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making every drop count

CRDC1606 Technical Research Report

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Grower Led Irrigation System Comparison in The Gwydir Valley

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Executive Summary

The 2015-2016 season was the fourth year where the Gwydir Valley Irrigator Association (GVIA) and Sundown Pastoral Company have managed the Keytah Irrigation System Comparison trial. This is a unique project which is run by growers with the specific intention to collect relevant commercial data. This data is designed to provide cotton growers greater insight into the four different systems under review.

During the project the Gross Production Water Use Index (GPWUI) was calculated for each of the systems. There has been quite a bit of variation in these figures over the four years. This suggests that the efficiency of the systems can be significantly impacted by other variables, most especially the climatic conditions. Each of the four seasons has been very different climatically, from cool and wet, to hot and dry, with one season where there was no irrigation or rainfall to finish the crop. The strongest performing system when compared using the GPWUI was the lateral move, while the siphon produced the lowest average index.

The four seasons of research have shown the lateral move to have the highest average yield and gross production water use index. The Furrow siphon has produced the most consistent yield. The bankless channel had the second highest average yield and the drip the lowest average yield.

The siphon field had significantly higher labour requirements, but along with the bankless channel it had very low operating energy costs. In contrast both the pressurised systems, the lateral and drip, had high operating energy costs. These two systems also had high capital setup costs. When compared on an operation and maintenance basis, the Bankless Channel had the lowest total operating costs and the lowest operating, maintenance and ownership costs. This coupled with favourable yield and GPWUI results makes it a strong contender in many situations. Bankless channel however, may not be practical in some regions because of the earth works required to develop fields.

The project has shown that although important, water alone is not the only driver growers must consider when making decisions on irrigation systems. The reliability and the potential yield achievable under each of the systems are key considerations for growers. They must also look at the consistency of performance, capital investment needed and the resources of labour and energy when looking at changing irrigation systems.

Background

The GVIA in partnership with Sundown Pastoral Company initiated a grower led irrigation project in 2008. It was initially funded from 2008-2012 under the Raising National Water Standards Program by the National Water Commission. Additional funding from the CRDC enabled the project to continue from 2012-2015.

At the start of this project, the Keytah system comparison trial had a total of three years of data; 2009-2010, 2011-2012 and 2013-2014. The addition of a fourth year of data has increase grower confidence in the data, enabling them to make more well informed investment decisions.

The trial has been well received by growers and industry since its inception. This data has continually added to grower's capacity, knowledge and understanding of the alternative irrigation systems, providing growers greater insight into the requirements and resource implications of alternative irrigation systems for cotton production.

Many growers have altered their irrigation systems following a visit to Keytah or from discussions with people involved in the project, fifty percent of growers attending the 2014 Keytah field day indicating they intended to adopt changes to their operations using information from the project. A grower survey from 2012 confirmed that growers wanted a set of long term data to utilise in their decision making with regard irrigation system choices. This desire remains relevant with, 85 percent of growers surveyed at the 2014 field day wanting the project to continue.

As the Keytah trial is run every second season, the GVIA compliment it with additional trials focussing on optimising one of the four systems being compared. This helps to maintain momentum for the GVIA and growers, but also provides an opportunity for the project to be flexible in meeting grower needs. These trials include; Telleraga Pipe-through-bank (2008), Redbank Row Configuration and Water Regime (2010-2011), the Row Configuration Optimisation (2014-2015).

The GVIA project is a grower-led initiative, focused on commercial reality. It will complement existing data and enable extensive collaboration with industry and research partners.

Methods

The project includes two trials to be run over two seasons:

1. 2015/2016: Keytah system comparison trial for sub surface drip, lateral move, furrow siphon and bankless channel, and
2. 2016/2017: A second system comparison trial at an alternative site, to increase confidence in the data whilst optimising production, without necessarily being adjacent to each other.

Although there are two separate trials over two seasons, similar methodologies will be utilised at each trial to measure, monitor and communicate the results and benefits of each of the trials.

Methodology:

- Establish a project steering committee to over-see the grower-led approach and technical aspects of the trial;
- Assess soil moisture prior to planting and post picking using an EM38 and Soil cores;

- Utilise capacitance probes, head ditch and tail-water meters, and storage meters to collect raw water-use data;
- Utilise other forms of water-use efficiency assessments such as IrriSat;
- Record water applied and rainfall throughout the season;
- Maintain records of labour and energy costs for the systems;
- Analyse results between the systems; drip, lateral, furrow and bankless, and across the different water-use-efficiency techniques; hard data, satellite technology or modelling, and incorporate into previous year's results;
- Evaluate the resource requirements and management considerations for each of the systems; and
- Evaluate project's ability to achieve outcomes through surveys at field days, presentations and at industry events.
- Develop a tailored communication strategy including;
    - the timing of field days or workshops including conferences;
    - opportunities to deliver results to the industry;
    - social media and internet promotion activities;
    - update promotional information packs with new results and new flyers;

Results

The system comparison trial was completed in April 2016, with ginning during May 2016.

Soil Moisture

EM38 and soil cores were taken to assess the starting and finishing soil moisture levels. The soil cores were collected as per guidelines from QDPI. The intention was to use this data to calibrate the EM38. Unfortunately, it was not possible to calibrate the EM38, so only soil core information has been utilised.

