Seasonal Benchmarking Report

Healthy Headwaters Centre Pivot - Lateral Move Benchmarking 2014/15

Report Number 30416.79951

Prepared for

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This report has been prepared for the Healthy HeadWaters Water Use Efficiency (HHWUE) project, which aims to achieve water use savings in the Queensland Murray-Darling Basin.

The HHWUE project is delivered in Queensland by DNRM with funding from the Australian Government's Sustainable Rural Water Use and Infrastructure Project, as part of the implementation of the Murray-Darling Basin Plan in Queensland

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This document provides information to address the intent of Project Number 30416. as agreed to by Department of Natural Resources and Mines (DNRM).

Executive Summary

Through targeted investment in efficient irrigation infrastructure, the Healthy HeadWaters Water Use Efficiency (HHWUE) project aims to achieve water use savings in the Queensland Murray Darling Basin (QMDB). The HHWUE project is delivered in Queensland by the Department of Natural Resources and Mines with funding from the Australian Government's Sustainable Rural Water Use and Infrastructure Program. The benchmarking project is funded by the HHWUE project to demonstrate to irrigators the potential water savings that may be achieved through improvements to existing on-farm irrigation infrastructure.

The project benchmarks centre pivot (CP) and lateral move (LM) machines in the QMDB to identify best practice, ideas and effective operating procedures to improve performance.

Since commencement in 2010, the project has reviewed the performance of large moving irrigation systems over the 2010/11, 2011/12, 2012/13, 2013/14 and the 2014/15 summer crop seasons. The scope of the project was increased in recent seasons to include additional machines, as well as to include energy benchmarking of the field operations.

Throughout the 2014/15 season we saw a degree of variation in climate across the QMDB, with some regions experiencing moderate, scattered late season rainfall and other regions experiencing water shortages. This season has seen excellent results with operating CPLM machines. A variety of crops were considered in this seasons benchmarking. Crops that were grown include; cotton, mung beans, corn, sorghum, Cowpeas and fodder crops.

Considering the water use indices, the Irrigation Water Use Index (IWUI) has shown variability for all crops in the season as it depends directly on yield and irrigation applied. Consistencies in Gross Production Water Use Index (GPWUI) values have emerging for specific crops over the duration of the four year project. The GPWUI determined for cotton across the QMDB was 2.98 (bales/ML), mung beans achieved 2.46 (bales/ML), corn achieved 8.38 (bales/ML), sorghum achieved 3.48 (bales/ML), Red Caloona Cowpeas achieved 2.44 (bales/ML) and no yield data was attained for the fodder crops. Considering cotton was the largest data set, the GPWUI value achieved means that on average for the 2014/15 season across the QMDB, 2.98 bales of cotton are grown for every 1 ML of total water used by the plant (including effective rainfall, soil moisture and irrigation). The consistency that is developing with the GPWUI values means that it could be used as a tool for yield predictions and water and financial budgeting.

The energy benchmarking component has provided useful data for the project and its participants. Energy use has been divided into the various field operations of preparation, establishment, in-season, irrigation, harvest and post-harvest. Energy use and cost data, used in conjunction with commodity prices and market information, will enable growers to make economic decisions regarding which crop to plant based on the associated returns and energy costs. Irrigation energy components vary from approximately 13 percent to 81 percent of the total in-field energy costs to produce a crop, depending on the crop type.

Historically growers have had a perception that irrigation consumes a lot of energy to grow a crop. The energy benchmarking results from this season show that in some cases this is correct; however, in other cases the irrigation energy component is relatively low.

This season included providing the grower with data sheets to allow them to collect data on the energy use as they progress throughout the season. This has shown an improvement in data accuracy at the end of the season and a better understanding of the outcomes. With more access to internet based videos, a short video clip that runs through the data collected as a highlight video of the season is compiled and posted on the media sharing site YouTube, to increase understanding of the practices and results conducted under the HHWUE Project. In combination with the video clip, WaterBiz staff have made themselves available to work through the data with each individual grower to enable process benchmarking to be undertaken.

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1. Introduction

Through targeted investment in efficient irrigation infrastructure, the Healthy HeadWaters Water Use Efficiency (HHWUE) project aims to achieve water use savings in the Queensland Murray Darling Basin (QMDB). The HHWUE project is delivered in Queensland by the Department of Natural Resources and Mines (DNRM) with funding from the Australian Government's Sustainable Rural Water Use and Infrastructure Program, the Department of Agriculture and Fisheries (DAF) and the Cotton Research and Development Corporation (CRDC). The benchmarking project is funded by the HHWUE project to demonstrate to irrigators the potential water savings that may be achieved through improvements to existing on-farm irrigation infrastructure.

1.1 Benchmarking

Benchmarking is widely used in business to provide a mechanism for improvement and implementation of best practice management. This project is aimed at benchmarking centre pivot (CP) and lateral move (LM) machines in the QMDB to identify best practice, ideas and effective operating procedures to improve performance.

The benchmarking project has provided measured data relating to the seasonal performance of large moving irrigation systems (centre pivots and lateral move machines) in the industry at a field scale. This project has better informed both irrigators looking at changing their current irrigation systems to large moving irrigation systems and policy makers who have the perception that a large moving irrigation system is more efficient than the current systems of irrigation.

1.2 Group Composition - Irrigators

The 2014/15 season saw 15 CP and LM machines and one surface irrigation (siphon) crop participate in the benchmarking project. The lower participation rate for this season can be attributed to less crops being produced due to water availability.

1.3 Project Reporting

The project commenced in 2010 and is now complete following the 2014/15 summer season. To date, the project has specifically reviewed the performance of large moving irrigation systems over the 2010/11, 2011/12, 2012/13, 2013/14 and 2014/2015 summer crop seasons. The irrigators who participated in the project have found the data useful in assessing their performance against other irrigators in a similar situation, and through the on-farm improvements that can be made by each irrigator based on knowledge shared between the irrigators participating in the project.

This project has now completed its final season. As with the previous seasons, this document reports on the results of the season and provides analysis of the results to benchmark the current industry practise. Furthermore, this report will make reference to the previous seasons.

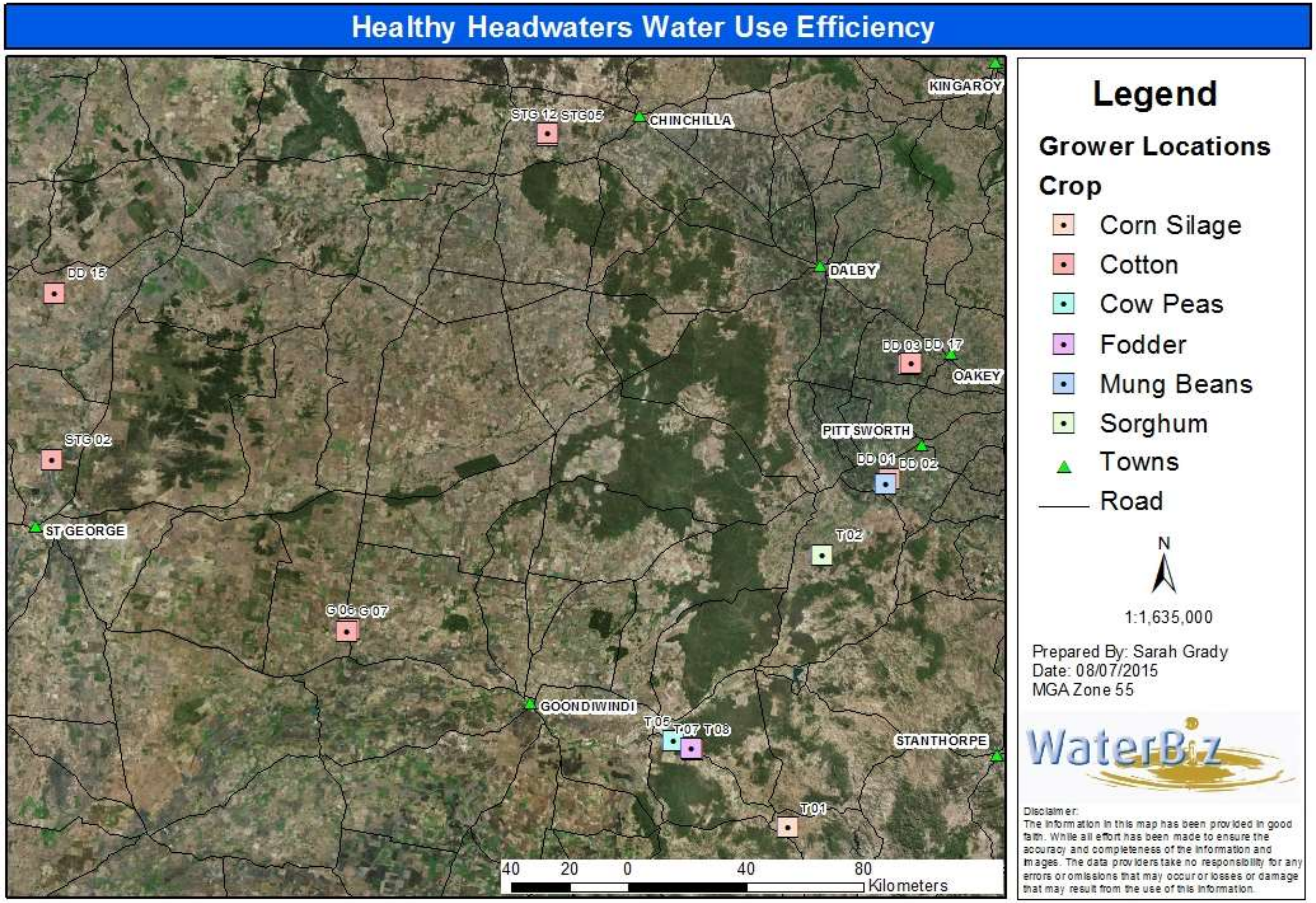

Figure 1 **Irrigators Location and Crop Type**

Table 1 Irrigators location and machine type

Location	Centre Pivot	Lateral Move	Surface	Total
Dalby	2	3	0	5
Goondiwindi	2	0	0	2
St George	2	1	1	4
Texas	5	0	0	5
Total	11	4	1	16

Table 2 Crops grown and machine type

Crop	Centre Pivot	Lateral Move	Surface	Total
Cotton	6	2	1	9
Corn	0	1	0	1
Corn Silage	1	0	0	1
Red Caloona Cowpea	1	0	0	1
Mung Beans	0	1	0	1
Sorghum	1	0	0	1
Fodder	2	0	0	2
Total	11	4	1	16

2. Project Scope

The methodology for the project is broken into two sections: the field scale seasonal water use and the field scale energy benchmarking.

The seasonal water use data was collected from participating irrigators over a single year growing period and included:

- Crop type;
- Seasonal water use;
- Rainfall over the season;
- Crop Yield;
- Soil Moisture;
- Flow rate for systems from previous seasons data;
- Irrigation type (CPLM and siphon irrigation controls); and
- Irrigation events, volumes applied and CPLM machine movements from the Pressurised Irrigation monitoring System (PIMS), data loggers fitted to the CPLM machines.

A comparison of water use was performed for each of the crop types grown using the Irrigation Water Use Index (IWUI) and Gross Production Water Use Index (GPWUI). Water use indices are the main mechanism to allow the benchmarking of the growers beyond yield. The two indices reported benchmark the grower's ability to produce product from irrigation water (IWUI) and the growers ability to produce product from all available water sources (GPWUI). In many cases the available water sources act as dependent variables (that is, as seasonal rainfall reduces, irrigation water applied increases)

The energy benchmarking involved collecting the following data from participating growers through an interview process using the form located in Appendix A:

- Field Preparation;
- Crop establishment;
- In-season;
- Irrigation;
- Harvest; and
- Post-harvest activities

The energy benchmarking data was then processed using the EnergyCalc software (http://econcalc.nceaprd.usq.edu.au), developed by the National Centre for Engineering in Agriculture (NCEA). EnergyCalc provides a report of each assessment summarising energy used (volume, power), cost ($), emissions CO_2 (kg), summary of energy usage, tractor and pump energy inputs, and performance indicators for processes (GJ/ha and GJ/yield, $/ha and $/yield, kg CO_2/ha and kg CO_2/yield). The performance indicators were used to provide a means of comparison between the various crops grown for the season.

