Irrigation systems, designs and scheduling options

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Key words

irrigation system choices, water scheduling, water budgets, managing water across the farm, strategies for limited water, irrigation scheduling technologies

Take home message

The key message from the system research is that no single irrigation system suits every situation. Selecting and optimising the system for your farm and water reliability is the most important priority.

System choices will be impacted by water reliability, labour resourcing as well as topography and soil type.

The primary focus areas for enhanced irrigation performance are:

- Design and drainage to minimise waterlogging and deep drainage
- Irrigation scheduling to apply the right amount at the right time and optimisation of irrigation system performance.

Background

The *Smarter Irrigation for Profit Phase 1* (SIP1) project enabled the completion of valuable research in areas including irrigation system audits, irrigation scheduling, investigation of new technology, evaluation of system design and water use efficiency. The project demonstrated that improved water productivity hinged on ‘getting the basics right’. It found that participating Australian irrigators could achieve a 10-20 percent improvement in farm profitability by adopting best practice and precision irrigation technologies. This initial project has now led to phase 2.

Smarter Irrigation for Profit Phase 2 (SIP2) is a partnership between the major irrigation industries of cotton, dairy, sugar, rice and grains research organisations and farmer groups. The objective of SIP2 is to improve the profit of over 4,000 cotton, dairy, rice, grains and sugar irrigators.

Smarter Irrigation for Profit Phase 2 has 14 sub-projects covering three main components:

- Development of new irrigation technologies including new sensors, advanced analytics to improve irrigation scheduling and strategies to reduce water storage evaporation
- Cost effective, practical automated irrigation systems for cotton, rice, sugar and dairy
- A network of 36 farmer led optimised irrigation sites located on commercial farms across Australia.

This paper draws on some of the findings from SIP1 and SIP2 which will help inform grain growers of the importance of optimised irrigation to maximise irrigation water use efficiency and profitability.

Irrigation systems and designs

One of the optimised irrigation sites is located on the property “Keytah” near Moree, where over the last ten years an irrigation system comparison trial has been running. The comparison includes examples of siphon, bankless channel, lateral move, and subsurface drip, and has focused principally on cotton irrigation, although the lateral move has also been used to provide supplementary irrigations to cereal and chickpeas. The system comparison trial investigated performance on both a yield and gross production water use basis.

Definitions

Surface irrigation: water applied via siphons, small pipe through bank, bankless channel, siphon-less or bay irrigation systems where water flows over the soil surface.

Overhead irrigation: water applied via lateral move or centre pivot irrigation systems where water is applied over the top of the crop.

Subsurface drip: water applied via a drip tape buried in the soil.

Key points to note about the trial

The trial includes a range of seasonal conditions including 2011-2012 where there were two major flood events, and 2013-2014 where there were hot dry conditions with minimal in crop rainfall during the cotton growing season. The performance of the siphon and bankless channel fields may have been impacted by variables such as flooding (siphon 2011-2012) or poor establishment due to surface crusting which meant the field had to be replanted 20 days after other fields in the trial (bankless 2009-2010), so results for these seasons should be viewed with this understanding.

The 2017-2018 season was the first set of data for the Smart Siphon (a remote-control siphon system), while the four previous seasons were irrigated with traditional siphons. Indications are that more uniform application from the smart siphon may improve performance, but additional data needs to be collected before any conclusions can be made.