Table 1: Soil Moisture 2015-2016

System	Pre-plant 0-80cm	Post-picking 0-80cm	Used Reserves
Siphon Furrow	214.2	229.8	-15.6
Lateral Move	259.6	150.8	108.8
Subsurface Drip	257.1	213.5	43.7
Bankless Channel	246.3	229.5	16.8

Crop Management

Table 2: Crop Management activities 2015-2016

Activity	Siphon Furrow	Lateral Move	Subsurface Drip	Bankless Channel
Soil core and EM38	19th October 2015	19th October 2015	19th October 2015	19th October 2015
Pre-Irrigation		8th October 2015		
Variety	Sicot 74BRF			

Planting	20th October 2015	20th October 2015	20th October 2015	19th October 2015
Watered-up	23rd October 2015	23rd October 2015	23rd October 2015	20th October 2015
First Defoliation	24th March 2016	29th March 2016	29th March 2016	29th March 2016
Picking	13th April 2016	19th April 2016	19th April 2016	18th April 2016
Soil core and EM38	26th April 2016	26th April 2016	26th April 2016	26th April 2016

Irrigation Water

In 2015-2016 the lateral move received 60mm pre-irrigation. All other systems were watered up.

The last irrigation for all systems was in late February 2016. All systems would have benefited from the application of further irrigation water or in-crop rainfall, neither of which occurred.

Table 3: Irrigation Water Applied 2015-2016

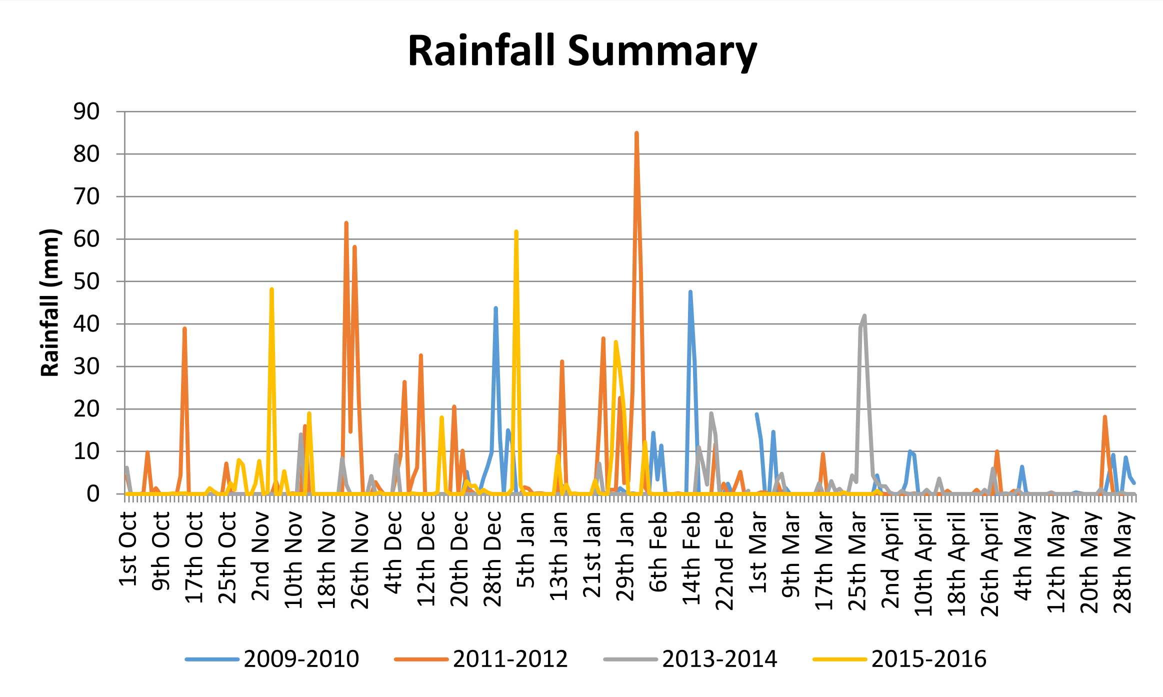
System	Date of Last Irrigation	Number of Irrigation	ML/ha
Siphon Furrow	19th February 2016	6	6.91
Lateral Move	27th February 2016	12 + 1 pre-irrigation	4.85
Subsurface Drip	23rd February 2016	North 10 South 11	5.57 5.58
Bankless Channel	21st February 2016	5	6.06

Climatic Data

The trial has been run over four seasons each with noticeably different climatic conditions. 2009-2010 was a typical season - 2011-2012 was wet and overcast with two flood events, 2013-2014 was hot and dry with very little in crop rainfall, while in 2015-2016 the season was again quite typical, but there was not sufficient irrigation water to fully irrigate the trial.

