A Review of Centre Pivot and Lateral Move Irrigation Installations in the Australian Cotton Industry

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Executive Summary

Executive Summary

In 2001 a comprehensive review of centre pivot and lateral move (CPLM) irrigation systems in the Australian cotton industry was undertaken by Foley and Raine (2001). Interviews of 31 growers provided a detailed look at the design, management and performance of these systems, and where relevant, compared them to furrow irrigation. The review was specifically targeted towards cotton growers and included interviews across the entire cotton industry from Emerald in Queensland to Hillston in New South Wales. It is apparent that the number of CPLM systems used within the cotton and grains industry has significantly increased since 2001.

The 2001 survey was repeated in 2011 in the Queensland Murray-Darling Basin with funding from Healthy HeadWaters Water Use Efficiency project and in 2011-12 across the rest of the cotton and grains regions with funding from the Cotton Research and Development Corporation. The two data sets were combined to provide an Australian examination of changes in design, operation and management of CPLM systems over the preceding decade.

In total, this analysis covered 173 systems irrigating an area of 13,969 ha. Of this area 42% was irrigated by centre pivots and 58% by lateral moves. Lateral move machines made up a larger proportion of the systems at 34% in the 2011-12 survey compared to 24% in 2001.

- The average water applied by CPLM systems in 2011-12 was 30% less than that applied using furrow irrigation whilst maintaining similar yields.
- The two leading factors driving the adoption of CPLM systems for the 2011-12 respondents were the same as in 2001: labour savings and water savings.
- Labour required reported for CPLM systems was substantially higher in 2011-12 than 2001. The median labour requirement compared to furrow irrigation reported for centre pivots was 25% and for lateral moves 30% compared to 2001 where the reported figures were 10% for centre pivot and 20% for lateral move.
- Most centre pivot operators had an accurate assessment of their system capacity, with 68% within 1 mm/day over or under the calculated value. For lateral move operators, the figures were less accurate with 59% having a difference of more than 2 mm/day over or under from the calculated value.
- Of systems in 2011-12, 59% were designed to apply more than 110% of peak ET requirement which is a marked improvement compared to the 2001 review. However, for managed system capacity, only 20% of systems in the 2011-12 survey were able to apply more than 110% of the peak ET, 25% had a managed system capacity of between 90% and 110% of the peak ET, and 55% would be unable to meet the crop's water demand as the managed system capacity was below 90% of peak ET. This is a concerning discovery.
- It appears that many systems could have a supply pressure in excess of that required. Irrigators ran their supply point pressure at an average of 19 psi above their regulator pressure possibly consuming unnecessary energy.
- Automatic control systems were more common in 2011-12 than in 2001, but their use remains low considering the value of these systems in reducing labour and increasing flexibility.

- Wheel ruts and bogging remains a prevalent issue but most growers consider the problems minor and were able to overcome them within the first few seasons.
- The mix of emitter systems in use changed considerably between 2001 and 2011-12. The proportion of moving plate sprinklers increased significantly from 4% to 54% at the expense of Low Energy Precision Application (LEPA) systems which fell from 48% to 19%.
- Capacitance probes were the scheduling tool most commonly used by growers. Where growers in 2001 generally reported using one of a number of scheduling tools, in 2011-12 growers tended to use a combination of tools for both furrow and CPLM irrigation systems.
- The depth of water typically applied per irrigation with CPLM systems ranged from 5 mm to 50 mm. 52% of growers applied between 15 mm and 30 mm compared to 33% in 2001. 11% fewer growers are applying 15 mm or less and 7% fewer growers are applying more than 45 mm.
- The proportion of growers that practised fertigation through their CPLM system in 2011-12 was higher (72%) than in 2001 (45%). 34% of growers believed that fertigation resulted in a decrease in total seasonal fertiliser use, whilst 47% of growers reported that it reduced the fertiliser required as up-front applications prior to planting.
- The capital cost of systems ranged between $610 and $6,000 per hectare, with a median value of $2,570 per hectare. This compares to $1,250 to $2,500 per ha reported in 2001.
- 79% of CPLM operators used pressure points as an indicator of problems within the system. Only 38% of growers who had flow meters fitted used them to assess changes in supply or a problem of delivery to the CPLM field. Of the NSW cohort 79% recommended that a performance audit should be done before the final payment is made.
- Only 25% of participants indicated they had measured their uniformity, with a range of values given from 50% to 100% (90% is the benchmark).

In summary, CPLMs continue to be favoured by growers for their potential to save water and labour, to maximise rainfall capture and minimise waterlogging and to provide soil health advantages through stubble retention and minimum tillage. Whilst previous major issues such as bogging must be managed, most growers have been able to overcome these issues within reasonably short timeframes.

The following recommendations should be considered by growers interested in investing in CPLM systems:

- System capacity is critical. Managed system capacity in particular needs to be high enough to satisfy peak crop demand and your irrigation management, while minimising capital and operating costs.
- It is important to ensure that operating pressure is minimised while still allowing optimum system performance. Energy costs are an increasing component of operating costs and may affect the financial viability of these systems.
- Expect it will take several years before you get the best performance out of a CPLM system. There will be a significant time investment in planning and setting up the system and learning to manage it.
- Learn as much as possible from growers and consultants operating CPLM machines, both within your region and in other regions.

There has been increasing interest in Centre Pivot and Lateral Move (CPLM) irrigation systems from irrigators looking to improve their on farm water use efficiency and address labour shortages.

- Attend as many information events as possible, such as field days, farm walks and the National CPLM Training Course.
- Adequate field drainage is needed under CPLM systems.
- Choice of emitter system should be based on a wide range of factors, information sources and discussions with growers using each type of emitter.
- Carefully plan the system to ensure it suits the soil type and performs as required without excessive capital or operating costs. Sorting out potential design or management issues during the planning phase, possibly with the help of a consultant, will be significantly more cost effective than trying to rectify poor designs after installation.
- The performance of systems should be checked after installation and at regular intervals. Flow rate and pressure should be checked using calibrated sensors to ensure that mounted sensors are accurate. Uniformity, application depth and travel speed should be measured and the control panel calibration checked. Some suppliers do not calibrate control panels in the field.
- Get good advice on the financial, management and tax implications of such a large investment.

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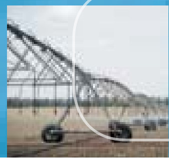
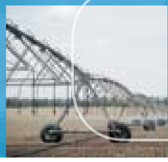
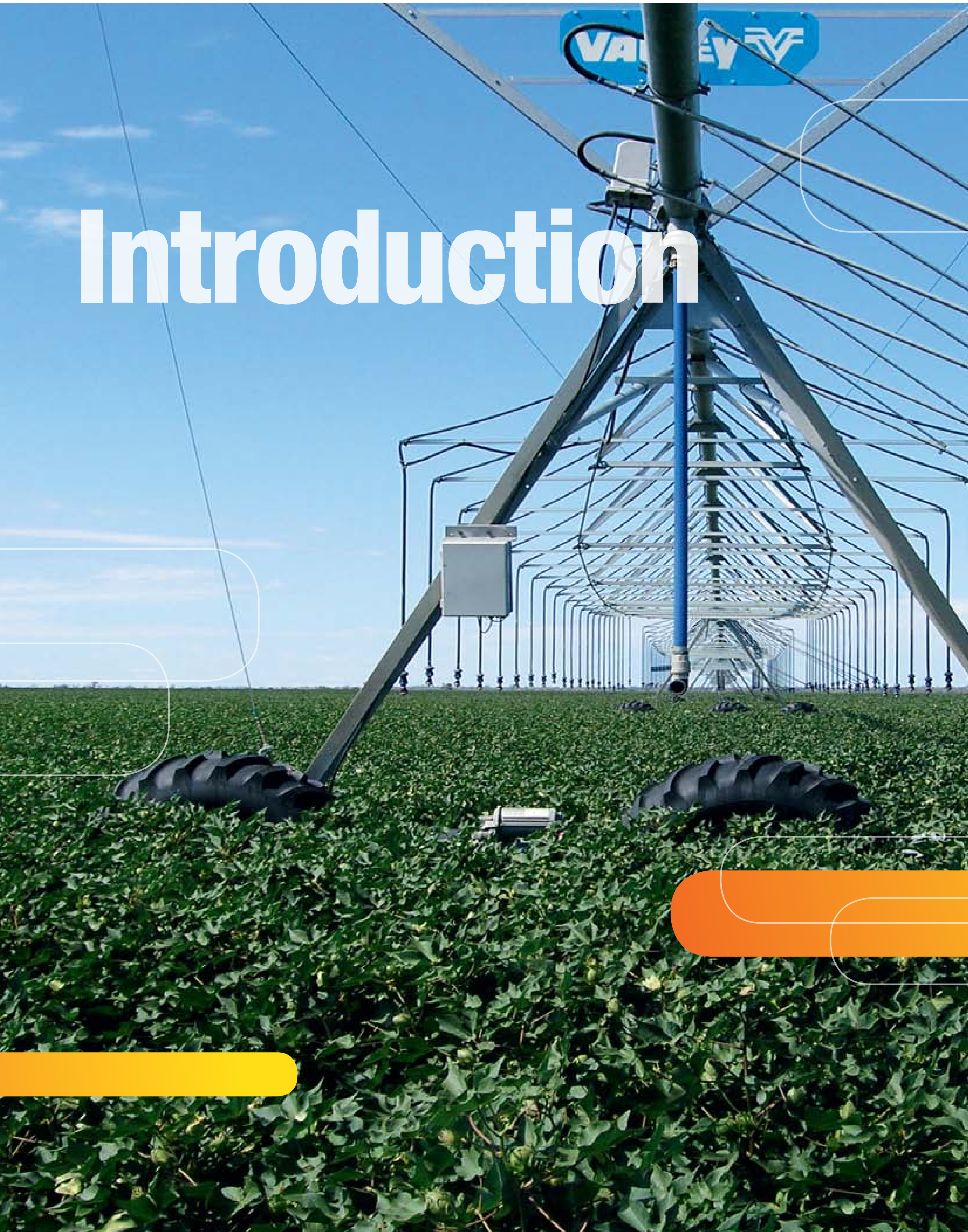




Introduction



1 Introduction

Australian cotton irrigators have faced a history of reduced water availability due to drought and increasing environmental demands. Their production systems and management reflect this history of limited supply, where they aim to maximise profitability per megalitre of water applied through improved water management and innovation. More recently the Australian Government's water reforms have heightened irrigators thirst for new irrigation technologies that require less labour and achieve water savings. On-farm irrigation infrastructure funding programs have stimulated investment in a range of improved irrigation technologies, including Centre Pivot and Lateral Move (CPLM) irrigation systems. The Healthy HeadWaters Water Use Efficiency (HHWUE) project in Qld is one such program operating across the Queensland Murray-Darling Basin (QMDB) and the Sustaining the Basin: Irrigated Farm Modernisation (STBIFM) program is another operating in the northern valleys of NSW.

In 2001 a comprehensive review of centre pivot and lateral move irrigation systems in the Australian cotton industry was undertaken by Foley and Raine (2001). Interviews of 31 growers provided a detailed look at the design, management and performance of these systems, and where relevant, compared them to the dominant form of irrigation in the cotton industry, furrow irrigation. The review was specifically targeted towards cotton growers and included interviews across the entire cotton industry from Emerald in Queensland to Hillston in New South Wales. Although there is no definitive information on the total number of irrigators using CPLM in the cotton industry, it is apparent that the number of CPLM systems used within the cotton and grains industry has significantly increased since 2001. With the accelerated adoption under infrastructure programs has come more questions surrounding design, operation and management of CPLM irrigation systems.

