested product and burnt trash.
- *Herbicide management:* Minimise herbicide losses in runoff and deep drainage.
- *Erosion management:* Minimise losses of sediment in runoff as well as chemicals attached to these sediments.

While sediment loss from sugarcane farms is not currently regarded as an important issue in the Burdekin (Brodie and Bainbridge, 2008), it is included in the framework for the sake of generality.

Water and N management are complex issues in a water quality context because both water and N can ‘leave’ farms through a pathway that has no direct local environmental impact, i.e. via the crop. For water this loss pathway is evapotranspiration (ET), while for N it is the N contained in harvested cane removed from the field and crop residue (trash) that is burnt. Water received by the crop (i.e. irrigation plus rainfall) in excess of ET has the potential to increase runoff and deep drainage. Similarly, N applied to the crop in excess of that lost through the crop has the potential to increase N concentrations in runoff and deep drainage. Thus water quality goals for water and N are expressed as minimising the difference between water or N received by the crop and that lost through the crop.

Framing the water and N goals in this way shows that there are two quite different strategies that can be employed to meet these goals, those being:

- Reduce applications of irrigation water or N fertiliser, whilst maintaining crop yields, and /or
- Increase uptake of water or N by the crop, without increasing water or N inputs.

Thus there can be clear and positive links between profitability, productivity and improved water quality.

The herbicide and sediment goals are treated in a simpler manner as there are no significant loss pathways from fields which do not have a potential environmental impact. Thus the goals focus on minimising losses from farm fields. Strategies for achieving these goals are considered below.

For each goal there are management strategies that could be employed to help achieve that particular goal (Table 3). With irrigation, the strategies are to decrease the amount of water applied and/or increase ET. The former can be achieved through improving irrigation management. This requires two steps: (1) better timing of irrigation applications relative to crop stress (i.e. good irrigation scheduling), and (2) better matching the amount of water applied to the soil water deficit at each irrigation (e.g. through tactics such as controlling inflow rates, cut off time, etc, in a furrow irrigation system). ET will be increased through better crop growth, achieved through improving overall crop husbandry (irrigation scheduling, weed control, variety selection, etc). For N management, the strategy to reduce the N surplus is to match, as closely as possible, N fertiliser applications to the N removed with the crop at harvest, accounting for N from other sources. This should require a move away from the traditional systems of fertilising to achieve target yields, towards focussing on actual production from a field, which is very often determined by things other than N availability. Increasing crop growth, as described above, should also help reduce N losses.

Table 3. Management strategies to achieve the four water quality goals.

Water management	Nitrogen management	Herbicides management	Sediment management
• Reduce the amount of irrigation applied through better control of irrigation timing and the amount of water applied at each irrigation • Increase ET through better crop growth	• Fertilise to replace N or to realistic yields • Account for additional N sources (organic N and/or ground water N) • Increase N uptake through better crop growth • Minimise runoff and deep drainage • Minimise erosion	• Minimise herbicide applications by reducing weed populations(targeted spraying, controlling seed banks, trash blanketing, etc) • Maximise efficacy of product use (timing and manner of application, post-application management) • Minimise runoff and deep drainage • Minimise erosion	• Avoid cultivations • Maintain surface cover • Minimise runoff

Strategies for minimising herbicide losses and erosion are conceptually simpler (Table 3). For herbicides the strategies focus on minimising the needs for using herbicides and then maximising the efficacy of the product when it is used. Erosion is generally controlled by high levels of ground cover, and exacerbated by cultivation. Thus the strategies for erosion are to minimise cultivation and maximise ground cover.

The systems nature of water quality management is illustrated by the interactions between the strategies for the different goals. Minimising runoff and deep drainage is a strategy for minimising losses of N and herbicides (Table 3), so good irrigation management, a strategy for the water management goal, will be required to achieve the N and herbicides goals. Irrigation management and sediment loss are linked through runoff minimisation. Increasing crop growth is a strategy relevant to both the water and N management goals. There is conflict between some goals and strategies. An example is controlling weeds through cultivation: This will reduce the need for herbicides but increase the likelihood of sediment loss. In this case the goals may need to be prioritised in the local context so that a choice of strategies can be made.