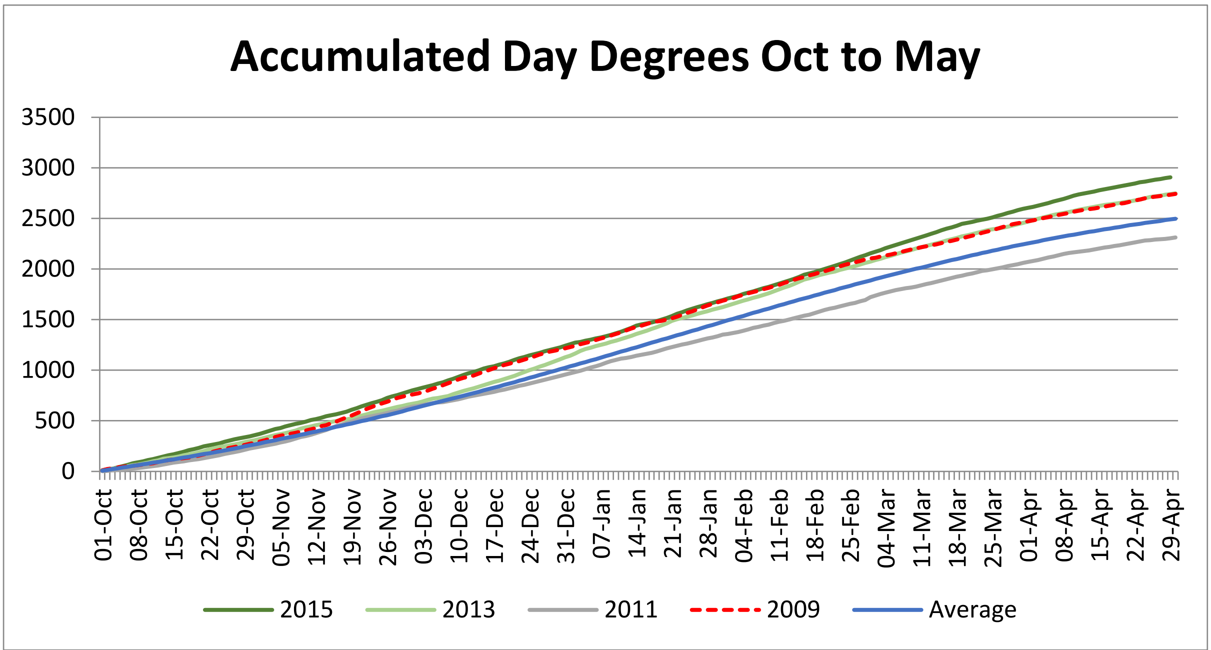
The trial site received a total of 319mm of rainfall from October 2015 to April 2016. The daily rainfall data (figure 1), indicates that there were only six effective rainfall evens during the season where more than 10mm of rain was received (79% effective rainfall). There was no rainfall during March and April and no irrigation after February. The furrow siphon received its last irrigation on the 19th February, the bankless channel on the 21st of February, the subsurface drip in the 23rd February and the lateral move on the 27th February as shown in table 3 above.

Figure 1: Rainfall



The lack of sufficient irrigation water and an accumulated day degrees which was slightly above the long-term average as shown in figure 2 following, may have impacted the performance of each of the systems in the 2015 -2016 season.

Figure 2: Accumulative Day Degrees



Yield

The results for the 2015-2016 season are shown in figure 3 below. Despite receiving no irrigation or rainfall after mid-February the trail has yielded well. The strongest yield performer this season was the bankless channel.

The siphon field cut-out earlier than the other fields and received its first defoliation on the 24th March 2016, the remainder of the trial was first defoliated on the 29th March 2016.

Picking in the siphon field started 19 days after first defoliation on the 13th of April, while the bankless was picked on the 18th of April (21 days after first defoliation) and the remaining fields picked on the 19th April (22 days after first defoliation).

Figure 3 following shows that the yield for the bankless channel in 2015-2016 was 14.6 bales/ha, noticeable higher than that for the other three systems, which ranged from 12.2 to 12.8 bales/ha. When compared on a bale per mega litre basis the lateral, bankless and the drip were all strong performers at 2.61, 2.41 and 2.30 bales per mega litre respectively.