Wigginton et al (2011) with funding from HHWUE repeated the Foley and Raine (2001) CPLM survey across irrigators in the QMDB to assess changes and progress over the previous 10 years. In order to examine the changes in CPLM irrigation systems across the whole of the Australian cotton industry, the Cotton Research and Development Corporation (CRDC) funded NSW DPI in 2012 to capture the same data for NSW cotton irrigation regions. The two data sources have been combined to provide an Australian data set to examine changes in design, operation and management of CPLM systems since Foley and Raine's review in 2001.

Comparing the results of this survey with those from the 2001 review reveals changes in grower decision making and management practices that have occurred over this period.

1.1 Method
1.1.1 Survey sampling

The surveys were designed to obtain a sample of cotton irrigators using CPLM systems across NSW and Southern QLD cotton regions. The survey participants were selected by the project team. The format of the two later surveys was based on that used by Foley and Raine (2001), although it was modified to make it more applicable for a range of crops and some additional questions were added to explore new themes or practices.

The 2011-12 surveys covered 30 from the QMDB in March and April 2011 and 28 growers from NSW from April to September 2012, 58 growers in total. This included 27 growers who operated centre pivots, 23 who operated lateral moves and eight who operated both types of systems. The survey for the NSW component was undertaken about one year later than the QMDB component.

The 2001 survey involved a total of 31 interviews with growers and five interviews with the major centre pivot and lateral move irrigator dealer and supply companies. The grower survey encompassed more than 80% of CPLM users within the cotton industry at that time.

It was intended to repeat the survey of major CPLM dealers and suppliers, and this was done in the QMDB phase where eight CPLM suppliers within that region were interviewed, which was nearly all of them. The results are provided in the report by Wigginton et al (2011). In the second phase covering the remainder of the cotton and grains regions in NSW, insufficient responses were obtained from dealers or suppliers to add meaningfully to the findings so the information from the dealer and supplier interviews is not reported in this review.

1.1.2 Seasonal conditions at the time of survey

Over the 2010-11 and 2011-12 seasons when the interviews for these surveys were done, growers had typically experienced wet conditions, with the need for irrigation reduced accordingly. This was especially the case for the QMDB cohort which was surveyed following the 2010-11 season, while the NSW cohort was surveyed following the 2011-12 season. Prior to the wet conditions, longer term operators had experienced drought conditions for a number of seasons. In the early stages of drought, crops would have been well watered but the source was more heavily irrigation than rainfall. As drought became more severe, a number of them explained that they were severely restricted for water and were only supplementary irrigating with their CPLM system, which would have resulted in low yields from very low irrigation water use. During very wet years, there were good yields from high rainfall and low irrigation water use, except where the rainfall was persistent and reduced yields. Therefore, the summary information provided here is a product of unusually highly variable weather conditions. The results in this report may be usefully compared between irrigation systems (furrow and CPLM). Because of the mix of seasonal conditions, the results may also provide an accurate summary of long term averages but caution is advised when comparing with data from other seasons or locations.

1.1.3 Survey design

Questions were grouped under various topic headings including:

- the CPLM dimensions and configuration
- furrow irrigation areas, yield and water use
- pump and water supply
- operation management and problems
- sprinkler packages
- tyres and wheels
- farming system
- crop water requirements
- application strategies
- system performance and productivity
- runoff management
- agronomic considerations
- maintenance, and
- purchase decision-making.

1.1.4 Data collection

The surveys were face-to-face interviews, which took approximately two hours to complete. They were conducted on-farm with either the farm owner or irrigation manager. Fifty-eight cotton and grains irrigators were interviewed across the cotton growing regions from Southern Qld to Southern NSW. The NSW data was collected following the 2011-12 season and the Queensland data collected following the 2010-11 irrigation season. This sample of irrigators operated a total of 173 CPLM systems irrigating an area of 13,969 ha.

1.2 Definitions

A number of standard terms are used throughout this document. They are clarified here for reference and are the same definitions used by Wigginton et al (2011).

Crop water productivity is often expressed as a Water Use Index. The two most common water use indices are Irrigation Water Use Index (IWUI) which expresses the yield per unit of irrigation water applied, and the Gross Production Water Use Index (GPWUI) which expresses yield per unit of total water used, which includes irrigation water applied, soil moisture and rainfall.

$$\textit{Irrigation Water Use Index (IWUI)} = \frac{\textit{Total yield (bales or tonnes)}}{\textit{Irrigation water}\ \text{applied (ML)}}$$

$$\textit{Gross Production Water Use Index (GPWUI)} = \frac{\textit{Total yield (bales or tonnes)}}{\textit{Total water used (ML)}}$$

System capacity is the maximum possible rate at which a CPLM system can apply water to the field. The area used in this calculation should be the number of hectares of summer crop fully irrigated in the peak water use period of the growing season. If the irrigated area changes between summer seasons, the system capacity will also change. System capacity in this document refers to the maximum system capacity at which the system will operate.

$$\textit{System Capacity (mm/day)} = \frac{\textit{Pump discharge (ML/day) X 100}}{\textit{Area Irrigated (ha)}}$$

Managed system capacity is the capacity of the system after taking into account machine downtime for field operations and the efficiency of the emitters. Machine downtime is accounted for by the Pumping Utilisation Ratio (PUR) which is the percentage of time that a machine is able to be used. For example if a machine is able to irrigate for 9 days out of 10 on average, the PUR would be 90%. Application efficiency (Ea) takes account of water losses in the emitter system (e.g. evaporation). Typical application efficiency for Low Energy Precision Application (LEPA) is 0.98 and for low pressure sprinklers is 0.9 to 0.95.

Managed System Capacity (mm/day) = Managed System Capacity (mm/day) x PUR x Ea

Irrigation uniformity is a measure of how evenly water is applied across the irrigated area. A range of uniformity measures exists including Distribution Uniformity (DU) and Christiansen's Uniformity Coefficient C_U.

Survey Results

2 Survey Results

2.1 Number of systems and area

In total there were 173 systems irrigating an area of 13,969 ha with 42% of this area being irrigated by centre pivots and 58% by lateral moves. Table 1 provides the results for the total number and area of CPLM installations for all the growers surveyed. The median areas for CPLM systems in 2011-12 indicated that 50 per cent of the survey participants had a centre pivot less than 40 ha in area, and for lateral moves 50 per cent of participants had an area less than 143 ha.

Table 1: Summary of CPLM systems 2011-12 survey

	Centre Pivot	Lateral Move
Number of systems	115 (66%)	58 (34%)
Total Area (ha)	5901 (42%)	8068 (58%)
Minimum Area (ha)	18	15
Maximum Area (ha)	106	360
Mean Area (ha)	51	139
Median Area (ha)	40	143

Lateral move machines now make up a larger proportion of the systems at 34% of the sample surveyed compared to 24% in 2001 (Table 2). As lateral move machines typically cover a larger area, the area now irrigated by lateral move systems has increased to 58% from 45% in 2001.

Table 2: Summary of CPLM systems 2001 survey

	Centre Pivot	Lateral Move
Number of systems	57 (76%)	18 (24%)
Total Area (ha)	2915 (55%)	2385 (45%)
Mean Area (ha)	~70	~165

The smaller average size may simply reflect differences in the sample of growers surveyed between 2001 and 2011-12 or other influences such as lower upfront capital costs, lower overall running costs, or reduced reliability of water supply. The shift in these proportions could also indicate a greater level of ease with lateral move systems as past issues have been addressed through improvements in machine hardware, guidance systems and system capacity and more widespread familiarity with the advantages and disadvantages of these systems.

The reason for the decrease in the average area observed in the survey for both centre pivot and lateral move systems is unclear. It may indicate that survey participants are obtaining better overall performance from smaller systems, which is supported by the improved Design System Capacity reported from the participants (see section 2.8.2). However, the survey responses indicated that seven participants would choose a smaller system in future and twelve would choose a bigger system.

2.2 Experience of using CPLM

Growers participating in the survey had owned a machine for an average of 8 years. The median period of ownership was 5.5 years indicating over 50 per cent of the surveyed growers had owned a machine for less than 5.5 years. 10% had owned a machine for two or less years. Across the sample, the period of ownership of CPLM systems ranged from one year to 32 years of experience (Figure 1). This compares with the 2001 survey which reported only one indicator which was an average ownership of machines then being used of 10.7 years with the highest being 23 years.

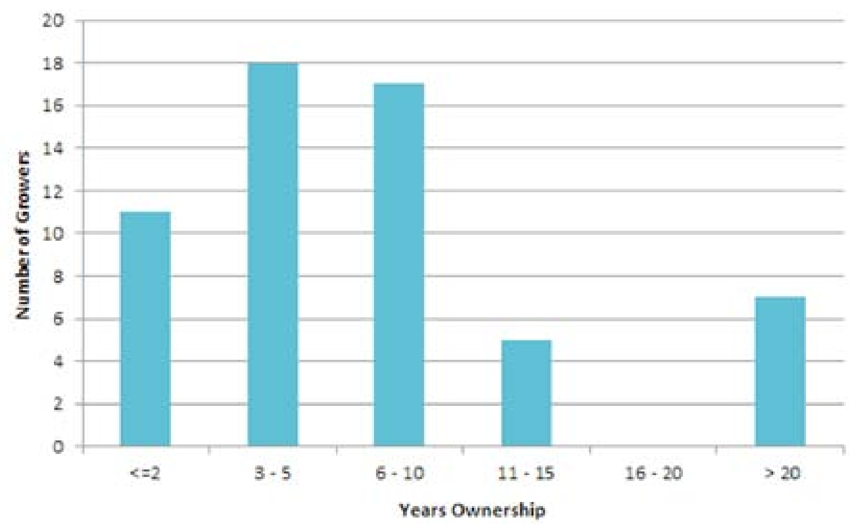


Figure 1: The number of years growers have owned a CPLM system 2011-12.

Figure 2 shows the years of operating experience with CPLM systems. The combined years of experience with CPLM systems on their farm reported by participants was an average of 10 years. The median period of combined experience was 5 years indicating over 50 per cent of the surveyed farms had a combined experience of CPLM systems of less than 5 years. 20% had a combined experience of two or less years. One participant reported a combined experience of 96 years.

This compares with the 2001 survey which reported only two indicators which were an average experience of CPLM systems of 6.4 and 27% of the participants had two or less years of experience.

There is an increase of 3.6 years of average experience since 2001. This is less than might be expected with about a decade between the two studies, reflecting the increased number of new users who have adopted CPLM systems since 2001.

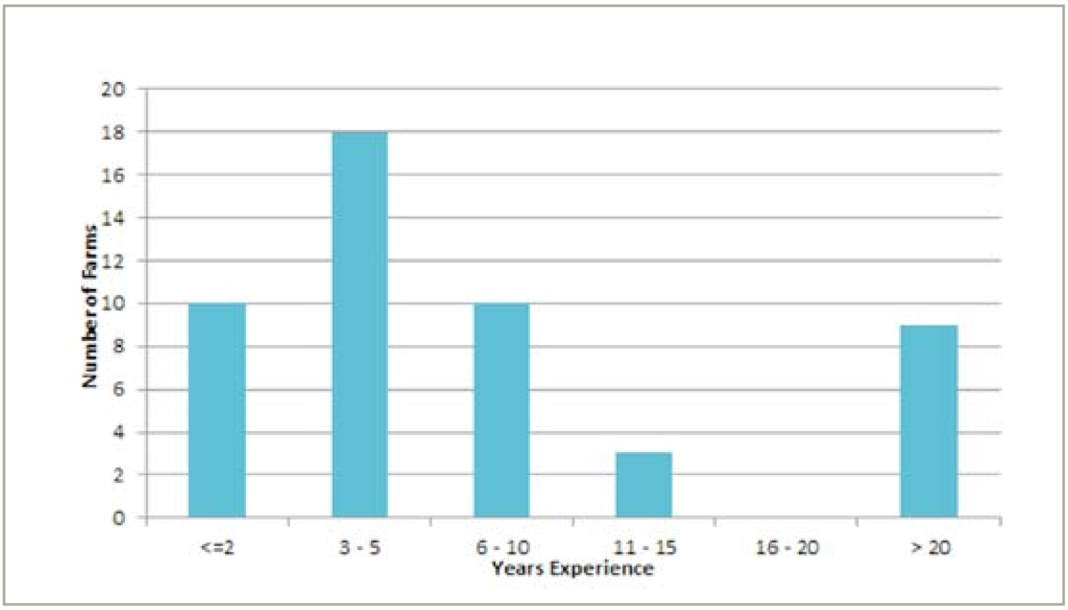


Figure 2: The total number of staff-years experience with CPLM per farm 2011-12.