3. Data Collection - 2014/2015 Season

Data was collected for both the seasonal water use and energy benchmarking using the methodology described in Sections 3.1, 3 and 3.2. In summary, water use data was collected using a data logger attached to individual machines while energy benchmarking data was collected using field data sheets (Appendix A) in combination with a follow up interview at the end of the season.

3.1 Seasonal Water Use

The measurement and evaluation of seasonal water use aims to provide an evaluation of the managed machine. Seasonal water use is critical data for irrigators as water is generally the limiting input for crop production. The benchmarking of this input is aimed at helping irrigators grow more crop per unit volume of water used.

The two key parameters used for seasonal irrigation benchmarking are as follows:

Irrigation Water Use Index (IWUI):

$$IWUI = \frac{Total\ production\ (Bales - or - tonnes)}{Irrigation\ water\ applied\ (ML)}$$

Gross Production Water Use Index (GPWUI):

$$GPWUI = \frac{Total\ production\ (Bales - or - tonnes)}{Total\ water\ applied\ (ML)}$$

Where total water applied includes:

- Irrigation water applied and,
- Effective rainfall.

Soil moisture, irrigation water applied and effective rainfall values were used to determine the seasonal water use and are discussed in Sections 3.1.1, 3.1.2 and 3.1.3.

3.1.1 *Soil Moisture*

Soil moisture was determined to ensure water usage volumes accounted for changes in soil moisture from the start to the end of the season. The initial soil moisture was obtained at the plant date for each of the crops, following a qualitative assessment conducted by the growers and their agronomists. The final measurement of soil moisture was assessed by looking at the timing of the last irrigation within the soil moisture balance compared with the first defoliation or harvest date for crops other than cotton. The water balance was completed at first defoliation for cotton and harvest for other crops to ensure consistency between regions and another qualitative assessment was conducted to determine the soil moisture.

3.1.2 *Irrigation Water Applied*

Irrigation water applied is a measure of the total water applied by the machine over the season. It is calculated by multiplying the total run time of the machine for the season by the measured flow rate of the machine. To effectively measure run time, data loggers (PIMS units) were installed to log end of machine pressure and location (Figure 2). When the data loggers were logging pressure at the end of the CPLM machines, it was assumed that they were irrigating, thereby providing a measure for run time. Any discrepancies with run time and water applied were resolved by checking the data with the growers.

Figure 2 Installed PIMS unit on a Centre Pivot

3.1.3 *Effective Rainfall*

Total rainfall data for each of the crops grown has been collected for the calculation of GPWUI and to provide an explanation of why irrigation volumes vary between crops and region. Figure 3, adapted from grower rainfall records and Bureau of Meteorology (BoM) data, shows a rainfall map covering the project area for the in-crop periods.

The field measurements of effective rainfall are reliant on irrigator's judgment and other land issues such as soil infiltration rate and rainfall intensity which have not been considered in these observations. Field runoff was observed by growers to determine the amount of effective rainfall available to the crop, essentially the amount of rainfall which infiltrates the soil and is available for plant uptake.

Temporally sediment loss, is considered a characteristic of runoff, no sediment loss was observed, therefore it is considered all rainfall which fell on the crop was effective rainfall.

Furthermore, due to the spread of properties within the region, the reported effective rainfall values vary considerably.

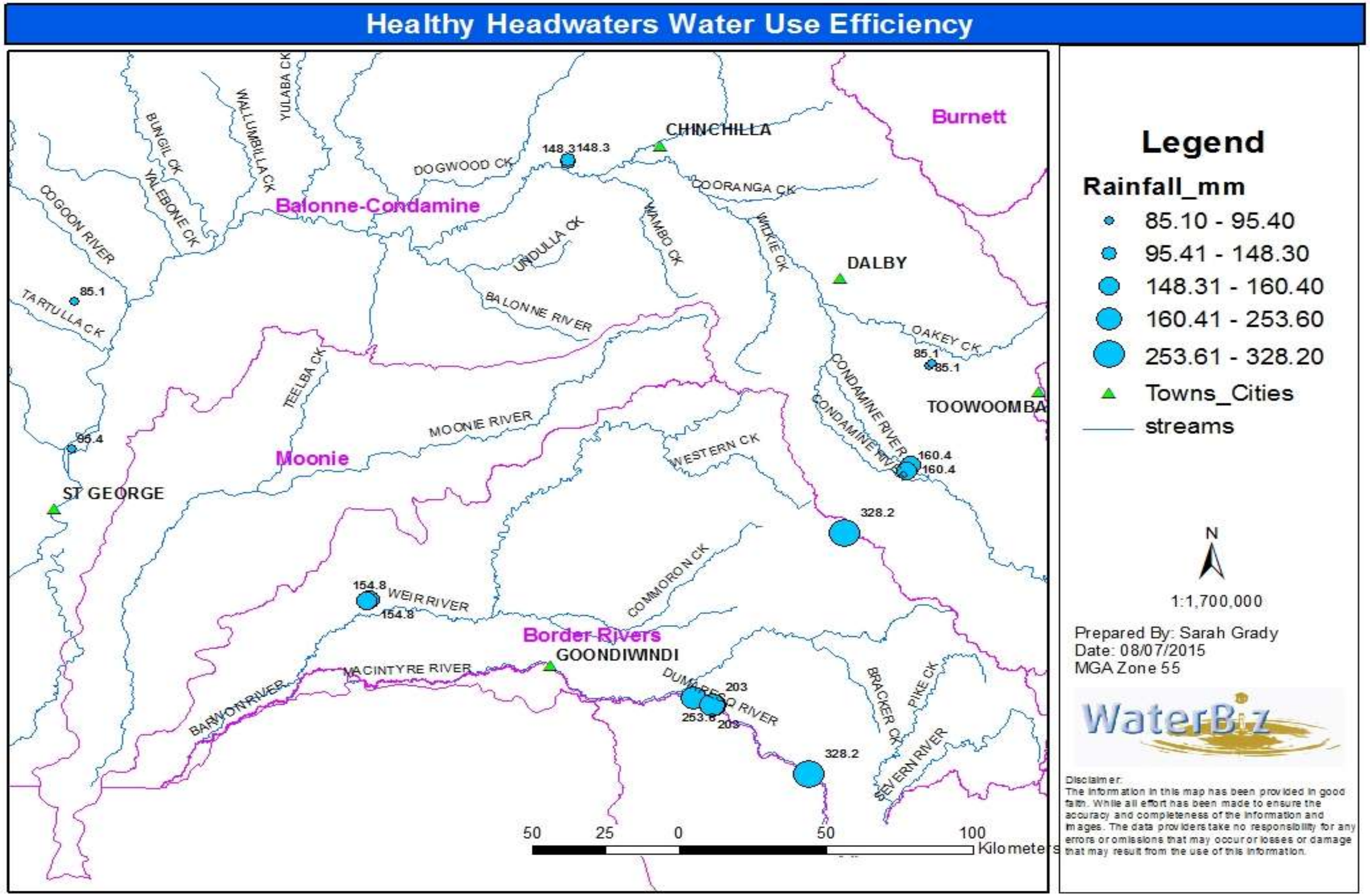

Figure 3 Growers In-crop Rainfall Map

3.1.4 *Surface Irrigation Comparison*

In order to demonstrate the difference between CPLM machines and other irrigation methods, data was collected from a 59 ha surface irrigated cotton crop in St George, to present a control for the study. Reduced water availability and numbers of participating growers in the 2014/15 study, resulted in only one surface irrigated crop being observed as a control. By comparing different irrigation types to the CPLM system, we obtain a more holistic view of water use efficiency in the QMDB.

3.2 Energy Benchmarking

EnergyCalc software, developed by the National Centre for Engineering in Agriculture (NCEA), was used to perform the energy calculations with the data collected from the growers. EnergyCalc divides energy usage of crop production into six processes; preparation, establishment, in-season, irrigation, harvest and post-harvest activities. This enables both the total energy inputs and the energy usage of each production process to be assessed.

Data that was collected from the growers included:

- Crop – type, area, production (expected and achieved – bales/ha, tonnes/ha).
- Land preparation, crop establishment and in-crop – energy cost per unit, number of operations, litres of diesel per operation, area, tractor power (kW), tractor load (%), tractor speed, work width, and work rate (%).
- Irrigation – energy cost per unit, number of irrigations, area, water applied (ML/ha), diesel consumed (L/h) or electricity consumed (kWh), pump operating flow (L/s, ML/d), pump operating head (m or PSI), pump operating efficiency, hours per shift, and area per shift.
- Harvest and post-harvest – energy cost per unit, number of operations, litres of diesel per operation, area, tractor power (kW), tractor load (%), tractor speed, work width, and work rate (%).

A report of each assessment was compiled by EnergyCalc summarising energy used (volume, power), cost ($), emissions CO_2 (kg), summary of energy usage, energy cost per ha, tractor and pump energy inputs, and performance indicators for processes (GJ/ha and GJ/yield, $/ha and $/yield, kg CO_2/ha and kg CO_2/yield). Performance indicators were used to provide a means of comparison between the various crops grown for the season.

As a scope limit for the energy calculations, the energy assessment analysed the energy required to grow the crop on a field basis for each of the CPLM machines investigated. The energy assessments did not consider transport or storage of the crop away from the field.

Section 4 presents the results from the 2014/2015 season.

4. Results

The results are presented on a crop basis covering the yields, IWUI, GPWUI and seasonal energy consumption.

4.1 Cotton

4.1.1 *Crop Yields*

Figure 4 and Table 3 summarise the cotton yields by region (bales/Ha) for the 2014/15 season, including only CP and LMs. Two participants from Dalby received the lowest yields for cotton in the 2014/15 season (9.0 bales/Ha, Figure 4). Dalby also produced the lowest average yields (9.67 bales/Ha) for a region. The highest yield recorded was achieved in the St George region (14.20 bales/Ha).

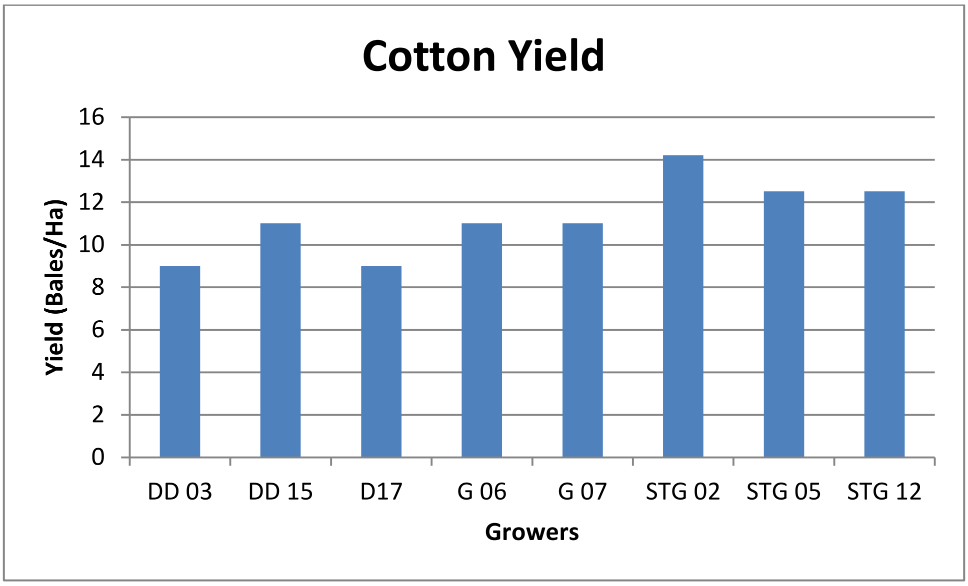

Figure 4 2014/15 cotton yields CPLM

Table 3 Cotton yields by region (bales/ha) in the 2014/15 season – CPLM only

Region	Number of Machines	Average yield (bales/ha)	Median Yield (bales/ha)	Minimum Yield (bales/ha)	Maximum Yield (bales/ha)
Dalby	3	9.67	9.00	9.00	11.00
Goondiwindi	2	11.00	11.00	11.00	11.00
St George	3	13.07	12.50	12.50	14.20
Total	8				

The average yields achieved using CP and LM machines were similar (10.84 and 12.60 bales/Ha respectively). In contrast variation was observed in yields, from 9.00 and 11.00 bales/Ha to 12.50 and 14.20 respectively (Table 4).