Figure 3: Yield and Irrigation Water Use Efficiency 2015-2016

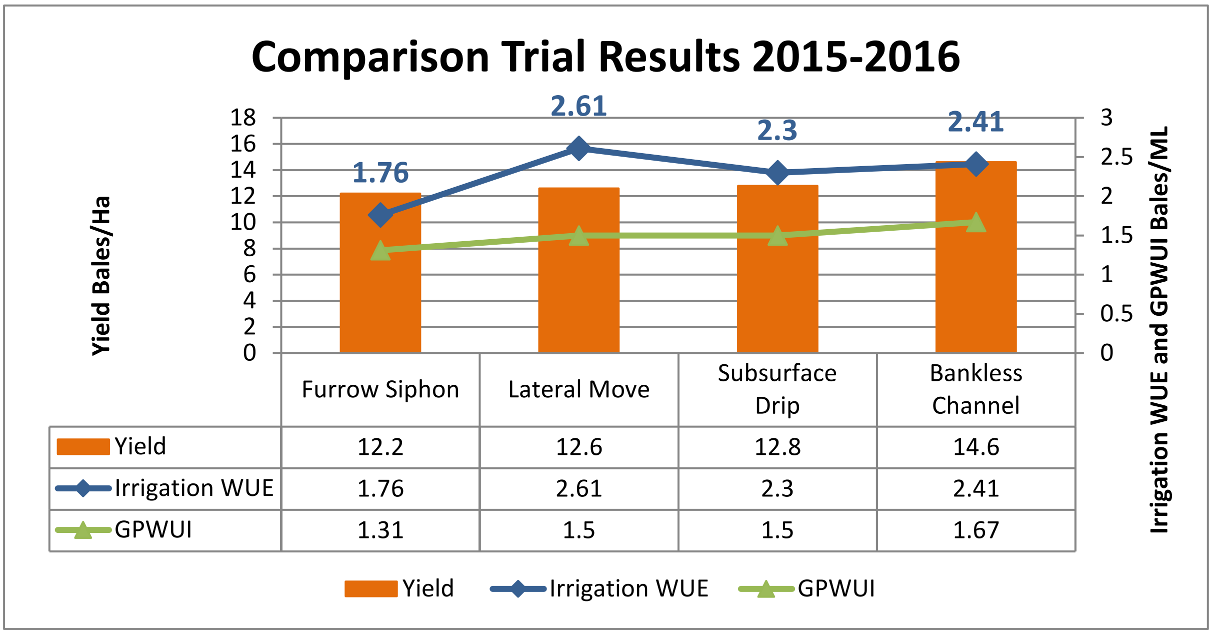
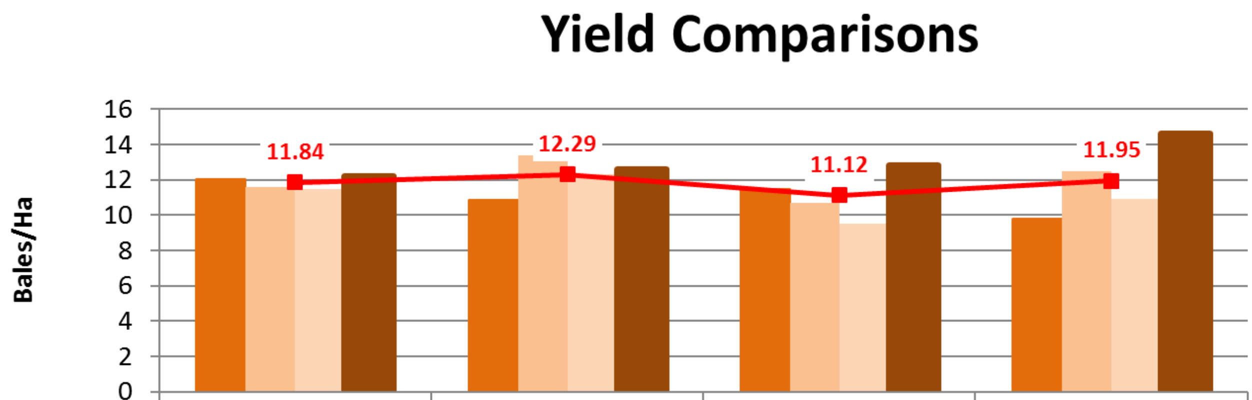


Figure 4 following combines the yield data for the four years of the trial. When combined, the lateral move is found to have the highest average yield over the four seasons. It is however important to note that there were significant establishment issues with the bankless channel in the 2009-2010 season which resulted in a significantly lower yield than expected.

Despite running out of water in the 2015-2016 season all systems produced their highest yield for the four years. The system with the most consistent yield over the four years has been the furrow siphon system, although it appears to have been more impacted by the lack of a final irrigation in 2015-2016.

