Herbert Demonstration Farm Project

Final Report

(2009-13)

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This project was a collaborative project between the Queensland Department of Agriculture, Fisheries and Forestry (DAFFQ), Terrain NRM, HCPSL and TropWater.

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1 Introduction

The Herbert demonstration farms project was funded by the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) and supported by Terrain NRM, TropWATER and Herbert Cane Productivity Services Ltd (HCPSL).

The Herbert Demonstration Farm project began in 2009 and was concluded in 2013. This project compares two classes of management systems on adjacent blocks that have similar soils as well as environmental conditions over a fallow period to a second ratoon crop.

The project is designed to intensively monitor economic, agronomic and biophysical (water quality) components between a Conventional farming (CF) versus a Best Management Practice (BMP) farming system.

The primary aim of the demonstration farm project was to showcase alternative farming systems, identify knowledge gaps, and inform future research and investment.

The demonstration farm project also acted as a platform for extension based learning and a forum to initiate discussion in regards to farming systems and elements of farming systems. This includes the efficacy of alternative farming technologies and techniques such as zonal tillage methods, mound planting, sub-surface fertiliser application, electromagnetic and yield mapping.

It must be emphasised that the site was set up as a demonstration site and not a multi-replicated and statistically rigorous trial. A degree of caution is required when interpreting the data because the treatments are single replicates. However the site met the purpose it was established for, which was to be a demonstration site for industry to observe new farming practices first hand.

2 Background

The Herbert sugarcane growing region is the largest sugarcane growing region in the Wet Tropics. It has a production area of approximately 64 500ha, accounting for approximately 40% of the sugarcane production in the Wet Tropics area.

The Herbert demonstration farm was established in 2009 and is located in the lower Herbert area, approximately 5km west of Ingham. There were two farming systems being investigated (Table 2). The first farming system comprises industry-endorsed best management practices (which will be referred to as the “BMP” farm management system or site 1), while the other has followed conventional management practices (which will be referred to as “CFMS” or site 2- being the Conventional Farm Management System) for the Herbert region. Yields, Commercial Cane Sugar (CCS) and profitability, nitrogen regimes after legumes, fertiliser placement, alternative herbicide strategies, operational costs, and surface water quality (nutrients, sediment and herbicides) were monitored and assessed during the duration of the project.

3 Herbert Demonstration Farm Site

The Herbert sugarcane monitoring site (Farm 0082, Block A-5-3; Figure 1) is located approximately 5 km west of Ingham (S18.62843 E146.06468) (Figure 1). Slope is 2%, draining SSE (Table 1). The dominant soil found at the site is a Mottled, Eutrophic, Grey, Dermosol (Australian Soil Classification, Isbell, 1996). Details are very dark greyish brown (10YR32) moist; silty clay loam, A horizon; Dark grey (2.5Y41) moist; orange and brown mottles; medium heavy clay, B horizon with sub-angular blocky strong 5-10mm structure. This soil is alluvial plain and is common to sugarcane farms within the Herbert catchment.

The Hawkins Creek Bureau of Meteorology (BoM) site (No. 032191), which is approximately 2.5 km North of the monitoring site, is the nearest complete climate weather station with an average annual rainfall of 2476 mm. However, in 2010 the site recorded its highest ever average annual rainfall of 4152 mm. The site has no supplementry irrigation.

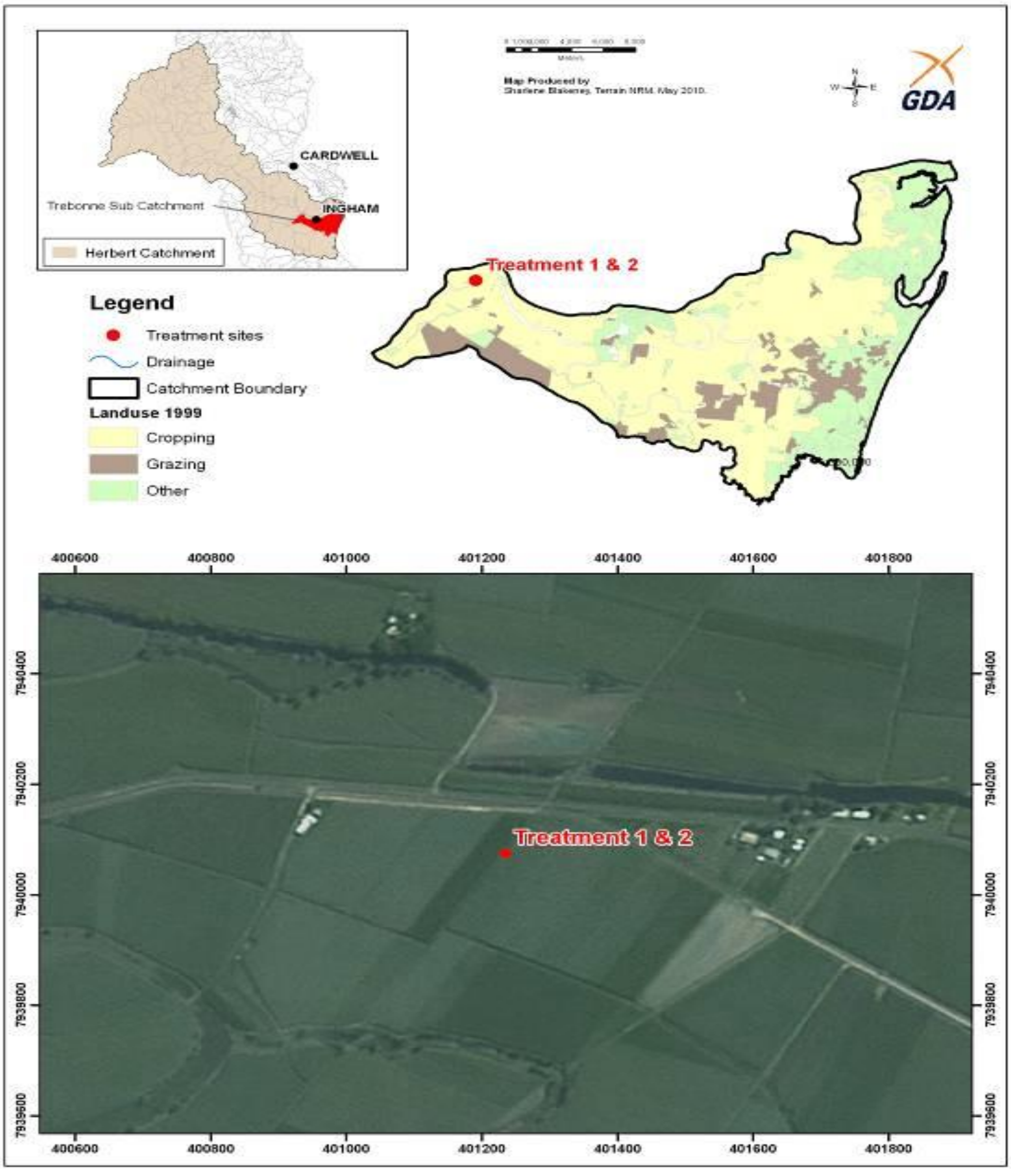


Figure 1. Location of sugarcane monitoring site in the Herbert catchment.

Table 1. The physical features for Herbert sugarcane site plots

Plot	Layout Area (m^2)	Length (m)	Width (m)	Slope (%)	Slope shape
1	21600	245	89	2%	Flat and constant
2	13400	245	55	2%	Flat and constant

4 Sites (Management practices)

An overview of the management practice undertaken in each site is given in Table 2. Specific nutrient and weed management practices are discussed further in the following sections. The physical features of each site are also outlined in Figure 2.

Table 2. Summary of management practices at the Herbert sugarcane site.

The characteristics of both systems are outlined below:

Conventional "CFMS" Farm Management System Practices- site 2

- Single cane row at 1.62m spacing
- Furrow planted
- Full cultivation in plant cane
- Surface fertiliser application in ratoons
- Legume fallow with full incorporation prior to planting
- Use of herbicides restricted under the Reef Protection regulations
- GPS guidance used at planting

Improved or "BMP"Farm Management System Practices- site 1

- Wide row at 1.83m spacing
- Mound planted
- Reduced cultivation and zonal tillage
- Subsurface fertiliser application in ratoons
- Permanent mounds
- Controlled traffic
- Legume fallow with minimal incorporation (by mulching) prior to planting
- Minimal use of herbicides restricted under the Reef Protection regulations in plant and ratoons
- GPS guidance used at planting and harvesting

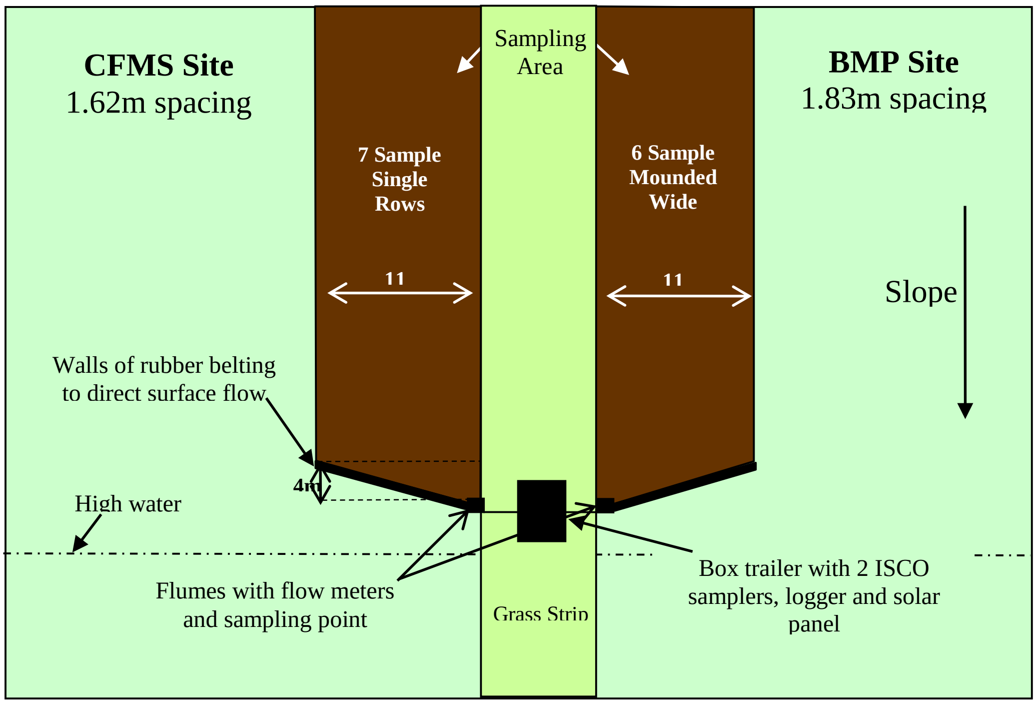


Figure 2. Herbert sugarcane monitoring site: CFMS Site (left) and BMP Site (right)

4.1 Nutrient management

4.1.1 Soil testing and mapping

After the block had been cultivated to remove the previous cane crop, the grower was requested to undertake a generic soil test for the whole site, which is typical industry practice. This occurred on November 2009. Nutrient applications for this site would be based upon this soil test.

During the fallow period prior to legume planting, the whole block was also mapped with a *Veris 3100* electromagnetic mapping unit. The electro-conductivity map revealed that 5 distinct soil zones were present within the block (Figure 3). A GIS centroid point was attributed and established to these distinct soil zones to become the points for intensive soil monitoring activities to occur throughout the duration of the projects life.

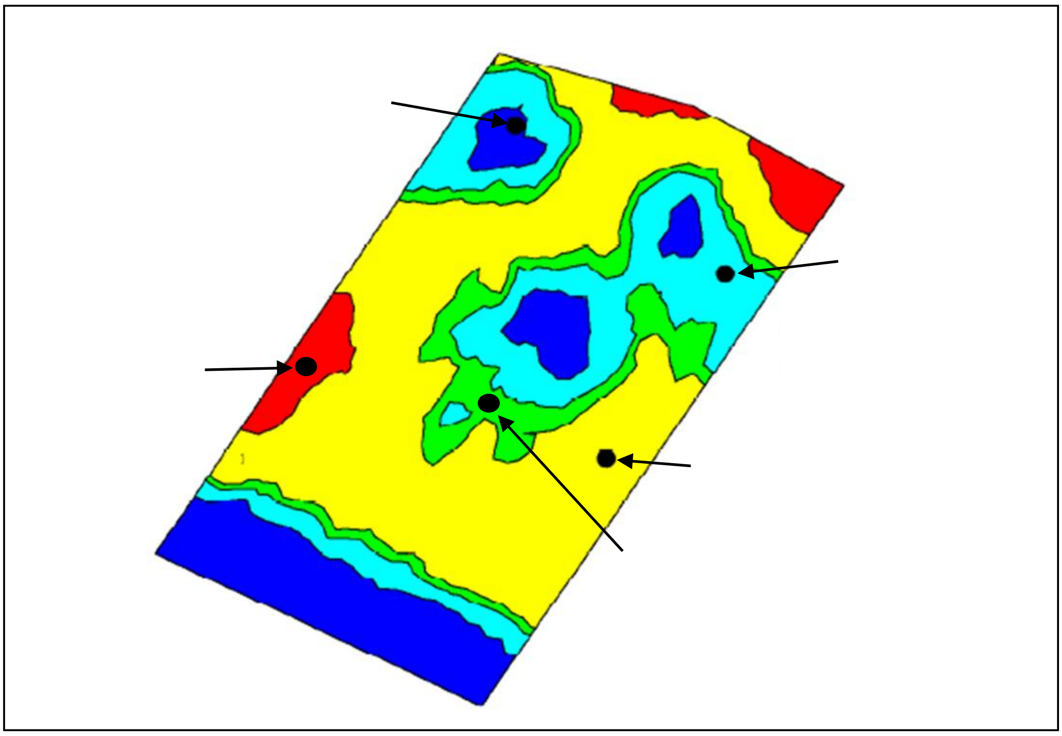


Figure 3. EC map of the block highlighting different zones within the block.

Soil sampling occurred at periodic intervals and sampling points were strategically selected using an EM map of the paddock. Samples were taken in March 2010 at depths of 0-20, 20-90cm and were analysed for nutrients present. Samples for N were not taken. In June and September 2010 further soil tests were taken at depths of 0-20, 20-60, 60-90cm and were only tested for N. Sampling in November 2010 was abandoned due to saturated conditions. Samples taken in September 2011, post-harvest, were only taken at a depth of 0-20cm due to extremely hard ground.

Samples for mineral nitrogen were placed in eskies chilled with freezer bricks in the field, then sent to the laboratory for analysis. Samples were air dried and ground <2 mm with analytical methods as described in Rayment and Lyons (2011) undertaken.

4.1.2 Management of the legume fallow crop

The key difference in nutrient management between the sites was the management of the legume fallow crop post-desiccation. There was minimal incorporation at the BMP Site, compared to full incorporation of the legume stubble at the CFMS Site. Minimal incorporation of legume stubble is considered BMP as this delays N mineralisation to a growth stage where the cane plant can better utilise available N.

On the 19th of December 2009 a legume (Lablab purpureus (L.) cultivar Rongai) break crop was established on both sites. It was estimated that this crop provided approximately 86 kg N/ha (exclusive of roots). The crop was chemically desiccated on the 14th of May with an application of Glyphosate @ 1440 g a.i./ha and 2,4-D Amine @ 713 g a.i./ha.