The control crop exhibited similar yields to the CP and LM machines in the St George region, 14.2 bales/Ha (Table 4).

Table 4 Cotton yields by irrigation type (bales/ha) in the 2014/15 season

Irrigation Type	Number of Fields	Average Yield (bales/ha)	Median Yield (bales/ha)	Minimum Yield (bales/ha)	Maximum Yield (bales/ha)
Centre Pivot	6	10.84	11.00	9.00	12.50
Lateral Move	2	12.60	12.60	11.00	14.20
Siphon	1	14.2	14.2	14.2	14.2
Total	9				

4.1.2 *Irrigation Water Use*

On average the Dalby region (141.56 mm), followed by the St George region (252.68 mm) applied the least irrigation water, compared to Goondiwindi (449.30 mm Figure 5). The Dalby region obtained the highest IWUI (5.74 bales/ML), also recording the highest average IWUI (4.20 bales/ML), followed by Goondiwindi (2.47 bales/ML) and St George (2.28 bales/ML Table 5).

The surface irrigated crop (STG 13) recorded an equal study group high yield of 14.2 bales/Ha, however it required significantly more water to achieve this yield, therefore a low IWUI was observed, 1.44 bales/ML.

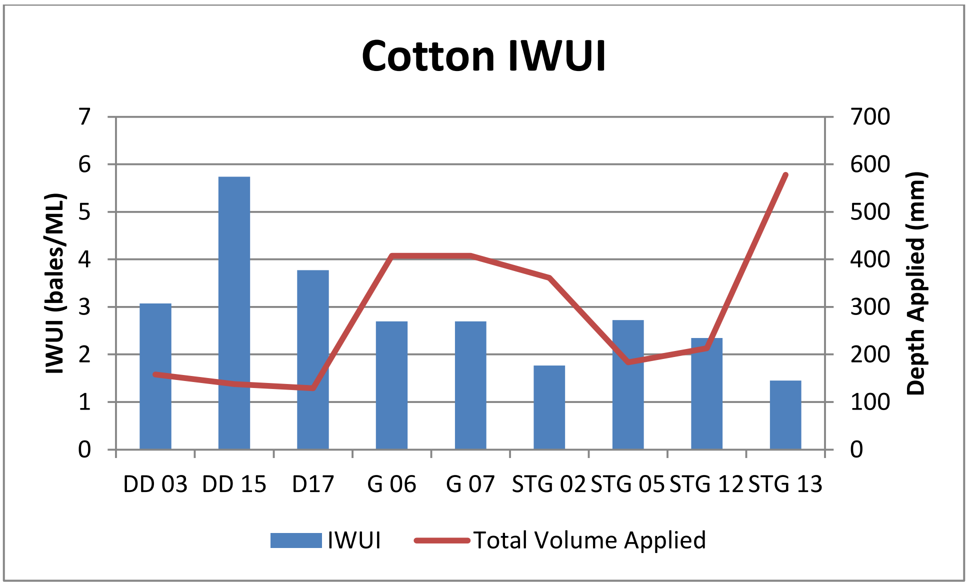

Figure 5 2014/15 cotton IWUI

Table 5 Cotton IWUI (bales/ML applied) for 2014/15 season – CPLM only

Region	Number of Machines	Average IWUI (bales/ML)	Median IWUI (bales/ML)	Minimum IWUI (bales/ML)	Maximum IWUI (bales/ML)
Dalby	3	4.20	3.76	3.06	5.74
Goondiwindi	2	2.47	2.47	2.24	2.70
St George	3	2.28	2.35	1.77	2.72
Total	8				

Table 6 summarises the cotton IWUI (bales/ML) by irrigation type for the 2014/15 season. The lowest average IWUI was achieved using a CP machine (2.81 bales/ML), while the highest average IWUI was achieved using a LM machine (3.76 bales/ML).

Table 6 Cotton IWUI per irrigation type (bales/ML applied) for 2014/15 season

Irrigation Type	Number of Machines	Average IWUI (bales/ML)	Median IWUI (bales/ML)	Minimum IWUI (bales/ML)	Maximum IWUI (bales/ML)
Centre Pivot	6	2.81	2.71	2.24	3.78
Lateral Move	2	3.76	3.76	1.77	5.74
Surface	1	1.44	1.44	1.44	1.44
Total	9				

4.1.3 *Gross Production Water Use*

Figure 6 shows the cotton GPWUI (bales/ML) for the 2014/15 season plotted against the irrigation depth applied (mm) for each of the regions. The St George region obtained the lowest average GPWUI (1.81 bales/ML) while the Dalby region obtained the highest average GPWUI (3.05 bales/ML Table 7). The St George region obtained the lowest individual GPWUI (1.55 bales/ML) and a Dalby grower achieved the highest individual GPWUI (3.98 bales/ML) for the regions (Table 7).

The siphon irrigation crop (STG 13) used as a control for the study achieved impressive yields, yet received a lower GPWUI than CP and LM irrigation as it required significantly greater amounts of water to attain this yield.

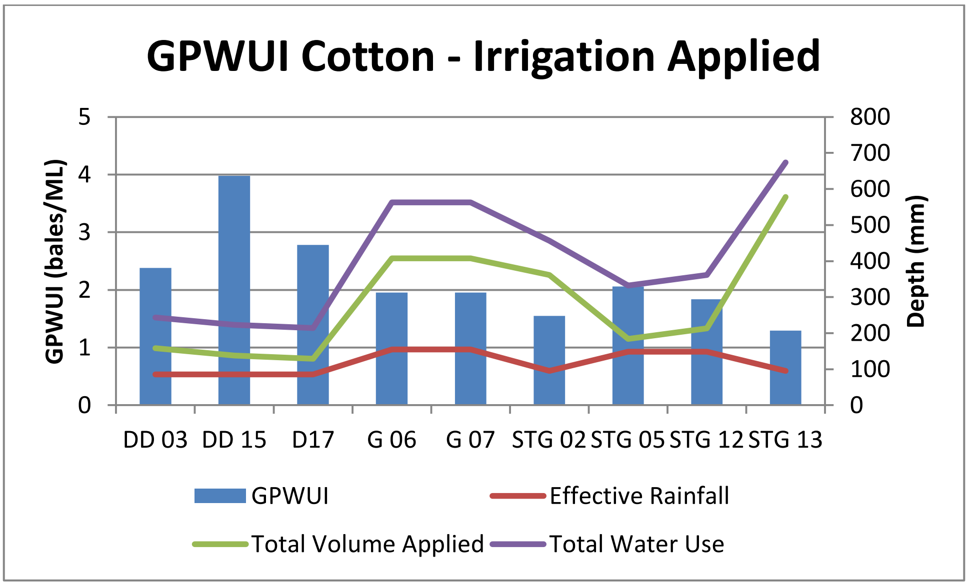

Figure 6 2014/15 cotton GPWUI

Table 7 Cotton GPWUI (bales/ML) for 2014/15 season – CPLM only

Region	Number of Machines	Average GPWUI (bales/ML)	Median GPWUI (bales/ML)	Minimum GPWUI (bales/ML)	Maximum GPWUI (bales/ML)
Dalby	3	3.05	2.78	2.38	3.98
Goondiwindi	2	1.95	1.95	1.95	1.95
St George	3	1.81	1.84	1.55	2.06
Total	8				

Table 8 shows that the average GPWUI achieved using LM machines was considerably higher than that achieved by the CP machines (2.76 bales/ML and 2.16 bales/mL respectively).

Table 8 Cotton GPWUI per irrigation type (bales/ML applied) for 2014/2015 season

Irrigation Type	Number of Machines	Average GPWUI (bales/ML)	Median GPWUI (bales/ML)	Minimum GPWUI (bales/ML)	Maximum GPWUI (bales/ML)
Centre Pivot	6	2.16	2.00	1.84	2.78
Lateral Move	2	2.76	2.76	1.55	3.96
Surface	1	1.29	1.29	1.29	1.29
Total	9				

4.1.4 *Seasonal Energy Consumption*

Energy use is presented below as GJ/bale and GJ/Ha, Figure 7 presents how much energy (Energy yield) is required to produce a bale of cotton (GJ/bale) and consequently how much energy (Energy Ha) was used per hectare (GJ/Ha) during the 2014/15 season. The Energy cost is presented as $/bale. Figure 7 shows that the average cotton energy use (GJ/Ha) was lowest for the St George region (2.80 GJ/Ha) and highest for the Goondiwindi region (6.24 GJ/Ha) for the 2014/15 summer season.

The average energy uses (GJ/bale) recorded across the participating growers showed minimal variation, with Dalby and St George recording the lowest average energy uses (0.31 and 0.35 GJ/bale respectively). A peak of 0.54 GJ/bale was observed in Goondiwindi. The Goondiwindi grower also recorded the highest individual energy cost ($17.39/bale), in contrast to a St George grower who recorded the lowest ($4.03/bale).

The average energy cost per bale across the regions was $11.63/bale, with the lowest average energy cost recorded in the St George region ($6.34/ bale Table 9).

The surface irrigated crop (STG 13) exhibited a moderately low energy cost for yield produced, $10.77/bale. The application of water is not as exact or controlled as CP and LM machines therefore less energy is required to irrigate the crop.

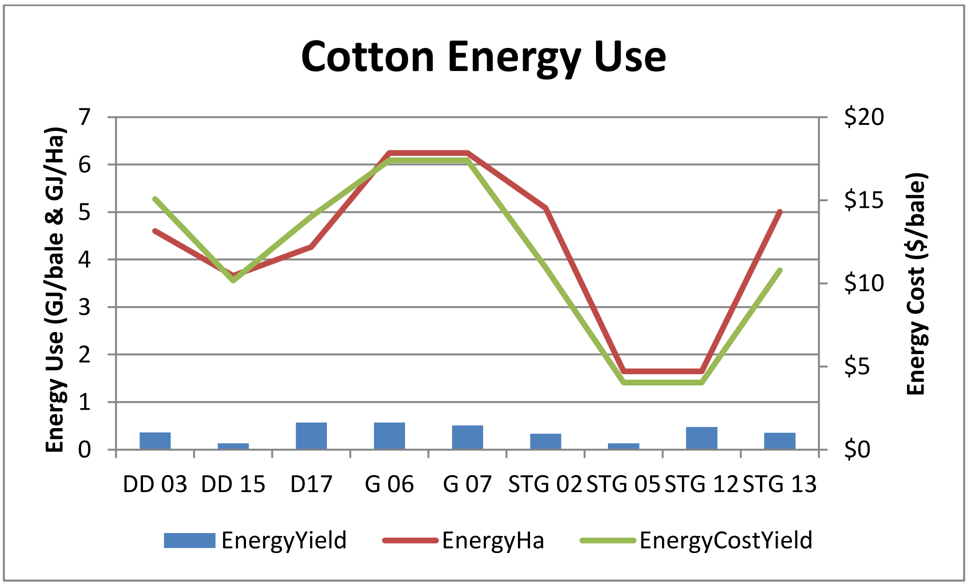

Figure 7 2014/15 cotton energy use

Table 9 Cotton regional energy use and cost (GJ/bale and $/bale) for 2014/15 – CPLM only

Region	Number of Machines	Average Energy Use (GJ/Ha)	Average Energy Use (GJ/bale)	Average Energy Cost ($/bale)	Minimum Energy Cost ($/bale)	Maximum Energy Cost ($/bale)
Dalby	3	4.18	0.35	13.09	10.17	15.07
Goondiwindi	2	6.24	0.54	17.39	17.39	17.39
St George	3	2.80	0.31	6.34	4.03	10.95
Totals	8					

Table 10 shows that on average CPs irrigating cotton used approximately the same amount of energy when compared to LMs (0.44 and 0.23 GJ/bale, Table 10) in the 2014/15 summer season. The average costs per bale were also similar between the CPs ($11.99/ bale) and the LMs ($10.56/ bale).