2.3 Crop types

There was a wide variety of crops being grown under CPLMs by the survey participants. Cotton was the main crop reported by 73% of participants, with other significant summer crops including sorghum, corn and soybean, and a few growing other crops such as peanuts and mungbeans. Winter crops included wheat and chickpeas.

Spreader bars on a lateral move system irrigating corn to better match the application rate to the soil infiltration rate.

2.4 Water sources

In total 28% of growers used groundwater only, and 56% used surface water only and 16% used both ground and surface water (Figure 3). This compares to 2001 where 50% of the growers surveyed obtain all of their water from surface supplies, 35% used only groundwater and 15% used a mix of water sources.

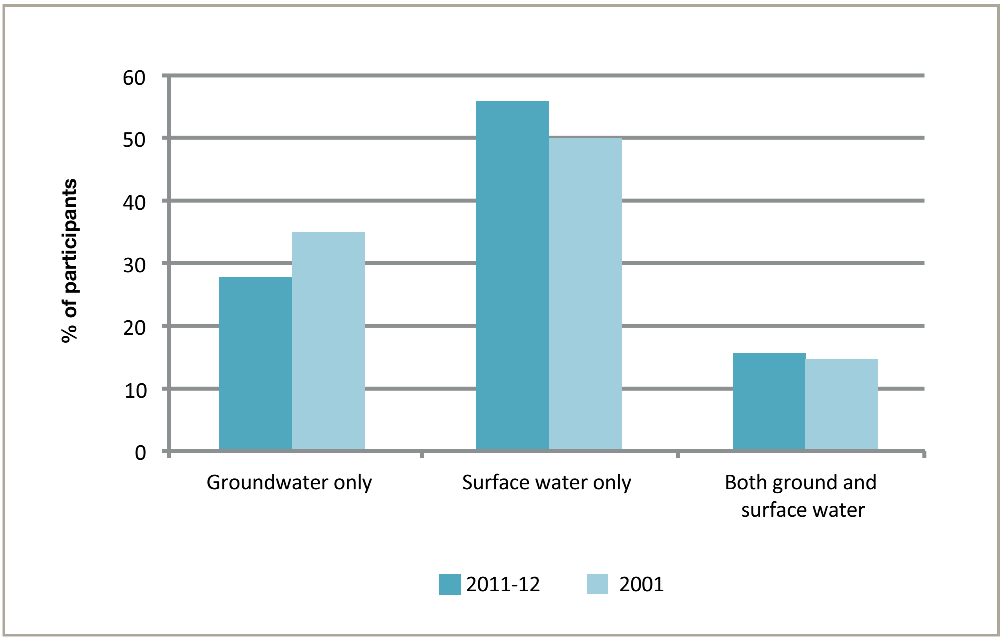


Figure 3: Proportion of growers using different water sources for CPLM irrigation in 2011-12 and 2001.

2.5 Soil types

CPLM systems are used on a wide variety of soil types (Figure 4). This feature was considered an advantage by growers as the following comments show:

"Suitable for irrigation on a range of soil types"

"Using variable rate irrigation to apply precisely i.e. EM survey – water applied according to soil."

Since 2001, there has been an increase in the area of lighter soils on which CPLM systems are used. The 2011-12 survey showed less CPLM systems on heavy clay soils compared with those surveyed in 2001. More sandy loam and sandy soils were present in the later survey. The greater range may indicate that the design of systems and particularly sprinkler packages have been adapted to take advantage of the flexibility of these systems.

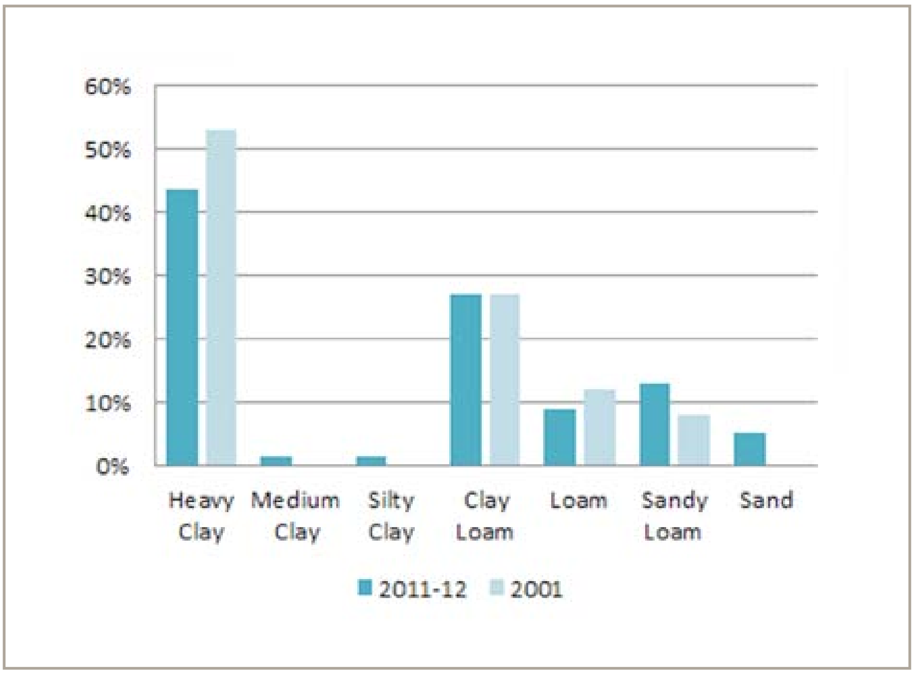


Figure 4: Proportion of growers using CPLM irrigation on different soil types in 2011-12 and 2001.

2.6 Yield and Water Use

Crop yield and water use information was collected for a wide variety of crops, across all farms. The data in Table 3 show that average water applied by a CPLM was approximately 30% less than that applied using furrow irrigation during the survey period irrigation seasons. While less water was applied, similar yields were achieved on average. The figures in brackets are the range of the responses.

CPLM irrigation systems can have significant water savings early in the season as a small amount of water can be applied to better match water demands of a small plant.

Table 3: The average yield and water applied to crops 2011-12.

	Furrow			CPLM		
	Sample Size	**Average Yield**	**Average Water Applied ML/ha**	**Sample Size**	**Average Yield**	**Average Water Applied ML/ha**
Cotton	44	10.4 b/ha (7.0-13.0)	6.2 (1.8-10.5)	50	10.1 b/ha (6.5-14.0)	4.3 (0.6-10.0)
Corn	6	13.0 t/ha (9.9-26.0)	5.02 (3.6-6.0)	10	10.3 t/ha (2.0-15.0)	4.14 (2.2-7.0)
Sorghum	5	7.2 t/ha (5.0-9.3)	2.68 (1.4-4.5)	6	8.6 t/ha (7.5-9.3)	2.2 (0.5-3.5)

Note: Figures in brackets represent the range of survey observations

The Irrigation Water Use Index (IWUI), which is the yield per unit of irrigation water applied, is presented in Figure 5 and for cotton in detail in Table 4. The error bars shown represent the range in values from the survey observations.

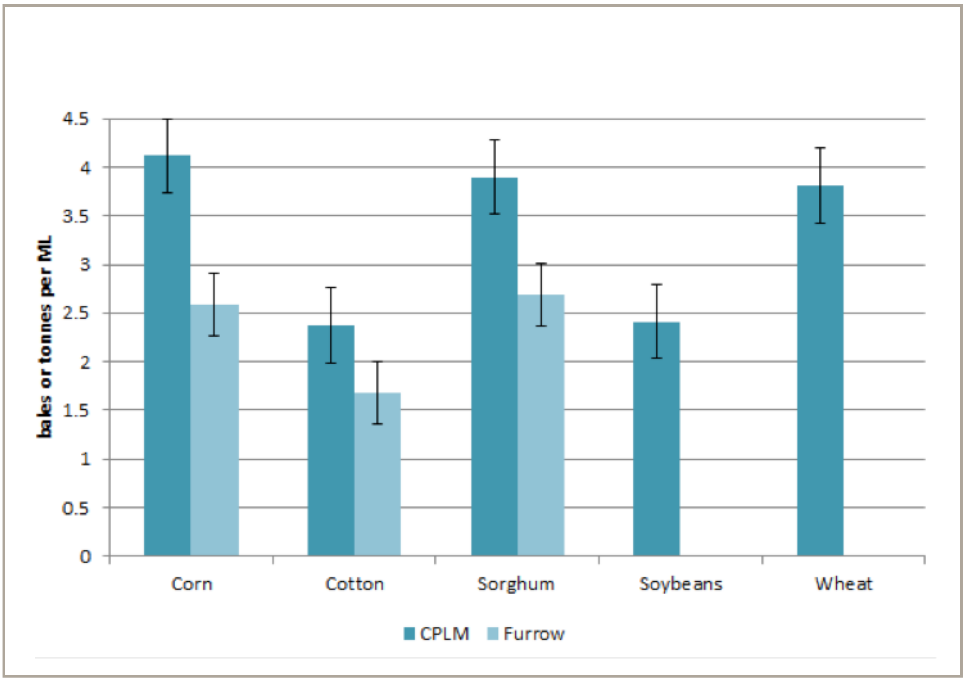


Figure 5: Average Irrigation Water Use Indices for Furrow and CPLM systems 2011-12.

Table 4: IWUI for Cotton crops 2011-12 and 2001 (b/ML).

		Mean	Median	Minimum	Maximum
2011-12	Furrow	2.0	1.81	0.82	5.7
	CPLM	3.14	2.50	1.0	16.7
2001	Furrow	1.1	-	0.6	1.6
	CPLM	1.9	-	1.4	2.6

The median IWUI for cotton across both systems is 2.0 bales/ML which closely agrees with the average figure of 1.97 bales/ML observed by Montgomery and Bray (2010) for the 2008-09 cotton season.

There is a large variation in IWUI for cotton around the average. For furrow irrigation, the range was from 0.82 b/ML and 5.7 b/ML. CPLM users reported a range from 1.0 b/ML to 16.7 b/ML.

The data for cotton in Table 3 shows that this wide range is due primary to the amount of water applied rather than the yields achieved. For example, the maximum value of 16.7 b/ML was achieved by applying just 0.6 ML of irrigation water to achieve a yield of 10 bales per ha, so high rainfall must have been recorded for this grower. Consequently, IWUI is greatly influenced by rainfall and this can vary considerably between seasons and individual growers.

The results obtained for the 2011-12 survey have been influenced by recent seasonal conditions. Many participants had only owned CPLM machines for a relatively short period of time (56% for less than 5 years). In the period when the interviews for this survey were done, growers were experiencing wet conditions and the need for irrigation reduced accordingly. This was especially evident for the QMDB cohort who experienced well above average rainfall during the survey season. Even so, the trend is clear for both the 2001 and 2011-12 surveys – IWUI was higher for CPLM systems than furrow irrigation for the survey respondents.