The goals and strategies identified in Table 3 were used as the basis of a water quality brochure (Attachment 3) that was widely distributed in the region.

Prediction of nitrogen loads from different management practice classes

Predicting water quality associated with each of the management practice classes (A to E) concentrated on tillage, as a driver of sediment loss, and N management. Thus focus was consistent with two of the four goals described above (Table 3) which are the primary water quality issues in the region (Brodie and Bainbridge, 2008). Each class, E ('bad') to A ('good'), combined decreasing tillage intensity with reducing N application rate, following practices identified in the collation of farming operations (Table 3) and consistent with those being generally practiced or promoted in the sugarcane industry (Table 4). Classes E to C represent practices currently common in the Burdekin region, while Class B is similar to the currently promoted 'best practice', with Class A being the possible future best practice that is currently under investigation. Irrigation management (amount applied and scheduling) in all classes was taken as the recommended practice in the region as there were other programs within the region (e.g. the Water Use Efficiency Initiative) that aimed to improve irrigation management.

Table 4. Fertiliser and tillage management within management classes.

Management class	Fallow and tillage system	N fertiliser management system
E	Bare fallow with high level of tillage for crop destruction and weed control (8 passes), seedbed preparation (6 passes) and crop establishment (6 passes).	330 kg ha^{-1} on Plant cane/ 400 kg ha^{-1} on Ratoon cane
D	Bare fallow with conventional tillage practice (as for E but number of passes halved, except for weed control).	190-210 kg ha^{-1} on Plant cane/ 270 kg ha^{-1} on Ratoon cane
C	Bare fallow (crop destruction as for D), then zero tillage (including planting)	Traditional BSES recom-mendations (Calcino, 1994)
B	As for C	'SIX EASY STEPS' (Schroeder *et al.*, 2005)
A	Legume (containing low N amounts) cover crop in fallow with no tillage following planting, then as for C	'N Replacement' adjusted for legume N input (Thorburn *et al.*, 2009)

N losses (as nitrate) in runoff and deep drainage varied across the simulated management classes at all sites, reducing with decreasing tillage intensity and N application rates (Figure 2). Of these two factors, N rate was the most important in determining the amount of N lost (data not shown). In the coarser textured soils of the two Delta sites, N losses were dominated by deep drainage. Conversely, losses were predominantly in runoff in the finer textured soil of the Mona Park and Mulgrave sites. The greatest reduction in N losses occurred between classes E and D. The marginal reduction in N loss declined from classes D to A.

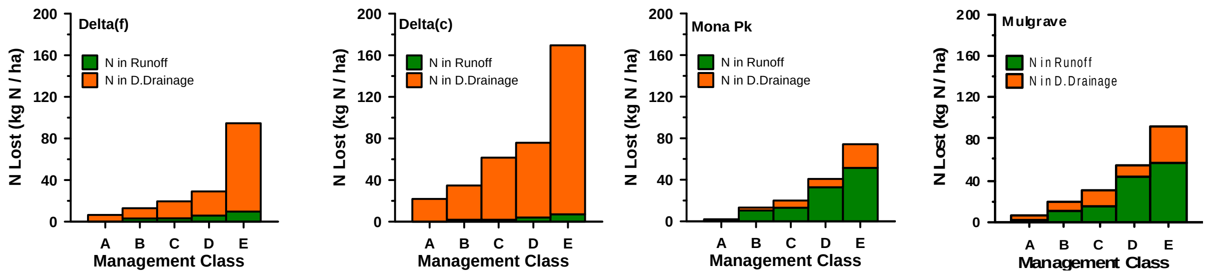

Figure 2. Predicted long-term annual losses of N via runoff and deep drainage at the four sites under five classes of management practices designed to meet water quality targets.