Figure 4: Yield Comparison over four seasons

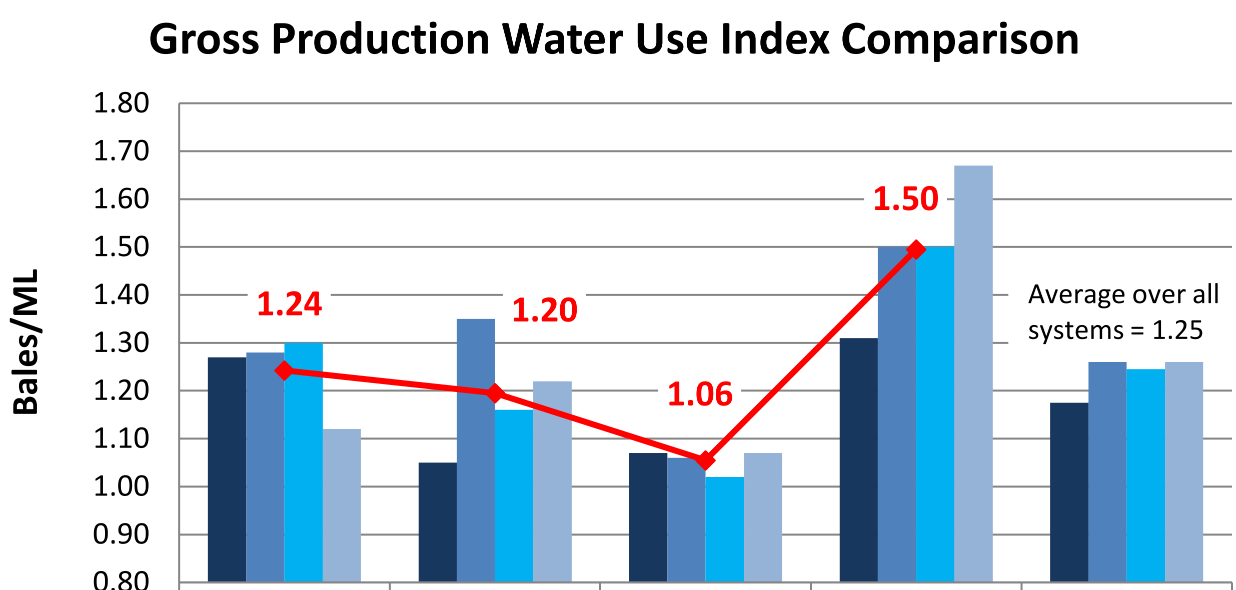


	Furrow Siphon	Lateral Move	Subsurface Drip	Bankless Channel
2009-2010	12.06	10.86	11.47	9.8
2011-2012	11.6	13.4	10.7	12.5
2013-2014	11.5	12.3	9.5	10.9
2015-2016	12.20	12.60	12.80	14.60
Average	11.84	12.29	11.12	11.95

2009-2010 2011-2012 2013-2014 2015-2016 Average

The variation in yield during the trial was less than the variation seen in water use efficiency and GPWUI between seasons.

Figure 5: Gross Production Water Use Index



	2009-2010	2011-2012	2013-2014	2015-2016	Average
Furrow	1.27	1.05	1.07	1.31	1.18
Lateral	1.28	1.35	1.06	1.50	1.30
Drip	1.30	1.16	1.02	1.50	1.25
Bankless	1.12	1.22	1.07	1.67	1.27
Average	1.24	1.20	1.06	1.50	

The Gross Production Water Use Index (GPWUI) is used to enable a comparison of the systems across years and across farms. It combines total seasonal water use (irrigation water and rainfall) with soil moisture and yield. The higher the GPWUI the more water efficient the crop.

Figure 5 above shows the GPWUI over the four years of the trial. It demonstrates that each season has been different. This may be a result of the variable climatic conditions in each season. The 2009-2010 season was a typical season, while 2011-2012 was very wet and cloudy with two flood events. 2013-2014 was a warm to hot season with almost no rainfall and the final year irrigation ceased in February and there was no rainfall for the last three months of the season.

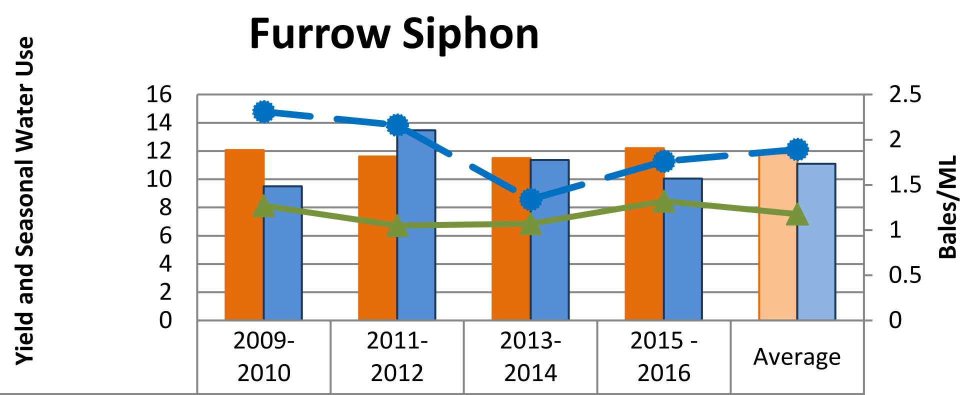
Individual system results

Furrow Siphon

The system comparison trial has confirmed that the Furrow siphon system does produce consistent yield and a reasonable irrigation water use efficiency and Gross Production Water Use Index which is comparable to the other systems. The average yield was 11.84 bales per hectare, an irrigation water use efficiency of 1.89 bales per mega litre and a GPWUI of 1.18 bales per mega litre.

During the floods of 2011-2012 there was some waterlogging in the siphon field as a result of very heavy rainfall events. This potentially impacted the yield and the water use efficency of the system. In contrast it produced the strongest GPWUI (along with the bankless system) in the hot dry 2013-2014 season.

Figure 6: Furrow Siphon System



	2009-2010	2011-2012	2013-2014	2015 - 2016	Average
Yield (Bales/Ha)	12.06	11.6	11.5	12.2	11.84
Seasonal Water (ML/Ha)	9.5	13.46	11.37	10.04	11.09
Irrigation WUE Bales/ML	2.31	2.16	1.34	1.76	1.89
GPWUI (Bales/ML)	1.27	1.05	1.07	1.32	1.18

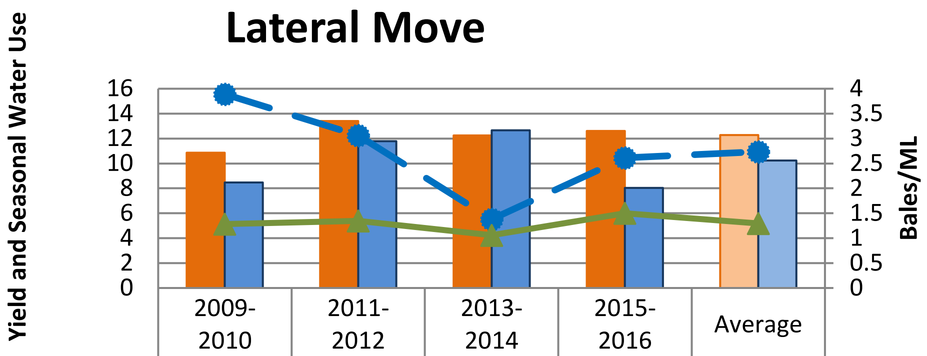
Lateral Move

The lateral move results shown in figure 7 below show that this system has the potential to produce the highest average yield, irrigation water use efficiency and GPWUI.