On the BMP Site the legumes were mulched on the 6th of June 2010 and left on the surface. The mulched legume was incorporated using a zonal rotary hoe on the 11th of June 2010. At CFMS Site, the incorporation of the legume trash began on the 26th of May with two passes using offset discs. On the 6th of June the site was then deep ripped and rotary hoed and finally deep ripped on the 10th of June 2010. Both sites were planted on the 13th of June 2010.

4.1.3 Nutrient applications following a legume fallow

At planting (12 June 2010), starter fertiliser containing 31 kg N/ha, 33 kg K/ha and 37 kg S/ha was applied to both sites (Table 3). An additional 50 kg K/ha was banded over the stool approximately three months later (16 September 2010).

Commonly, additional nitrogen fertiliser is applied around 3 months after planting; however, BSES Six Easy Steps and ReefWise Farming guidelines indicated no additional N would be required because of the N contribution from the legume fallow crop and the medium N mineralisation index. While it is not mandatory to account for legume N contribution, BMP was followed. As a result, only 31kgN/ha was applied in the starter fertiliser at planting.

Standard soil tests using randomised or transect sampling provided an average of the soil nutrient status. However, this method did not show nutrient variation within the block. EM mapping (Figure 3) was used to strategically sample at five designated GPS points to achieve a more precise understanding of the soil nutrient dynamics. A generic block soil test was also performed so that results could be compared. These samples were taken before planting on the 19th of March 2009.

BSES Six Easy Steps and ReefWise Farming guidelines stipulate that no additional P was required if P is greater than 50 mg/kg (BSES acid extraction) on low P sorption soils. While sample points 7.1 and 6 indicated the need for additional P (46 and 31 mg/kg P (BSES P)), the generic block soil test indicated a BSES P of 55 mg/kg BSES acid extraction. Therefore, no P was applied in the plant cane or the 1st ratoon phase.

The fertiliser program for the 2011-12 1st ratoon crop and 2012-13 2nd ratoon crop was the same on both sites. The difference was in the application method. Surface fertiliser application is a conventional practice in the Herbert region and will be used on the CFMS Site. Surface application, however, exposes the fertiliser to more potential loss pathways, which can lead to adverse agronomic and water quality outcomes. As a result, subsurface application is promoted as an improved practice and will be used on the BMP Site. Fertiliser for the 2011-12 1st ratoon crop, based on the original generic soil test, was Nitra King applied at 560kg/ha, which provided 152.3kgN/ha, 0kgP/ha, 92.4kgK/ha and 19kgS/ha (Table 4). Fertiliser for the 2012-13 2nd ratoon crop was CK140(S) at 560kg/ha, which provided 130kgN/ha, 11kgP/ha, 98kgK/ha and 21kgS/ha (Table 5).

After harvesting of the 1st ratoon crop soil samples were once again collected from the 5 GPS points based upon the EM map. Also soil samples indicated that all locations were now below the critical 50 mg/kg (BSES acid extraction) on low P sorption soil levels. This finding is “not deemed as typical” (after discussion with BSES Agronomists), as it was not expected that P levels would vary this much over a 3 year period. Based upon soil test results taken after the 1st ratoon crop, both sites received an application of P for the 2nd ratoon crop. 560kgN/ha was applied to both sites with other nutrients on the 15th of October 2012 (Table 5).

Table 3. Application of nutrient treatments at Herbert sugarcane site plots 2010-11

Site	Date Applied	Product	Nutrient analysis (%)				Nutrient applied (kg/ha)			
			N	P	K	S	N	P	K	S
1	12 Jun 2010	Liquid starter fertiliser (218 L/ha [A])	14	0	15	17	31	0	33	37
	16 Sept 2010	Potash (100 kg/ha [B])	0	0	50	0	0	0	50	0
2	12 Jun 2010	Liquid starter fertiliser (218 L/ha [A])	14	0	15	17	31	0	33	37
	16 Sept 2010	Potash (100 kg/ha [B])	0	0	50	0	0	0	50	0

[A] Applied sub-surface with sett. [B] Applied banded on surface.

Table 4. Application of nutrient treatments at Herbert sugarcane site plots 2011-12

Treatment	Product	Nutrient analysis (%)				Nutrient applied (kg/ha)			
	(amount applied)	N	P	K	S	N	P	K	S
1	Nitra King [A]	27.2	0	16.5	3.3	152.3	0	92.4	19
2	Nitra King [B]	27.2	0	16.5	3.3	152.3	0	92.4	19

[A] Applied sub-surface into the stool area. [B] Applied banded on surface on the stool area.

Table 5. Application of nutrient treatments at Herbert sugarcane site plots 2012-13

Treatment	Product	Nutrient analysis (%)				Nutrient applied (kg/ha)			
	(amount applied)	N	P	K	S	N	P	K	S
1	CK140(S) [A]	23.2	2	17.5	3.8	130	11	98	21
2	CK140(S) [B]	23.2	2	17.5	3.8	130	11	98	21

Applied sub-surface into the stool area. [B] Applied banded on surface on the stool area

4.2 Planting methods

The BMP Site used a mound planting method. A mound planter typically creates a furrow where multiple billets and fertiliser are placed, then discs and blades gather soil from each side to cover the furrow and create a mound profile (refer to figure 4). This operation eliminates the need for multiple cultivations, as everything is done in the one pass. Mound planting systems have been adopted by some growers in the Herbert region to minimise risks associated with water logging of cane setts after planting. The other advantages mound planting has over conventional planting include mound consistency for harvesting and a reduction in tillage after planting. The negatives for mound planting are usually noticed during dry periods when the mound can dry out causing poor germination and crop establishment.

The CFMS Site used a conventional billet planter. A conventional billet planter creates a furrow, drops the billets in the furrow and covers them with a small amount of soil (refer to figure 4). Further cultivations throughout the season gradually move soil in towards the cane, creating a mound profile.

Figure 4. Planting methods. Left conventional planting method. Right mound planting method.

4.3 Weed management

BMP Site - plant cane management.

At the BMP Site, the first herbicide application for the 2010/11 period occurred 12 days after planting on the 24th of June (Table 6). Residual herbicides are generally used in this application as the soil is bare following planting and the use of these products will provide weed control until the final spray following hilling up or prior to the onset of the “wet season”.

Based on the weed types and pressure, a tank mix of imazapic (48 g a.i./ha), Sprayseed (paraquat (176 g a.i./ha) and diquat (150 g a.i./ha)), paraquat (300 g a.i./ha), and 2,4-D (1750 g a.i./ha) was boom sprayed over the site following planting. The aim was to ensure effective weed control until the crop was at the out of hand stage (OOHS). However, the use of imazapic as the sole residual control allowed the escape of the Perennial Urochloa Grass (Urochloa mosambicensis). Ametryn (2048 g a.i./ha) was applied with a boom spray 21 days later to control this weed.

An over-row spray unit was used on the 11th of December, prior to the cane reaching OOHS. A directed spray below the crop canopy of Sprayseed (paraquat (270 g a.i./ha) and diquat (230 g a.i./ha)) for non-selective knockdown of existing weeds and Metribuzin (770 g a.i./ha) and S-metolachlor (1728 g a.i./ha) to provide residual control. The broadcast spray used Actril (2,4-D (866 g a.i./ha), ioxynil (150 g a.i./ha) to target vines. A final herbicide application targeting vines, broadleaf and woody weeds was applied because of higher than normal weed pressures. As heavy machinery was unable to drive onto the block, it was decided to aerially apply a tank mix of Tordon 75-D (2,4-D (300 g a.i./ha), picloram (75 g a.i./ha), 2,4-D (625 g a.i./ha) and fluroxypyr (333 g a.i./ha).

CFMS Site - plant cane management.

At the CFMS Site, the first herbicide application for the 2010/11 period was applied 12 days after planting on the 24th of June (Table 6). Residual herbicides are generally used in this application as the soil is bare following planting and the use of these products will provide weed control until the cultivation commences to fill in and hill up the field.

Based on the weed types and pressure, a tank mix of imazapic (48 g a.i./ha), atrazine (1100 g a.i./ha), Sprayseed (paraquat (176 g a.i./ha) and diquat (150 g a.i./ha)), paraquat (300 g a.i./ha), and 2,4-D (1750 g a.i./ha) was broadcast with a boom spray. This herbicide application was aimed at providing effective weed control until the cane was able to close in. However, the use of imazapic and atrazine allowed the escape of Perennial Urochloa Grass (Urochloa mosambicensis). Ametryn (2048 g a.i./ha) was applied with a boom spray 21 days later to control this.

An over-row spray unit was used on the 11th of December, prior to the cane reaching OOHS. The low spray used Sprayseed (paraquat (270 g a.i./ha) and diquat (230 g a.i./ha)) for non-selective knockdown of existing weeds and Velpar K4 (Hexazinone (264 g a.i./ha) and diuron (936 g a.i./ha) to provide residual control. The broadcast spray used Actril (2,4-D (866 g a.i./ha) and ioxynil (150 g a.i./ha) to target vines.

Due to higher than normal weed pressures a final herbicide application targeting vines, broadleaf and woody weeds was applied. As heavy machinery was unable to drive onto the block, it was decided to aerially apply a tank mix of Tordon 75-D (2,4-D (300 g a.i./ha), picloram (75 g a.i./ha), 2,4-D (625 g a.i./ha) and fluroxypyr (333 g a.i./ha).

The high weed pressure, in both sites can be largely attributed to the atypical season, which included record high rainfall levels and cyclone Yasi. The wet conditions not only provided ideal conditions for weed germination and emergence, but also slowed cane growth. Slower cane growth prevents the crop canopy from closing in sooner, hence allowing further weed germination and emergence.

Plot	Date	Product	Active ingredients
BMP site 1	Application #1 14th May 2010	Surpass (1.5 L/ha) Roundup (4 L/ha)	2,4-D (713 g/ha) Glyphosate (1440 g/ha)
	Application #2 24th June 2010	Flame (0.2 L/ha) Gramoxone (1.2 L/ha)	Imazapic (48 g/ha) Paraquat (300 g/ha)
	Application # 3 9th July 2010	Sprayseed (1.3 L/ha) 2,4-D (2.8 L/ha)	Paraquat (176 g/ha) Diquat (150 g/ha) 2,4-D (1750 g/ha)
	Application #4 15th August 2010	Ametryn (2.8 kg/ha)	Ametryn (2048 g/ha) &
	Application #5 11th December 2010	Actril (1.5 L/ha) Sprayseed (1.3 L/ha) Dual Gold (1.8 L/ha) Soccer (1.1 kg/ha)	2,4-D (866 g/ha) Ioxynil (150 g/ha) Paraquat (176 g/ha) Diquat (150 g/ha) S-Metolachlor (1728 g/ha) Metribuzin (770 g/ha)
	Application #6 31st January 2011	Tordon 75-D (1 L/ha) 2,4-D (1 kg/ha) Starane (1 L/ha)	2,4-D (300 g/ha)* & Picloram (75 g/ha)* 2,4-D (625 g/ha)* Fluroxypr (333 g/ha)
CFMS-Site 2	Application #1 14th May 2010	Surpass (1.5 L/ha) Roundup (4 L/ha)	2,4-D (713 g/ha) Glyphosate (1440 g/ha)
	Application #2 24th June 2010	Flame (0.2 L/ha) Atradex (2.2 kg/ha) Gramoxone (1.2 L/ha)	Imazapic (48 g/ha) Atrazine (1100 g/ha) Paraquat (300 g/ha)
	Application # 3 9th July 2010	Sprayseed (1.3 L/ha) 2,4-D (2.8 L/ha)	Paraquat (176 g/ha) Diquat (150 g/ha) 2,4-D (1750 g/ha)
	Application #4 15th August 2010	Ametryn (2.8 kg/ha)	Ametryn (2048 g/ha) &
	Application #5 11th December 2010	Actril (1.5 L/ha) Sprayseed (1.3 L/ha) Velpar K4 (2 L/ha)	2,4-D (866 g/ha) Ioxynil (150 g/ha) Paraquat (176 g/ha) Diquat (150 g/ha) Hexazinone (132 g/ha) & Diuron (468 g/ha)
	Application #6 31st January 2011	Tordon 75-D (1 L/ha) 2,4-D (1 kg/ha) Starane (1 L/ha)	2,4-D (300 g/ha)* & Picloram (75 g/ha)* 2,4-D (625 g/ha)* Fluroxypyr (333 g/ha)

Table 6. Application of herbicide treatments on Herbert sugarcane site plots 2011/12 located on the next page

BMP Site - 1st ratoon cane management
On the BMP Site, the first herbicide application for the 2011-12 season occurred 3 months after harvest on the 23rd of November (Table 7). In ratoons, residual herbicides are not always used for the OOHS spray; however, due to the thin trash blanket and predicted weed pressure, residual herbicides were used. With the aim of avoiding legislated PSII herbicides, a tank mix of Flame (imazapic (96 g a.i./ha)), 2,4-D Amine (2,4-D (500 g a.i./ha)) and Gramoxone (paraquat (325 g a.i./ha)) was applied as a directed spray.

***CFMS Site - 2nd ratoon cane management**.*
PSII herbicides are commonly used in conventional systems. As a result, for the CF site, it was decided to apply a tank mix of Diurex (Diuron (450g a.i./ha), 2,4-D (2,4-D Amine (500 g a.i./ha) and Gramoxone (Paraquat (375 g a.i./ha) with a directed spray (Table 7).

Table 7. Application of herbicide treatments on Herbert sugarcane site plots 2011-12

Plot	**Date**	**Product**	**Active ingredients**
Site 1	Application 23th Nov 2011	Flame (0.4 L/ha) Gramoxone (1.3 kg/ha) Amicide (0.8 L/ha)	Imazapic (96 g/ha) Paraquat (325 g/ha) 2,4-D (500 g/ha)
Site 2	Application 23th Nov 2011	Diurex (0.5 L/ha) Gramoxone (1.5 kg/ha) Amicide (0.8 L/ha)	Diuron (450 g/ha) Paraquat (325 g/ha) 2,4-D (500 g/ha)

BMP and CF Sites - 2nd ratoon management
Both sites were applied with the same knockdown herbicides to control broadleaf weeds (Table 8). Due to a good trash blanket cover after the 1st ratoon crop, grass weeds were not a significant issue in crop. Herbicides were applied aerially on the 7th of February, 2013.

Table 8. Application of herbicide treatments on Herbert sugarcane site plots 2012-13

Plot	**Date**	**Product**	**Active ingredients**
Site 1	Application 7 February 2013	2,4-D (0.85 kg/ha) Starane (0.8 L/ha)	2,4-D (625 g/ha)* Fluroxypyr (333 g/ha)
Site 2	Application 7 February 2013	2,4-D (1 kg/ha) Starane (1 L/ha)	2,4-D (625 g/ha)* Fluroxypyr (333 g/ha)

4.4 Field equipment

The automated surface runoff monitoring systems were installed on the Herbert site by DAFF and Campbell Scientific staff. Automated samplers, data loggers and the solar power system were housed in a box trailer. All physical monitoring hardware (runoff flumes, sample station enclosures, data loggers, non-refrigerated ISCO samplers etc.) were installed in August 2010. Due to budget constraints, a CR200 data logger was used during the 2010-11 wet season. However, in July 2011 the CR200 logger was upgraded to a CR800 logger. This upgrade allowed the site to be fitted with telemetry using Next G modems.