At both the Mona Park and Mulgrave sites, N in runoff, deep drainage, crop off-take and retained residues was < 100 kg ha^{-1}, substantially less than N fertiliser applications to these crops (Table 4). This difference implies that considerable N was lost through denitrification during these crops. While not an issue for water quality, these losses, if proven correct, are a significant concern from both financial and potential greenhouse gas points of view.

Estimation of regional nitrogen loads

Expert opinion of local extension was drawn upon to estimate the proportion of farmers practicing these classes in different districts of the region. The majority (50-60%) of farmers were practicing Class D, with fewer practicing Classes E and C. From these adoption estimates, the areas of the districts and the N applications defined for each class (Table 4), the regional average N fertiliser use (211 kg ha^{-1}) was determined. This N use compared well with data on actual use in the past five years (217 kg ha^{-1}), suggesting that the distribution of management practices were plausible. As well, the adoption estimates, the areas of the districts and predicted N loads for each class (Figure 2), long term regional N loads (5500 t yr^{-1}) could be predicted. These predictions compare favourably with the recent N load estimations in the region (3000-4500 t yr^{-1}, Brodie and Bainbridge, 2008) considering that predictions were based on current conditions, rather than historical (and variable) N usage and areas under sugarcane.

As described above, a simple regional 'calculator' was constructed to allow participative exploration of the relationship between different patterns of adoption and regional N loads (Figure 3). The calculator was used in a facilitated workshop with local farmers and extension officers to determine targets for the adoption of the different practices to meet regional water quality objectives. The water quality target required that N loads be reduced by 20% (i.e. predicted N loads reduced to 4400 t yr^{-1}) by 2013. There were many different combinations of management practice adoption that were predicted to meet the target. One example is having a net shift of 10% of farmers from Class E to Class B practices.

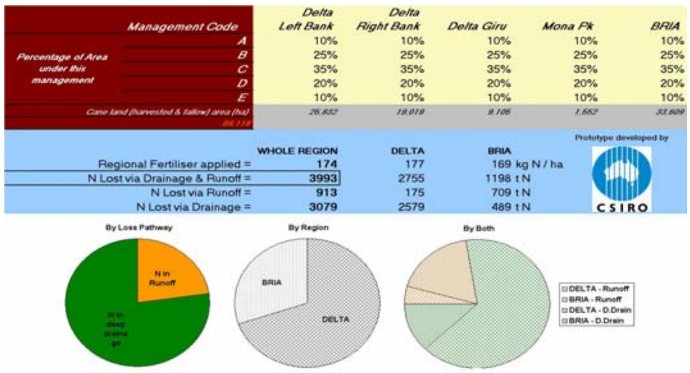

Figure 3. A screenshot from the regional nitrogen load calculator used participatively with stakeholders to assess the water quality benefits from adoption of various management practices.

Economic analysis of different management practice classes

As well as providing water quality benefits, the improving management practices from Class E to A would increase farm profitability (Table 5). Improvements were most marked in moving from Class E to D, due to significantly reduced tillage costs, and from Class B to A associated with increased yields assumed to result in the 'new farming system' that is the basis for Class A.

These field scale economic analyses have been subsequently used as the basis for a spatial analysis of the economic costs and benefits of improving water quality in the Burdekin cane lands (van Greiken, 2008).

Table 5. Average annual gross margins ($\$ ha^{-1}$) for the different management practice classes for the different soil types. The analysis used the prices and values at 2008. Standard deviations ($\$ ha^{-1}$) of the year-to-year variability are shown in brackets.