Forty eight percent of growers believe CPLM systems deliver greater yield than furrow irrigation systems. Their main reasons are because there is no waterlogging and water is applied more precisely. However, 33% of respondents indicated that their yields have either stayed the same or reduced under a pressurised system but their water use efficiency has improved. Other respondents also indicated that soil factors such as compaction and drainage issues were a problem. Table 5 contains a sample of the comments received by growers.

Table 5: Comments from irrigators on the impacts of CPLM systems on crop yields compared to furrow irrigation.

Positive impact on yield	No impact on yield
"Able to apply when needed. Plant when need to. No water logging. Increased yield."	"Yields lower by about 1 b/Ha but we can get water savings so b/ML is about 20% higher for CPLM compared to furrow irrigation."
"Due to reduced water logging and improved fertiliser application (amount and timing)."	"Although there is a yield penalty of about 5%, we do get water savings of 20-30%. Except in a dry year where water use between furrow and CP/LM is similar, but yields still 5% lower."
"Current crop more advanced, more prescriptive applications."	"Could do better in the future with CP."
"More precise"	"In return dollar per ML maybe, but yield per ha then no."
"Better crop establishment"	"Not sure, but district as a whole doesn't get above average yields with pressure systems."
"It's a more flexible system to fit with the variation in the season plus the crops"	"Some compaction may have affected yields from pressure system. At this stage an increase looks unlikely, happy to get the same yield."
"No waterlogging, more favourable conditions for the crop."	"Hope to get similar yields with reduced water."
"Consistently seeing better yields now. Worst soil, but best yields! Drought year – water savings not around, only about 10%. In a wet year, savings around 30%. Better soil health, no waterlogging, most vigorous crops."	"Cannot grow solid cotton. Problem with drainage."

2.7 Adoption Drivers

There are multiple factors that affected participants' decisions to adopt CPLM systems (Figure 6). The two leading factors driving the adoption of CPLM systems for the 2011-12 respondents were the same as reported in 2001: labour saving and water saving although their order was reversed. Other factors included (the percentage of respondents identifying each reason is shown in brackets):

- reduced waterlogging (34%)
- fertigation (26%)
- automation (24%)
- improved water distribution (17%)
- increased crop yield (16%)
- improved crop quality (16%).

The percentage of survey participants indicating each adoption driver was less in 2011-12 compared to 2001. The decrease for all adoption drivers was substantial except for the leading two. This suggests that individual survey participants now adopt these systems mainly because of the labour and water saving potential offered by CPLM. Automation may have declined as a driver not because of any change in desire, but because it is now recognised as an inherent feature of CPLM systems.

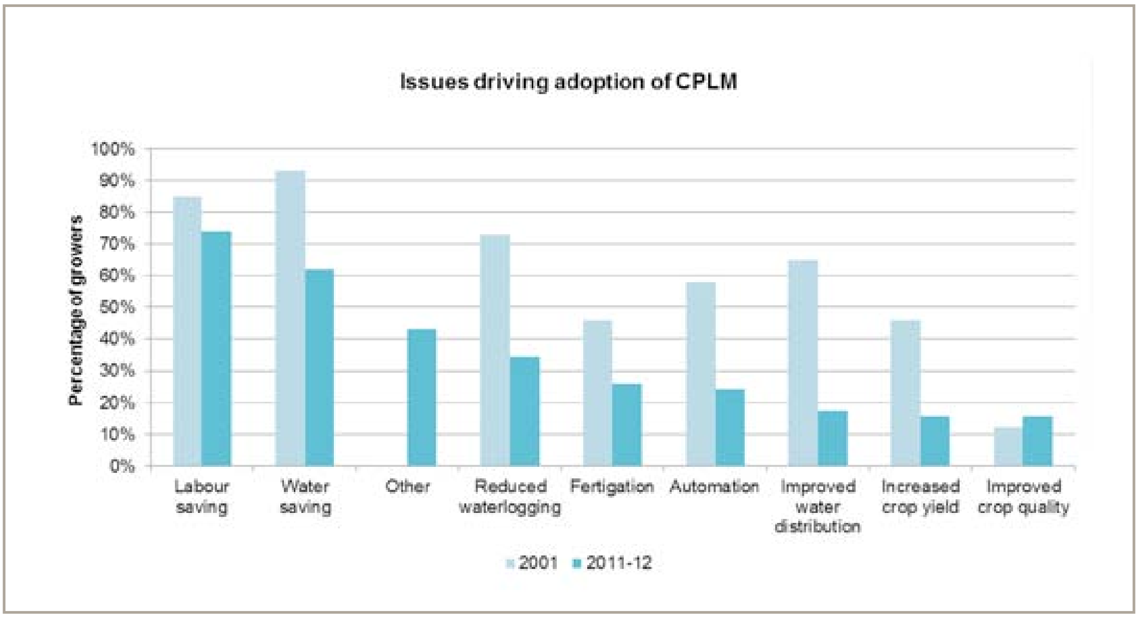


Figure 6: Issues driving adoption of CPLM systems in 2001 and 2011-12.

Respondents also indicated that having more cropping options open to them as well as improved crop establishment are major advantages of using CPLM:

"Gives confidence to put in more summer crops"

"Flexibility – can grow any crop under them"

"Brilliant for crop germination"

"Planting – fabulous as you can just put on 10 mm to get the crop up"

Other common responses were in relation to better water use efficiency, labour savings, and changes in farming practices such as no laser levelling, less ground preparation, and better management of water applications. These actions sometimes resulted in less waterlogging, less compaction, and yield increases. Table 6 is a sample of the responses collected.

Table 6: Motivation for using CPLM as an irrigation method

"Water reduction and the Australian dollar (high value relative to USD over recent years so a good opportunity to buy US-made equipment)."
"Better water efficiency compared to furrow. Cheaper than drip. Permanent bed system. Algae problems with drip. LM fitted the field better than CP. Labour advantage over flood irrigation."
"Loss of water from government cut backs. Water shortages. Water logging."
"Water efficiency, fuel and energy saving."
"Government grants – on-farm modernisation scheme"
"Ability to withstand a flood. Previous end-tows and travelling guns were time consuming and just got washed away in a flood."
"Developing country not suitable to flood irrigation (couldn't handle runoff/tailwater)"
"Previous flood block, difficult to water. Had to lift twice to get to field. Not long enough for lateral."
"Easier than end-tow – more flexible. Couldn't use furrow – labour constraints and soil unsuited."
"Low water availability, wanting to increase water use efficiency and also wanted to increase returns $/mm."
"Best option for the soil type – shallow top soil."
"Reduce labour, grow more crops with less water, minimum tillage system, flexibility in growing crops."
"They suited our soil types and labour efficiencies"
"Lay of the land was suited to a pivot. Originally it was put in to drought proof the property for the cattle enterprise. Then I had a contract with a major company. We live close to town, so didn't think we would grow cotton, but the development of Bollgard and the economics has allowed us to do so."

When asked about the disadvantages of using a CPLM system, responses given by the survey participants were mainly:

- the capital costs and depreciating assets
- higher running costs in fuel and electricity
- mechanical and maintenance problems
- difficulty employing staff with the skills required to run CPLM
- wheel rutting, compaction
- some disease problems
- machine obstructing field operations

These issues are indicated by the following comments:

- "Struggle to get highly trained, technical support"
- "Expertise for repairs and service difficult"

- "Difficult to get farm workers"
- "Staff skill level is different to furrow irrigation".
- "Overhead application sometimes causes boll rot – so have to stop irrigating early"
- "Increased soil disease – Verticillium wilt inoculums increasing in severity & frequency. Top 100 mm of soil is an ideal environment for them."
- "CPLM creates a physical obstruction for aerial application"
- "Have to walk LM off the field for some farming passes"
- "Spraying can be a bit harder going around structure due to wet ground."

2.8 Considerations when choosing a system

2.8.1 System Selection

Figure 6 indicates that labour saving was the main benefit expected from using CPLM and a major driver for adoption. Growers were then asked to quantify their labour requirement compared to the same area of surface irrigation (Figure 7). For centre pivot operators, 47% responded that their labour was less than ¼ of that required for furrow. The majority of lateral move operators (56%) responded that their labour requirement was ¼ to ½ of that for furrow. The median labour requirement compared to furrow irrigation reported for centre pivots was 25% and for lateral moves 30%. These figures are substantially larger than those reported in 2001 of 10% for centre pivot and 20% for lateral move. Of the 2011-12 respondents, 59% considered that a higher level of skill was required to operate CPLM compared to furrow irrigation.

Figure 7: Labour required for centre pivot and lateral move systems compared to an equivalent area of furrow irrigation 2011-12.

Lateral move systems usually require open supply channels that may cost in the tens of thousands to the hundreds of thousands to construct depending on the distance to the water source and the size of the irrigation project. This is a factor that may influence which type of system an irrigator would purchase. One grower reported having problems with trash in the supply channel, while other growers reported algae in the channels was a problem. Channel maintenance, including desilting, grading and spraying weeds, is necessary and respondents reported spending $250 to $10,000 per year on this.

While many respondents reported no particular issues, Table 7 is a sample of the comments collected when respondents were asked about their LM supply channels.

Table 7: Comments relating to LM supply channels.

"Be careful when putting in a channel – you may need one bigger than recommended if this channel also provides water for furrow irrigation."
"Try to minimise the width. This reduces evaporation and deep drainage, and minimises the size reduction of the field."
"Can't flush because channel below outlet, resulting in green algae growth. Waste of water because can't drain the channel."
"Lots of hidden costs eg. pipes which this landholder had on hand, but if had to pay for them would be extra $10,000."
"No problems thanks to overflow structure"
"The above ground guidance cable is located on the edge of the supply channel and the moisture subs up the banks. This means the weight of the cart produces wheel tracks that squish the soil around it moving the position of the ground cable. The other issue is erosion along the channel."
"Blow-out structures are a must to ensure channel cannot overfill. Underground wire steering would also be better."
"The road beside the lateral is only 1.5m wide – would have preferred a wider road."

2.8.2 System Capacity

System capacity is one of the most important parameters of CPLM design as it influences the ability of the system to meet crop water requirements.

Growers were asked to provide the design system capacity of their CPLM systems. Irrigators often have a perception of their system's capacity which may be derived from their designer, retailer, neighbour, etc. While it may be an accurate perception, it is useful to check the perception of their system capacity, with system capacity calculated based on the pump flow rate and area irrigated provided by the growers. An inaccurate perception may be due to being given incorrect information, poor design, differences between the design and the implementation of the system, deterioration of the system over time, etc.

In general, most centre pivot operators had an accurate assessment of their system capacity, with 68% in the 2011-12 survey within 1 mm/day over or under the calculated value (Figure 8). For lateral move operators, the majority (59%) had a less accurate assessment with a difference of more than 2 mm/day over or under the calculated value. System capacity is a function of flow rate and irrigated area, and as the irrigated area can be varied more readily in lateral move systems than in centre pivots, the greater difference may be attributable to the reported irrigable area figures having a lesser degree of accuracy.