The site was instrumented with ISCO 3700 portable samplers, Campbell Scientific data loggers (CR200) and a pluviometer mounted on a trailer (Figure 5). Surface water runoff is directed through two 9 inch Parshall flumes and water depth is measured with Greenspan PS7000 depth transducer. Data logging commenced on 2nd September 2010.

Figure 5. Monitoring station at the Herbert sugarcane site

4.4.1 Paddock discharge calculation

Parshall flumes (9 inch) are used to measure discharge from each treatment plot (Figure 6). The flume size and plot area were chosen to deal with up to approximately a 1:10 year 30 minute rainfall event (at 100% runoff). The location of each flume, ~50m from the bottom of the paddock, was selected to prevent submerged flow conditions. Conveyor belt strips, were buried in the ground and used as walls to direct surface water flow into each flume.
The standard discharge calibration equation (Walkowiak 2006) for converting water depth into discharge for a 9 inch Parshall flume is:

Q (L/s) = 535.4 H1.530

Q = KHn

Where: Q = flow rate
H = head measured at point Ha
K = constant, dependant upon throat width and units
N = constant power, dependant upon throat width

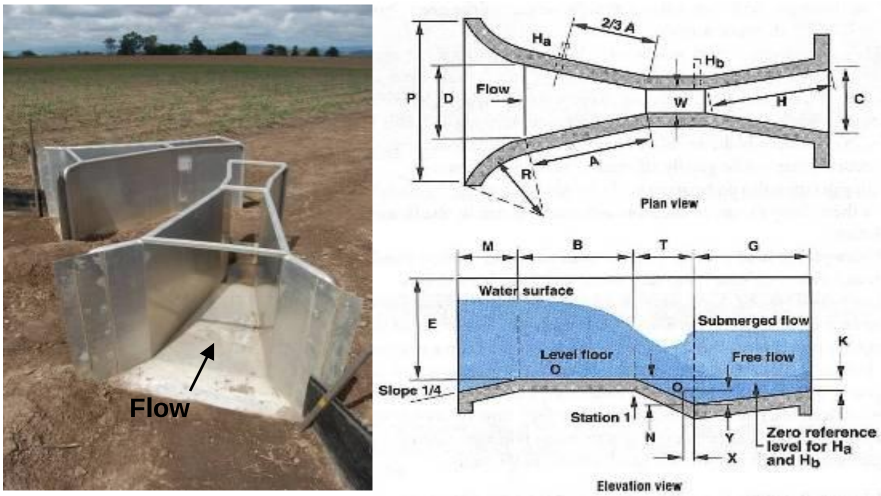


***Figure* 5. The 9 inch Parshall flumes (left) and critical dimensions (right)**

4.5 Runoff sampling

Runoff monitoring and sampling at the BMP and CFMS Sites commenced upon equipment installation in August 2010. Rainfall was measured using a Hydrological services TB4 tipping bucket rain gauge, with 0.2mm bucket. Bucket tips are recorded by the data logger allowing for measurements of rainfall volume and intensity.

Data was logged on a one minute interval during flow events and at hourly intervals during other times. Water samples were collected across the runoff hydrograph using a combination of water depth and time. Runoff from each treatment was measured using 9 inch Parshall flumes, located in the centre, bottom quarter of the paddock. Water depth was measured with a Greenspan PS7000 depth transducer located in a stilling well connected to the side of the flume. Pressures measured by the transducer are converted into discharge by the data logger using the flume discharge equation provided in section 4.4.1.

To avoid erroneous data logging, trigger height was set at 3mm. When water height within the flume rose above this height the logger was programmed to log accumulated discharge. Once a predetermined volume of water has passed through the flume the logger triggers the ISCO 3700 non-refrigerated portable sampler to take a sample. Samples are taken from a second stilling well on the opposite side of the flume and stored with the sampler that is located within the instrumentation trailer.
Critical information gaps identified were firstly, what sampling procedure to use and secondly, what discharge settings would be specific to the site. To obtain initial discharge volume trigger values the following equation was developed:

$$\text{Discharge trigger volume } (m^3) = \frac{\text{highest av. daily r'fall for sampling period (m)} \times \text{sample catchment area } (m^2) \times \text{runoff coefficient}}{\text{Number of samples possible}}$$

Where:

- Highest average daily rainfall (m) for November in the last 10years = 0.045m (Hawkins Creek BoM Site (No. 032191))
- Average sample catchment area (m2) = 2200
- Runoff coefficient of 0.6 (DNRM 2004)
- Number of samples = 1 sample / container. Total of 24 containers.

Advice from TropWATER staff in early October 2010 led to the modification of the sampling strategy used. Where 2 samples were collected in the one bottle and bottles were combined (typically2-3), individual bottles would now be selected (typically 3-5) and discreetly sampled. This strategy would allow more accurate load calculations to be determined. As there was no telemetry available, there was no way of strategically selecting samples based on the hydrograph. As a result, bottles were randomly selected.

Samples were retrieved by project staff as soon as possible after collection (typically within 24 - 48 hours, but was dependant on site access constraints). Unfiltered nutrient samples were sub-sampled into 60 mL polypropylene vials (Sarstedt, Germany). Samples for filtered nutrient analysis were filtered on-site through pre-rinsed filter modules (MiniSart 0.45 µm cellulose acetate, Sartorius, Germany). All nutrient samples were immediately stored on ice for transport back to the appropriate laboratory. Sample water for pesticide analysis was decanted into solvent-washed 1L amber glass bottles supplied by the Queensland Health and Forensic Scientific Services (QHFSS) laboratory and immediately stored on ice. The amber bottles were pre-cleaned with acetone and ethanol and blow-dried with nitrogen fitted with a carbon filter.

The 2011-12 wet season saw the upgrade of the loggers from CR200 to CR800 loggers. The upgrade would allow much more functionality and logging options. The update would also enable communication via telemetry. Telemetry function allowed site data to be relayed onto a project specific website and allowed remote monitoring of site conditions to occur.

The sampling strategy was also changed to multiplex sampling. Multiplex sampling involves taking many small samples over the hydrograph and combining them into one sample to obtain an Event Mean Concentration (EMC). Multiplex sampling was chosen as allows more events to be sampled, enables a wider range of analysis to be undertaken, requires less processing and maintains the integrity of the data. Changes also involved replacing carousels from 24 x one litre bottles to 4 x four litre bottles. As a result, the discharge trigger volume would also have to be recalculated. Calculations were based on a sample volume of 150ml using one 4L bottle, with the second as an overflow bottle, per event. Discharge trigger volumes were also updated throughout the season.

The sampling methodology used in the 2011-12 period was repeated for the 2012-13 period.

4.6 Agronomic sampling

The legume fallow was sampled on the 19 March 2010, at mid pod fill to ensure maximum plant N levels (Eaglesham et al. 1977). All above-ground vegetation was cut and weighed from eight sites, each 1.83m x 1m. From each sample, a sub-sample was weighed, dried and weighed again to attain a dry matter percentage. This percentage was used to calculate dry matter yield. Farm operations (including tillage, nutrient and pesticide applications) are being recorded in a comprehensive field diary.

4.7 Harvest data

Mill results provided average CCS units and tonnes of cane harvested from each replicate. Dollars per tonne ($/T) of cane were calculated using the 2010 cane price formula: (0.009xWSP) x (Relative CCS – 4)) + 1.2. 2010 World Sugar Price (WSP) = $410. Following this calculation, Tonnes of Cane per Hectare (TCH) were calculated by dividing harvested tonnes by replicate area (ha). It was then possible to calculate dollars per hectare ($/Ha) by multiplying average TCH by $/T.
A yield map was also taken with a Techagro/ Solinftec yield monitor. Using sensors located on the feed roller of the harvester, the Techagro yield monitor measures the mass flow of sugarcane through the harvester and creates a colour scale image indicating changes in yield across the paddock (DiBella et al. 2009).

4.8 Laboratory analyses

4.8.1 Water quality analysis

Nutrient samples from surface water runoff were analysed at TropWATER, James Cook University, for urea-N, ammonium-N, oxidised-N (nitrate + nitrite), total dissolved N, total N (total Kjeldahl nitrogen + oxidised-N), filterable reactive phosphorous (FRP), total dissolved P and total P (from total Kjeldahl P). All analyses were undertaken on automated flow analyser systems. Particulate N and P are determined by calculating the difference between total N and P with total dissolved N and P.
All pesticide samples collected during paddock runoff events were couriered to the QHFSS. The water samples were analysed by LCMS and GCMS. Organochlorine, organophosphorus and synthetic pyrethroid pesticides, urea and triazine herbicides and polychlorinated biphenyls were extracted from the sample with dichloromethane. The dichloromethane extract was concentrated before measurement by GCMS and LCMS (QHFSS method number 16315). Phenoxyacid herbicide water samples, which were collected in separate 1 litre amber glass bottles, were acidified and extracted with diethyl-ether. After evaporation and methylation (methanol, concentrated sulfuric acid and heat) the samples were extracted with petroleum ether and analysed by GCMS (QHFSS method number 16631).

4.8.2 Soil analysis

Soil physical-chemical properties and nutrient analyses were conducted by the Back Paddock Company in Brisbane. Analyses included pH (1:5 water), electrical conductivity, organic carbon, Colwell extractable P, BSES P, PBI, extractable cations Na, K, Ca, Mg and Al, effective cation exchange capacity, DTPA extractable Cu, Zn, Mn and Fe and particle size analyses.

Nitrogen load was calculated using an assumed bulk density of 1.2g/cm^3. Some caution must be used when interpreting the sampling results as there are only two sampling points on the CFMS Site and three sampling points on the BMP Site. Also, mineral nitrogen (ammonium-N and nitrate-N) loads from each site have been averaged and are not proportional to the area they represent on the EM map (Figure 3).

4.9 Data analysis

4.9.1 Water quality load calculations

Nutrient species and herbicide loads (active ingredient) lost in surface runoff were calculated with the BROLGA program (version 2.11; Queensland Department of Natural Resources and Water, 2007) for the 2010-11 dataset. Continuous time series flow data from each monitoring station, and the concentration data from each discrete water sample, would be entered into the Brolga database, and loads calculated using linear interpolation technique. Linear interpolation is considered one of the more suitable load estimation approaches (Letcher et al., 1999; Lewis et al., 2007). With the change from discrete sample collection to multiplex sampling in 2011, the 2011-12 and 2012-13 nutrient and herbicide loads were calculated simply by multiplying the Event Mean Concentrations (EMCs) for analysed nutrient and herbicide species by paddock discharge volumes to generate a per hectare surface water load for each event.

5 Results and Discussion

5.1 Soils

5.1.1 Soil nitrogen levels

On the BMP Site, total available N ranged from 17.47 mg/kg in the surface to <1 mg/kg at the 0.6m – 0.9m range on the 13th of June 2010. On the 7th of September 2010, 55 days later, these values changed from 97.18 mg/kg in the surface to 1.16 at the 0.6m – 0.9m range. Nitrate-N loads in the profile increased by 133kgN/ha from 74 kg N/ha in June 2010 to 207 kg/ha in September 2010 (Figure 7).

On the CFMS Site, total available N ranged from 32.78mg/kg in the surface to <1 mg/kg at the 0.6m – 0.9m range. On the 7th of September 2010, 55 days later, these values changed from 50.95 mg/kg in the surface to 1.77 at 0.6m – 0.9m range. Nitrate-N loads in the profile increased 63kgN/ha from 106 kg N/ha in June 2010 to 169 kg/ha in September 2010 (Figure 7).

These results confirm that delaying incorporation of the legume stubble will enable more legume nitrogen to be available when the cane crop has the opportunity to use the nitrogen present. Early incorporation increases the risk of higher potential N losses to the environment.

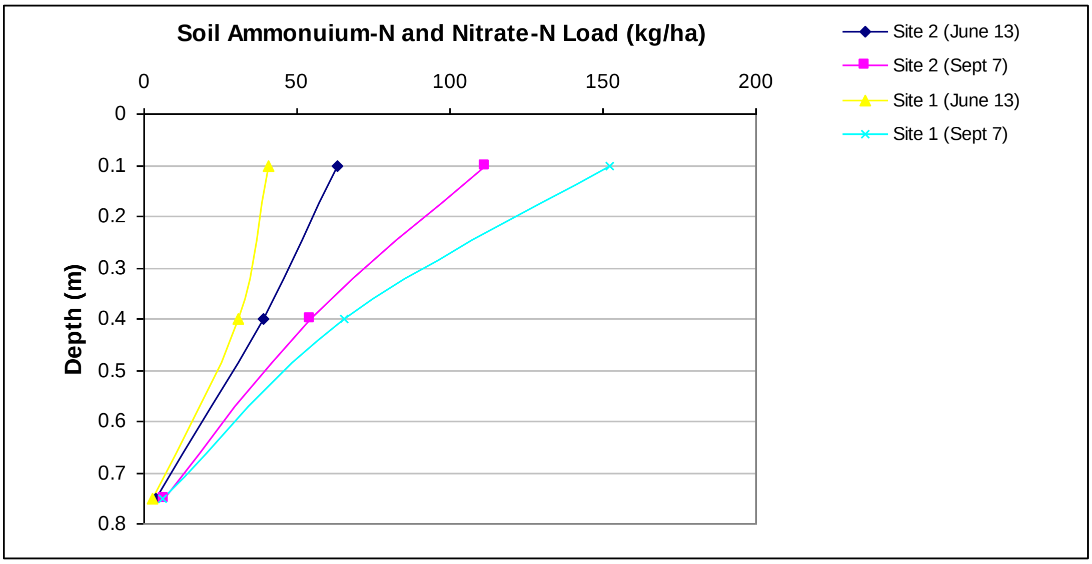


Figure 7. Soil ammonium-N and nitrate-N loads in the soil profiles of each site on the 13th of June and the 7th of September 2010. Note: assumed bulk density of 1.2 g/cm3.

5.1.2 Soil phosphorus levels

As previously discussed, the whole site was EC mapped and 5 distinct soil zones were identified. Over the duration of the trial, regular soil testing of these points was undertaken using GPS to ensure that the same position was sampled each time.

Soil tests taken on the 6th of June 2010; indicate P (BSES P) levels ranged from 72mg/kg – 31mg/kg in the surface (0-20cm) and from 46mg/kg – 16mg/kg in the 20-90cm range. On the 25th of September 2010, P (BSES P) levels changed to 36mg/kg – 13mg/kg in the surface (0-20cm). On the 2nd of October, 2012 soil P (BSES P) levels ranged between 44mg/kg – 31mg/kg. Figure 8 highlights these changes in soil test results for P (BSES P) for the 5 distinct soil zones over time. The grower was requested to take a composite soil test prior to planting as would be deemed as normal grower practice. The result for this test was 55mg/kg of P (BSES P) for 0-20cm. Refer to Figure 3 for the EC map of the block.

In regards to P management, the variability throughout the field poses a concern when dealing with current regulations as this block would not be permitted to apply any P over a crop cycle based upon the typical grower collected composite soil sample.

The use of the EC map has allowed for the identification of different soils within the block. The soil test sites based upon the EC map recognised the block is not homogeneous and is more heterogeneous in nature, hence permitting variable rate P applications to be considered in the future.

The difference between the 2010-11 and 2011-12 0-20cm samples were a concern due to the depletion of P levels in such a short period of time. It is not typical to see such reductions in soil P levels in such a short time frame (Schroeder, B 2012, pers.comm., 12 April).