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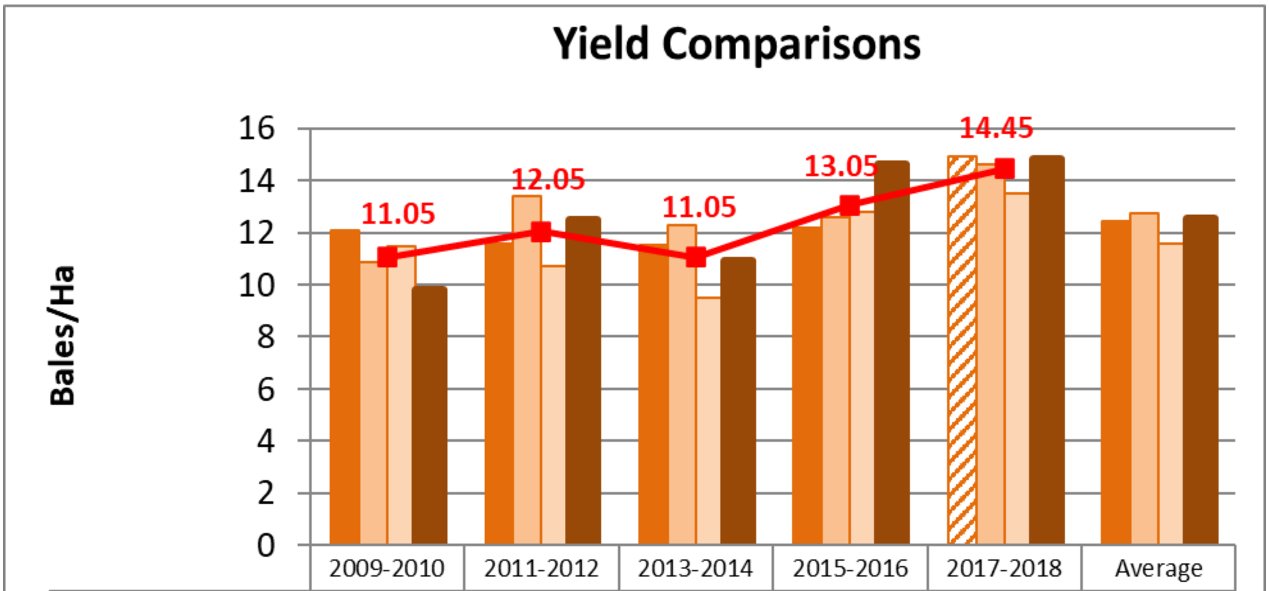
System comparison results

The trial has not found that there is any one system ideally suited to every season. Figure 1 combines the yield data for the five years of the trial. There was 1.16 bales/ha difference between systems and 3.4 bales/ha difference between season. This suggests that optimising the system for the prevailing conditions is critical for producers aiming to improve productivity and ultimately profit.



	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	Average
Siphon	12.06	11.6	11.5	12.20	14.90	12.45
Lateral Move	10.86	13.4	12.3	12.60	14.60	12.75
Subsurface Drip	11.47	10.7	9.5	12.80	13.50	11.59
Bankless Channel	9.8	12.5	10.9	14.60	14.80	12.52
Average	11.05	12.05	11.05	13.05	14.45	

Figure 1. Seasonal yield comparison in bales/ha cotton from 2009/10 to 2017/18 using different irrigation delivery systems at "Keytah" Moree. (Striped column in 2017-18 is the 'Siphon' treatment Smart Siphon system)

In the wet 2011-2012 season it was easier to manage irrigation volumes and minimise waterlogging despite extreme rain events with the lateral move. In contrast in the hot dry 2013-2014 season, irrigation scheduling needed to be intensely monitored to ensure crop water demands were met, especially with the overhead lateral move and drip systems. Having these systems set up with the appropriate system capacity, and attention to repairs and maintenance is essential, as any breakdowns where application volumes are just meeting crop requirements could have dramatic consequences.

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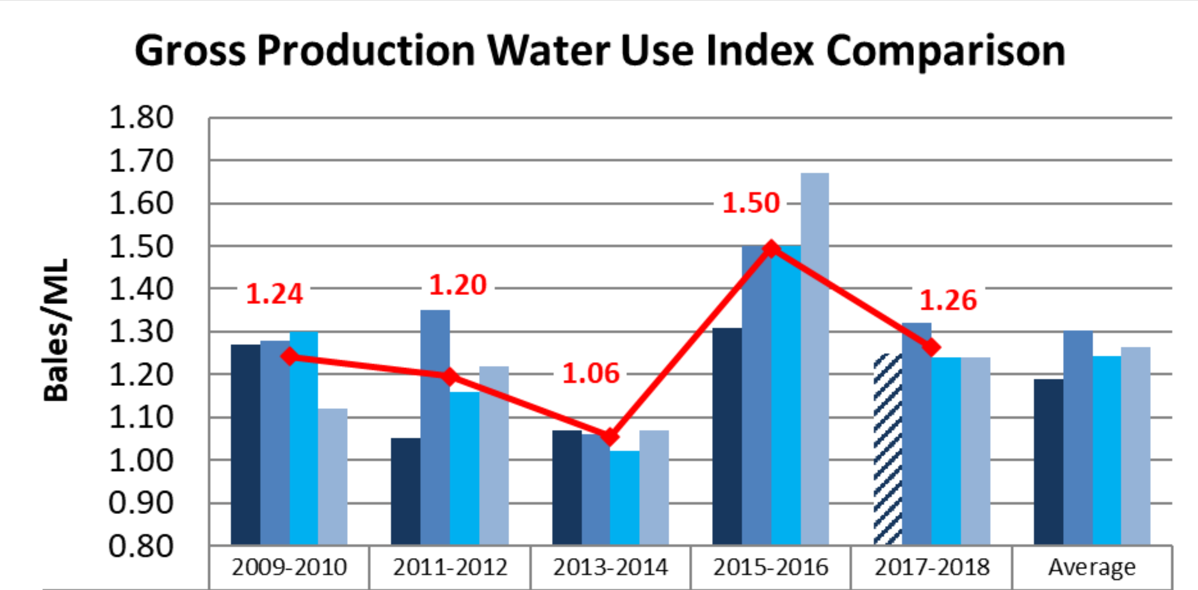
In addition to yield, the project considered the water use efficiency of the systems. The metric used was Gross Production Water Use Index (GPWUI) which includes measures of area, yield, irrigation water applied, used soil reserves and the in-season effective rainfall. GPWUI provides the most realistic index to make comparisons between systems and between seasons. The higher the GPWUI, the more productive all water used by the crop has been.