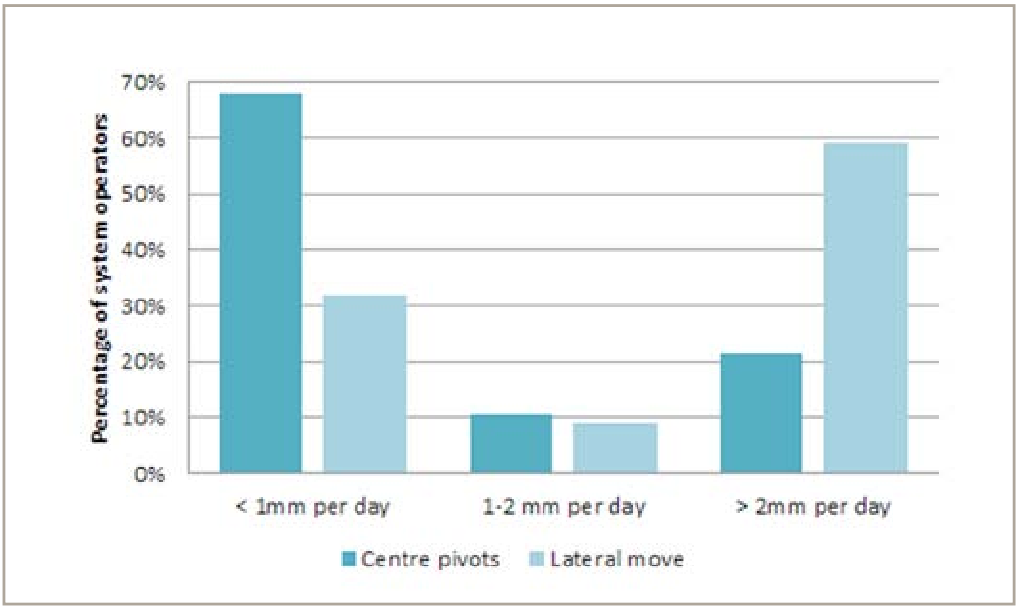


Figure 8: Difference between stated system capacity and calculated system capacity 2011-12.

Overall, there was a significant variation in design system capacity figures provided by the growers, which ranged between 4 and 32 mm/day.

The average daily peak evapotranspiration (ET) was calculated from the monthly Point Potential ET data for where each system is located for January, which is available from the Bureau of Meteorology. This figure was multiplied by a crop coefficient of 1.1 and divided by the number of days in the month (31). Design and managed system capacities presented as a proportion of ET for both the 2001 and 2011-12 surveys are shown in Figure 9. This approach accounts for the natural differences in potential ET (and therefore potential crop water needs) in different locations. In simple terms, Figure 9 provides an indication of whether a system is likely to be able to satisfy a crop's water needs during a period of maximum ET.

In terms of design system capacity, most systems in 2011-12 (59%) were designed to apply more than 110% of this peak ET requirement. This is an improvement compared to the 2001 review where only 26% systems were designed to apply more than 110% of peak ET.

However, allowance needs to be made for machine downtime and application losses – termed

managed system capacity. (See Section 1.2 'Definitions' for how to calculate both design system capacity and managed system capacity.) Managed system capacity is more critical than design system capacity as it must be at least equal to daily crop water use during intense periods of evaporative demand if the crop is to be properly supplied. The managed system capacity provides a better indication of whether a system is likely to be able to satisfy a crop's water needs during a period of time of maximum ET.

Of systems in the 2011-12 survey, only 20% had a managed system capacity able to apply more than 110% of the peak ET (compared to 18% in 2001) and 25% had a managed system capacity of between 90% and 110% of the peak ET (compared to 36% in 2001). The proportion of systems unable to meet the crop's water demand was 55% in 2011-12 compared to 46% in 2001. For these systems the managed system capacity was below 90% of peak ET which means at least 10% less water could be applied than the crop required for each irrigation event posing a significant risk to irrigators particularly during dry periods. At peak times, the crop would be irrigated daily so the water deficiency would accumulate rapidly with severe implications for productivity.

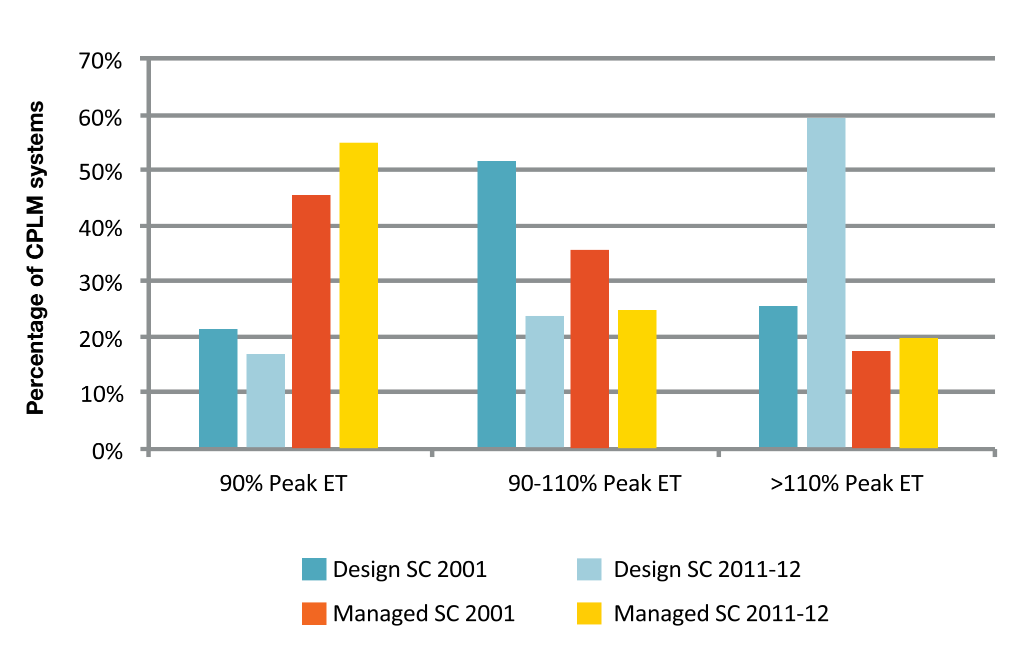


Figure 9: Proportion of CPLM system capacities expressed as a percentage of the average daily peak evapotranspiration (Peak ET January) rates in 2001 and 2011-12.

The change in designed system capacity figures from 2001 to 2011-12 demonstrates that growers and probably designers are better understanding the importance of adequate system capacity in meeting crop water needs and have made this a requirement in new system designs. However, the need to properly accommodate non-irrigation time is crucial in the design of these systems, and importantly, this study has found compared to 2001, there are now a greater proportion of systems (55%) with a managed system capacity that could not meet peak water demand. This may indicate that purchasers are underestimating the impact of their actual field operations on system performance and is a strong indication that growers are not operating their systems for enough hours during periods of peak crop water demand. A Managed System Capacity of 90 per cent of peak ET may pose a significant risk to irrigators particularly during dry periods. Peak ET periods commonly coincide with the key yield formation period for summer crops. There may be trade-offs in irrigator decision making between the additional cost of a managed system capacity to meet peak ET and risk to yield in years when this capacity may be required. Understanding the reasons for the decline observed between 2001 and 2011-12 is an area for further investigation.

Managed system capacity was also compared to both yield and Irrigation Water Use Index (IWUI) for cotton crops (Figures 10 and 11). Cotton was the only crop with sufficient reported data to allow this comparison. There appears to be no correlation between IWUI or yield with Managed System Capacity evident in this data, with values of both yield and IWUI fairly consistent across the spectrum of managed system capacities. These results are affected by the weather prevalent during the time the survey was conducted, which was wetter than usual following the 'millenium drought'. This was particularly the case during the Queensland component of data collection which encompassed two of the wettest seasons on record. The effect is to mask any consequences of inadequate Managed System Capacity by maintaining yield and reducing the irrigation water required and therefore lifting IWUI.

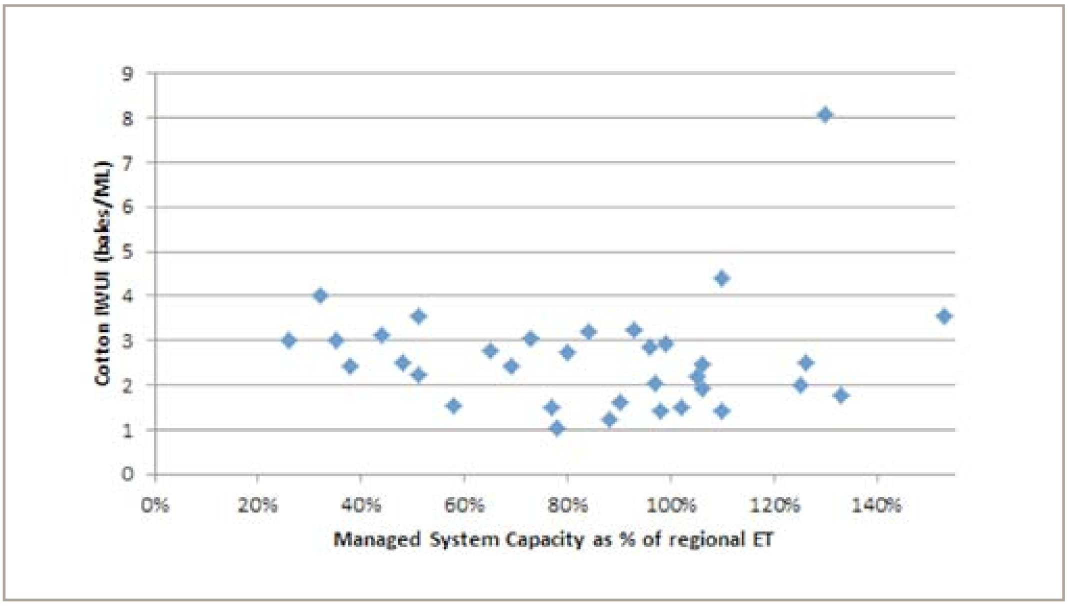


Figure 10: Relationship between managed system capacity and Irrigated Water Use Index (IWUI) for cotton crops 2011-12.

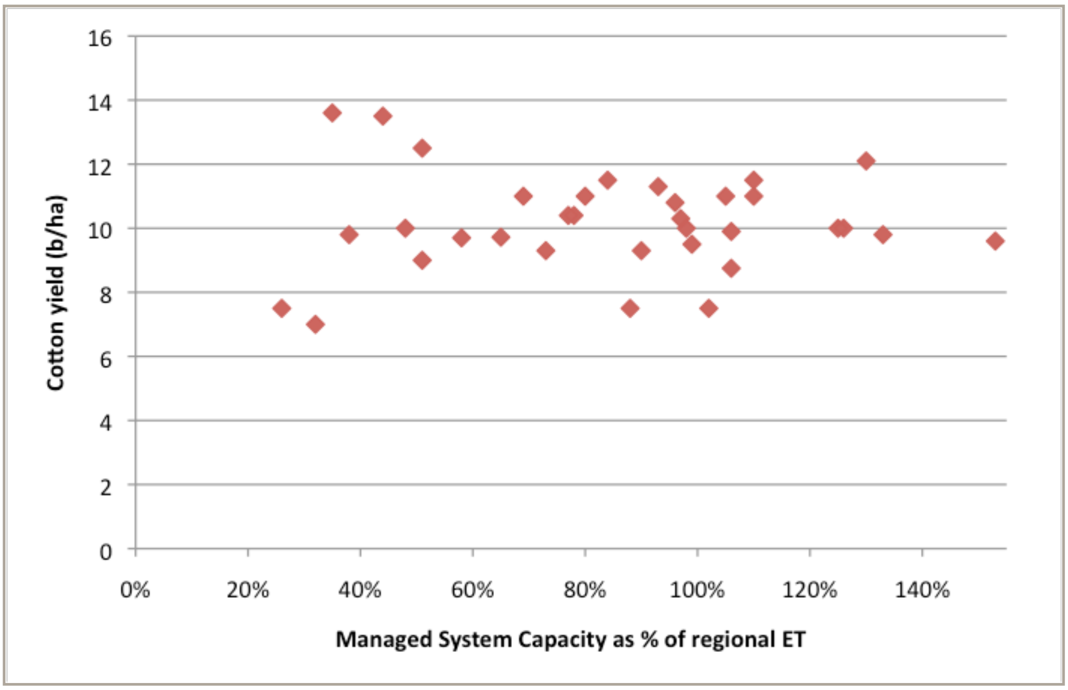


Figure 11: Relationship between managed system capacity and yield for cotton crops 2011-12.