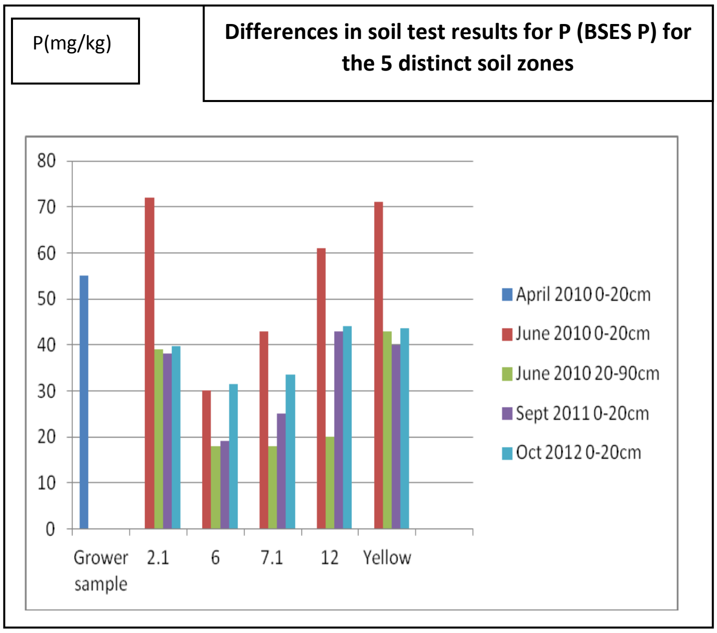


Figure 8. Differences in soil test results for P (BSES acid extraction method) for the 5 distinct soil zones.

5.2 Rainfall and runoff

The average rainfall for 2010-12 (at the Trebonne BOM site) was well above the median rainfall period between 1992-2012. The average rainfall for 2010 was 3422mm, 2011- 3246mm, 2012- 2530mm and 2013- 1553mm. Refer to Figures 9-12 for graphs on rainfall distribution during the period 2010-2013.

Between June 2010 and May 2012 the site experienced periods of significant waterlogging and crop stress. On the 3rd of February, 2011 Tropical Cyclone Yasi caused significant crop damage to the plant cane crop.

There was 9 rainfall runoff events in the plant crop (July 2010-June 2011), 5 rainfall runoff events in the 1st ratoon crop (July 2011- June 2012) and 4 rainfall runoff events in the 2nd ratoon crop (July 2012- June 2013).

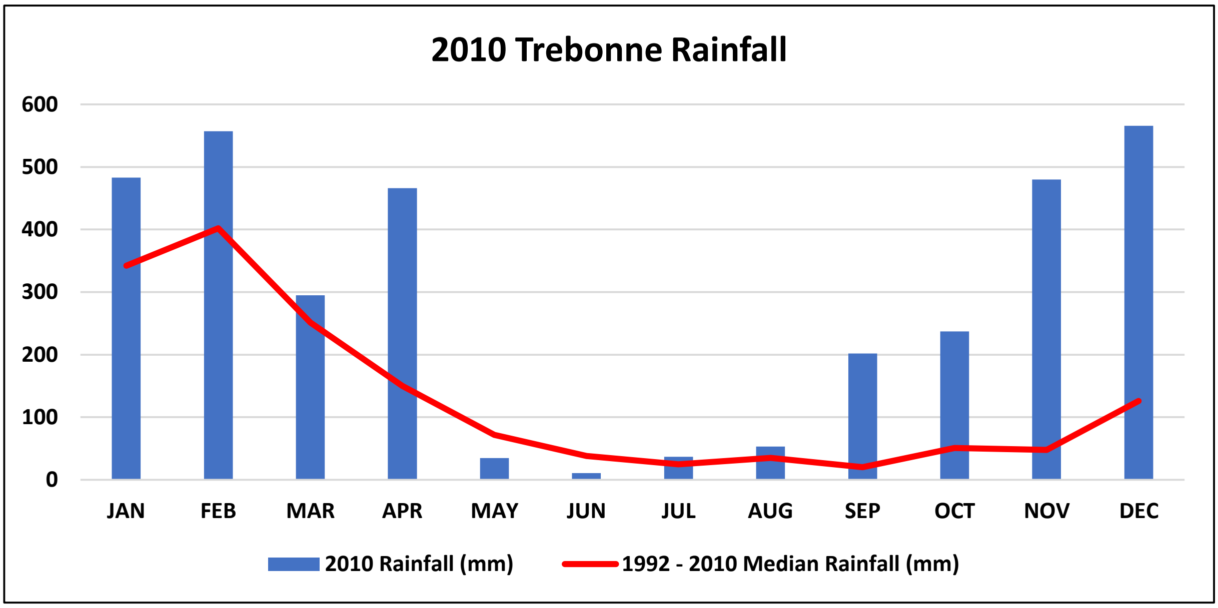


Figure 9. Total monthly rainfall at the Trebonne BOM site for 2010.

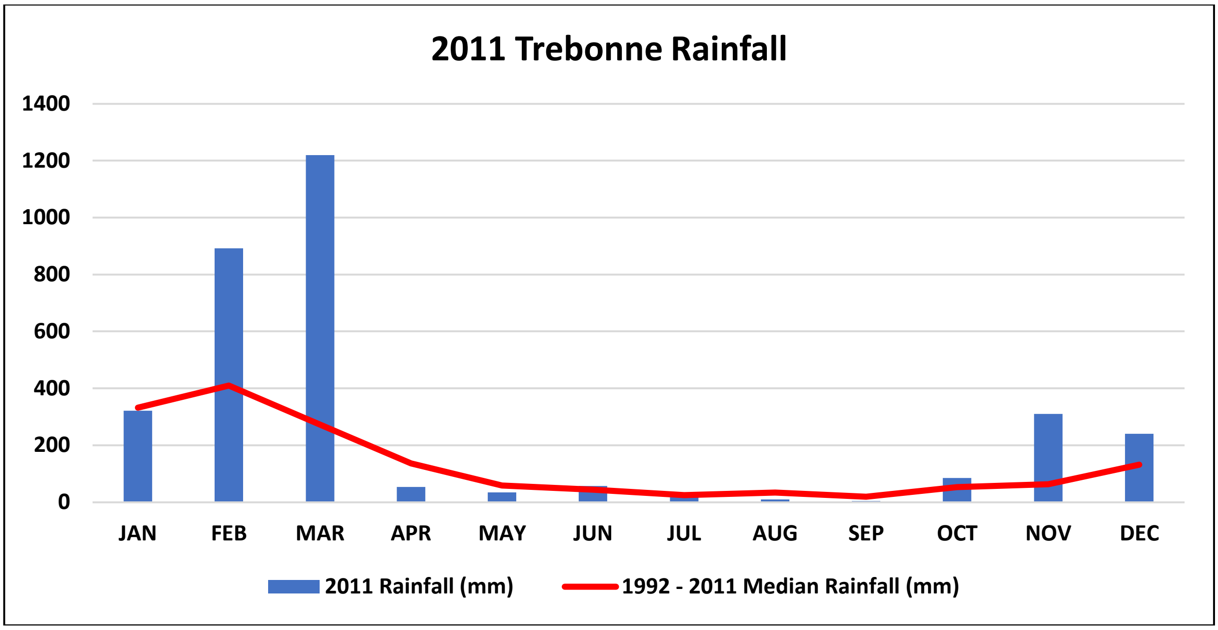


Figure 10. Total monthly rainfall at the Trebonne BOM site for 2011.

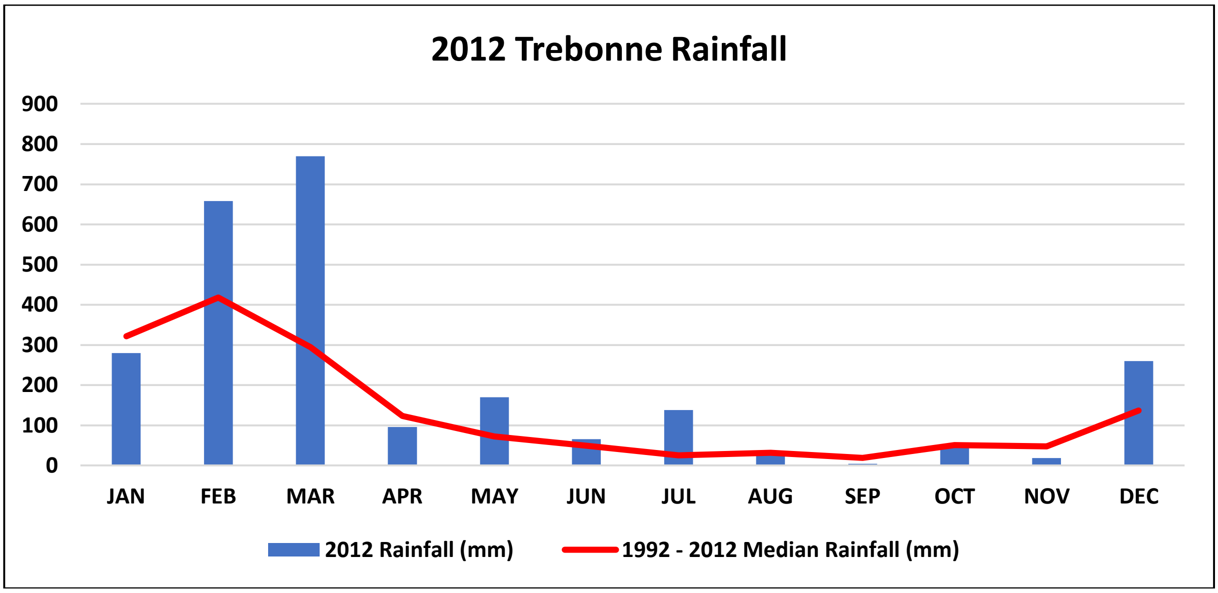


Figure 11. Total monthly rainfall at the Trebonne BOM site for 2012.

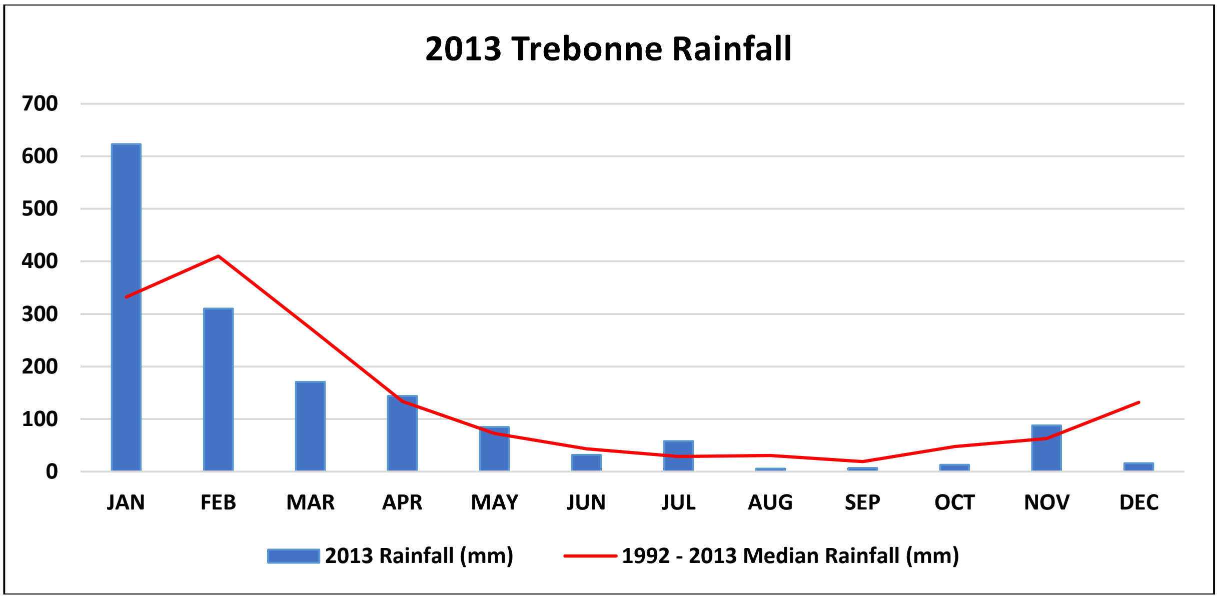


Figure 12. Total monthly rainfall at the Trebonne BOM site for 2010.

5.3 Runoff water quality

2010-11

A total of 35 nutrient samples and 21 pesticide samples were analysed during the 2010-2011 monitoring period. During the 2010-11 wet season, the amount of samples taken per rainfall event and the number of rainfall events sampled were dependent on budget constraints. While discreet sampling can provide a deeper understanding of results throughout the hydrograph, sampling using this strategy proved to be expensive and resource intensive. These factors are reflected in the limited data set for this sampling period.

During the 2010-11 sampling period over 18 events were logged and 7 were sampled (Figure 12). Incomplete logger data resulted in 2 of these events having to be excluded. Due to the magnitude of the wet season the samplers were turned off in late January 2011 to limit the number of samples being taken and keep analysis costs within budget. As a result the sampling period was limited to the 17th of September 2010 through until the 23rd of January 2011. The site was not irrigated during the reporting period.

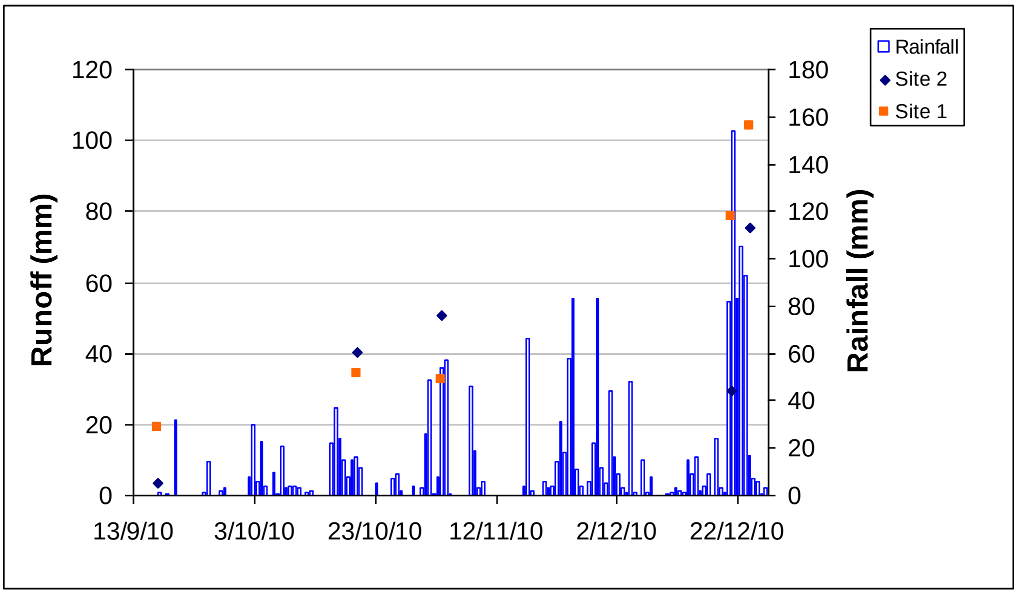


Figure 12.Total runoff (mm) from BMP and CF Sites from discrete runoff events through time and against rainfall (mm) during 2010-11 wet season.