	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	Average
Siphon	1.27	1.05	1.07	1.31	1.25	1.19
Lateral	1.28	1.35	1.06	1.50	1.32	1.30
Drip	1.30	1.16	1.02	1.50	1.24	1.24
Bankless	1.12	1.22	1.07	1.67	1.24	1.26
Average	1.24	1.20	1.06	1.50	1.26	

Figure 2. Seasonal Gross Production Water Use Index in bales of cotton per mega litre of water applied from 2009/10 to 2017/18 using different irrigation delivery systems at "Keytah" Moree. (Striped column in 2017-18 is Smart Siphon system)

The average GPWUI over the five seasons varied from 1.06 bales per megalitre (ML) in 2013-2014, a warm to hot season with almost no rainfall, to 1.50 bales per megalitre in 2015-2016, a more typical season. There were similar trends in the individual systems over each of the seasons, except in 2011-2012, where the lateral proved to be a standout in a wet overcast season.

Variation between seasons (0.44 bales/ML) have been found to be greater than the variation between systems (0.11 bales/ML). This reaffirms the yield findings, as optimising the irrigation system and management for the seasonal conditions is going to be the best way to enhance productivity and profitability.

The commercial research into automated siphons and automated bankless channel systems is continuing at Keytah in 2020-2021 as part of SIP2.

The key message from the system research is that no single system suits every situation. Selecting and optimising the system for your farm and water reliability is the most important focus for irrigators. Surface irrigation systems such as siphon, small pipe through bank or bankless channel (siphon-less) typically entail lower capital to set up, although bankless designs can involve significant

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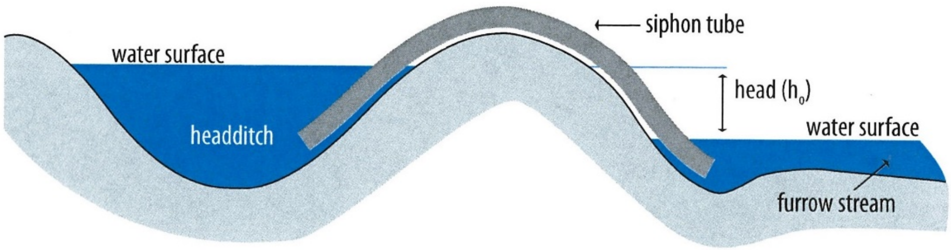
earth movement. Irrigators who have low water reliability will tend towards lower capital cost systems such as the traditional siphon but will then have high labour resourcing costs during operation. Those facing difficulty with labour resourcing have tended to transition towards bankless channel or siphon-less systems. Additionally, some producers have made investment in automated siphon systems to manage labour resourcing challenges. Where water reliability is higher, investment in overhead or drip systems is more feasible as the initial capital costs can more easily be recouped over a greater number of productive seasons.

In recent years there has been more detailed investigation of siphon-less or bankless channel systems. In 2018-2019 the GVIA (supported by the CRDC) worked with NSW DPI and CottonInfo to host a Siphon-less field day and developed a siphon-less booklet, which includes case studies of various designs being utilised by producers. To date however, we have limited information on the water use efficiency of the large number of designs being utilised by producers. The Smart Irrigation project being managed by Deakin University as part of SIP2 is utilising wireless sensor networks to collect field and crop data in bankless channel systems. Linkages between sensors, forecasting systems and automated irrigation infrastructure will enable precise delivery of water to crops as and when required. This will support irrigators to maximise productivity of water and optimise labour resourcing in these systems.