It does however suggest that in a hot dry season as seen in 2013-2014 that the GPWUI has the potential to be compromised. The lateral produced an average yield of 12.28 bales per hectare, an irrigation water use efficiency of 2.74 bales per mega litre and a GPWUI of 1.30 bales per mega litre.

In contrast the lateral system is well suited to wet seasons where there were many rainfall events. It is easier to manage irrigation volumes with this system under these conditions. There was no water logging in the lateral in the 2011-2012 season.

Figure 7: Lateral Move System



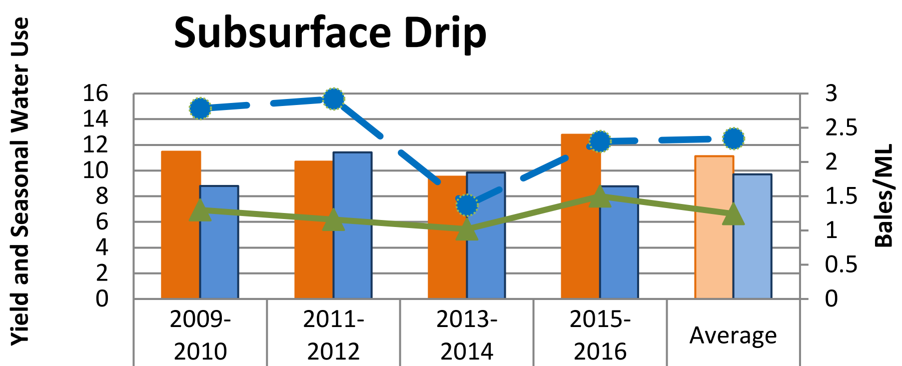
	2009-2010	2011-2012	2013-2014	2015-2016	Average
Yield (Bales/Ha)	10.86	13.4	12.26	12.6	12.28
Seasonal Water (ML/Ha)	8.46	11.79	12.65	8.04	10.24
Irrigation WUE Bales/ML	3.89	3.06	1.38	2.61	2.74
GPWUI (Bales/ML)	1.28	1.35	1.06	1.5	1.30

Subsurface Drip

Figure 8 following shows the findings for the assessment of the subsurface drip system. During the four years of the trial it has struggled to produce any consistency in yield, but has achieved good irrigation water use efficiency results.

The performance of the drip was expected to be stronger in the wet 2011-2012 season, but there was some difficulty in removing runoff following several heavy rain events. This caused some waterlogging which may have affected the result.

Figure 8: Subsurface Drip System



	2009-2010	2011-2012	2013-2014	2015-2016	Average
Yield (Bales/Ha)	11.47	10.7	9.52	12.8	11.12
Seasonal Water (ML/Ha)	8.8	11.42	9.84	8.77	9.71
Irrigation WUE Bales/ML	2.78	2.92	1.37	2.3	2.34
GPWUI (Bales/ML)	1.3	1.16	1.02	1.5	1.25

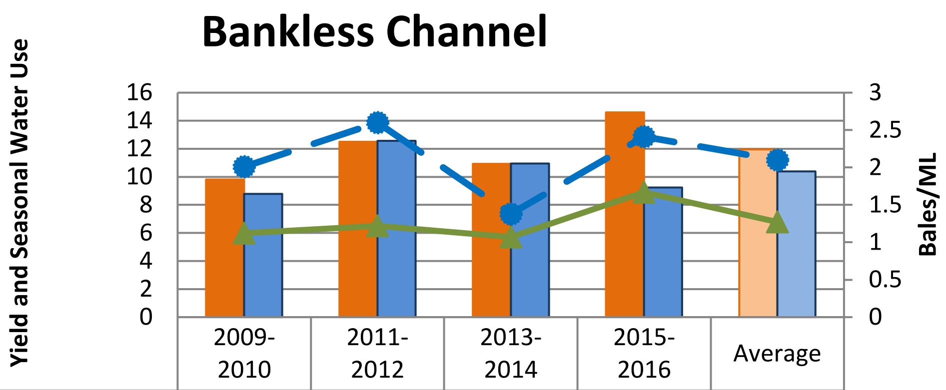
Bankless Channel

The bankless channel system results shown in figure 9 demonstrate that this system shows considerable promise. This is especially so if it is considered that the 2009-2010 season saw some significant establishment issues due to late field development. The yield achieved by the bankless channel system in 2009 – 2010 is believed to be low because of these establishment issues. The reduced yield would have influenced both the irrigation WUE and the GPWUI.

The system does not seem to have been impacted by any water logging in the wet 2011-2012 season. It produced the strongest GPWUI (along with the Siphon system) in the hot dry 2013-2014 season.

The yield result in 2015-2016 is significantly higher than all other systems, this may be the result of some other variable such as nutrition.