2.8.3 Machine Size

Lateral move machines ranged from 377 to 1,220 metres in width. The maximum size of a lateral move is limited by the maximum flow rate that can be delivered to satisfy the required system capacity, and is therefore also a function of the length of run. This means a narrow machine with a long run can have the same system capacity as a wide machine with a short run, assuming both have the same flow rate. The range of lateral move widths and channel lengths encountered are presented in Figure 12, along with the corresponding system capacity for each one. System capacity shows no significant relationship to machine width.

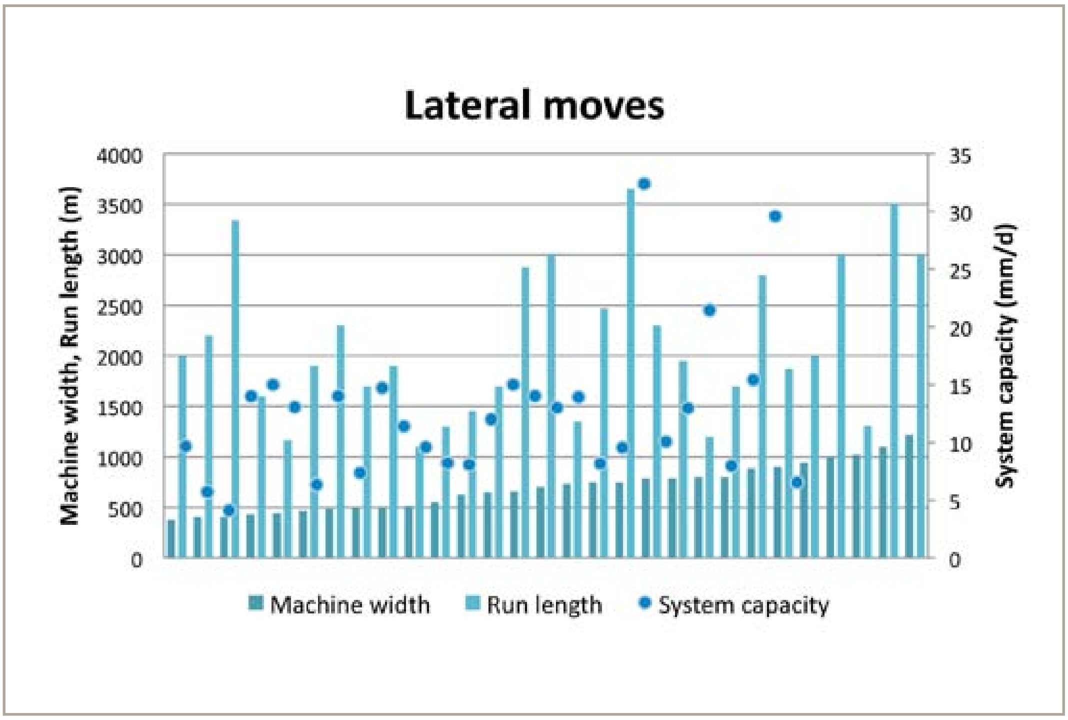


Figure 12: Lateral move machine width (m), channel length (m) and corresponding system capacity (mm/day) 2011-12.

Centre pivot machines ranged from 240 to 560 metres in length. For a given system capacity, the average application rate (AAR) under centre pivots increases with machine length. On some soil types, particularly hard setting soils with little to no crack development, significant runoff can occur at the outside of the circle if the AAR is too high for the detention capabilities of the soil. Machine length and likely AAR should always be considered in conjunction with soil type, emitter selection and proposed management techniques during machine design, especially for those with high system capacity. The range of surveyed centre pivot lengths is presented in Figure 13, along with the corresponding system capacity for each one. System capacity shows no correlation with machine length. Irrigation suppliers suggest the maximum area that could be covered by a centre pivot to deliver the system capacity required within the QMDB was around 80 to 100 ha (Wigginton et al 2011 p.13). This is consistent with the largest pivot encountered within both the NSW and Qld surveys, which was 106 ha.

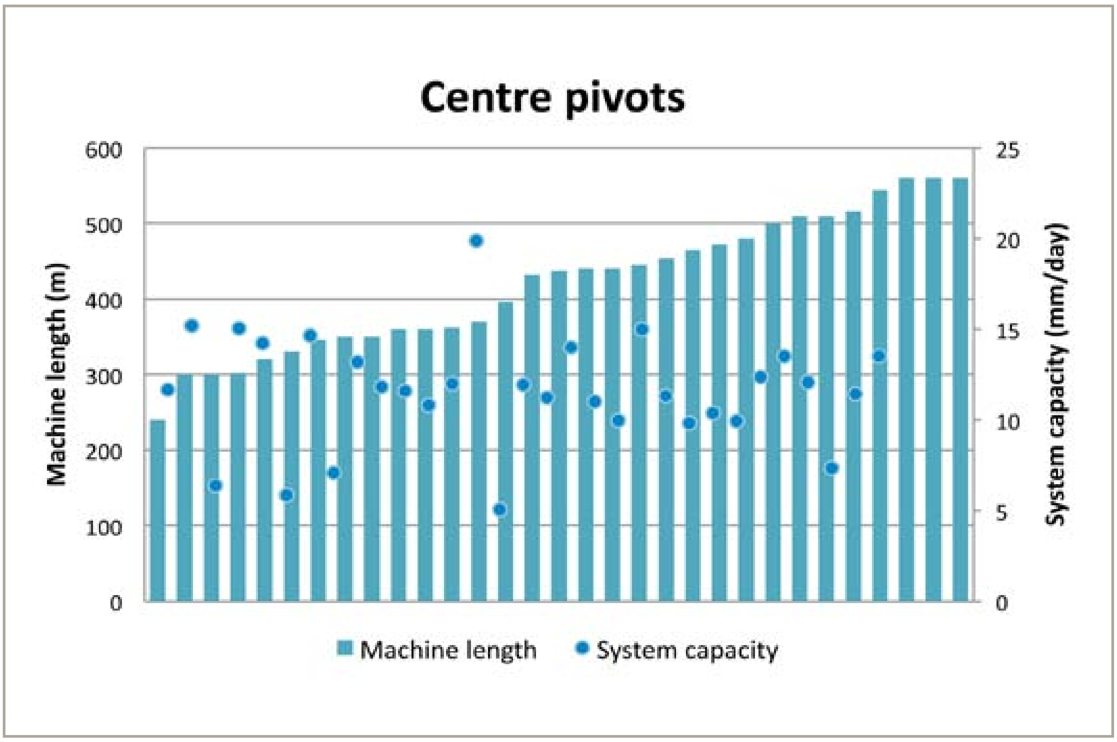


Figure 13: Centre pivot machine length (m) and corresponding system capacity (mm/day) 2011-12.

2.8.4 Operating pressures and energy use

Most growers considered the higher running costs of CPLM systems a disadvantage. Most of the energy costs in a pressurised system are associated with pumping water and can be minimised by keeping operating pressures as low as possible. This is achieved partly by good design (eg. appropriate pipe diameters) and by good management (eg. operating at the correct pump duty).

Most systems were fitted with pressure regulators rated at 15 psi or less and it is commonly recommended that the CPLM system supply point pressure (the centre or the cart) be no more than 15 psi greater than the pressure regulators, including the minimum of 5 psi above the regulator rated pressure to operate properly. This means the supply point pressure should commonly be no more than about 30 psi. However Figure 14 shows that 52% of systems in 2011-12 were operating above 30 psi. These operators may be incurring higher running costs than required to run their CPLM efficiently. This was an improvement compared with 2001 when 59% of systems were operating above 30 psi but there is room for further improvement. There were also no systems operating above 50 psi in the 2011-12 study compared to 13% in 2001.

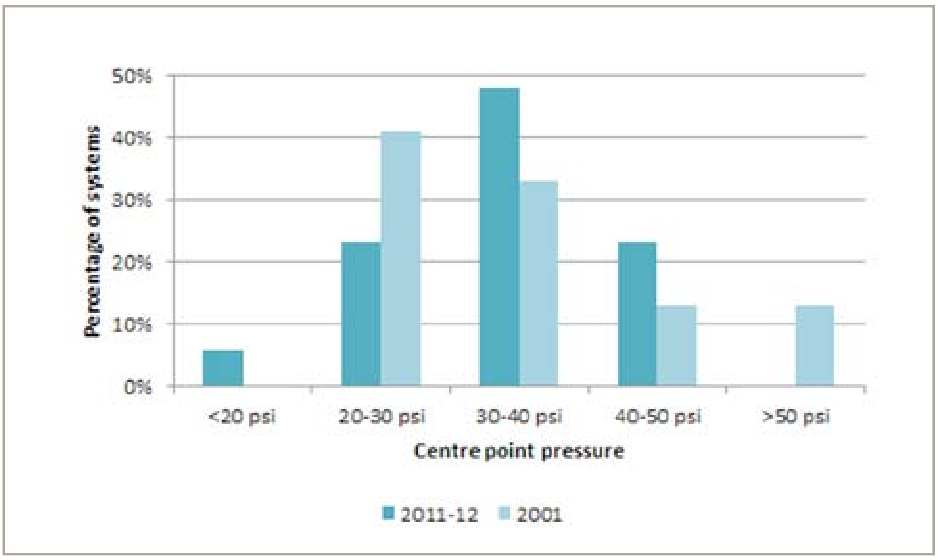


Figure 14: Proportions of irrigator-reported operating pressure at the centre (CP) or the supply point (LM) of the system for both 2011-12 and 2001 surveys.

This is further demonstrated when the difference between operating pressure at the supply point and the rated pressure of the regulators are compared. Figure 15 shows the difference between the regulator pressure and the operating pressure. Only a small percentage of irrigators (21%) were operating their systems at the conventionally optimal pressure difference.

On average, irrigators ran their supply point pressure at 19 psi above their regulator pressure, with a range of 0 to 40 psi. As pressure regulators require a minimum of 5 psi above their rated pressure to operate properly, there are four of the systems surveyed that were not operating properly (below the red line at 5 psi in Figure 15 - all four had zero difference ie. the supply point pressure was the same as the regulator pressure), three at the low pressure end and one at the high pressure end. At the other extreme, there were eight systems operating at 30 psi or more above the regulator pressure, possibly consuming significant unnecessary extra energy.

Figure 16 shows the regulator pressure ratings and the operating pressure recorded for each system surveyed.