Optimisation

It can be difficult to optimise traditional siphons as siphon placement, furrow entry conditions, and supply head height will impact flow rates. Flow through siphons increases as head increases and decreases as head decreases.



Source: J Purcell

Figure 3. Siphon placement

Transitioning to permanent small pipe through bank will help ensure more even flow rates as siphon outlets and head height will be more consistent and controllable. This will assist irrigation managers to improve irrigation application efficiency and distribution uniformity, both of which are important to improve irrigation water use efficiency.

There are two commonly recognised configurations which utilise permanent small pipe through bank; the Waverley double head ditch design, and the smart siphon.

- The Waverley design manages the irrigation of siphon sets with a second field head ditch filled from the main head ditch. Water is delivered into the field head ditch to irrigate each siphon set. Research into the automation of the Waverley site was included in SIP1 and SIP2 managed by the University of Southern Qld (USQ), Centre for Agricultural Engineering (CAE). It provides a

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commercial example of optimisation and autonomous broad-acre irrigation. The system utilises water level sensors, automated gate control, and modelling techniques which operate synchronously and autonomously from Taggle IrriMATE advance sensors using SISCOweb. These products are now available for improved manual or remote control of broad-acre irrigation, representing interim steps toward fully autonomous optimised irrigation control.

- The Smart Siphon is an elbow fitted to the head ditch side of the small pipe through bank. This elbow is turned on via a pulley in sets of up to 150 siphons by lowering the elbow into the water. The siphon sets can be remotely controlled via a smart phone app, and work is continuing to integrate information from water level sensors and water advance meters to manage irrigations.

Both these small pipe through bank set ups can be initially installed as manually controlled systems, with the potential to transition to more automated or autonomous control over time. There have been continuous improvements in the cost and availability of connected sensor technologies for remote monitoring of irrigation, and improved measurement will inform management, allowing better use of valuable water resources for agricultural production. Commercial scale deployment of remote-controlled furrow irrigation is now common for less than $800/ha. Furrow irrigation optimisation under the USQ project has shown an average 10 to 15% water saving per irrigation event.

Overhead and drip systems readily lend themselves to optimised application through remote control, automation, and autonomous irrigation. Care must be taken to ensure that the managed system capacity is sufficient to deliver to the peak crop water demand. For optimised irrigation it is also essential to conduct regular system audits to ensure accurate application and even distribution across the whole system.

In addition to the investigation of autonomous furrow irrigation, the USQ SIP1 and SIP2 projects have also investigated autonomous broad-acre pivot irrigation systems for cotton and dairy pasture. The autonomous pivot cotton project is at Jondaryan on the Darling Downs. It involves ongoing development of VARIwise cotton yield prediction. VARIwise controlled cotton irrigation has led to a 6% yield improvement and 14% more efficient water use. The VARIwise Yield Predictor has regularly predicted final cotton yield to within 3% of actual yield six weeks prior to picking.

These overhead or drip systems do work well for opportunistic irrigation of either summer or winter cereals. This is especially true for lateral moves, as the crop is generally planted on the flat, meaning there is no requirement to adjust land preparation techniques to transition from cotton to a cereal. Keytah has utilised the lateral, to supplementary irrigate cereals and a chickpea crop.

Observations from southern NSW

Monitoring of commercial irrigated cereal crops in the Murray and Murrumbidgee Valley's over three years from 2014-2016 found that 38% achieved at least 80% of their water limited yield potential. Grower surveys found that average and 'best ever' yields in 2015 were 5t/ha and in 2016 7t/ha, 25% of those surveyed reported best ever yield approaching the calculated mean physiological potential of 9t/ha.

Observations from this monitoring showed that management issues such as waterlogging or water stress at flowering coupled with seasonal conditions, including high temperatures or scalding from water being present during warmer conditions, may have contributed to crops not reaching their full water limited yield potential. Wetter years, or seasons with milder conditions during grain fill seem to produce higher yields.

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Smarter irrigation for profit key learning sites - southern NSW

This project includes four key learning sites at Condobolin, Kerang, Darlington Point and Finley. The project is looking at a range of irrigated cropping systems to investigate options to maximise profit per megalitre.