Figure 9: Bankless Channel System



	2009-2010	2011-2012	2013-2014	2015-2016	Average
Yield (Bales/Ha)	9.8	12.5	10.93	14.6	11.96
Seasonal Water (ML/Ha)	8.78	12.57	10.95	9.25	10.39
Irrigation WUE Bales/ML	2.01	2.6	1.38	2.41	2.10
GPWUI (Bales/ML)	1.12	1.22	1.07	1.67	1.27

Operational Data

Over the four years of the trial, data associated with the operation of each of the systems has been compiled. This is displayed in table 4 below. It includes labour, energy, capital and depreciation costs of each of the systems.

As expected, the labour requirement of the siphon system is very high compared to the other three systems. Labour is the biggest contributor to the total operation, maintenance and ownership cost of the siphon system. In contrast the bankless has very low labour costs; other costs associated with the set-up and maintenance of the bankless system are similar the costs associated with setting up a siphon system. This means that when compared as a profit or loss relative to the siphon system (with water applied for an average year) that the bankless channel is more profitable than a siphon system.

The operational data for the two pressurised systems, shows that although the lateral move and the subsurface drip both produced favourable water use efficiency results, they were significantly more expensive to install than either the furrow siphon or the bankless channel. This has meant that they have produced losses on a $/ha basis relative to the furrow siphon system. In addition, the labour required to manage these two systems is more technical than typically required for the siphon or bankless systems.

Table 4: System Operational Costs

	Furrow Siphon	Lateral Move	Subsurface Drip	Bankless Channel
Operating Labour Cost @$40/hr ($/ha/yr)	$134.40	$22.40	$8.00	$11.20
Operating Energy Cost (fuel in L/ML/ha)	2.82	35.4	37.5	0.72
Operating Extras (rotobucks, siphon placement etc.)	$18.00			
Total Operating Cost ($/ha/yr.)	$171.01	$196.99	$186.65	$15.65
Ongoing Maintenance Cost ($/ha/yr.)	$20	$110	$25	$15
Field Maintenance Cost ($/ha/yr.)	$80	$50	$40	$140
Capital Setup Costs ($/ha)	$1,000	$3,880	$8,500	$1,250
Total Operational, Maintenance, Ownership Cost ($/ha/yr.)	$291	$551	$592	$196
Profit or Loss relative to Siphon with water applied for average year ($/ha)		-$35	-$661	$150

Discussion

2015-2016 season

The 2015 2016 season had a reasonably typical start but finished with higher than average accumulated day degrees and no effective rainfall past the end of January. In addition, there was not sufficient water to fully irrigate the trial, the last irrigations were applied in late February.

The yield performance for each of the systems was strong with all but the lateral move producing their highest yield over the four years of the trial. The yield of the bankless channel was noticeably higher than the other systems, which may have been caused by some other variable such as nutrition.

The yield of the furrow siphon was the lowest of the four systems. It received its last irrigation a few days before the bankless channel. It cut out before all the other systems and was defoliated five days before the other systems. This suggests that the furrow field was more badly impacted by the shortage of irrigation water at the end of the season.

The irrigation team adjust the irrigation scheduling of the drip system slightly in the 2015-2016 season to try to improve the yield performance of the system. The yield achieved in the 2015-2016 season was 12.8 bales per hectare, more than a bale above any previous yield achieved with drip in the trial.

The Irrigation WUE and the GPWUI for the siphon system was below that achieved for the other three systems in 2015-2016. However, the GPWUI in 2015-2016 was the highest achieved by the siphon over four seasons. This coupled with the earlier cut out and slightly lower yield of this system compared to the other systems, suggests that it may have been more significantly impacted by the lack of rainfall and irrigation at the end of the season.

The GPWUI for both the lateral and the drip systems was strong - 1.50 bales per mega litre, the highest achieved for either system over four years.

The bankless channel produced an even better GPWUI - 1.67 bales per mega litre, which is in part due to the very high yield achieved this season.

Four-year comparison

To enhance the value of the system comparison data it is important to look at the results over the four years of the trial. This information is presented in figures 4 to 9.

When the results are presented for each of the systems over the four years, it is possible to see trends in irrigation WUE and GPWUI which are most probably due to the seasonal conditions.

If we ignore the bankless channel results for 2009 – 2010, we can see that the irrigation WUE in 2009 – 2010 and 2011-2012 are quite high, possibly reflecting the typical 2009 – 2010 season and the cool wet 2011 – 2012 season. There is a noticeable reduction in irrigation WUE in 2013-2014 when there was very little in crop rainfall and warmer than average temperatures. The Irrigation WUE then increased in 2015 – 2016 when there was a shortage in irrigation water. All systems show similar trends, however the degree of impact of the hot dry 2013-2014 season on irrigation WUE was more pronounced in the lateral and drip systems.

As similar trend, can be seen with the GPWUI. The average GPWUI across all systems for 2009-2010 and 2012-2012 are 1.24 and 1.20 bales per mega litre respectively. The average of 1.20 bales per mega litre in the wet 2011-2012 was better than expected given that there was flooding and some water logging. In 2011 – 2012 the lateral performed strongly as it was possible to more precisely manage the applied water thus avoiding any water logging. It was expected that the result from the drip should have been similar to the lateral, however as with the siphon and bankless, there was difficulty in removing excess rainfall from this field, and some water logging was experienced.