2011-12
During the 2011-12 sampling period over 25 events were logged and 11 were sampled. A program error resulted in the first event of the season being missed. Following this, a further 2 larger events were missed due to sampler malfunctions. Miscommunication from sampling staff then resulted in the next event being sampled but not collected. As a result, the first event that was sampled and collected for the 2011-12 season was on the 16th of January 2012.

As the majority of the key sampling events were missed it was agreed that analysis of samples would be of little value. In order to attain the best quality data within the prescribed budget, sample analysis of the 2011-12 wet season was limited to established events and it was agreed, by key project staff, that a more focused sampling effort and analysis budget would be devoted to the 2012-13 sampling season.

2012-13
During the 2012-13 sampling period the first 5 paddock runoff events were sampled. Five initial runoff events following fertiliser application were sampled for nutrient water quality, with a total of 13 nutrient samples subsequently analysed during the 2012-2013 monitoring period. With the late application of herbicides to both sites (early February), only the first two runoff events following application were analysed for herbicide water quality (although previous studies have indicated that the first 1-2 runoff events account for the vast bulk of herbicide load from cane fields). The samples collected from each site for these two events were analysed for herbicides applied in the 2012-13 crop (2,4-D and fluroxypyr) and also for the presence/absence of residual herbicides from herbicide applications occurring earlier in the crop cycle (i.e., diuron, atrazine, metolachlor).

5.3.1 Total suspended solids (TSS)

Suspended solids were not sampled at this site. It was decided that TSS wasn't a significant concern for Herbert cane farms based upon previous research undertaken in the region (pers. Com. Brodie 2009).

5.3.2 Nutrients

2010-2011
The first 372 mm and 223 mm of wet season surface runoff leaving the BMP and CFMS Sites respectively was monitored for water quality during the 2010-2011 wet season. The total nitrogen load from the BMP Site (3.7 kg/ha) was higher (Figure 14), with oxidised nitrogen accounting for the dominant proportion of load (1.8 kg/ha) from this site (Figure 13). Particulate and dissolved organic nitrogen made similar proportionate contributions to load (~1 kg/ha), with ammonium nitrogen making a minor contribution (Table 9). The total nitrogen load leaving the CFMS Site in surface runoff was 2.1 kg/ha, ~1.5 kg/ha less than the BMP Site (Table 10). The relative total loads of particulate, oxidised and dissolved organic nitrogen leaving the CFMS Site during monitoring were all similar (654-728 g/ha), with ammonium nitrogen making only a small contribution to total nitrogen load (48 g/ha) leaving the paddock in runoff.

The major differences in nitrogen load at the two sites were due to pronounced variations in the temporal patterns of nitrogen loss, particularly associated with early runoff events. The bulk of the difference between the two treatments was due to the much higher nitrogen load leaving the BMP Site. In the first run-off event for the year (17/09/2010-19/09/2010), ~2 kg/ha of TN left the BMP Site in runoff compared to ~0.5 kg/ha from the CFMS Site (Figure 14). Nitrogen loads lost in subsequent events from both treatments were relatively similar. The comparative run-off volumes leaving each site in this initial event were significantly different (BMP Site: 3.7mm versus CFMS Site: 8.9mm which likely played a major underlying role in the differences in nutrient loads.

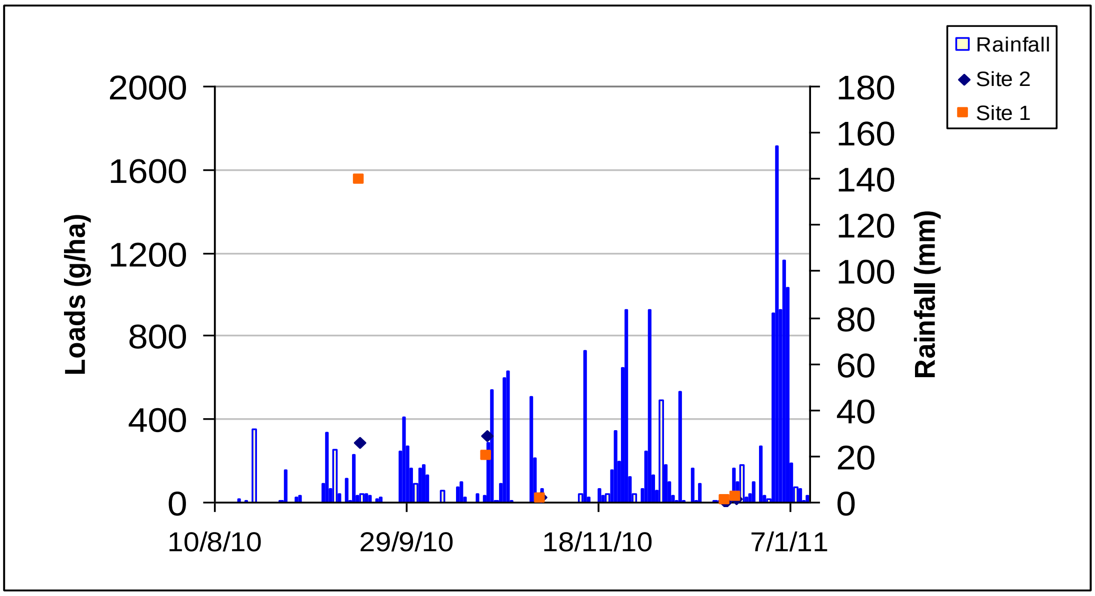


Figure 13. Temporal dynamics of NOx runoff loads (g/ha) from Sites BMP (site 1) and CFMS (site 2)from discrete runoff events through time during 2010-11 wet season

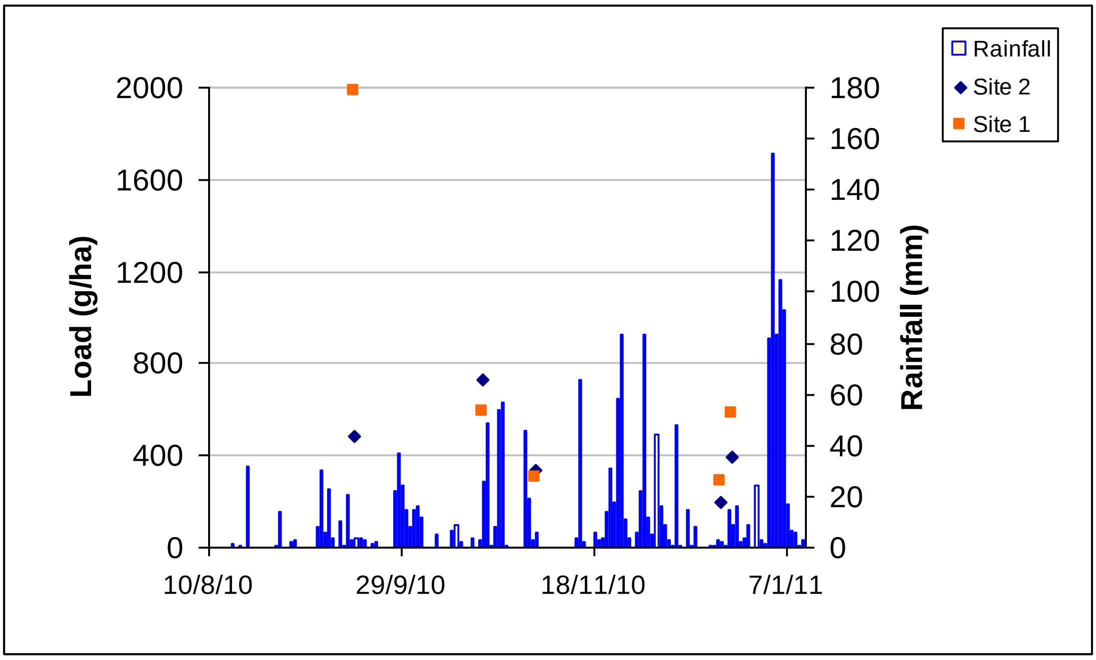


Figure 14. Temporal dynamics of total nitrogen runoff loads (g/ha) from Sites BMP and CFMS from discrete runoff events through time during 2010-11 wet season

As these results are based on a single, atypical season and are not replicated, it is not possible to make any conclusions regarding differences associated with nitrogen or phosphorus losses. While it can be reported that there are nitrogen and phosphorus losses for both sites, losses made up less than 1% of the total water volume exported from the paddock. At this site P levels measured as filtered reactive P are extremely low; this could be attributed to no P fertiliser being applied prior to or during the growth stage in the plant and 1st ratoon crops.

Table 9. Nutrient water quality results (nitrogen and phosphorus species) and cumulative load calculations for surface runoff events at BMP Site (17/09 - 26/12/10).

Event	Runoff (mm)	Total N (g/ha)	Oxidised-N (g/ha)	Ammonium-N (g/ha)	Particulate-N (g/ha)	Dissolved organic N (g/ha)	FRP (g/ha)
17/9/10 - 19/9/10	19	1986	1547	37	152	252	3
20/10/10 - 21/10/10	34	587	219	14	164	190	11
3/11/10 - 4/11/10	32	301	20	6	216	59	7
21/11/10 - 23/11/10	78	289	7	18	149	115	47
24/11/10 - 26/12/10	104	579	24	6	337	213	116
Total	267	3742	1817	81	1018	829	184

Table 10. Nutrient water quality results (nitrogen and phosphorus species) and cumulative load calculations for surface runoff events at CF Site (17/09 - 26/12/10).

Event	Runoff (mm)	Total N (g/ha)	Oxidised-N (g/ha)	Ammonium-N (g/ha)	Particulate-N (g/ha)	Dissolved organic N (g/ha)	FRP (g/ha)
17/9/10 - 19/9/10	4	486	284	12	10	181	1
20/10/10 - 21/10/10	40	731	324	18	210	178	11
3/11/10 - 4/11/10	51	333	23	3	256	51	7
21/11/10 - 23/11/10	29	194	3	2	66	123	12
24/11/10 - 26/12/10	75	397	20	14	167	196	70
Total	199	2,141	654	49	709	729	101

2011-12
There are no results to report here due to a series of system failures with the sampling equipment during the 2011-12 season first significant rainfall events as mentioned in section 5.3 Runoff Water Quality.

2012-13
The first 420 mm and 379 mm of wet season surface runoff leaving the BMP and CFMS Sites respectively, was monitored for nutrient water quality characteristics during the 2012-2013 wet season (Table 11). The total nitrogen load leaving the BMP Site (3.91 kg/ha) was slightly lower than that leaving the CFMS Site (4.4 kg/ha). Dissolved organic nitrogen accounted for the dominant proportion of load (1.8 kg/ha) leaving the BMP Site, whereas Ammonium-nitrogen was the dominatant nitrogen species in the CFMS Site runoff (2.08 kg/ha). Total inorganic nitrogen loads (fertiliser-derived nitrogen; combined Ammonium-Nitrogen, NOx-Nitrogen and Urea-Nitrogen) were slightly lower from the BMP (~2.5 kg/ha) compared to the CFMS (3.5 kg/ha). In both treatments, these losses of inorganic nitrogen in surface water runoff accounted for <3% of fertiliser nitrogen applied to the paddock for the year. The range of runoff loads from both Sites is very similar to surface water nitrogen loads documented leaving cane fields in the Wet Tropics under the concurrent P2R program (Armour et al., 2013).

The dominant proportion of the inorganic nitrogen load leaving the two sites in surface water runoff was associated with early runoff events. Ammonium-Nitrogen and NOx-Nitrogen were the species accounting for the bulk of inorganic load leaving each paddock, with Urea-N a relatively minor contributor to total surface water runoff loads. Higher NOx-Nitrogen and Ammonium-Nitrogen EMCs occurred in the first 2-3 runoff events following application, before concentrations decreased substantially in later events.

Loads of Filterable Reactive Phosphorus (the biologically available form of phosphorous and likely in this environment a reasonable surrogate for fertiliser-derived phosphorus) were slightly higher from the BMP site (~1.5 kg/ha) compared to the CFMS site (~1.2 kg/ha). These loads equated to 10-15% of phosphorus applied as fertiliser to the paddocks for the year.

Table 11. Nutrient water quality results (nitrogen species) and cumulative load calculations for surface runoff events occurring on the Ingham Demonstration Farms Sugarcane treatments (24/12/2012-18/02/2013).

		Total Filterable Nitrogen		**Ammonium Nitrogen**		**Particulate Nitrogen**		**NOx - Nitrogen load**		**Dissolved organic Nitrogen**	
Sample Date	**Treatment runoff (mm)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**
BMP											
24-25/12/2012	56	0.71	1329	0.18	344	0.02	42	0.24	456	0.28	530
31/12/2012	42	0.69	1306	0.18	332	0.17	320	0.36	674	0.16	300
22-24/01/2013	252	2.12	776	0.13	46	0.56	204	0.95	347	1.05	383
9/02/2013	50	0.21	354	0.01	25	0.12	205	0.02	40	0.17	289
15/02/2013	20	0.18	483	0.03	80	0.16	432	0.01	20	0.14	383
Total	**420**	**3.91**		**0.53**		**1.03**		**1.58**		**1.80**	
CFMS											
24-25/12/2012	45	2.31	3379	1.68	2454	0.21	306	0.36	525	0.27	400
31/12/2012	39	0.47	1209	0.11	284	0.08	212	0.26	651	0.11	274
22-24/01/2013	232	1.33	547	0.26	107	0.41	170	0.40	163	0.67	277
9/02/2013	41	0.15	295	0.02	31	0.06	112	0.01	23	0.12	241
15/02/2013	22	0.14	433	0.01	22	0.10	294	0.01	23	0.13	388
Total	**379**	**4.41**		**2.08**		**0.86**		**1.03**		**1.30**	

Table 12. Nutrient water quality results (phosphorus species) and cumulative load calculations for surface runoff events occurring on the Ingham Demonstration Farms Sugarcane treatments (24/12/2012-18/02/2013).

		Total Filterable P		Filterable Reactive P		Particulate P		DOP	
Sample Date	**Treatment runoff (mm)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**	**Load (kg/ha)**	**EMC (µg/L)**
BMP									
24-25/12/2012	56	0.28	527	0.24	456	0.14	257	0.04	71.5
31/12/2012	42	0.09	165	0.07	140	0.13	237	0.01	24.5
22-24/01/2013	252	1.12	411	1.02	372	0.80	293	0.11	39.0
9/02/2013	50	0.16	273	0.15	242	0.18	292	0.02	31.0
15/02/2013	20	0.03	80	0.02	66	0.13	357	0.01	14.0
Total	**420**	**1.68**		**1.50**		**1.37**		**0.18**	
CFMS									
24-25/12/2012	45	0.49	716	0.47	681	0.13	191	0.02	35
31/12/2012	39	0.07	188	0.06	157	0.07	189	0.01	31.0
22-24/01/2013	232	0.57	235	0.48	197	0.58	240	0.09	38.0
9/02/2013	41	0.12	229	0.10	192	0.12	235	0.02	37.0
15/02/2013	22	0.07	198	0.05	167	0.10	305	0.01	31.0
Total	**379**	**1.32**		**1.16**		**1.01**		**0.16**	

5.3.3 Herbicides

2010-2011

Atrazine, its major degradation products, desethylatrazine (DEA) and desisopropylatrazine (DIA), and Ametryn were the highest of monitored pesticide loads from the CFMS Site. Loads of DEA and DIA were greater than that of the parent compound. Runoff losses as a proportion of amount of herbicide applied were all < 1%, and a cumulative load of <1 g a.i./ ha. Due to resourcing constraints, collection of pesticide samples in the latter stages of the monitoring period were limited to single samples during runoff events, negating the capacity to calculate loads. Following a late season application of Velpar K4 (11 December 2010), concentrations of diuron and hexazinone in individual samples in late December runoff were high (diuron 170-300 µg/L, hexazinone 18-85 µg/L). These were the highest discrete concentrations of any pesticide sample/product collected throughout the study period from this site. With over 500 mm of rainfall occurring during the period 21-26 December 2010, run-off loads for these herbicides were likely to have been substantially higher than those documented in earlier, more comprehensively monitored wet season events.