The minimum energy cost was achieved using a CP machine ($4.03/ bale) while the maximum energy cost was achieved also using a CP machine ($17.39/ bale).

The two Goondiwindi machines where located in adjacent fields on the same property therefore their energy usage was observed as exactly the same.

Table 10 Cotton energy use and cost per irrigation type (GJ/bale and $/bale) for 2014/15

Irrigation Type	Number of Machines	Average Energy Use (GJ/bale)	Average Energy Cost ($/bale)	Minimum Energy Cost ($/bale)	Maximum Energy Cost ($/bale)
Centre Pivot	6	0.44	11.99	4.03	17.39
Lateral Move	2	0.23	10.56	10.17	10.95
Surface	1	0.35	10.77	10.77	10.77
Totals	9				

The process to grow cotton includes site preparation, establishment, in-season, irrigation, harvest, and post-harvest. Considering the major energy consumption operations growing cotton, Figure 8 shows that on average for a CPLM crop, approximately 44 per cent of the energy is consumed during irrigation, 17 per cent during harvest and 17 per cent during post-harvest.

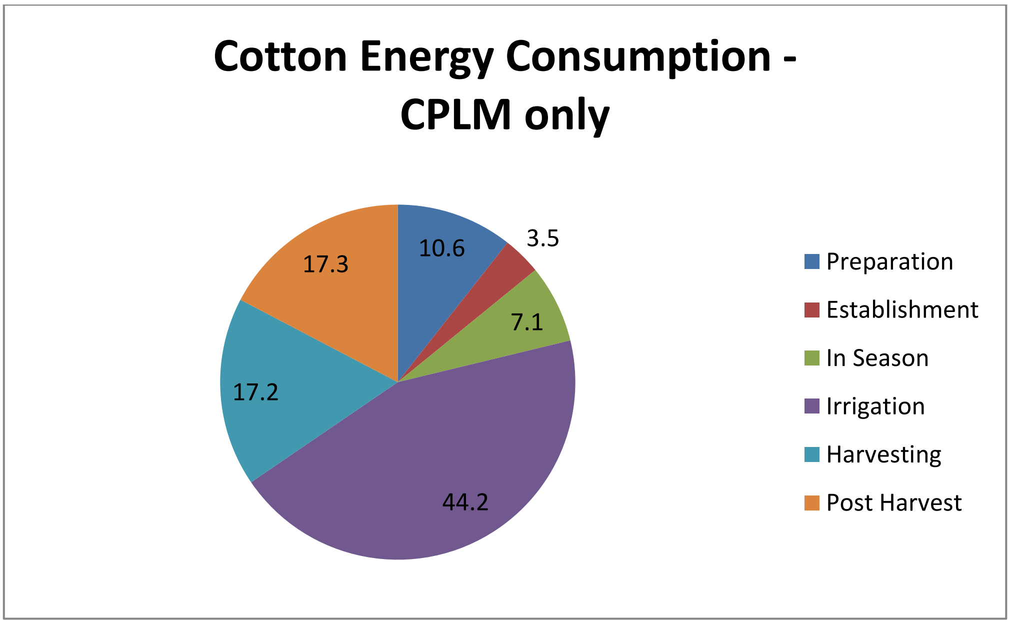

Figure 8 2014/15 cotton energy use by percentage process

In Figure 9, we can see that a surface/siphon irrigated cotton crop energy consumption differs considerably from a CPLM crop, with the primary energy consumption (52.8 percent) occurring post-harvest. The most significant different is the energy consumption during irrigation, with surface irrigation only using 5.9 percent compared to 44.2 percent in CPLM crops.

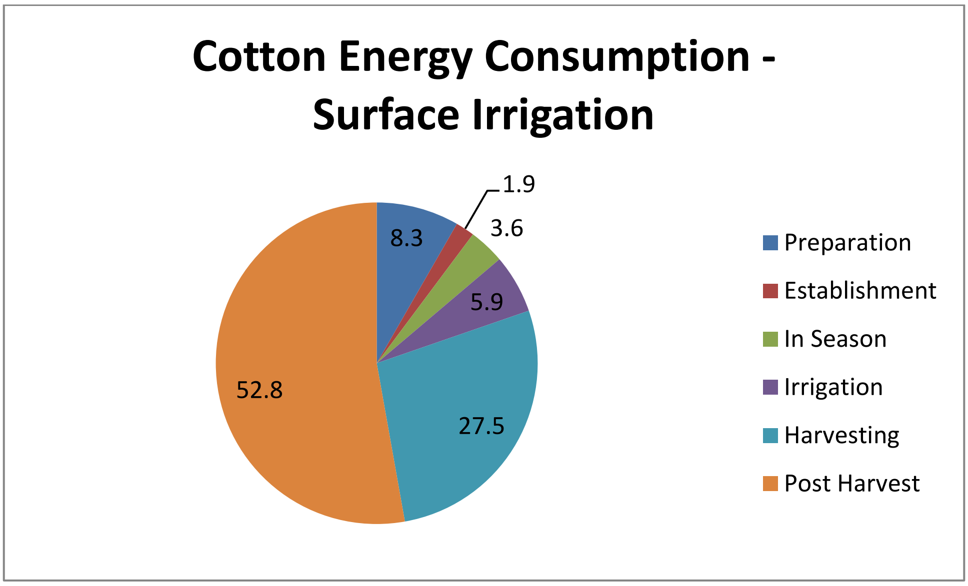

Figure 9 2014/15 cotton energy use by percent process - surface irrigation

4.2 Other Crops

4.2.1 *Crop Yields*

Dalby and Texas grew a wide variety of crops in the 2014/15 summer season, with no crop type being repeated across the regions.

Table 11 shows that corn silage achieved the highest yield (54.36 tonnes/Ha), whereas Red Caloona Cowpea achieved the lowest yield (1.79 tonnes/Ha). The fodder crops were grazed, therefore no yields were recorded.

Table 11 2014/15 other crop yields

Crop	Yield (tonnes/Ha)
Mung Beans	2.20
Corn	10.50
Corn Silage	54.36
Sorghum	7.00
Red Caloona Cow Peas	1.78
Fodder	0
Fodder	0

Table 12 Other crop yields (tonnes/Ha) in the 2014/15 season

Region	Number of Machines	Average Yield (tonnes/Ha)	Median Yield (tonnes/ha)	Minimum Yield (tonnes/Ha)	Maximum Yield (tonnes/Ha)
Dalby	2	6.35	6.35	2.20	10.50
Texas	3	21.05	7	1.79	54.36
Total	5				

Note: the two (2) Fodder crops from Texas were removed from the data set. As their yields were not calculated the average calculations would have been affected.

Crop yields are not reported on per irrigation type for other crops as the population size for the 2014/15 season is too small too accurately draw conclusions. Table 12 shows the irrigation type for other crops grown in the 2014/15 season for the project.

Table 13 Irrigation type for other crops

Location	Centre Pivot	Lateral move	Total
Dalby	0	2	2
Texas	5	0	5
Total	5	2	7

4.2.2 *Irrigation Water Use*

Figure 10 shows that growers who applied larger amounts of irrigation water generally achieved lower IWUIs. There is significant variation in the IWUIs with a minimum of 2.44 tonnes/ML and a maximum of 13.26 tonnes/ML being achieved. The discrepancy between crop types makes it difficult to discern trends, as different crops have different growth rates and resulting yields.

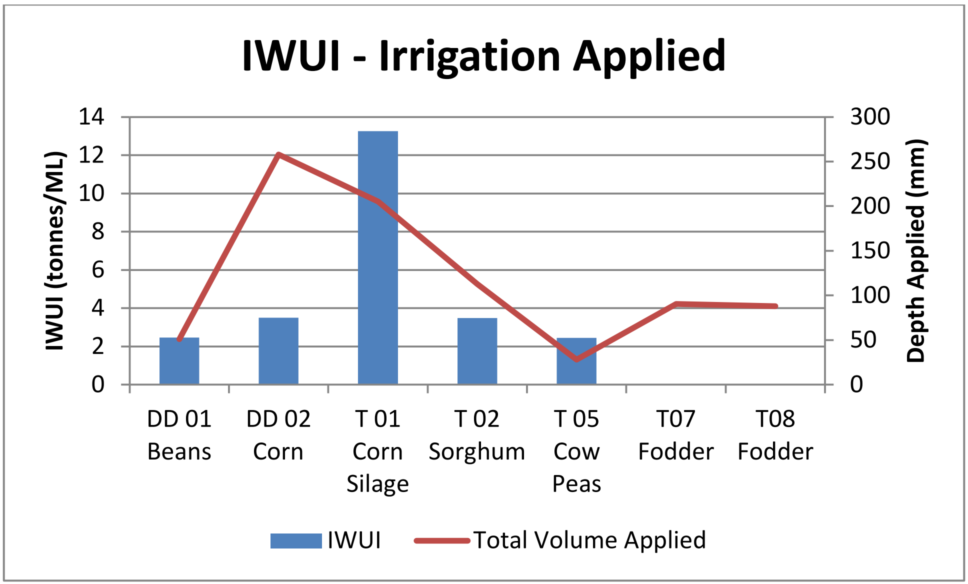

Figure 10 2014/15 other crops IWUI (Yield was not recorded for the fodder crops, therefore a IWUI could not be calculated)

Table 14 Other crops IWUI (tonnes/ML applied) for 2014/15 season

Region	Number of Machines	Average IWUI (tonnes/ML)	Median IWUI (tonnes/ML)	Minimum IWUI (tonnes/ML)	Maximum IWUI (tonnes/ML)
Dalby	2	2.98	2.98	2.46	3.50
Texas	3	6.39	3.48	2.44	13.26
Total	5				

Note: the two (2) Fodder crops from Texas were removed from the data set. As their yields were not calculated the average calculations would have been affected.

IWUIs are not reported on per irrigation type for other crops as there is insufficient data for the 2014/15 season to provide accurate conclusions.

4.2.3 *Gross Production Water Use*

Figure 11 shows that the grower who received the highest total water use also achieved the highest GPWUI. With the exception of corn silage (7.36 tonnes/ML), the average GPWUI across the QMDB was reasonably consistent, with Texas achieving the lowest GPWUI of 2.44 tonnes/ML and Dalby the highest (3.50 tonnes/ML).