The average GPWUI drops significantly in the hot dry 2013 – 2014 season and then increases noticeably in 2015 – 2016 when the trial ran out of irrigation water. The marked increase in GPWUI in 2015 – 2016 may be a result of the crop using more of the soil moisture reserves than in the other years of the trial. The average GPWUI across all systems over four seasons was 1.25 bales per mega litre.

When comparing the yield of the four systems over four years we can see that the furrow siphon has been the most consistent yield performer. From a long-term budget and on farm gross margin perspective this can be beneficial.

The highest average yield over the four seasons was 12.29 bales per hectare for the lateral move, while the lowest average yield was 11.12 bales per hectare for the drip system. The average yield for the bankless channel would have been higher if there had not been the establishment issues in the first year of the trial.

An important aspect of the comparison of these four irrigation systems is the operational components as shown in table 4.

The siphon system has high physical labour requirements associated with management of rotor-bucks, siphon placement and actually irrigating. It is estimated that this costs over $130/ha/yr. The next most labour intensive is the lateral move, the labour needed for this system however must be more technically skilled than the labour needed for the siphon system.

The energy costs associated with pressurising water is also important. Both the lateral and drip in the trial are run with diesel engines and use on average over 35L/ML/ha. In seasons, such as 2013 – 2014, when they are run constantly to maintain water to the crop they may be very costly to run.

Combining the labour and energy costs of each of the systems it can be clearly seen that the least expensive system is the bankless.

The capital setup costs are also important. The lateral cost close to $4,000/ha while the drip system costs over $8,000/ha. Both the flood irrigation systems cost around $1,000/ha to setup.

If all these aspects are considered the total operating, maintenance and ownership costs per hectare per annum for the lateral and drip are over $550, the siphon is $291 and the bankless is $196. If the profit or loss is compared with the average water applied for an average year relative to the siphon system it suggests that the bankless would deliver a profit of $150/ha, the lateral a loss of $35/ha and the drip a loss of over $600/ha.

Conclusions

The results from the four years of the grower-led irrigation system comparison trial shows that there is no single system which will deliver perfectly to the requirements of the industry. Irrigation needs will differ by farm, by region and by season.

There are indications that improvements in water use efficiency can be achieved with the lateral move and drip systems, and that good yield can be achieved with the lateral move. The difficulty with both these systems is that there is a high capital setup cost and a high operating energy requirement. As a result, the data suggests that growers would be carrying a loss relative to the siphon system if they were to invest in either of these systems. An additional consideration is water reliability; in regions where there is low reliability it may be necessary to carry the capital costs in a season where the system is not utilised, as irrigation water is not available.

The two flood irrigation systems, siphon and bankless, have significantly lower capital setup costs and minimal energy requirements. The siphon system however does have a high labour requirement and it is becoming increasingly difficult to source this labour.

This suggests that the bankless channel system is the preferred option, but the topography of the farm will impact on the suitability of this system. The bankless system works most effectively when the slope is developed correctly. In many cases this will require the removal of large volumes of top soil. The removal of 0.5 – 1m of top soil has the potential to have significant yield impacts and is not seen by many growers as a preferred course of action. Where there are existing siphon fields, it may not be practical to change to bankless.

In addition, the trial showed that the seasonal conditions can have significant impacts on the WUE and hence the suitability of each of the systems. In hot dry seasons it will be necessary to run the lateral or drip systems almost continuously to maintain the crop. This has the potential to significantly increase the cost of running these systems. The water use efficiency of all systems was effected in the hotter dryer seasons. In wet over cast seasons there is more flexibility to manage applied water in the pressurised systems than in the flood irrigation systems. However, it is still critical to ensure that any excess water can freely drain from these fields following heavy rainfall.

The findings highlight that growers looking to make investment in irrigation upgrades need to consider a range of factors including; soil, topography or existing land use, water reliability, crop type and financial capital. In addition, growers need to consider the availability of labour and the energy requirements of each of the systems.

The GVIA grower-led irrigation system comparison has demonstrated that although WUE is important, changes to irrigation systems focused solely on WUE may not be practical. To remain profitable and productive, growers need to conduct an analysis of all the components that contribute to the efficiency of an irrigation operation.

Publications

Appendix

Table 4:

30 Inch	System	Ha's	Ha's Picked	Total Modules	Average Turnout	TOTAL BALES	ACTUAL YIELD/HA	ACTUAL YIELD/ACRE	Irrigation Water Applied (meg/ha)	WUE of Applied Irrigation Water (bales/meg)
K28	Furrow Siphon	86.7	86.7	261	**41.7%**	**1055**	**12.2**	**4.92**	6.91	1.76
K29	Bankless Channel	32.7	32.7	112	**42.3%**	**478**	**14.6**	**5.92**	6.06	2.41
K30 nth	Subsurface Drip	5.5	5.5	19	**41.2%**	**145**	**12.8**	**5.19**	5.57	2.41
K30 sth		5.9	5.9	19					5.58	2.23
L1	Lateral Move	124.4	124.4	394	**41.7%**	**1573**	**12.6**	**5.12**	4.85	2.61

NB: There were 2 broken rounds from L1, that were not included