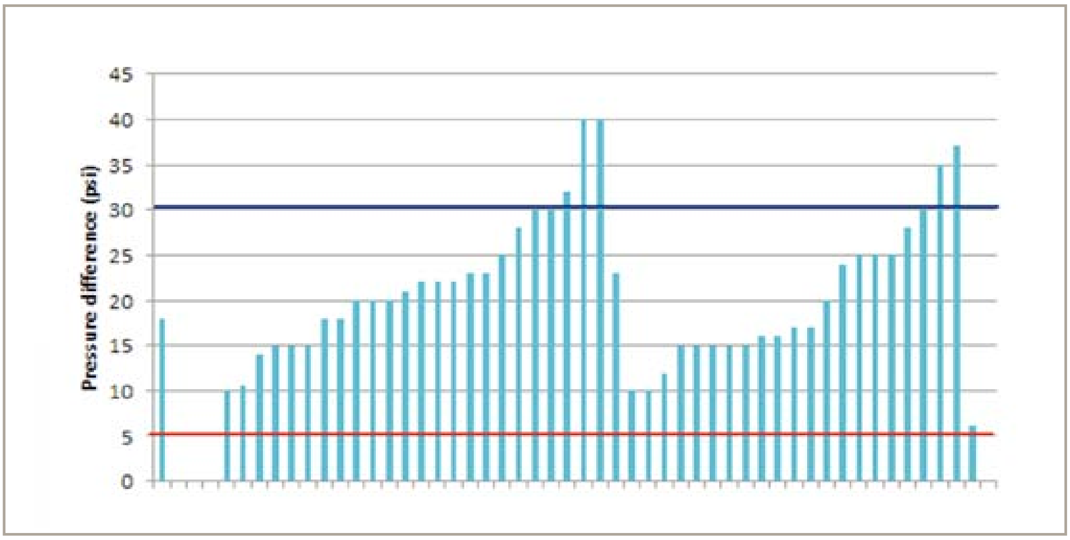


Figure 15: Difference between operating and regulator pressures for all systems surveyed 2011-12.

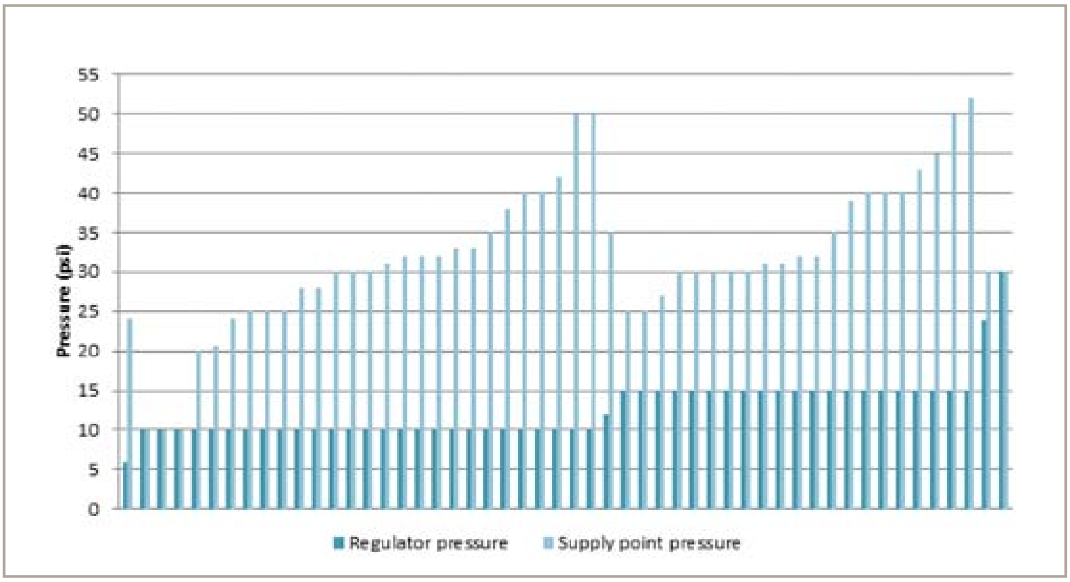


Figure 16: Operating and regulator pressures for the systems surveyed 2011-12.

These results were validated by grower responses on the issues related to energy costs. 57% of irrigators were concerned about the cost of operating their system, 62% considered the costs when the system was designed, and 43% have considered decreasing the total pumping pressure head in order to reduce operating costs (Table 8).

Table 8: Growers concerned about system energy costs 2011-12.

	No	Yes
Are you concerned with the cost of operation of your system?	43%	57%
Did you consider the operational power costs when the system was designed?	38%	62%
Have you considered decreased pumping head to decrease energy costs?	57%	43%

2.8.5 Farming in circles

In 2001 50% of centre pivot users planted their fields in a circle whereas in 2011-12 only 30% did so. Circular planting was done mainly to avoid field operations over wheel ruts formed by the centre pivot irrigator. Reasons for planting in straight rows were for the practicality of field operations, especially harvest. Samples of their comments are in Tables 9 and 10.

Of the centre pivot irrigators surveyed in 2011-12, five out of 33 (15%) reported that they irrigated the triangular corner sections that remain in a square field irrigated by a round system. The rest of the centre pivot irrigators don't irrigate the corners at all, with some mentioning that their irrigated fields were circular and did not have corner sections, and others that they treated the corners as dryland. Nine out of 33 (27%) reported that they used an end-gun on their system, and five of them did so to irrigate the corner sections, which means the remaining four fitted end-guns for the purpose of increasing the irrigated area.

Table 9: Comments from respondents who reported they farmed in circles under centre pivot.

"We 'crowded up' the wheel tracks for the pivot – can't drive machinery across these"
"Too hard to pick under the pivot if I didn't farm in circles"
"Harvest in straight rows. Position the CP at 12 o'clock in line with the rows, and when close to the CP walk it a small distance, harvest, then walk it back."
"I use GPS and do winter cropping with large equipment"
"Yes for cotton, no for mungbeans, wheat, chickpeas and sorghum. I leave a 24m swath (for spray width) on one section of circle which is planted radially. The rest of the area is planted in circles moving from one side of the 24m swath to the other."
"Getting concentric circles is difficult, even with a GPS. I treat every tower as a new starting point to centre correctly."
"We leave a 6 row swath radially, then plant the rest of the area in a circle. Winter crops are planted straight through due to having a drawbar planter that pulls slightly sideways. "
"Wheel ruts keep water on field if runoff occurs"
"Circle is better for higher demanding crop and when doing in-crop ripping with summer crops."
"Summer crop is planted on the circle and winter crop is planted straight through."

Table 10: Comments from respondents who reported they did not farm in circles under centre pivot.

"I calculated an 11% loss when sowing in circle. Also, we do direct drilling so there is no tracking issue from furrows."
"Easier to manage and inter-row cultivate – easier on machines"
"Logistics of working under a pivot is difficult and just easier to go up and down. Pivot is in the way if you plant in a circle."
"If you plant in a circle you need a better operator and you also waste area near the pivot for turning."
"GPS works better straight"
"Have to plant in two halves because of turning area issues. Need a good marker arm or a GPS. GPS issues occur if the ground is uneven or the circle is egg shaped."
"Trying to achieve tram-tracking and minimum tillage. We leave the pivot on the paddock at picking so there is less movement of the pivot when picking the crop."
"Have thought about planting in a circle, but harvest not practical."
"I did plant cotton in a circle for one CP, but I would not do it again. The idea was to incorporate a refuge area from the centre to the outside as a headland. Although it was efficient during the growing season (good for planting and spraying), it was not efficient for picking. Round bales were left all over the paddock. I wouldn't do it again for this reason."
"Inter-row cultivation: can't get the precision required with circles. Spraying: coming out at the end of a row is logistically better. Picking: modules located at end of the field, again logistically better. I can see no advantage – why would you plant in a circle?"
"Machinery can't fit under CP so you have to turn at the machine anyway."
"Every row is a different length."

Some growers who planted in a circle reported that they also harvested in a circle using methods such as the following:

- "All turning was done off the circle. Also the chaser bins were off the circle."
- "Round, turn in middle, 'C' shaped"

However the majority of growers who planted in a circle harvested up and down:

- "Up and down. Leave module pad in middle"
- "We harvest in straight rows. We position the CP at 12 o'clock, in line with the rows, and when we get close to the CP, we walk it a small distance, harvest, then walk it back."
- "Up and down, same as all our machinery operations"
- "Up and down – move the pivot one way or other at picking."

2.8.6 Water quality

In 2011-12, 35% of growers surveyed reported having water quality issues. Approximately half of these had corrosive water problems, compared to 25% of growers in 2001. These 2011-12 growers subsequently have opted for either poly-lined, stainless steel piping or under-slings on their machines. The other half reported problems with filter blockages caused by vegetative matter, silt, and sludge from the bottom of bores, or various water-living creatures. Regular flushing seemed to be the most common method of alleviating these problems.

The following are some of the responses collected:

"Only a problem on the suction screen – waterbugs caused a problem in first season. We increased the size of the suction screen openings and put in booster pumps to increase pressure to wash screens."

"No quality problems except grass getting in supply channel, and some algae growing in the channels."

"All sub-mains had to be replaced with plastic – very hard water, high in iron – eats gal."

"Our bore water is hard and I need to clean the nozzles once a month."

"An inline filter after the pump is important as it saves on nozzle cleaning."

2.8.7 Power supply and control

A larger proportion of growers in 2011-12 used diesel powered machines (79% compared to 65% in 2001). The remaining 21% used mains power and all of these were centre pivots (Table 11). All of the lateral move systems were diesel powered, and all of the hydraulic drive machines were diesel powered.

Table 11: Energy sources 2011-12.

	No. Centre Pivots	No. Lateral Moves	Total
Hydraulic power supplied by diesel generator set	2	4	6 (10%)
Electricity supplied by diesel generator set	18	25	43 (69%)
Electricity supplied from mains	13	0	13 (21%)

Note: The percentage of the total systems is shown in brackets.

Of the machines surveyed, 90% had electric tower drives and 10% had hydraulic tower drives (Table 12). Of the centre pivot machines 55% had electric tower drives powered by diesel generator, 39% had electric tower drives powered from the mains, and 6% had hydraulic tower drives powered by a diesel motor. Of the lateral move machines, 86% had electric tower drives powered by diesel generator and 14% had hydraulic tower drives powered by a diesel motor.

Table 12: Machine drive types 2011-12.

	No. Centre Pivots	No. Lateral Moves	Total
Electric tower drives	31	25	56 (90%)
Hydraulic tower drives	2	4	6 (10%)

Note: The percentage of the total systems is shown in brackets.

Although automatic control systems were more common in 2011-12 (40%) than in 2001 (10%), their use remains low considering the value of these systems in reducing labour and increasing flexibility. Most of the current automation systems have the ability for complete control by either mobile phone or the office computer. Of those growers without automatic controllers, some still had an automatic shut off feature if problems such as low pressure occurred.

2.8.8 Wheel rutting and bogging

Of total survey participants, 64% experienced problems with wheel ruts and/or bogging, less than the 79% in 2001. Despite this being one of the most prevalent issues with CPLM systems most growers consider the problems minor and were usually able to overcome them within the first few seasons of operation.

Of the total survey participants, 59% alleviated wheel rutting and bogging by modifying their irrigation strategy or sprinkler set up. Most who had taken action overcame the issues through the use of 'boombacks' and half-throw sprinklers around the towers. Table 13 lists typical grower comments. High on the list was the need to check the tyre pressures and to use different tyre configurations to alleviate bogging.

Table 13: Methods used by growers to reduce wheel rutting and bogging.

"Fitted spreader-bars and more sprinklers"
"Using brown coal compost, green manure. Use of EM Fertiliser (Efficient Microbes) to improve soil structure. Ca/Mg ratio. Also reduced application rate."
"Half-circle sprinklers at towers. Maintain beds in 'm' shape. Maintain soil structure to improve infiltration rate."
"I no longer deep rip, first irrigation is fast and light to pack the wheel tracks, I will use a disc plough on the wheel tracks at end of the season. Bogging only a problem when we have had a breakdown eg. do a gear box, wheel keeps turning but cannot move forward so buries itself."
"No changes to the machine i.e. no boombacks, no half- throw sprinklers. Our idea is that the cotton growing around the wheel tracks will dry out soil, therefore we fully water this cotton. We also know that if we apply 20mm the machine will walk well both up and down the field. If we were applying more than this it may be an issue. Bogging is only an issue when crossing the tail drain (from previous furrow irrigation layout) which is located midway down the field."