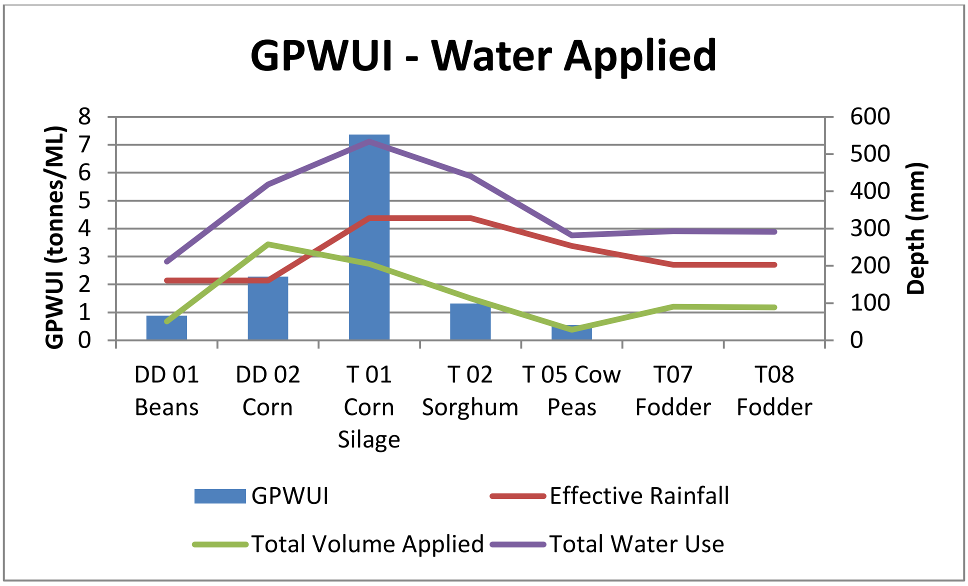

Figure 11 2014/15 other crops GPWUI

Table 15 Other crops GPWUI (tonnes/ML) for 2014/15 season

Region	Number of Machines	Average GPWUI (tonnes/ML)	Median GPWUI (tonnes/ML)	Minimum GPWUI (tonnes/ML)	Maximum GPWUI (tonnes/ML)
Dalby	2	1.58	1.58	0.88	2.28
Texas	3	3.08	1.32	0.55	7.36
Total	5				

Note: the two (2) Fodder crops from Texas were removed from the data set. As their yields were not calculated the average calculations would have been affected.

GPWUIs are not reported on per irrigation type for other crops as there is insufficient data for the 2014/15 season to provide accurate conclusions.

4.2.4 *Seasonal Energy Consumption*

Energy use is presented below as GJ/Ha and GJ/tonnes, while energy cost is presented as $/tonne. Figure 12 and Table 16 show that the Texas region had the highest average energy use per hectare (2.00 GJ/Ha) and the highest average energy use per tonne (0.23 GJ/tonne).

A considerable difference is observed between the average energy cost ($/tonne) between Dalby and Texas, with Texas ($7.83/tonne) considerably higher than Dalby ($0.82/tonne, Table 16).

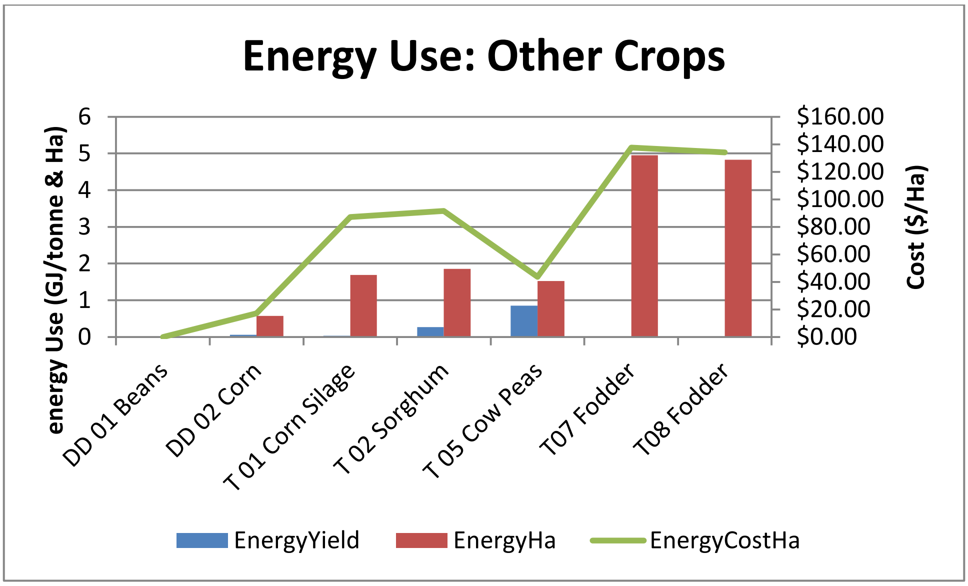

Figure 12 2014/15 other crops energy use

Table 16 Other crops energy use and cost (GJ/tonne and $/tonne) for 2014/15

Region	Number of Machines	Average Energy Use (GJ/Ha)	Average Energy Use (GJ/tonne)	Average Energy Cost ($/tonne)	Minimum Energy Cost ($/tonne)	Maximum Energy Cost ($/tonne)
Dalby	2	0.28	0.03	0.82	0	1.63
Texas	5	2.00	0.23	7.83	0	24.44
Total	7					

The process to grow other crops includes site preparation, establishment, in-season, irrigation, harvest and post-harvest. Considering the major energy consumption operation growing other crops, Figure 13 shows that on average; approximately 23 per cent of the energy is consumed during preparation, 44 per cent during irrigation and 23 per cent during harvest

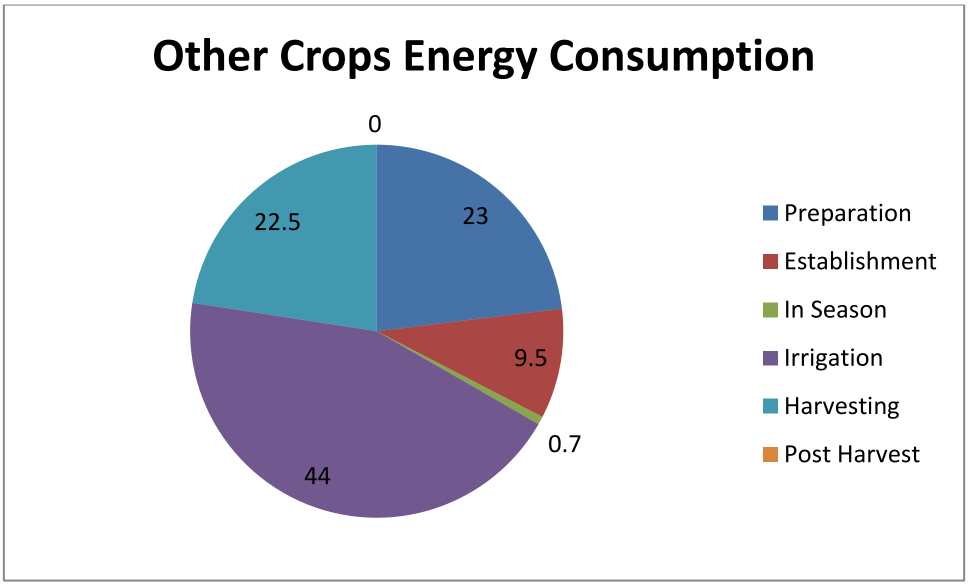

Figure 13 2014/15 other crops energy use by percentage process

5. Discussion and Analysis

All regions received significantly less annual rainfall than last year, participating properties averaged 162.98mm during the 2014/15 season compared to 318.93mm in the 2013/14 season. Similarly to last season the majority of this rain arrived at the end of the season. This provided little assistance to production and caused delays to crops that were about to be harvested. This section of the report discusses the results in three major topics; yield, water use and energy use.

This season, contrary to previous seasons, has seen a movement away from cotton in favour of other crops. While not as prominent, cotton is still the dominant crop across the basin. This season's crops were too few individually to draw meaningful benchmarking conclusions, so this report addresses other crops as a bundled entity.

With a dry lead up to the 2014/15 season, water availability was a significant constraint with numerous growers deciding against irrigating crops or scaling down their irrigation operations. The season progressed with little or no rain across the basin, with growers having to continually irrigate for the majority of January and February. Scattered rain arrived in late March, however most crops had been defoliated and were about to be harvested. The rain had an effect on the grade of the crops and caused delays in harvesting.

5.1 Yield

Figure 14 shows the average cotton yields by region for the last five years of the project. Based on the historical cotton yields, all growers produced a higher average cotton yield for the 2014/15 season compared to last season. Dalby growers produced the lowest average yield for the 2014/15 season. St George growers produced the highest average yield for the 2014/15 season, with a significant increase from last year's average cotton yield.

Each region has a slightly different reason for the variation in yield, which is related to either limited availability of water, or oversupply of rainfall, as discussed in Sections 5.1.1 through 5.1.4.

All regions saw an increase in yield from the 2013/14 season, which may be the result of climatic factors in conjunction with smaller crop sizes due to water limitations, which allowed for better crop management.

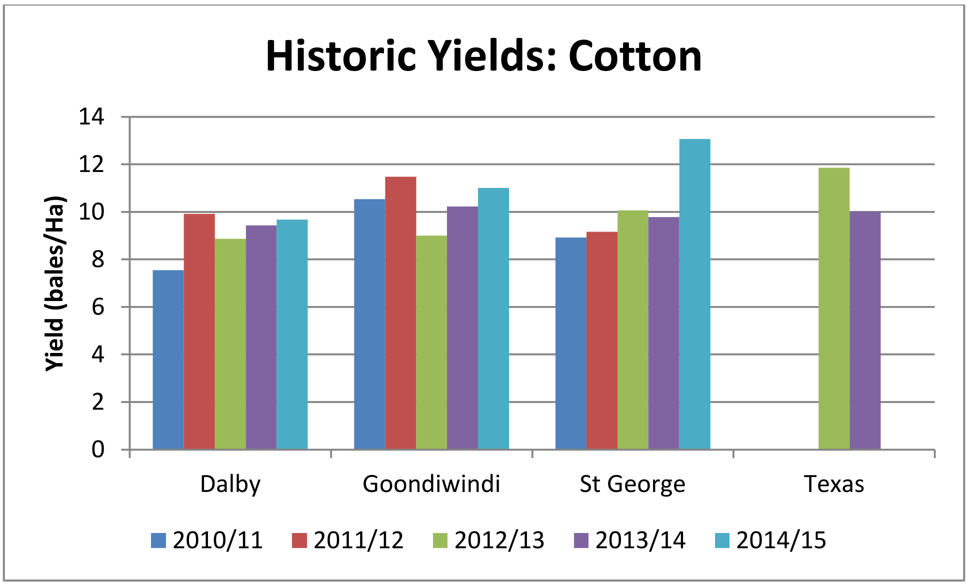

Figure 14 Historical cotton yields by region

Cotton growers have encountered the driest season across all regions since the commencement of the study in 2010. Minimal in-season rainfall was received by all growers, which has not been reflected in the yields this season (Figure 15). Goondiwindi growers applied the highest volume across the regions and received the most rainfall. However crop yields are dependent on the timing of application not simply the volume applied, also differing soils also contribute to higher yields with a reduced water application.

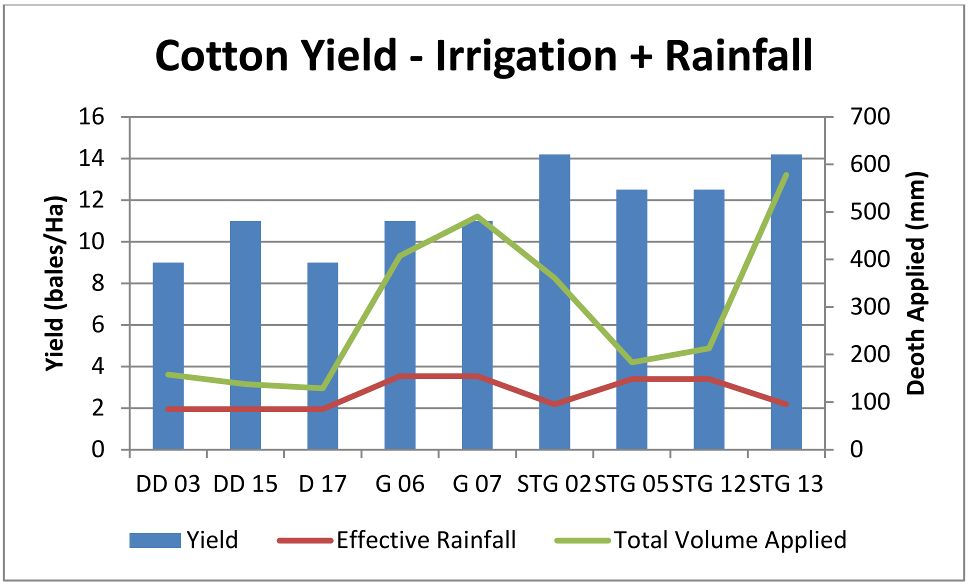

Figure 15 Cotton yields by region, against rainfall and irrigation

Yield weights are not comparable across the observed crops, as different crops produce different yield weights (Figure 16). In the case of the corn silage the entire foliage of the plant was accounted for in the yield.