Soil type	**Management practice class**				
	E	**D**	**C**	**B**	**A**
Mona Park	818 (88)	1043 (87)	1052 (91)	1136 (92)	1363 (104)
Mulgrave	713 (126)	946 (124)	951 (127)	1038 (133)	1157 (163)
Delta-c	1742 (127)	1959 (127)	1935 (145)	1971 (171)	2153 (205)
Delta-f	1901 (121)	2106 (121)	2092 (129)	2132 (139)	2367 (154)

Communication of project results

Results of the project were communicated at a number of forums. A major activity was the 'Big Impacts from Small Changes' event held 22nd and 23rd May 2007 to showcase the project in each of the Mulgrave and Airdmillan districts. Approximately 50 farmers attended the events, as well as other stakeholders (~30) from relevant agencies and organisations. At the event, BSES Ltd extension staff presented results from the demonstration sites, concentrating on the results from Site 7 (Appendix 1) at the Mulgrave meeting and Site 4 (Appendix 1) at Airdmillan. The measurement and modelling of water quality was also presented. A range of other speakers also presented information relevant to water quality initiatives in the region. These included representatives from *Bowen Burdekin Integrated Floodplain Management Action Committee*, *Mulgrave Area Farmer Integrated Action* group, *North Burdekin Water Board* and *NQ Dry Tropics NRM*.

Project results were presented at meetings within the Burdekin Cane Productivity Initiative throughout the project. In particular, there was a major effort to present project results and impacts in the final stages of the project (Table 6). Project results were also used to in various training workshops in the region, such as the 'Focus on Water' meetings (four held in February and June 2008) and a series (13 to date) of 'Nutrient Management Workshops'.

For selected demonstration sites, results were summarised in 'flyers' that were distributed at the above communication events (Attachment 4) and also to BSES Ltd extension officers in other regions to promote the activities and results from these sites.

Project activities and/or results were also promoted in BSES Ltd Burdekin newsletter (twice), BSES Bulletin (five articles to date, with use of project material continuing) and Australian Canegrower (March 2009).

The water quality BMP brochure (Attachment 3) derived from the project results was also distributed widely.

Intellectual Property and Confidentiality

We request that Attachment 1 not be distributed or published, as it is in review for journal publication.

Table 6. Details of Cane Productivity Initiative meetings in 2008 at which results from the project were featured.

Mill region and district	Date	Venue
Invicta		
Mulgrave	22/2/08	Chris Hesp
Mona Park/Clare	25/2/08	AACC shed
Millaroo	3/3/08	John Cambruzzi
Dalbeg	3/3/08	Dalbeg Inn
Selkirk/Bartlett	7/3/08	Tom Pontarelli (McLain Rd)
Giru/Shirbourne	7/3/08	Giru Bowls Club
Upper Haughton/Stockham Rd	10/3/08	Russell Jordan
Pioneer and Kalamia		
Jardine/Barratta	25/2/08	Lance Smith
Waterview/Sextons	3/3/08	Eddie Pearce
Aerodrome	6/3/08	BSES
Dicks Bank/Airville/McDesme	10/3/08	BPS
Burstalls/Airdmillan	11/3/08	Paul Kiehne
Pioneer/Colevale/Kalamia	12/3/08	Brandon Tavern
Jarvisfield/Kilrie	13/3/08	Quartermaine shed
Rita Island	14/3/08	Rita Island Hall
Inkerman		
Inkerman Hill, Fredericksfield	10/3/08	Greg MacElroy
Leichhardt	11/3/08	Chad Mann
Causeway, Osbourne, Marshalls	12/3/08	Loui Michielin
Iona, Koolkoona	13/3/08	Richard Wall
Darveniza, Groper Creek	14/3/08	Bruno Santarossa
Down River, Ramsden	17/3/08	Inkerman Hall

Environmental and Social Impacts

This project has developed and communicated the knowledge base to meet the environmental objectives and social expectations of a cleaner greener cane industry in the Burdekin region, with reduced nutrient and sediment losses is a challenge. This will provide substantial environmental benefits within the region, and in regional aquatic and marine ecosystems. These outcomes will help the sugarcane industry in the region to increasingly meet societal expectations in this area. It will also improve the local socio-economic benefits that flow from a successful and sustainable sugarcane industry.