Results from the 2019 winter season at the Irrigated Cropping Council (ICC) site near Kerang provided information on different irrigation approaches and different wheat varieties. The irrigation approaches included were one spring irrigation, a pre-irrigation followed by one spring irrigation, a full spring irrigation consisting of three applications and a pre-irrigation followed by three in-crop irrigations. There were some varietal differences, and the conclusion was that the best result was from the first irrigation in spring, however it was important that the crop was sufficiently developed, either with adequate biomass or tiller numbers to respond. The irrigation had to be timed to crop growth stage and the crop not subject to moisture stress. The decision on whether to pre-irrigate or not and on how many in-crop irrigations are justified will be impacted by water availability, price and seasonal conditions.

Table 1. Results ICC trial Kerang 2019 (wheat)

	Irrigation (ML)			Yield (t/ha)	IWUE (t/ML)
	Pre	Spring	Total		
No pre-irrigation + 1 spring	0	1.5	1.5	3.62	2.41
No pre-irrigation + 3 spring	0	3.4	3.4	5.00	1.47
Pre-irrigation + 1 spring	1.75	1.0	2.75	4.95	1.80
Pre-irrigation + 3 spring	1.75	2.9	4.65	6.15	1.32

IWUE = Irrigation Water Use Index measure yield per megalitre of applied irrigation water

The project is continuing in 2020 with the ICC demonstration this year aiming to highlight the importance of timing when partially irrigating. Treatments will include no irrigation, pre-irrigation only, pre-irrigation plus an irrigation at GS47, pre-irrigation plus two in crop irrigations at GS47 and GS65, pre-irrigation plus three in crop irrigations at GS47, GS65 and GS85, and a final treatment where irrigations are based on soil moisture sensors.

Getting the basics right

Getting the basics right was one of the take home messages associated with SIP1. As a general rule, there is always opportunity to make improvements to irrigation performance, this entails some key steps.

1. Irrigation design and drainage: Surface irrigation is the most common system due to the low capital cost and low energy requirements. Well-designed and managed surface irrigation can achieve application efficiencies of 95%, but efficiency comes from design and management. The focus should be on minimising potential for waterlogging and reducing losses from deep drainage.

   Application efficiencies can be improved by better design with research cited in the reference document 'Soils Under an Irrigated Environment' noting that, excessive deep drainage on self-mulching clay resulted in 1.2ML/ha increase in irrigation water use over two irrigations when water was ponded for extended periods. Additionally, waterlogging during winter and early spring especially on heavy clays with low permeability or sodicity was found to reduce tiller numbers.

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2. Scheduling irrigations at the right time and the right volume to optimise plant performance (correct depth, correct position, and correct timing) remains critical regardless of the crop type. An understanding of what is happening in the soil and the plant is important and monitoring is essential for accurate scheduling. The use of a range of sensors, as automated or autonomous systems can be extremely beneficial, enabling not only the optimal starting time, but critically also the optimal finishing time. Cut-off times suited to convenience or labour, lead to potential waterlogging, deep drainage, and yield loss.

   For cereals, scheduling irrigations to ensure there is no water stress from booting GS40-49 through to grain fill (GS70-89) is important. The period from GS30 to GS39 is stem elongation and it is at this time when yield potential is being established, so avoidance of water stress at this time is equally important. Water stress can be both too little and too much water. Many of the irrigation crops monitored in the Soils Under an Irrigated Environment program suffered from drought stress before the first spring irrigation reducing the yield potential of the crop. Additionally, wheat is susceptible to 'scalding' when high temperatures coincide with water on the surface.

3. Optimised irrigation involves maximising the systems irrigation water use efficiency. As identified, no system is perfect, but by optimising whichever system is available, the productivity per megalitre can be improved. Efficiency comes from design and management and is not an inherent characteristic of the system itself.

   With overhead or drip systems, growers should perform regular audits to check application uniformity, and system capacity. Couple this with regular repairs and maintenance to pumps, supply lines and filters to maximise irrigation water use efficiency. The audits conducted as part of SIP1 showed that many irrigators could save money and improve productivity by running periodic checks or audits and giving attention to maintenance.

   Start and stop surface irrigation events at the right time, avoid stressing the crop from too much or too little water. Monitor the supply head height to ensure even flow rates from siphons and check siphon placement is uniform so that flow rates are more consistent.

   Very often the use of sensors such as soil moisture monitors, channel level sensors or water advance systems will help inform these decisions and are invaluable in the process of optimising irrigation systems. Investment in automation or autonomous systems are further steps that will allow easier optimisation of every irrigation event.

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Thank you to researchers: Sam North (NSW DPI)

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