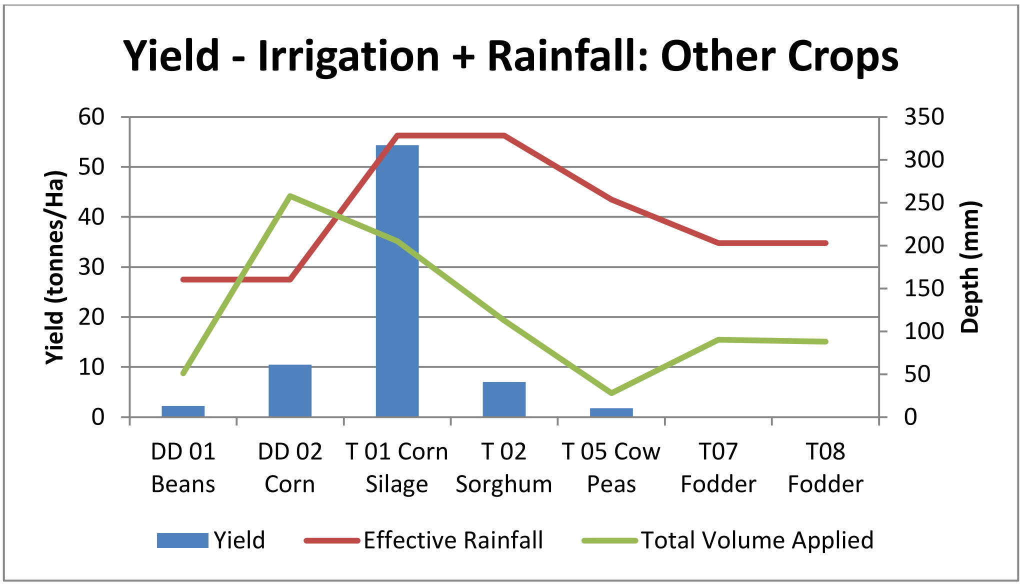

Figure 16 Other crops: yield by region – rainfall and irrigation applied

5.1.1 *Dalby*

The Dalby region had a great variety of crops grown in the 2014/15 season, with crops including cotton, mung beans and corn. The large variety in crop selection is attributed to a combination of commodity prices, projected gross margins and water availability.

Mung beans and corn were only grown in the Dalby region for this benchmarking data set, producing 2.20 and 10.5 (tonne/Ha) respectively. This is a significant increase from mung beans (1.63 tonnes/Ha) and corn (5.8 tonnes/Ha) grown in the Dalby region in the 2013/14 season.

The Dalby region exhibited the lowest cotton yields in the 2014/15 season, predominantly due to water limitation. However, the average yield slightly increased (0.24 bales/Ha) from the 2013/14 season.

5.1.2 *Goondiwindi*

Similarly to St George, only cotton was grown by participating farmers in this region. Cotton grown in the Goondiwindi group saw the least variability of the region, and the second highest average yield for the 2014/15 season, with an increase from 10.22 to 11.00 (bales/Ha).

5.1.3 *St George*

Cotton grown at St George showed a consistently high yield across the region, producing the highest individual yield in the basin. The same grower has achieved the highest yields for the 2013/14 and the 2014/15 seasons with 13.32 and 12.35 bales/Ha respectively. In a record dry season the benefits of adequate system capacity and a full supply of water meant that the crop was able to respond quickly to each irrigation event and with no water logging, achieving a yield of 14.20 bales/Ha in 2014/15.

Cotton was the only crop grown (participating in the study) in this region.

5.1.4 *Texas*

No cotton was grown in the Texas region this year; however it exhibited the greatest variety of crops grown in this study, growing corn silage, sorghum, Red Caloona Cowpea and fodder crops.

The irrigated fodder crops were grazed so no yield data was retrieved.

Corn silage (54.36 tonnes/Ha), sorghum (7.00 tonnes/Ha) and Red Caloona Cowpeas (1.79 tonnes/Ha) were only grown in the Texas region, making it difficult to infer meaningful benchmarking conclusions.

5.1.5 *Surface Irrigation*

The cotton crop surface irrigated in St George achieved similar yields to the other cotton crops in the St George region for the 2014/15 season, 14.2 bales/Ha.

5.2 Water Use Indices

Compared to previous seasons, cotton growers have encountered the driest season across all regions since the commencement of the study in 2010 (Figure 17). This decrease in rainfall has not however been reflected in an increase of irrigation water (Figure 18). Stricter water management has seen water use decrease and IWUI and GPWUI values increase.

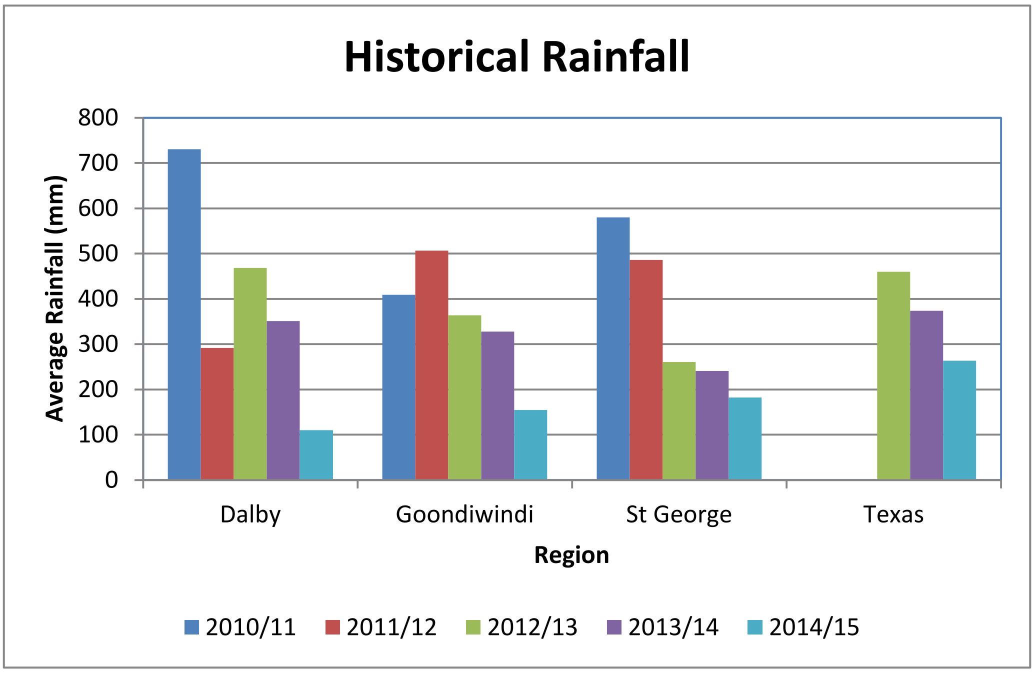

Figure 17 Historical Rainfall for all Regions

*No growers from Texas participated in the 2010/11 or 2011/12 studies.

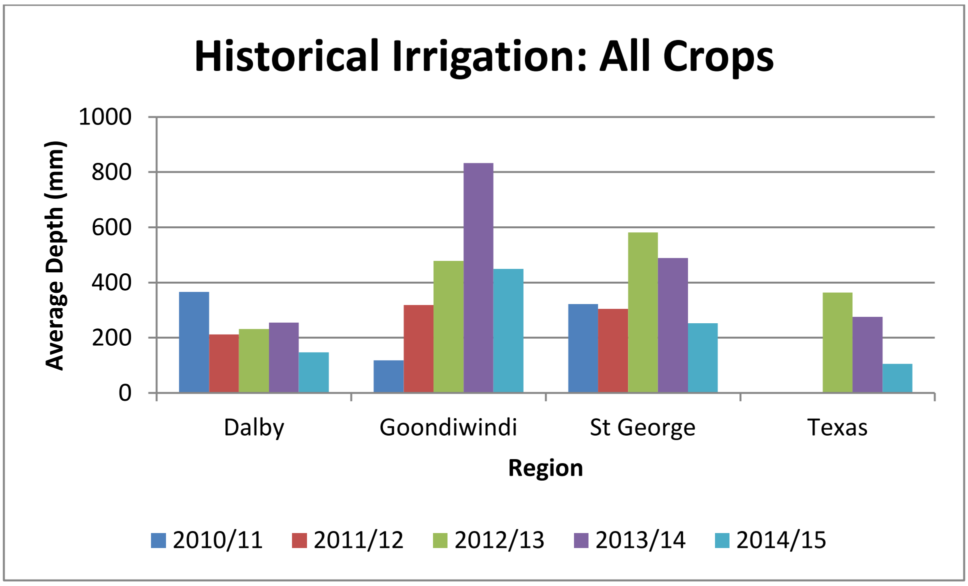

Figure 18 Historical Irrigation for all Regions

*No growers from Texas participated in the 2010/11 or 2011/12 studies.

Similarly to the yield analysis, this year's water use indices have been dominated by the effect of rainfall, or lack thereof. Compared to previous seasons, cotton growers have encountered the driest season across all regions since the commencement of the study in 2010. Cotton growers across the QMDB encountered increased IWUI and GPWUI values compared to the 2013/14 season as observed in Figure 19.

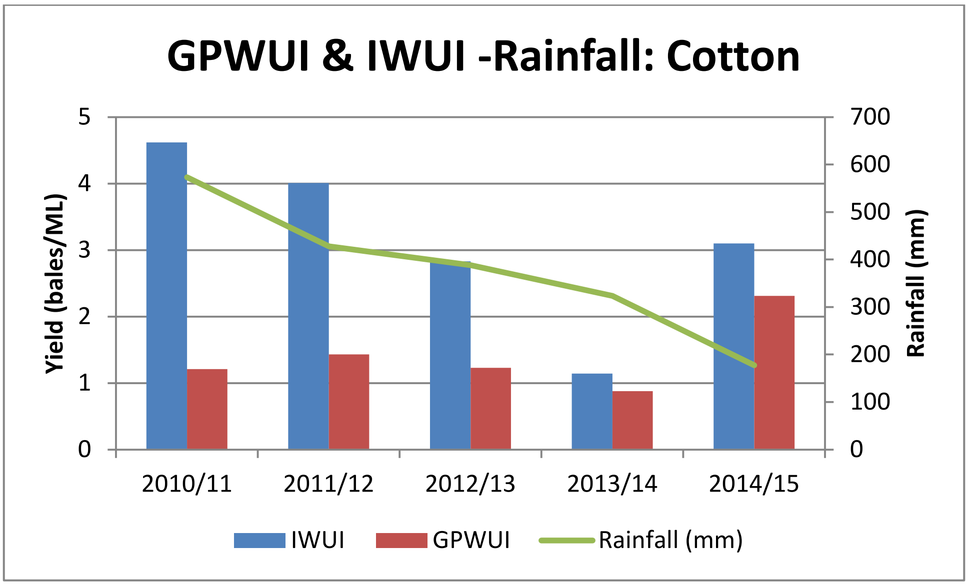

Figure 19 Historical average water use indices cotton

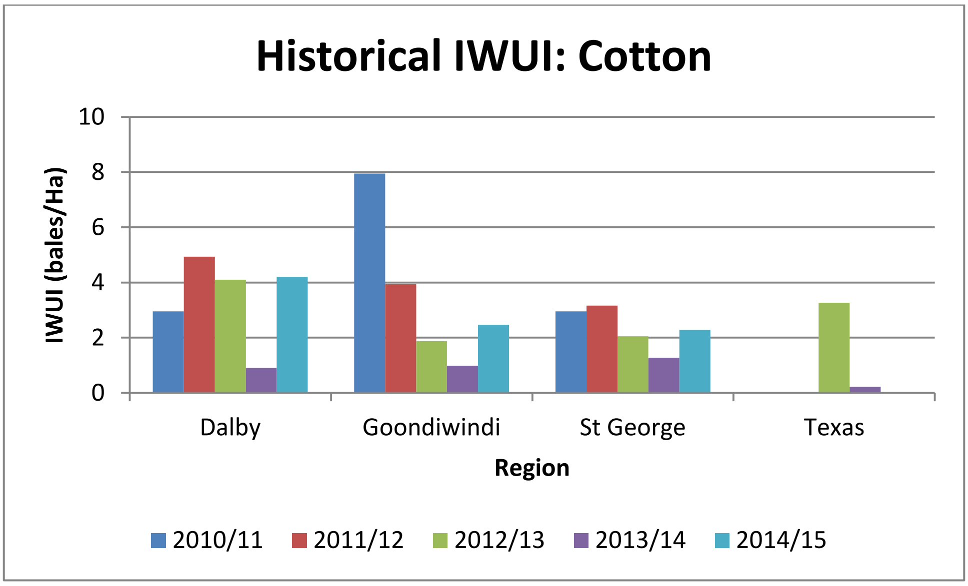

Figure 20 Historical average IWUI cotton

*Texas grew no cotton in the 20112/13 and 2013/14 season.