Expected Outcomes

Outcomes to date

Project evaluation

Results of the project evaluation (Attachment 2) illustrate outcomes achieved by the project through farmers' changes in understanding, knowledge, attitudes, skills and/or aspirations in regard to water quality. Both at the start and end of the project the vast majority of farmers surveyed were aware of environmental and water quality issues and aspired to manage their farm to reduce environmental impact. Over the life of the project, there was an increase in the awareness of ground water quality in the region and a 41% increase in the number of growers who use water tests to determine irrigation water quality. One area where there had been a notable improvement in growers' understanding was regarding irrigation efficiency, with ~60% of those surveyed undertaking some practice change to improve irrigation efficiency.

Of the different water quality-related activities that occurred in the region during the life of the project, this project (CSE012) was the best known. Most farmers surveyed believed that the project had enabled them to learn new practices to help them farm sustainably and profitably (72% of those surveyed) and helped them become aware of new practices to reduce environmental impacts (54%). Most (61%) also believed the project had communicated its results to other growers and the wider community.

There was little difference in survey responses from farmers in the districts where project activities were centred (Mona Park, Mulgrave and Airdmillan) with the two outlying districts (Kilrie and Leichhardt). Both had a similarly high awareness of project and interest in improving irrigation efficiency. There was a small tendency for lower scores from farmers in the two outlying districts to questions about the role of the project in their knowledge acquisition.

Burdekin water quality improvement plan

The research undertaken in this project underpinned the process used, and outcomes reached in the sugar lands component of the Burdekin Water Quality Improvement Plan (WQIP). Firstly, the water quality goals and strategies developed in the project (Table 3) were adopted as the framework for best management practices for sugar lands in the WQIP (Dight, 2009, pp 59-61). Secondly, the management practice classes (Table 4), predicted N loads for each class (Figure 2), and N load 'calculator' (Figure 3) were the basis of the target setting for water quality improvement for sugar lands (Dight, 2009, pp 86-91). The identified practices have been the basis for practice change incentive funding in the recent Reef Rescue program (pers. comm., Ian Dight, NQ Dry Tropics).

Other outcomes of the project

Anecdotal evidence suggests that the project has achieved other positive outcomes on a number of levels. These outcomes include:

- Providing farmers and extension personnel with a better understanding of actual crop water use and the major pathways through which water is lost from irrigated fields.
- Using this information to understand the effect of management practices on water loss. For example, the increase in deep drainage following a deep ripping operation observed at the Delta-f site during the project has prompted a number of Delta growers to reconsider the need for this practice.
- 'Busting the myth' that there is no deep drainage in the heavy clay soils of the Burdekin-Haughton Water Supply Scheme (BHWSS). (There was 200-300 mm yr^{-1} observed at the Mona Park and Mulgrave sites, Table 1.)
- An improvement in understanding and awareness of irrigation practices, e.g. inflow rates, irrigation duration, irrigation frequency, and how they may impact on water use efficiency.

- In the BHWSS, the effect of water logging has been recognized.
- BHWSS farmers have updated their knowledge of their soils and water management. They recognise that management practices such as gypsum applications, cultivation and irrigation have changed the soil characteristics and that their irrigation management now needs to also change.
- There is now some information and experience on irrigation a trash blanketed field in the Delta (demonstration Site 4, Appendix 1).
- Validation of the yield results from other row spacing trials.

Thus the results have also provided a contemporary, improved information base for extension activities, and improved the knowledge of extension officers.

Finally the project has shown how successful a collaborative approach can be where it draws on the strengths of each organisation.

Outcomes expected

The activities conducted in this project will support a more sustainable sugarcane industry in the Burdekin region, with the socioeconomic and environmental benefits that flow from that.

Future Research Needs

Developing and testing 'A Class' practices to provide predicted benefits

The 'A Class' practices assessed in this project should underpin future improvements in environmental performance of Burdekin sugarcane production. However, the practices were largely hypothetical and the benefits associated were based entirely on simulation results. Thus, there are large gaps in knowledge associated with them that need to be addressed before Class A practices can be confidently promoted as giving the environmental and economic benefits as predicted in this study.