At the BMP Site, the load of ametryn was higher (928 mg/ha) than any other pesticide from either site (Figure 15). Atrazine, and its degradates DEA and DIA, made minor contributions to herbicide loads from BMP Site, with the cumulative load of DEA and DIA again exceeding loads of the parent compound atrazine. Interestingly, atrazine was not directly applied to BMP Site in 2010-2011, with these loads possibly related to spray drift from the neighbouring CFMS Site, or residual herbicide in the soil from applications in previous years. Similarly to CFMS Site, the total cumulative load of ametryn was < 1 g a.i./ha, indicating proportionate runoff losses < 1% of herbicide product applied. Ametryn was applied to both treatments at the same rates and the same time. Similarly to the nitrogen loads, the differences in total ametryn loads between sites were due to the much greater losses of ametryn in the first runoff event of the year (17/09/10 - 19/09/10).

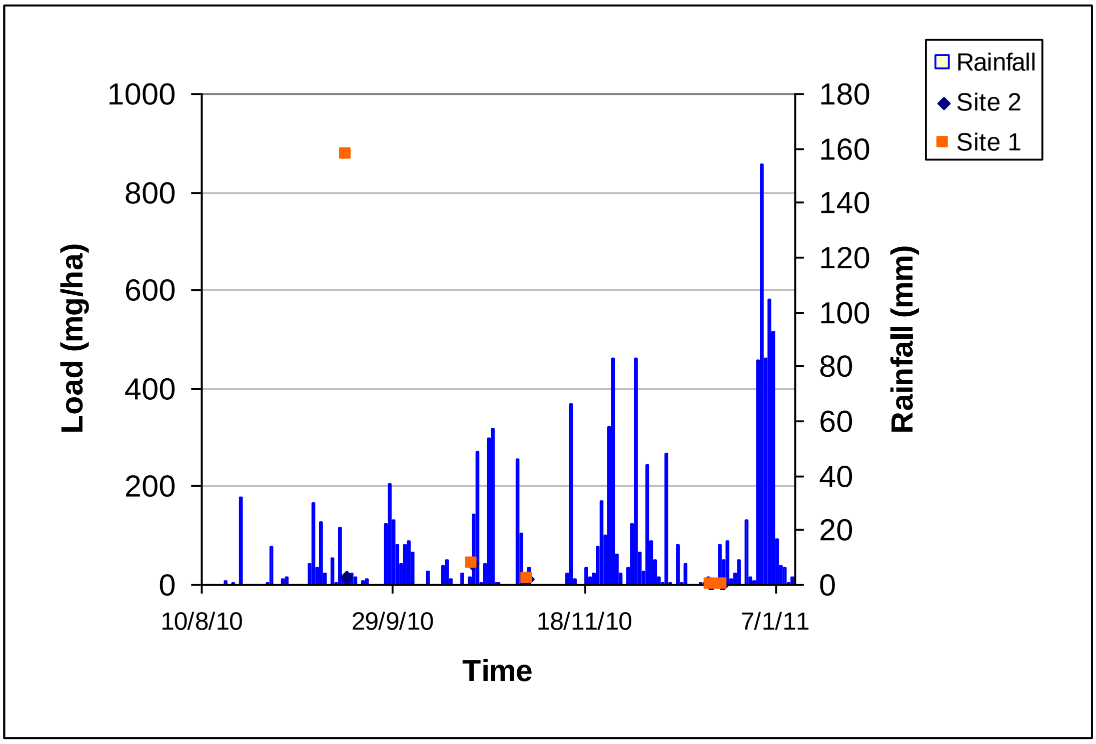


Figure 15. Temporal dynamics of ametryn runoff loads (mg/ha) from BMP- Site 1 and CFMS- Site 2 from discrete runoff events through time during 2010-11 wet season.

With a similar sampling program to the CFMS-Site 2, collection of pesticide samples in the latter stages of the monitoring period at Site 1 were limited to single samples during runoff events, negating the capacity to calculate loads. Following a late season application of Dual Gold (11/12), concentrations of metolachlor in individual samples (60-65 µg/L) were the highest discrete concentrations of any pesticide sample/product collected throughout the study period from Site 1. Like the diuron-hexazinone dynamics outlined for Site 2, with over 500 mm of rainfall occurring through the period 21-26/12, run-off loads for metolachlor was likely to have been substantially higher than those documented earlier from Site 1.

2011-12

There are no results to report here due to a series of system failures with the sampling equipment during the 2011-12 season first significant rainfall events as mentioned in section 5.3 Runoff Water Quality.

2012-13

The single aerial application of herbicides for the 2012-13 crop occurred on the 7th of February, 2013 and consisted of 2,4-D (531 g.a.i./ha) and fluroxypyr (266 g.a.i./ha). This application was shortly followed by +100 mm of rainfall over the 9th and 10th of February, which produced substantial paddock runoff from both treatments (Table 13). Given the identical herbicide applications to both treatments, subsequent herbicide runoff loads were similar at both sites. Total load losses of 2,4-D (~4 g.a.i./ha) and fluroxypyr (~0.4 g.a.i./ha) equated to less than 1% of applied herbicide for both products. A number of additional herbicides such as atrazine (maximum concentration 0.04 µg/L), diuron (maximum concentration 0.03 µg/L), metolachlor (maximum concentration 0.06 µg/L), metribuzin (maximum concentration 0.02 µg/L), haloxyfop (maximum concentration 0.02 µg/L) and metsulfuron methyl (maximum concentration 0.01 µg/L) were all detected at low concentration across both sites.

Cumulative load losses from paddocks in 2012-13 were relatively minor and demonstrate the value of using lower rate and shorter lived herbicides when applications are required during the high risk wet season window of December to March.

Table 13. Pesticide water quality results (2,4-D and fluroxypyr) and cumulative load calculations for surface runoff events occurring on the Ingham Demonstration Farms Sugarcane treatments (22/01/2013-18/02/2013).

		2,4-D		Fluroxypr	
Sample Date	**Treatment runoff (mm)**	**Load (g/ha)**	**EMC (µg/L)**	**Load (g/ha)**	**EMC (µg/L)**
BMP					
22-24/01/2013	252	BD	<0.01	BD	<0.01
9/02/2013	50	3.05	5.1	0.32	0.55
15/02/2013	20	0.46	1.2	0.08	0.21
Total	**322**	**3.51**		**0.4**	
CFMS					
22-24/01/2013	232	BD	<0.01	BD	<0.01
9/02/2013	41	3.6	7	0.27	0.54
15/02/2013	22	0.79	2.4	0.1	0.29
Total	**295**	**4.39**		**0.37**	

5.4 Agronomic

5.4.1 Planting method

The CFMP Site was planted using a conventional furrow planter, while the BMP site was planted using a mound planter. Mound planting is gaining popularity in the Herbert because it minimises the risk of plant cane failure due to wet weather events post planting; as discussed in section 4.3. Figure 16 highlights the differences in germination at planting after 8 weeks.

Pers. Com. A. Hurney (1998) that higher tiller counts soon after planting may not be directly linked to final stalk counts and yield.

.

Site	Average tiller emergence (m)
CFMP	9.56
BMP	6.2

Note: 3 monitoring locations were selected per treatment.

Figure 16 Germination and establishment at 8 weeks after planting

5.4.2 Opportunities associated with controlled traffic

Controlled traffic methods were adopted as a part of the BMP site. The following was observed during the duration of the project for the BMP site:

- Improved water infiltration rates compared to the CFMS
- Less compaction of the row area compared to the CFMS
- Improved in-field trafficability for cultivation, spraying and harvesting (refer to figure 17 to highlight the differences after a significant rainfall event.)

Figure 17. Differences between the row and inter-row after significant rainfall at the BMP site (plant cane). Left: Inter-row area. Right: Row area. Note that Lawrence Di Bella has sunk up to his knees in the row area.

5.4.3 Harvest results

Plant cane harvest results
At harvest, the CFMS site yielded 8.41 TCPH more than the BMP site and an increased CCS of 0.36 units (table 14).

First ratoon harvest results
The BMP site yielded 8.9 TCPH more than the CF site, and was 0.2 units higher in CCS than the CFMS site (table 14).

Second ratoon harvest results
The BMP site yielded 13.51 TCPH more than the CFMS site. The CF site was 0.15 units higher in CCS than the BMP site (table 14).

Table 14. Harvest data for both sites

	Plant cane			1st ratoon cane			2nd ratoon cane		
	CCS	TCPH	TSPH	CCS	TCPH	TSPH	CCS	TCPH	TSPH
Site 1	15.54	52.68	8.19	14.2	87.38	12.41	12.85	107.39	13.8
Site 2	15.9	61.09	9.71	14	78.48	10.99	13	93.88	12.2

Note: Plant cane harvest figures were affected by an exceptional wet season and tropical cyclone Yasi.

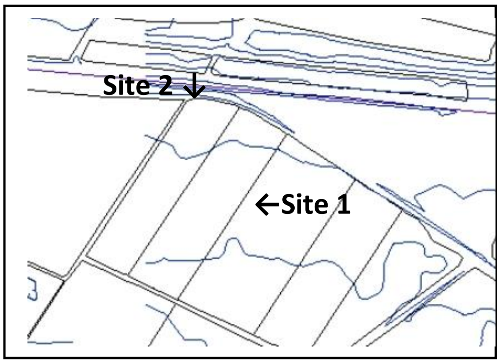
5.4.4 Weed control.

Some of the yield difference between sites could be attributed to different weed pressures within the respective sites. In the BMP site Sprayseed, Dual Gold and Soccer were applied at the OOHS, compared to the CFMS site where Sprayseed and Velpar K4 were applied. The CFMS site remained weed free until harvest time, while the BMP site became heavily populated with broadleaf weeds (primarily Ageratum and Ipomea spp.). BSES research indicates that significant yield losses can be experienced due to weed infestations in plant cane crops. Research undertaken by Makepeace and Williams (1988) expresses the relationship between weed control and yield and emphasises the importance of weed control; their findings may explain some of the reasons why a yield difference between the two treatments occurred.

5.4.5 Understanding drivers of yield variation.

Yield variation can be driven by a number of factors. Some of the primary drivers of yield variation are: soil type, soil moisture (particularly water logging), soil chemistry and exposure to sunlight (Hogarth and Allsopp 2000). Due to the scale of the 2010-11 wet season, many areas in the Herbert region were subject to prolonged waterlogging conditions, which contributed to low yields (HCPSL 2011).

Figure 19 reveals soil type changes across the block, while Figure 18 shows the changes in elevation across the block. The lowest part of the block is the bottom corner of the BMP site.



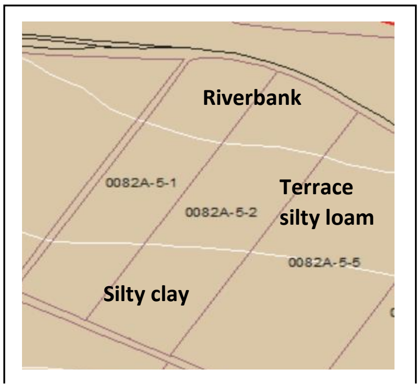
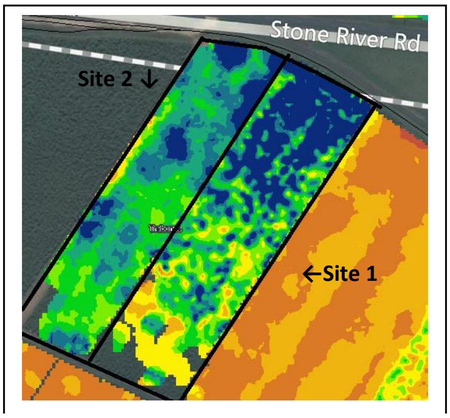
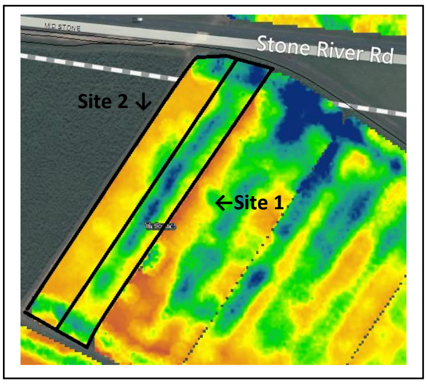


Figure 18- left. Contour map of the block. Figure 19- right. Soil type difference for the site.

The yield maps indicate significant variation in yield across the block (Figure 20). It appears yield variation may be strongly related to changes in soil type and elevation at the site. Of particular relevance is the yield variation seen in the lowest parts of the block. While soil type will influence the yield variation, it is suggested that water logging due to the reduced elevation played a significant role in the yield variation seen at both sites. This is supported by site observations throughout the 2010-11 wet season (being the plant and 1st ratoon crops), which consistently indicated water logged conditions at the bottom end of the block.





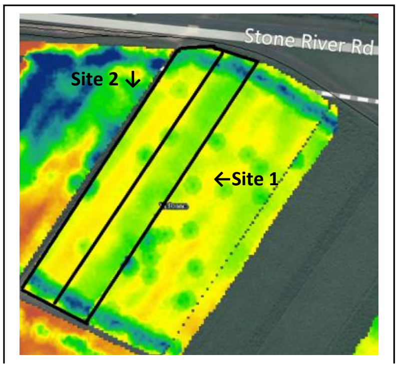


Figure 20. Yield maps of the blocks.

- Above left- Plant cane yield map (harvesting technique caused the lack of yield point data in the bottom of the field. Note that the CFMS site had the higher yield.

- Above centre- First ratoon cane yield map. Note that the BMP Site had the higher yield.

- Above right - Second ratoon cane yield map. Note that the BMP Site had the higher yield.

5.5 Economics

This economic analysis involves the use of DAFF's Farm Economic Analysis Tool (FEAT) to undertake a comprehensive evaluation of the implied revenues and costs of both management practices in isolation. From these results, a comparison between the gross margins and variable costs of each management system were examined. Revenues were calculated based on a 5-year average (2008-12) sugar price of $440 per tonne, which is assumed constant across the analysis to enable an objective assessment to be made regarding the costs for each treatment and the relative level of production. Furthermore, yields and CCS levels were obtained from the grower's harvest data reported by the mill.
Information collected during the trial period was entered into FEAT growing expenses spreadsheets to calculate production costs. Variable costs for fallow, plant and first ratoon cane were established by taking into consideration numerous farm-specific details including chemical and fertiliser usage, machinery operations and fallow crop practices. Chemical and fertiliser prices were determined by averaging region-specific price lists obtained from local suppliers during July, 2013. Machinery operating costs were calculated systematically by taking into account tractor size, fuel & oil consumption, repairs & maintenance as well as implement speed, width and field efficiency. The labour requirement for each farm management system was calculated using the work rate for each operation and costed at $30/hour. Cost and gross margin comparisons have been presented on a per hectare basis. This economic analysis involves a partial farm analysis that focuses on the direct impact on farm gross margin due to the management practice changes. Accordingly, it does not take into consideration the fixed costs associated with the farming business or any capital costs associated with introducing the new practice.