Generally the IWUI will be directly proportional to the effective rainfall. Figure 19 shows this has been the trend for the past four years. However the 2014/15 season has seen a divergence from this trend, with lower rainfall prompting higher IWUI and GPWUI values. This may be attributed to rainfall falling within the growing period when moisture was required. More significant may be the fact that growers did not receive substantial rainfall at the conclusion of the season which hinders production and harvest, as experienced in previous seasons.

The GPWUI is a measure of the crops or plants ability to convert all of the available water into produce. In many cases the GPWUI relates less directly to rainfall and more to plant stress. Figure 21, shows significant increases in GPWUI for the Dalby and St George regions and a slight drop for Goondiwindi growers. This may be attributed to growers adopting a more conservative approach this season due to extended water limitations. The reduced crop numbers and size of the crops meant, crops received optimum amounts of water, with swifter application, meaning the crop received water when it needed it.

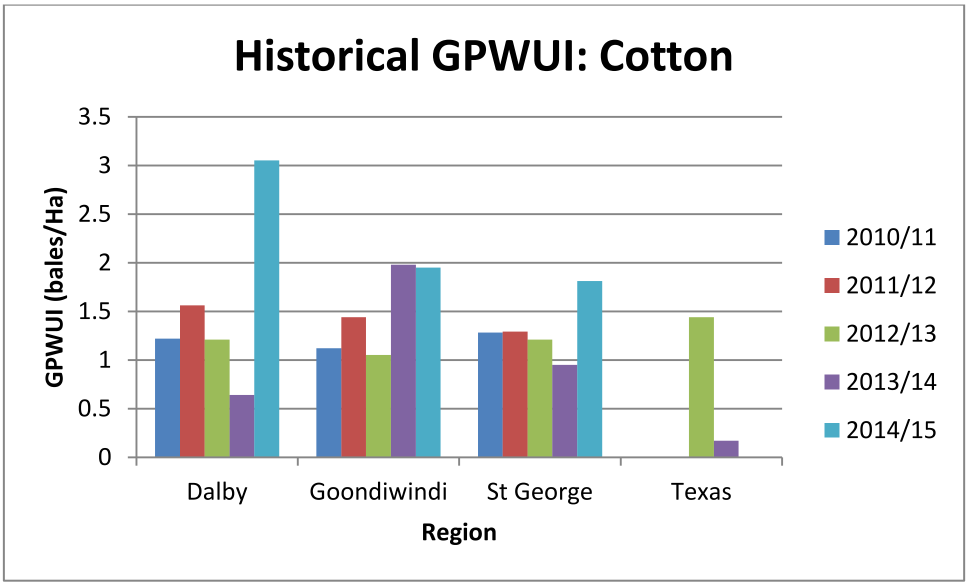

Figure 21 Historical average GPWUI cotton

*Texas grew no cotton in the 2010/11, 2011/12 and 2014/15 seasons.

5.2.1 *Dalby*

The Dalby region saw the equal highest participation rate across the QMDB for the 2014/15 season. In addition to cotton, the Dalby region produced mung beans and corn. The greatest water use variations were also observed in the Dalby region, 50.96mm on mung beans contrasted to 257.90mm on corn.

The Dalby region contained the three growers with the highest IWUIs for cotton, 3.78, 3.08 and 5.74 bales/ML respectively. Increasing 366 per cent from the 2013/14 season, showing an enormous improvement in irrigation efficiency. The mung beans and corn were relative to the other regions across the basin in their IWUIs.

The average GPWUI for cotton, (3.18 bales/ML) although the highest of any region in the 2014/15 season, exhibited the most variation amongst the participating growers (2.67 bales/ML). The two growers of other crops achieved slightly below average GPWUIs (tonnes/ha) in relation to the rest of the basin.

No other growers produced mung beans or corn in the QMDB so comparisons were unable to be made.

5.2.2 *Goondiwindi*

Cotton was the only crop produced by participating growers in the Goondiwindi region. The IWUI increased a substantial 152 per cent from the 2013/2014 season, yet the GPWUI, 1.95 bales/ML remained consistent with last season, decreasing only 1 per cent,.

The substantial average IWUI (2.70 bales/ML) increase and similar GPWUI value, is unique to the Goondiwindi region, this may be attributed to the significant decrease in the irrigation water applied, coupled with an increase in yield, meaning more efficient use of water and production processes. The IWUI and GPWUI were increased by reduced water use throughout the season and an increased yield at the conclusion of the season.

5.2.3 *St George*

St George saw a significant variation in irrigation applied to cotton, while maintaining consistent IWUIs for the 2014/15 season. The average IWUI for this season, 2.28 bales/ML was considerably higher, up 79 per cent compared to the 2013/14 season.

The GPWUIs similarly to the IWUIs were up from the 2013/14 season (90 per cent). The average IWUI relates to what is considered an average crop. St George achieved the lowest IWUI of the three participating regions, 1.77 bales/ML which planted cotton despite its significant increase compared to last year, where it achieved the highest IWUI average.

In terms of historical values and grower feedback, a GPWUI greater than 1.2 bales/ML indicates an ideal growing season. A GPWUI of between 1 and 1.2 bales/ML has tended to be an average season and below 1 bales/ML indicates that plant stress has been experienced. The St George region achieved an average GPWUI of 1.81 bales/ML, indicating the plants received ideal amounts of water for the prevailing conditions.

Participating growers only produced cotton in the St George region in the 2014/15 season.

5.2.4 *Texas*

There was no cotton grown in the Texas region in the 2014/15 season, however growers produced the widest variety of other crops; corn silage, sorghum, Red Caloona Cowpeas, and fodder crops. The diversity in crops provided significant variations in IWUI and GPWUI achieved. Additionally yield data was not gathered for the fodder crops, therefore the IWUI and GPWUI values could not be calculated.

The corn produced exhibited significantly greater IWUI and GPWUI than other crops as it was used as silage, achieving greater yields; this brought the average of the region up. The sorghum and cowpeas achieved close to average IWUI (3.48 and 2.44 bales/ML respectively) and GPWUI (1.32 and 0.55 bales/ML respectively) values for the Texas region in the 2014/15 season.

5.2.5 *Surface Irrigation*

The water use indices are extremely important, as the surface irrigated crop achieved the equal highest yield in the study group, yet required significantly more water to achieve it. An IWUI of 1.44 bales/ML and GPWUI of 1.29 bales/ML show that surface irrigation is not as effective as CP and LM machines in applying water.

5.3 Energy Consumption

5.3.1 *Centre Pivot and Lateral Move Machines*

Figure 22 and Figure 23 illustrate the fluctuating energy consumption from season to season, dependant on climatic factors and irrigation practices. The 2014/15 season saw a marked reduction in energy use per bale and energy use per hectare, as irrigation amounts decreased. These reduced results was not aided by climatic factors, as study low rainfalls increased dependency on irrigation, smaller crop sizes allowed for more efficient water management and reduced energy wastage.

Dalby exhibited the most significant energy per bale reduction, decreasing 73 per cent from the 2013/14 season. Goondiwindi saw the greatest reduction in energy use per hectare with a 40 per cent reduction.

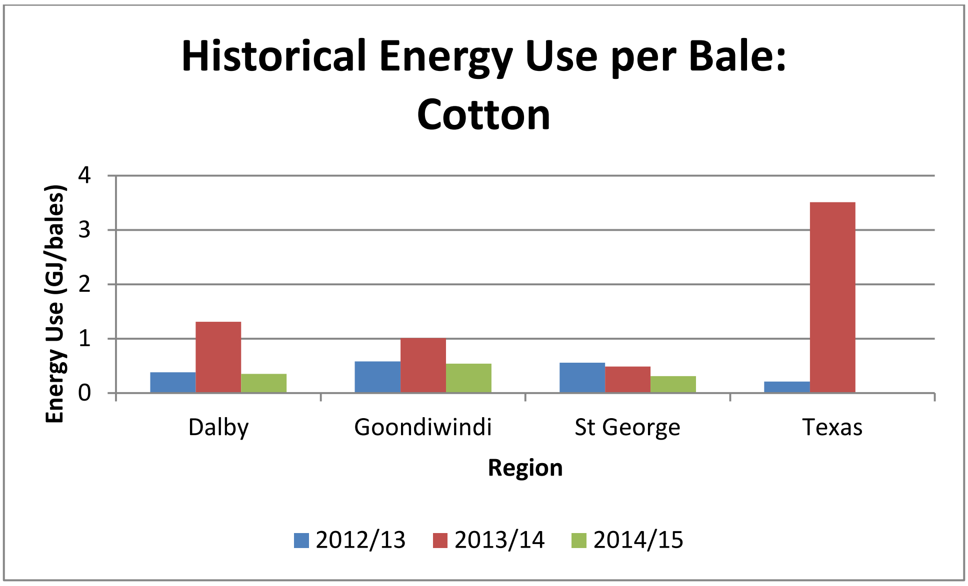

Figure 22 Cotton historical energy use based on bales

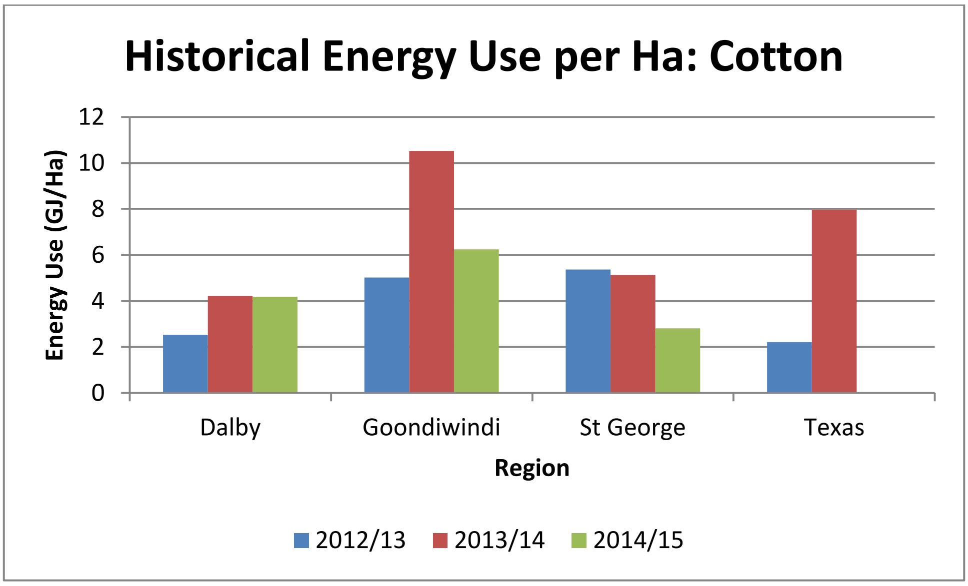

Figure 23 Cotton historical energy use based on area

Australia has a highly mechanised agriculture sector, with energy consumption (diesel and electricity) representing a major cost for growers. The total energy inputs to agriculture operations are significantly influenced by the management and operation methods adopted (Baillie, 2011).