Firstly, the impact of controlled traffic, an integral part of the 'new farming system' on soil hydrology is largely not understood. Soil hydrology controls the flow of chemicals and sediment moving with soil water, and controlled traffic has had substantial impacts on soil hydrology in other farming systems. Thus it is important to measure these interactions to understand chemical loss pathways (and hence water quality) in this farming system. Additionally, soil hydrology dictates the performance of irrigation management. Understanding soil hydrology will be vital for development and extension of efficient irrigation management practices in the new farming system.

Secondly, the N management practices needed to deliver the predicted low N loads in the 'A Class' practices have not been field tested. Legumes are an integral part of the 'new farming system' and they contribute a significant amount of N to the subsequent sugarcane crop (as evidence by the very high amounts of soil mineral N at the Delta-f site). N losses from new farming systems could be greater than from more conventional systems if N inputs from legumes are not off set by adequate reductions in N fertiliser inputs. Indeed, the suite of farming operations included in the A Class practices in this study (a legume crop containing very low N, followed by N Replacement management of N fertiliser) were the only ones that resulted in lower N loads than from B Class practices. N cycling and N losses from various legume/N fertiliser management combinations need to be evaluated before 'A Class' practices can be promoted in the region.

Thirdly, an important factor in the predicted environmental and economic performance of A Class practices in this study was increased cane yields. Local opinion suggested that yields were higher in the 'new farming system' and model parameters were adjusted to ensure such an increase. However, few reliable data were available to support this approach. Such data are needed before 'A

Class' practices can be confidently promoted as giving the environmental and economic benefits predicted in this study.

Other biophysical issues

Interactions between irrigation management and water quality
As water is the main 'vector' for sediment and chemicals leaving land, there should be strong interactions between irrigation management (amount and timing of irrigation) and water quality outcomes of sugarcane farming. Preliminary results in this project suggested that, surprisingly, these interactions were weak. These results need to be confirmed to provide a stronger basis for understanding irrigation management-water quality issues.

Trash blanketing
Trash blanketing has the potential to underpin a more sustainable farming system in the Burdekin region. However, it was not included as a potential management practice because information on irrigation management in trash blanketed systems was not available. This information gap is inhibiting the adoption of trash blanketing in the region, and needs to be addressed.

Denitrification and nitrous oxide emissions
The N balance results from, and subsequent simulations of the Mona park and Mulgrave sites suggest that the denitrification is a significant (main) loss pathway for N. These results imply that nitrous oxide emissions and hence greenhouse gas impacts of sugarcane farming in these areas will be very high. These results need to be confirmed to help the sugarcane industry in the region position itself for the possible impacts of a carbon pollution reduction scheme.

Socioeconomic barriers for adoption of sustainable practices

This project has found that improving environmental outcome of Burdekin sugarcane farming also increases on-farm profitability. Yet many farmers will resist changing to practices with these better outcomes. It is important to better understand the barriers to sugarcane farmers adopting new management practices.

Estimating N loads at a regional scale

The 'scaling up' of N loads from fields to whole-of-region scale was based on substantial simplifying assumptions. These assumptions should be validated to ensure the impacts of water leaving Burdekin sugarcane production areas are as low as predicted.

Knowledge base in other regions

While this project has build a substantial knowledge base underpinning farming best management practices, irrigation management and water quality for the Burdekin region, a similar knowledge base does not exist in other regions. For the sugar industry to be able to meet and demonstrate its environmental credentials it is vital that such a knowledge base be developed.

Recommendations

We recommend that SRDC consider the research needs identified in this report.