5.5.1 Economics results

The Herbert demonstration farm has provided data from both the conventional and improved management systems since 2009. During 2009/10, 2010/11, 2011/12 and 2012-13, data was obtained for fallow, plant, first ratoon and second ratoon cane, respectively. The FEAT programme uses the data collected to calculate gross margins from each management system during each stage of the crop cycle (i.e. fallow, plant cane, etc). The results are examined in order of crop stage. An analysis that summarises all the presently available information is subsequently presented.

5.5.1.1 Fallow

Table 1 compares the fallow management costs associated with the trial site. Note that the two treatments have similar costs regarding land preparation and the use of ameliorants; with the difference between the two systems explained by the higher costs from utilising a mulcher to incorporate the legume fallow crop within the improved management system.

	CFMS	BMP
Land Preparation	$205/ha	$205/ha
Ameliorants	$211/ha	$210/ha
Legume crop	$222/ha	$299/ha
Total fallow cost	$638/ha	$714/ha

Table 1: Fallow cost comparison

5.5.1.2 Plant Cane

Table 15 compares the profitability of each management system in plant cane by analysing plant cane yields, CCS levels, growing and harvesting costs, and gross margins on a per hectare basis. The data for this analysis was collected from the same farm blocks as the fallow analysis.
The costs of growing the plant cane crop (inclusive of labour) for each treatment was initially calculated. Table 15 shows that the improved management system resulted in a total growing cost of $1,696/ha, which is $101/ha lower than the conventional management system. Similarly, once harvesting costs were included, the total variable costs of the improved management system were $170/ha less than those for the conventional management system. Nonetheless, despite having higher production costs, the conventional management system recorded a higher gross margin due to it producing a larger cane yield and CCS level. Figures 21 and 22 present the breakdowns for the plant cane variable costs of the conventional and improved management system, respectively.

Table 15: Plant cane comparison

	CFMS	BMP
Sugar ($/tonne)	$440/t	$440/t
Average cane yield	61.09t/ha	52.68 t/ha
CCS	15.9	15.54
Revenue (net of levies)	$2,875/ha	$2,404/ha
Growing costs breakdown:		
Land preparation	$323/ha	$225/ha
Planting and seed cane	$794/ha	$787/ha
Fertiliser	$265/ha	$265/ha
Weed and pest	$415/ha	$419/ha
Total growing cost	$1,797/ha	$1,696/ha
Harvesting costs	$501/ha	$432/ha
Total variable costs	$2,298/ha	$2,128/ha

Gross margin	$577/ha	$277/ha

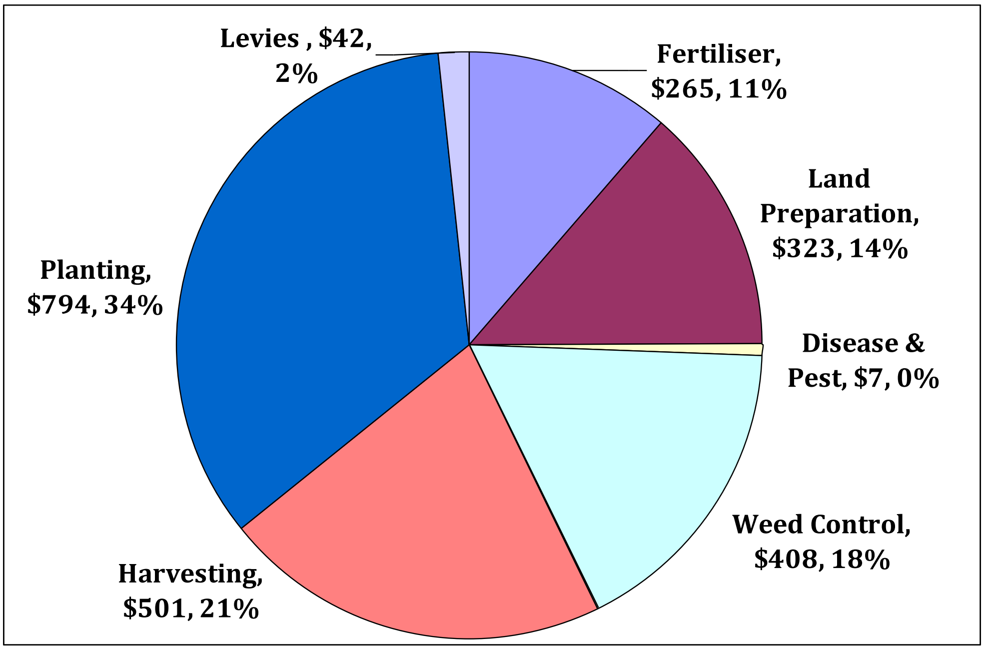


Figure 21: CFMS – Plant Cane Variable Costs ($/ha)

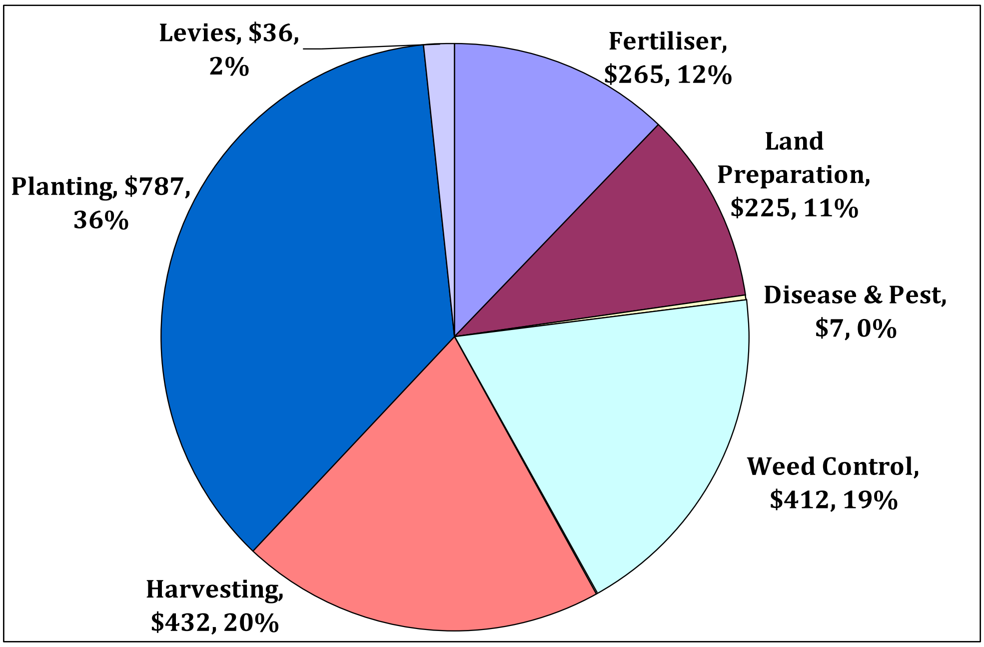


Figure 22: BMP – Plant Cane Variable Costs ($/ha)

Importantly, neither management system attained its full yield potential due to the impact of cyclone Yasi. Additionally, the improved management system was affected by large weed pressures that may have reduced yields due to increased competition for nutrients within the soil. In particular, it is thought that the environmental conditions did not favour the herbicides chosen, therefore reducing their efficacy. This consequently lowered revenue and, in turn, the gross margin.

5.5.1.3 1st Ratoon

Table 16 expands on the previous analysis to compare the profitability of each management system during the first ratoon crop stage of the demonstration farm. The data for this examination was collected from the same blocks used for the fallow and plant cane trials.

Both sites recorded similar growing costs with only $9/ha difference between the two management practices (see Table 16). Interestingly, the saving in fertiliser costs realised within the improved management system was offset by higher herbicide costs from using a more expensive substitute for Diurex (Flame), which is now under restricted use in the Wet Tropics. The total variable costs were higher for the improved practice treatment as a consequence of increased harvesting costs associated with the higher yield. Overall, the improved system generated a significantly higher gross margin per hectare ($357/ha) due to the higher yield and CCS level. The 1st Ratoon variable costs for both management systems are presented in Table 16 and depicted graphically in Figures 23 and 24.

	CFMS	**BMP**
Sugar ($/tonne)	$440/t	$440/t
Average cane yield	78.48 t/ha	87.38 t/ha
CCS	14	14.2
Revenue (net of levies)	$3,103/ha	$3,525/ha
Growing costs breakdown: *Fertiliser* *Weed and pest*	 $391/ha $28/ha	 $367/ha $43/ha
Total growing cost	$419/ha	$410/ha
Harvesting costs	$644/ha	$717/ha
Total variable costs	$1,063/ha	$1,126/ha
Gross margin	$2,040/ha	$2,398/ha

Table 16: 1st Ratoon Comparison

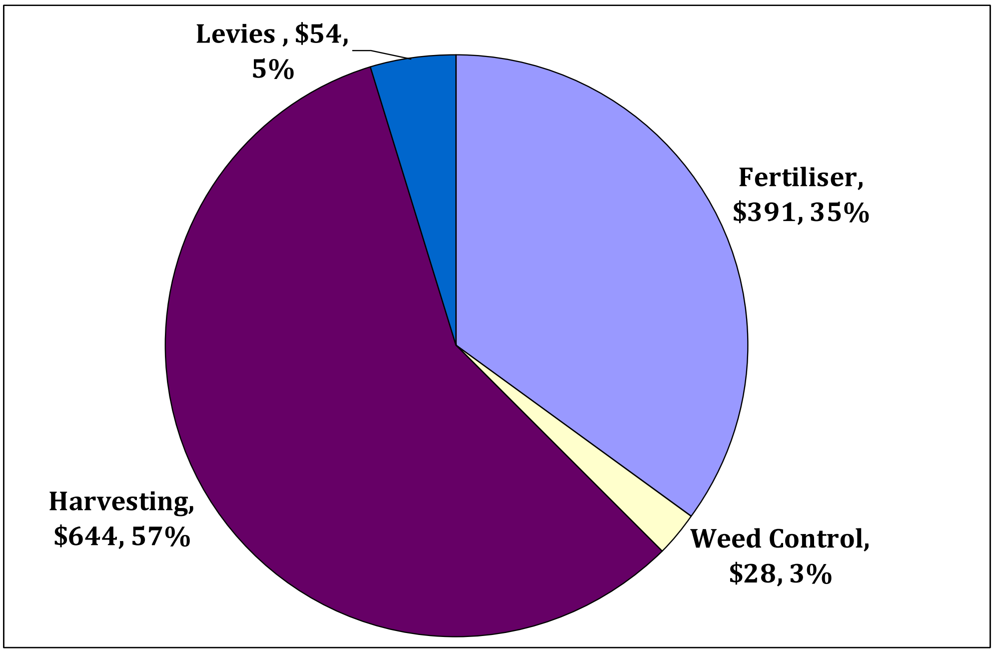


Figure 23: CFMS – 1st Ratoon Variable Costs ($/ha)

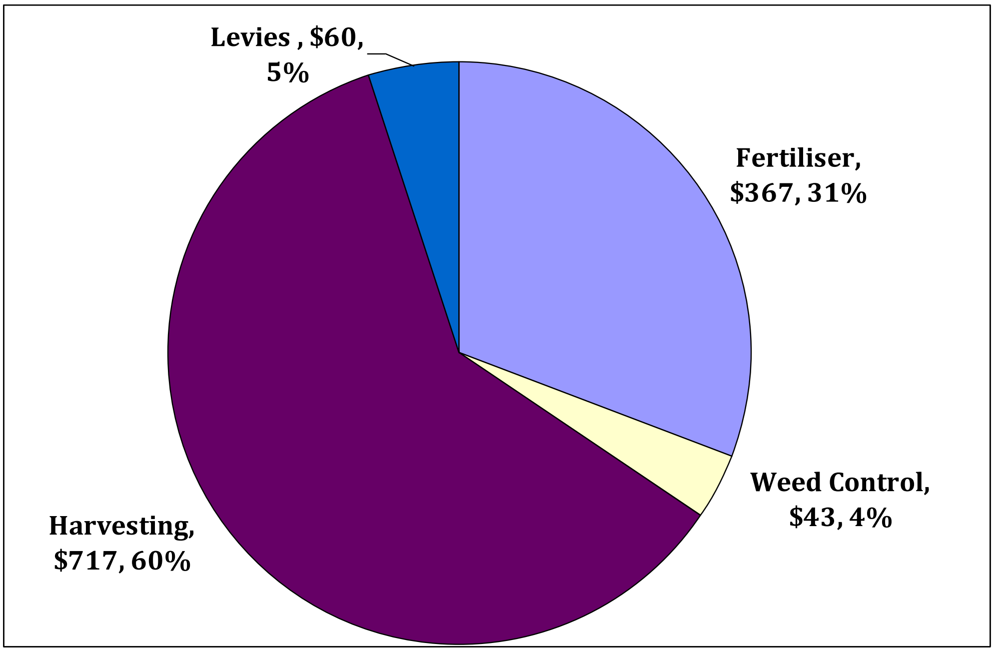


Figure 24: BMP – 1st Ratoon Variable Costs ($/ha)

5.5.1.4 2nd Ratoon

Overall, the improved system generated a higher gross margin per hectare than the CFMS Site (i.e. $306/ha) in the second ratoon crop due to a considerably higher yield; this is despite the improved management system producing a relatively lower CCS. Although both systems had the same growing costs, the total variable costs were higher for the improved practice treatment due to the higher harvesting costs associated with the higher yield. Table 17 compares the profitability of each management system during the second ratoon crop stage, while a breakdown of the variable costs for both management systems are displayed in Figures 25 and 26.