Figure 24 shows that in the 2014/15 season irrigation water energy use accounted for 44 per cent of total energy costs, while harvesting operations account for approximately 20 per cent of overall energy use, with the remaining 36 per cent being consumed by tillage, planting and in-crop activities.

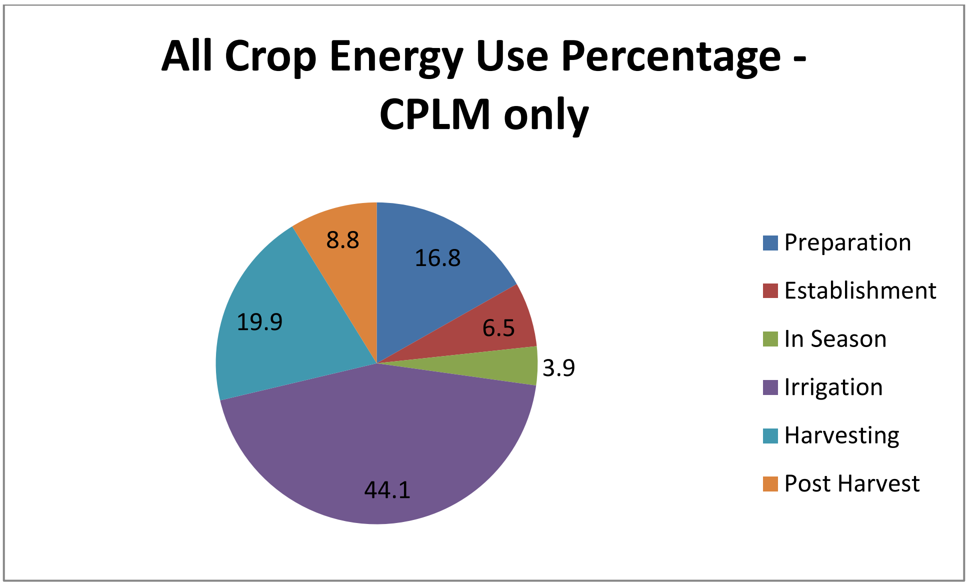

Figure 24 Energy use percentage for all crops – CPLM only

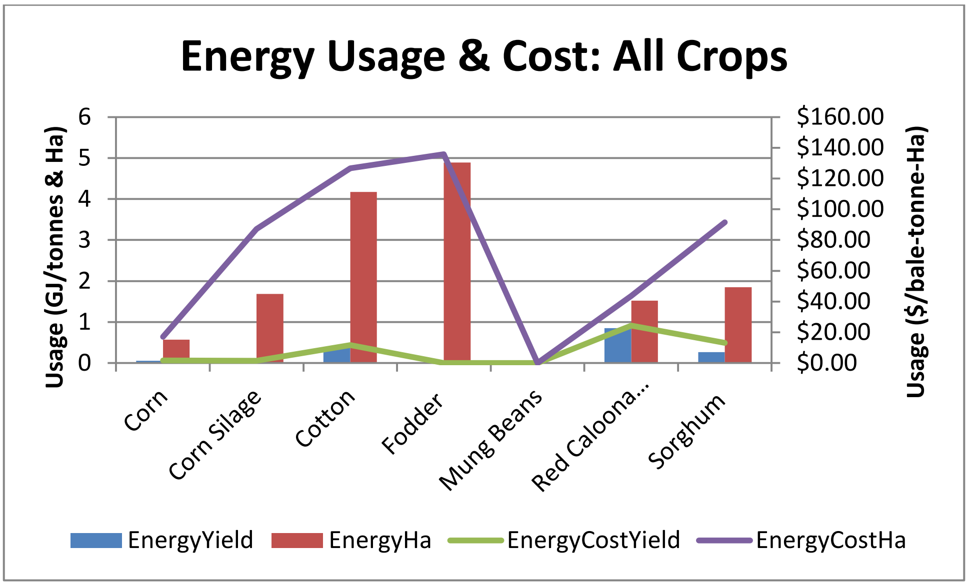

Figure 25 Average in-field crop energy use and energy cost

Figure 25 illustrates that the energy requirements per hectare to produce the average cotton crop is substantially greater than other crops (excluding fodder crops). Fodder crops top the energy usage per hectare (4.89 GJ/Ha), closely followed by cotton (4.17 GJ/Ha) and finally there is a significant gap to sorghum (1.85 GJ/Ha).

The energy requirement per yield is greatest for Red Caloona Cowpeas (0.85 GJ/tonne), followed by cotton (0.38 GJ/bale) then sorghum (0.26 GJ/tonne). Corn silage has the lowest energy requirements at 0.03 Gigajoules to produce a tonne.

No Energy data was retrieved for mung beans.

The corresponding costs are proportionate to the amount of energy consumed as illustrated in Figure 25.

Fodder crops were grazed, not harvested, therefore no quantitative data could be gathered. While they required a high amount of energy, being marginally higher than cotton, as no yield data was gathered no correlations may be drawn between energy inputs and crop outputs.

Cotton is an extremely high intensity crop. Therefore it is understandable that it would have high energy requirements. It also requires more tillage and higher irrigation amounts compared to other crops. The greatest contributor to the energy consumption is irrigation, followed by preparation and harvest. This coupled with the lowest tonnage of crop produced creates high energy cost per unit of production.

5.3.2 *Surface Irrigation*

The energy requirement per bale for surface irrigated cotton is relatively low, 0.35 GJ/bale. Reduced energy consumption is observed, however this comes at the cost of efficiency, as represented in the low IWUI and GPWUI results.

In the 2012/13 Healthy Headwater Report two surface irrigation controls were observed. On average the surface irrigation fields used approximately $4 to $5/bale less energy than the CP and LM machines, which is comparative to the $3 to $6 less observed in the 2014/15 season. The change in energy costs by the overhead system would appear to be small enough to be covered in savings from labour and other cost savings the machines bring. Increased opportunity for double cropping is a further advantage to offset the additional energy costs of CPs and LMs.

6. Conclusion

The 2014/15, and final season experienced a long dry summer with marginal rains falling immediately prior to harvest. The strong reliance on water tested the management skills of the growers and the design capabilities of the CPLM machines. Any flaws were reflected in the data.

Despite the harsh conditions on man and machine, most growers were able to produce reasonable crops. The profitability of the crops for the 2014/15 season is significantly higher than the 2013/14 season as energy use requirements of crop production decreased.

This season saw less variety of crops and fewer growers producing them compared to previous seasons. This can be attributed to water limitations and climatic constraints.

Considering the water use indices, the IWUI has shown variability for all crops in the season as it depends directly on yield and irrigation, and not on rainfall. As the seasonal rainfall affects irrigation demand and yield, some variability is expected. Consistency in GPWUI values has emerged for specific crops over previous seasons and showed an increase in the 2014/2015 season. This is mainly due to smaller crop sizes, which enables better management and water to be delivered precisely when and where it is required to produce optimum yields.

The energy benchmarking component has provided useful data for the project and its participants. Energy use has been divided into various field operations of preparation, establishment, in-season, irrigation, harvest and post-harvest. Energy use and cost data, used in conjunction with commodity prices and market information, will enable growers to make economic decisions regarding which crop to plant based on the associated returns and energy costs. The energy data has revealed the variance component irrigation contributes to various crops. Irrigation energy components vary from approximately 13 to 81 per cent of the total in-field energy costs to produce a crop, depending on the crop type.

Historically, growers have had a perception that irrigation consumes a lot of energy to grow a crop. The energy benchmarking results from this season show that this is correct in most instances; however, in other cases the irrigation energy component is relatively low. This was mainly observed in crops other than cotton where the energy input was relatively low compared to cotton. The results from each season continue to enrich the knowledge available to growers and stake holders regarding the decisions made in producing crops in irrigated agriculture.

Centre-Pivot and Lateral Move machine accuracy of application is superior to surface irrigation/siphon techniques. CPLM machines can apply small amounts of water at each application, allowing for more frequent irrigations to meet crop water demand, providing a more direct and accurate water application. These systems can reduce labour requirements, but on-going energy costs are higher when compared to surface irrigation. Surface irrigation is well suited to cracking clay soils; which fully optimise surface irrigation techniques achieving performance levels similar to CPLM machines, requiring less energy. Higher water use indices are observed with surface irrigation/siphon as application rate accuracy is inferior when compared to CPLM machine application.

7. Recommendations

This report provides irrigation benchmarking data that is site specific and is influenced by variables that are outside the scope of this project. Due to this fact it is not the best practice to make recommendations of farming practices based on the results achieved. Continuous improvement will enable this project to become a credible guide for growers in the QMDB.

Due to the availability and convenience of the internet based videos, the workshop component of the project has progressed to an online video clip prepared by WaterBiz staff. This has made the workshop and results summary from the season more readily available to interested stakeholders within the QMDB. In addition, WaterBiz staff are available either in person or by phone to work through the data with each individual grower to enable the process of benchmarking to be undertaken.

The uploaded video may be found at: https://youtu.be/nn-uFmaQKNM

8. References

Baillie, C. (2011), On-Farm Energy Use, in Australian Cotton Production Manual - 2011, Cotton CRC Development and Delivery Team & Australian Cotton Researchers, pp. 23-25.

Chen, G. and Baillie, C. (2007), Development of Energy/Calc – A Tool to Assess Cotton On-Farm Energy Uses, National Centre for Engineering in Agriculture Publication 10002565/1, USQ, Toowoomba

9. Appendices

Appendix A. Grower Energy Benchmarking Interview Form

	Grower					Date		
	Contact							
	Farm							
	Field							
	Soil Type							
	Crop			Planted Area				
	Plant Date			Maturity Date				
	Yield		Bales		Tonne			
	Plant Available Water	Initial		Final				
	Operations	1	2	3	4	5	6	7
	Stage							
	Process							
	Operation							
	Practice							
	Area Covered							
	Times run							
Tractor	**Diesel per op (L)**							
	Diesel per Ha (L/Ha)							
	Power (kW / hp)							
	Load (%)							
	Speed (Km/h)							
	Width (m)							
	Work Rate (%)							
Pump	***Source Per Op (L / kWh)***							
		Diesel / Electric	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*
	Water per Ha (ML/Ha)							
	Source per Hour (L/h / kWh)							
		Diesel / Electric	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*
	Flow Rate (L/s)							
	Head (m)							
	Pump Efficientcy (%)							
	Hours per Shift							
	Area per Shift (Ha)							
Motor	***Source Per Op (L / kWh)***							
		Diesel / Electric	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*
	Sourceper Hour (L/h / kWh)							
		Diesel / Electric	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*	*Diesel / Electric*
	Power (kW / hp)							
	Load (%)							
	Working Time (h/y)							
	Hours per Day							
	Days per Week							
	Months							
	Weeks							
Vehicle	***Diesel per Op (L)***							
	Distance per Year (km/y)							
	per 100km (L/100km)							

Grower		Date	
Contact			
Farm			
Field			

CP / LM Information

Engine	Engine Make	
	Engine Model	
	Engine Age	
	Season Engine Hours	
	Engine kW Rating	
	Engine RPM	
Pump	Pump Make	
	Pump Model	
	Pump Age	
	Pump kW Rating	
	Pump RPM	
	Pump TDH	
	Pump Flow Rate	
CP / LM	Machine Make	
	Machine Model	
	Machine Age	
	Machine kW Rating	
	Machine RPM	
	Machine Length	
	Sprinkler Type	
	Water Source	
	Water Meter Reading Start	
	Water Meter Reading End	
	Standard Application Amount	
	Number of Applications	
	Runoff Occurred	
	Soil Probe Reading	
	Rainfall Chart	
	Varitey	
	Energy Consumption	
	Previous Cropping History	