List of Publications

Referred papers

1. Thorburn, P., Davis, A., Attard, S., Milla, R., Anderson, T. and McShane, T., 2007. Best management practices to improve the quality of water leaving irrigated sugarcane farms:

Guidelines for the Burdekin Region. ACTFR Report No. 07-36. Australian Centre for Tropical Freshwater Research, James Cook University, Townsville. 22 pp.
2. Thorburn, P.J., Davis, A. and Attard, S.J., 2007. Improving off-farm water quality of sugarcane production in the Burdekin region, Queensland. In: Sharing the Water; Food Fibre, People And Environment, Proceedings of the 2007 Conference of the Australian National Committee on Irrigation and Drainage, Bundaberg, 19-22 August, 2007 (Australian National Committee on Irrigation and Drainage), 6 pp (on CD).
3. Attard, S.J., Thorburn, P.J., Biggs, J.S., Kemei, J., and Anderson, T., 2008. Farming practices to meet the water quality challenge in the Burdekin region. Proceedings Australian Society Sugar Cane Technologists, 30: 353-354.
4. Thorburn, P.J., Attard, S.J., Biggs, J.S. and Kemei, J., 2008. Farming practices to improve water quality in the Burdekin region. In: Global Issues, Paddock Action. Proceedings of the 14th Australian Agronomy Conference, 21-25 September 2008. Adelaide, South Australia. Australian Society of Agronomy, 2 pp (on CD).
5. Thorburn, P.J., Attard, S.J., Biggs, J.S. and Kemei, J., 2008. Farming practices to meet the water quality challenge in the Burdekin region, Queensland In: Soils 2008, Proc of Conference, Palmerston North, New Zealand, 1-5 December, 2 pp (on CD).
6. Thorburn, P.J., Brodie, J., Milla, R., Shannon, E., Attard, S., Anderson, T. and Davis, A., 2009. Systems analysis underpinning development of management action targets to meet water quality objectives in sugarcane production systems. In: Van Ittersum, M.K., Wolf , J. and Van Laar, H.H. (Eds), Proceedings of the Conference on Integrated Assessment of Agriculture and Sustainable Development: Setting the Agenda for Science and Policy. Egmond aan Zee, The Netherlands, 10-12 March 2009. Wageningen University and Research Centre, Wageningen, pp 490-491.
7. Thorburn, P.J., Biggs, J.S., Attard, S.J. and Kemei, J., 2009. Environmental impacts of fully irrigated sugarcane production. Agriculture Ecosystems and Environment, submitted.

Conference abstracts

8. Thorburn, P.J., Dawes, L., Kemei, J., Charlesworth, P., Attard, S.J. and Cairns, R., 2006. Sustainable irrigation in the Burdekin: Losses of farm chemicals in runoff and deep drainage. Proceedings of the Australian Society of Sugar Cane Technologists, 28: 598.
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10. Thorburn, P.J. and Attard, S.J., 2007. A framework to guide improved off-farm water quality in the Burdekin. Proceedings of the Australian Society of Sugar Cane Technologists, 29: 536.

List of attachments

1. Draft paper - Environmental impacts of fully irrigated sugarcane production.
2. Project evaluation report.
3. Brochure describing water quality ‘bent management practices’ developed in the project.
4. Flyers promoting activities and results at selected demonstration sites.

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Appendix 1 Details of the issues addressed and results found at the demonstration sites

Site number/ District	Issue	Possible Causes	Actions	Results
1. Mona Park	• Irrigation doesn't get to the end of the field • Deep drainage	• Saline water • Drill length • Hill profile • Conventional cultivation	• Maintain detailed water use records	• Improved understanding of crop water use • Inflow rates adjusted to improve efficiency • Better able to judge the cost-benefit of purchasing better quality water • Use of better quality water is the only long term solution • Trial completed
2. Mona Park	• Possible run-off of nutrients in irrigation water	• Fertiliser applied directly after harvest then irrigated	• Record water use • Sample run-off	• Little nutrient run-off • N that did run-off was concentrated in the first irrigation and was captured in the recycle pit for re-use • Trial completed
3. Mona Park	• Water penetration • Deep drainage	• Drill length • Hill profile • Conventional cultivation	• Stop busting the furrow centre • Change to minimum till ratoons • V-out the furrow • Install Enviroscan	• As a result of the trial practice changed; last year minimum till, fertilising with a stool splitter and increased irrigation inflow rates (to reduce deep drainage) were implemented across the whole farm. • 2006: 1st ratoon Q208^{A} 114.14 t ha^{-1} – original practice • 2007: 2nd ratoon Q208^{A} 143 t ha^{-1} – changed practice • Trial completed