	CFMS	**BMP**
Sugar ($/tonne)	$440/t	$440/t
Average cane yield	93.88 t/ha	107.39 t/ha
CCS	13	12.85
Revenue (net of levies)	$3,341/ha	$3,758/ha
Growing costs breakdown: *Fertiliser* *Weed and pest*	 $386/ha $57/ha	 $386/ha $57/ha
Total growing cost	$443/ha	$443/ha
Harvesting costs	$770/ha	$881/ha
Total variable costs	$1,213/ha	$1,323/ha
Gross margin	$2,128/ha	$2,434/ha

Table 17: 2nd Ratoon Comparison

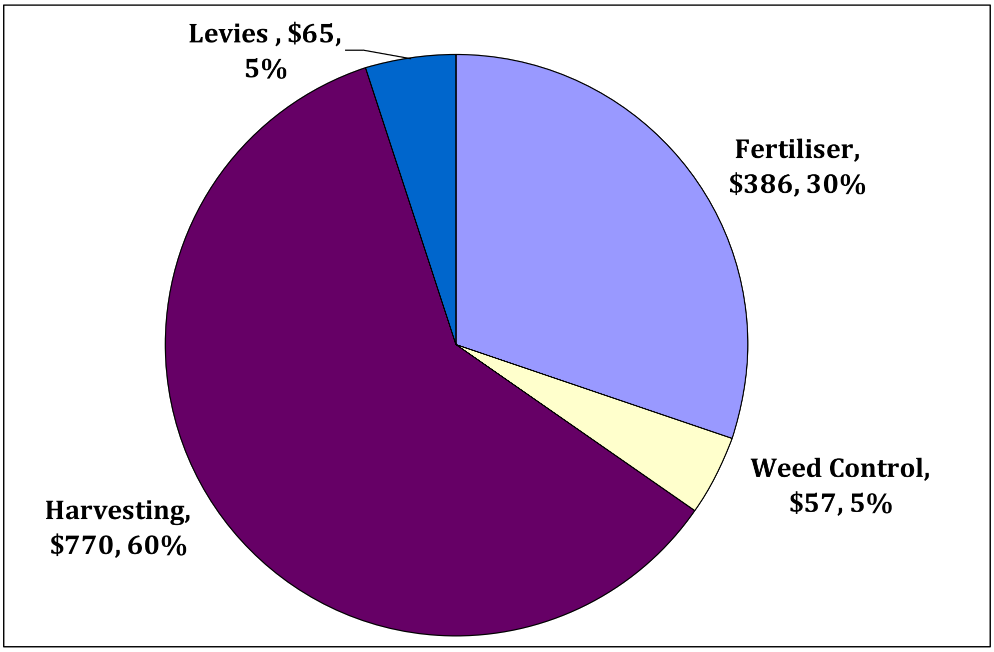


Figure 25: CFMS – 2nd Ratoon Variable Costs ($/ha)

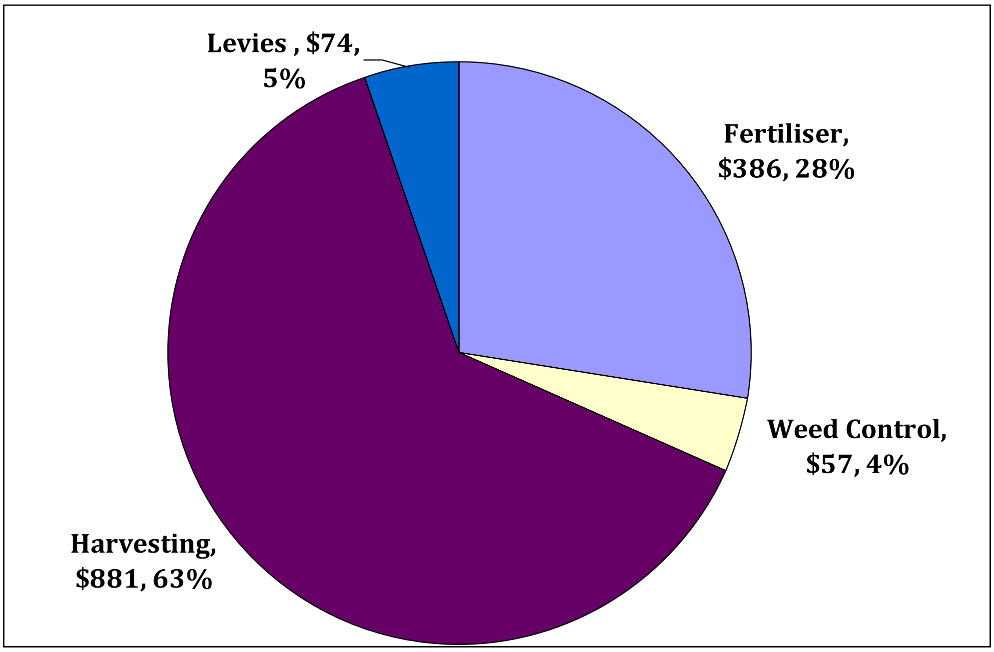


Figure 26: BMP – 2nd Ratoon Variable Costs ($/ha)

5.6 Summary of the Economic Analysis

A comparison of the average sugar yield over the life of the trial provides an indication of the relative productivity of each management system. However, analysing the average gross margins for each system allows for a more meaningful comparison to be made about each farming system as this takes production costs into account. Both of these indicators are examined as follows.

Table 18 compares the sugar yield, expressed as tonnes sugar per hectare (ts/ha), for both treatments during plant, first ratoon and second ratoon cane as well as the average sugar yield. As can be observed, the average sugar yield is greater for the improved management system over the life of the trial. Figure 27 illustrates these results graphically.

	CFMS	BMP
Plant cane (ts/ha)	9.71	8.19
1st ratoon (ts/ha)	10.99	12.41
2nd ratoon (ts/ha)	12.20	13.80
Average (ts/ha)	10.97	11.46

Table 18: Sugar Yield Comparison - CFMS Vs BMP Systems

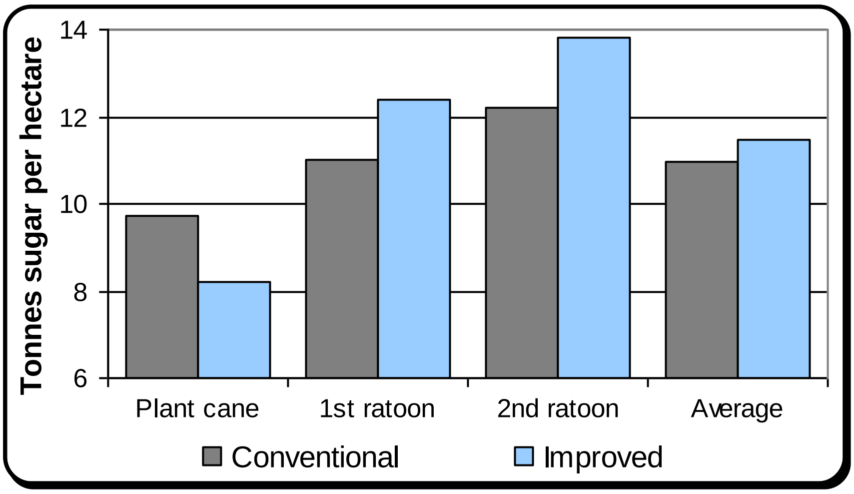


Figure 27: Sugar Yield Comparison – CFMS (referred to as Conventional in this graph) Vs BMP (referred to as Improved in this graph)

The incremental gross margins for fallow, plant, first ratoon and second ratoon cane as well as the average over the 4 years are presented in Table 19. While the BMP system accrued relatively higher fallow costs as well as a considerably lower gross margin in plant cane, it generated a substantially higher gross margin in each of the ratoon crops. Consequently, the improved management system has generated a higher gross margin on average ($72/ha or 7% higher) over the trial period so far. These results are depicted in Figure 28.

	CFMS	BMP
Fallow	-$638/ha	-$714/ha
Plant cane	$577/ha	$277/ha
1st ratoon	$2,040/ha	$2,398/ha
2nd ratoon	$2,128/ha	$2,434/ha
Average Gross Margin	$1,027/ha	$1,099/ha

Table 19: Gross Margin Comparison - Conventional Vs Improved System ($/ha)

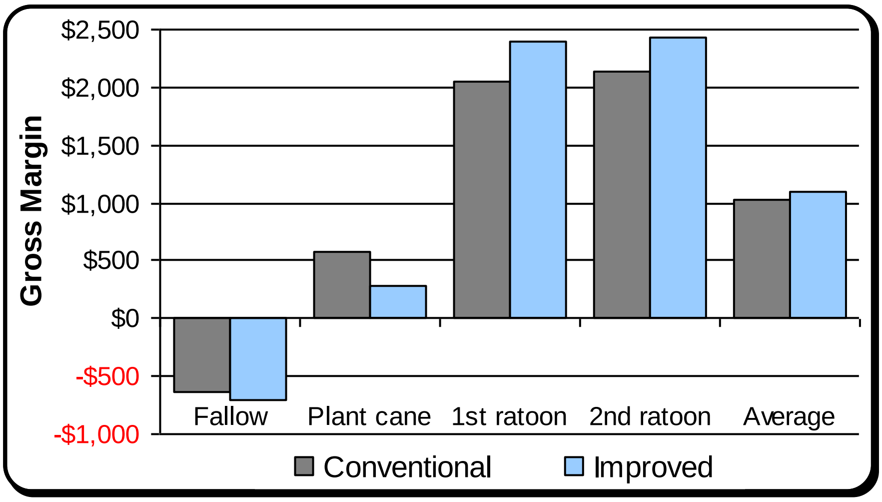


Figure 28: Gross Margin Comparison – CFMS (referred to as Conventional in this graph) Vs BMP (referred to as Improved in this graph) ($/ha)

5.7 Economic conclusions

This report provides an update to the results of the economic analysis for two different farm management systems currently being trialled at the Herbert Demonstration Farm. The trial involves comparing the CFMS practices to the BMP practices, which include reduced tillage, mound planting, and using alternatives to traditional PSII chemicals. The results of the analysis indicate that the CFMS benefited from lower legume fallow crop costs and a higher sugar yield in plant cane. On the other hand, the BMP Site incurred lower plant cane growing costs and a higher first and second ratoon sugar yield. Overall, the average gross margin of the BMP Site was $72 per hectare (or 7% in relative terms) higher than the CFMS Site.

The trial data indicates that the BMP Site has provided modest net economic benefits, even though at this stage the analysis lacks successive ratoon data. It is important to note the limitations of these results; this analysis involves a single-replicate trial that includes plant cane, first ratoon and second ratoon harvest data and both treatments produced historically low plant cane yields (t/ha) due to adverse effects from cyclone Yasi. Additionally, the BMP Site's plant cane yields were thought to be reduced by heavy weed pressure resulting from suspected herbicide treatment failure due to environmental conditions.

6 Extension activities

The site has proven to be a valuable extension tool, which has been used to demonstrate new farming systems. Through a dedicated extension effort it has become a platform for learning and a forum to initiate discussion about farming systems and farming components such as water quality runoff, legume / fallow management, zonal tillage methods, mound planting, sub-surface fertiliser application and electromagnetic and yield mapping.
During this reporting period the following groups have inspected the site:

- ❖ In excess of 250 growers and industry technical staff have visited the site on 6 occasions as a part of the Herbert cane industry productivity forums between 2010 and 2013.
- ❖ Four overseas sugarcane industry delegations visited the site from the USA, Brazil (2 groups) and Argentina, between 2011 and 2013.
- ❖ Approximately 15 staff from Terrain NRM visited the site in 2011.
- ❖ Approximately 120 delegates from the International Society of Sugarcane Technologists (ISSCT) Agronomy and Engineering Workshop, held in September, 2012. (Figure 31)

- 65 delegates from a HRIC GIS conference, 2012. (Figure 30)
- 3 representatives from the USA and Australian Everris fertiliser company, 2013.
- 18 delegates from the Terrain NRM regional workshop, 2011.
- 15 delegates from the Sustainable Agriculture Initiative (SAI) with representatives from food and beverage manufacturing companies in attendance. These companies had a particular interest in sourcing products from industries that produce its foods in a sustainable manner, 2012.
- A grade 11 biology class from Gilroy Santa Maria College, 2011. (Figure 29)
- 125 primary school children from State Schools with the Herbert and Burdekin areas, 2013. (Figure 32)

Presentations undertaken on-site have focussed on the importance of sustainable agriculture and environmental stewardship. The site has been particularly beneficial in allowing groups to openly discuss issues pertaining to industry sustainability and the environment.

Figure 29. Grade 11 Biology class from Gilroy Santa Maria College, 2011 (left) and Brazilian delegation, 2011 (right).

Figure 30. Left- HRIC GIS conference attendants. Right-Project steering group.

Figure 31. Presentation to the ISSCT Agronomy and Engineering Workshop, September 2012.

Figure 32. Visit by primary school children in August, 2013.

7 Key learnings

The Herbert Demo Farm project has been successful in achieving its intended purpose of showcasing alternative farming systems and technology.

A degree of caution is needed when interpreting the results provided in this report due to the lack of replication inherent within the project design and the limited monitoring period.

The key learnings from the Herbert Demo farm project are as follows:

Technologies

1. Electromagnetic mapping has demonstrated application in identifying soil management zones within a block.

2. Yield monitoring has proven to be a valuable tool to assess yield variation within a block or site.

3. GPS autosteer technology offers significant opportunities for the cane industry to implement a controlled traffic farming system.

4. GPS autosteer technology allows growers to undertake zonal tillage and zonal application of soil amendments (e.g. lime).

Yield

5. Differences in yield between sites are difficult to quantify due to the nature of the project design i.e. lack of replication and multiple variables, however the wider row spacing of 1.83m appears to have no negative impact in ratoons.

6. Yield mapping technologies can identify zones of varying productivity.

Legume management

7. Pre-formed mounds are critical to ensure establishment and growth of legume fallow crops.

8. Retaining the legume on the surface, rather than incorporating it, was successful in delaying the availability of the N in a more mobile form until the cane crop was mature enough to utilise the available N.

Controlled traffic

9. Controlled traffic improves machinery trafficability, water infiltration rates and reduces compaction areas in the root zone of the crop.

Phosphorous variation in field

10. There are natural variations in P levels within a block, enabling opportunities like variable rate P applications to occur.

11. The significant ‘within block’ P change that has occurred over one year, suggests potential benefits to annual soil tests.

12. Government regulations concerning P applications need reviewing, when considering the P variation within a cane block.

Nitrogen and phosphorus loss

13. Nitrogen and phosphorus were detected in water samples collected from the site.

14. However, quantification of differences in total N and P losses from either site is difficult due to the lack of replication, atypical sampling seasons and inconsistent sampling data.

15. The majority of runoff loss is associated with the first few rainfall events after application of fertilisers.

16. N and P loss to runoff was lower than expected and within the acceptable range.

Weed management

17. An effective fallow and plant cane weed management program will significantly reduce weed pressure in subsequent ratoon crops.

Pesticide loss

18. Pesticides were found in runoff from both sites. However, quantification of differences in herbicide load from either site is difficult due to the lack of replication, atypical sampling seasons and inconsistent sampling data.

19. The most significant factor affecting pollutant runoff is time between application and rain. Undertaking risk assessments in regards to proximity to rainfall events reduces risk of potential losses.

Runoff

20. In the plant cane phase, different profiles created after planting can have a significant role in determining runoff volumes, which will lead to differences in pollutant export.

21. Due to resource and budget constraints, multiplex sampling, compared to discrete sampling, has proven to be the most appropriate sampling program.

22. Valuable local knowledge has been obtained in regards to project design and process. This knowledge will provide a foundation to guide further investigations into water quality monitoring in the Wet Tropics.

Trial design

23. All future trials should be designed with 2 more replicates to provide more scientific rigor.

Extension

24. The site has proven to be a valuable resource to demonstrate new farming and environmental monitoring systems. The site has allowed for significant discuss to occur concerning sugarcane sustainability and raising concerns about environmental issues pertaining to the industry.

8 Conclusions

Future investment into similar projects should be considered in the future. The Herbert Demonstration Farm project has provided worth, exceeding the expectations of all parties involved with the project. The number of people who have visited the site and the discussion concerning sugarcane farming practices and sugarcane sustainability are all positive indicators of the success for the project.

It must also be noted that the site has been a catalyst for change in farming practices for some Herbert growers, who have adopted new farming methods based upon their observations and involvement with the site. Increased adoption of minimum tillage, mound planting, adoption of wider row spacings, improved nutrient, legume and weed management practices have been observed in the Herbert region (between 2009-2013); not all this change can be attributed to this project, however it has reinforced the concepts in the minds of some growers.

9 Acknowledgements

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- A special thanks to the growers and trial co-operators Orazio and Anthony Marino. Their support and interest in the project was amicable and greatly appreciated by the research team.

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