Site number/ District	Issue	Possible Causes	Actions	Results
4. Airdmillan	• Wants to move to a green cane trash blanket (GCTB) system • Irrigation in (GCTB) compared to burnt	• Poor water infiltration • Soil health issues	• GCTB implemented • Installed two enviroscans • A 7 day cycle and a 25% increase in flow rate was trialled in comparison to a 14 day cycle. • Soil health testing • Trial harvested	• In GCTB area: ▪ Able to determine the appropriate irrigation cycle and amount. ▪ Good lateral soakage into the stool. ▪ Higher beneficial nematode counts ▪ Lower weed pressure and associated control costs ▪ Grower believes that yields have increased • 2006: GCTB – 98.7 t ha^{-1} @ 15.13 CCS • 2006: Burnt – 89.2 t ha^{-1} @ 15.19 CCS • 2007: GCTB – 98.3 t ha^{-1} @ 14.63 CCS • 2007: Burnt – 82.4 t ha^{-1} @ 14.28 CCS • Trial completed
5. Airdmillan	• Fertiliser run-off • Fertiliser comparison	• Placement of fertiliser • Choice of fertiliser	• Trial different application methods – stool splitting and side dressing • Compare different fertiliser products – Urea and Nutrismart	• No significant differences in nutrient run-off between application methods • Nitrate levels in both were very low (<25mg/L) • No significant yield differences between products ▪ Urea: 126 t ha^{-1} @ 14.4 CCS ▪ Nutrismart: 121 t ha^{-1} @ 15.4 CCS • Moved to a more economical fertiliser option (urea). Product costs were similar but the application rate for urea was lower. • Trial completed

Site number/ District	Issue	Possible Causes	Actions	Results
6. Airdmillan	• Irrigation in dual row • Production in dual row • Poor lateral water movement	• High infiltration soil • Poor soil health • Steep slope • Short drills	• Water use monitored • Installed two Enviroscans	• Increased lateral movement of water • High production • Reduced planting costs • Reduced chemical applications • No tillage plant and ratoon • 2006: 158 t ha^{-1} @ 14.5 CCS • 2007: no harvest results due to a harvesting error • Trial completed
7. Mulgrave	• Improving irrigation scheduling • Effect of current practices on root development	• Over irrigation	• Monitored water use (Enviroscans) • Varied irrigation schedules between sections of the block (farmer practice vs. BSES scheduling) • Measured irrigation rates • Trial harvested	• Improved root activity at depth in the BSES section of the block • Reduced water use: BSES 13.5ML ha^{-1}, Salter 17 ML ha^{-1} • Improved irrigation efficiency • Better time management • Reduced waterlogging • Improved yield • 2007: BSES – 126 t ha^{-1} @ 16.9 CCS • 2007: Salter – 112 t ha^{-1} @ 17.0 CCS
8. Leichhardt	• Irrigation management under centre pivot • Poor water penetration Irrigation management for GCTB vs burnt	• Lack of knowledge of appropriate irrigation schedule under this new system • Low EC water • Poor soil structure Problems were encountered throughout the season due to rutting, ponding and infiltration	• Monitoring with Enviroscans to understand the effectiveness of the irrigation applications • Mix channel water with salty bore water • Monitor in one season under burnt, followed by a season under green	• Increase EC of irrigation water to improve soakage • Trial harvested green to start that phase of the work • Trial continuing

Site number/ District	**Issue**	**Possible Causes**	**Actions**	**Results**
9. Mona Park	• Irrigation scheduling in a wide bed system	•	• Compare 1.52m and 1.83m dual row systems • 3 Enviroscans installed for monitoring purposes	• Confirmed results of other row spacing trials • Single row: 173.5 t ha^{-1}@ 16.08 CCS • Dual row: 194.6 t ha^{-1} @ 16.00 CCS