"3-wheeled towers, disc the wheel track, turn sprinklers off close to tower, use boom backs. "
"Use of LEPA emitters and removal of sprinklers at the wheels"
"Keep wheel tracks dry at start of the season. Freshly ploughed ground is where we get our problems. Have to get the ground settled. Will run dry after a shower of rain to compact wheel tracks."
"Lower tyre pressure gives greater contact area and reduced force on the soil."
"With zero till, the tracks do get deeper. When towing the (movable) pivot back, make sure you get it on the same spot."
"We laser-levelled the paddock as rainfall in low spots would not dry out quick enough and it would bog on the third run. Boombacks fitted only one way and only irrigate uphill."
"We had too much water during installation, and the alignment cable was not straight, causing the machine to walk out of tracks. Boombacks fitted for both directions. Initial runs will be at lighter application rates to avoid bogging issues and to establish tracks."
"Going slower helped as there is less passes"
"Only initially a problem, once stubble cover was established, no more bogging problems."
"Tyres degrade with exposure to the elements – no cover."
"Bog easier at the wrong pressure – use correct pressure."
"In our soils its important that we wash the mud off our tyres as it is operating to clean the grip to prevent bogging."
"Tyre selection is really important. Size and pressure help to stop bogging. It took me 15 years to realise how important tyre pressure was! It allows the tyre to flex so that it flicks the mud off."

2.8.9 Drainage, Runoff and Waterlogging

Most survey participants (75%) believed there was less runoff from their CPLM fields compared to their furrow fields, and the remaining 25% either did not have tailwater systems on their CPLM fields or did not have furrow irrigation to compare. None believed there was more runoff.

The main reason given for this was growers not completely filling the soil profile under a CPLM system and therefore increasing the effectiveness of rainfall, with most growers tending not to see runoff from their CPLM fields at all unless there was a significant rainfall event.

Of the growers surveyed, 93% believed that irrigation by CPLM diminishes the effects of waterlogging and 7% believed it did not. Table 14 contains a sample of the responses collected.

Table 14: Growers comments regarding CPLM systems diminishing the effects of waterlogging.

"Decreased water after rainfall, especially if we receive a rainfall event straight after watering"
"More precise use of water – variable rate irrigation system"
"Diminished the effects of waterlogging. More frequent smaller applications, less waterlogging and improved growth."
"Reduced the effects as you don't fill the profile to field capacity"
"Diminished the effects of waterlogging. But once the profile is 90% full, waterlogging will occur after rainfall."
"Diminished the effects of waterlogging. Not filling profile, thus room to capture rainfall."
"Diminished the effects of waterlogging. Must have field lasered properly for good drainage."

In 2011-12 40% of survey participants had installed systems onto new country without levelling or drainage works (Figure 17) compared to 83% in 2001. The decrease in the proportion unwilling to make this extra capital investment in the 2011-12 survey, suggests the importance of drainage is now more widely appreciated.

In 2011-12 43% of those surveyed installed systems onto previously furrow irrigated country, compared to 7% in 2001. The increase in the proportion willing to install CPLM systems on land that was already productive suggests that better soils, consistent slopes and installed drainage works are now viewed more highly for these systems and probably reflects the expectation of better performance from CPLM systems compared to furrow systems (see section 2.6). The remaining 17% in the 2011-12 survey installed their systems on new country that had been levelled or had drainage work done compared to 10% in 2001.

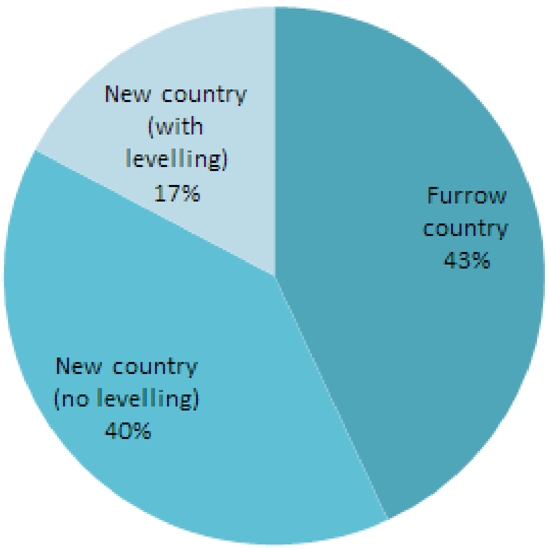


Figure 17: Land preparation undertaken by growers for CPLM fields 2011-12.

2.9 Choosing an emitter system

The mix of emitter systems in use changed considerably between 2001 and 2011-12 (Figure 18). In particular, the proportion of moving plate sprinklers increased significantly from 4% to 55% at the expense of Low Energy Precision Application (LEPA) systems which fell from 48% to 19%. These changes may be partially due to the differences in the study participants as some irrigators in the 2011-12 study may be more likely to have systems set up for grain and cotton crops, whereas irrigators in the 2001 study were more likely to have systems tailored specifically for cotton. However, grower comments in the later study suggest that this change is mostly because previous concerns associated with the use of sprinklers on cotton crops (such as potential effects on pollination and lint quality) have not eventuated in practice.

This change in emitter use is also consistent with the findings of the 2001 review which suggested that the performance of systems fitted with static plate sprinklers could be improved by conversion to moving plate sprinklers.

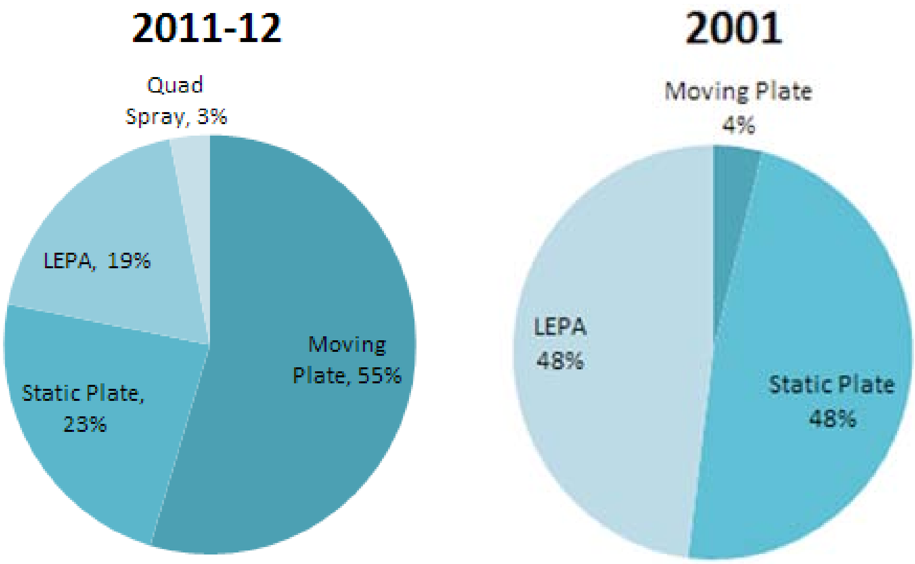


Figure 18: Proportion of emitter types used for in-crop irrigation reported by irrigators in 2011-12 and 2001.

Many survey participants commented that they left their emitter spacing as it was originally set up while many others indicated that they had put a lot of thought into setting up their sprinklers to suit crop type, soil type, having dry wheel tracks, etc. A sample of their comments is in Table 15.

Table 15: Grower comments on their emitter spacing.

"We sow on the flat, so there are no rows. Better infiltration – suggested by retailer."
"Based on soil type, for more efficient and even watering"
"1m spacing to fit with 1 metre spacing of crop"
"2 metre spacing because the emitter runs up the centre beds. This leaves dry wheel tracks for ground preparation and less water lying around for evaporation."
"One emitter for every row for evenness of application"
"Use sprinkler to germinate – centre of 2m bed. Use bubbler to irrigate furrows – every 2m."
"Water every row (1m spacing) for more uniform applications"
"Water every 2nd row. Ability to alternate after every 2nd run."
"With LEPA, the topsoil is dryer so cracks can be used for infiltration. This does not affect in-field operations such as spraying as 100% of LEPA water goes into root zone, even on a hot day."
"Germinate with sprinklers. Ground cracks enough, then irrigate with 1m hose dragging on ground – it clips straight into the spinner mechanism that was removed. We make sure water does not run ahead of the machine – if its not coping then change back to spinners. Takes 1 hour to change over."
"Spinners at 2m height and 2m spacing. Quad-sprays at 0.5m height and 2m spacing."

Only 9% of growers relied on rainfall alone to germinate their crops. 50% of growers used sprinklers alone, while 40% used sprinklers or LEPA in combination with rainfall to germinate their crops. No growers used LEPA systems alone to germinate crops.

The use of pressure regulators has increased from 58% of growers in 2001 to 95% in 2011-12. All of the survey participants who did not use pressure regulators used sprinklers.

Figure 19 shows that the most common regulator pressure used by growers was 10 psi or less (51%), followed by another 40% who used 11–15 psi regulators.

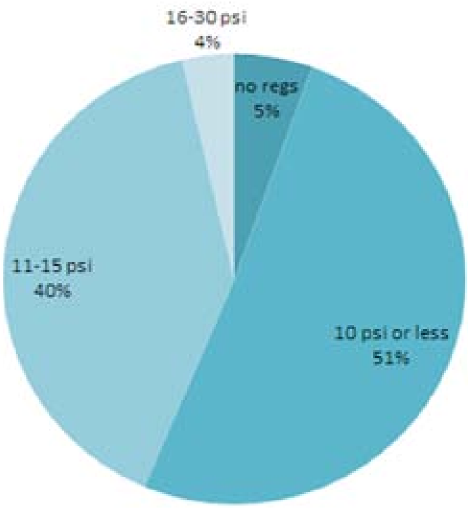


Figure 19: Proportion of growers using different pressure regulators in 2011-12 and 2001.

2.10 Agronomic Issues

2.10.1 Scheduling

Capacitance probes are the scheduling tool most commonly used by growers in the 2011-12 survey. Those growers who were not currently using capacitance probes intended to install them in the near future. Where growers in 2001 generally reported using one of a number of scheduling tools, in 2011-12 growers tended to use a combination of tools for both furrow and CPLM irrigation systems.

Irrigation decision-making for CPLM systems was different to furrow systems. The main difference between CPLM systems and furrow irrigation is the amount of water applied. CPLM systems apply less water per irrigation with more frequent irrigations. Therefore growers were more conscious of water use under a CPLM system as the volume of water stored in the soil is less. Although excessive vegetative growth of cotton was discussed in the 2001 study, this was not a concern for growers in 2011-12 suggesting that this issue has been resolved either through better management or the different characteristics in Bollgard® II varieties introduced since 2003.

Table 16 contains a range of comments collected regarding how a grower's use of irrigation scheduling tools differed between their CPLM and furrow fields.

Table 16: Grower comments on their use of irrigation scheduling tools for CPLM compared to furrow.

"Measure 80 cm for flood, and 70cm for lateral move."
"Watering more often and using a smaller application 15-30 mm"
"Tools do not differ, but deficit is less under the LM because less can be applied."
"Very similar. Checking probes knowing that CPLM have a lower tolerance for error. Weaker root system under CPLM."
"No difference"
"Utilise crop water use data (ETc) more so than probe data."
"Use Capacitance Probe – but there is a monitoring difficulty because of the length between irrigations."
"More conscious of water use with pressurised system."
"Tools do not differ. Probes located in top of row, one per lateral at end of field."

The depth of water typically applied per irrigation with CPLM systems reported by growers ranged from 5 mm to 50 mm with a median of 24 mm. In the 2011-12 survey, a greater proportion of growers (52%) applied between 15 mm and 30 mm compared to 33% in 2001. Those applying 15 mm or less have reduced by 11% and 7% fewer growers are applying more than 45 mm. The variation in applied depths is shown in Figure 20.

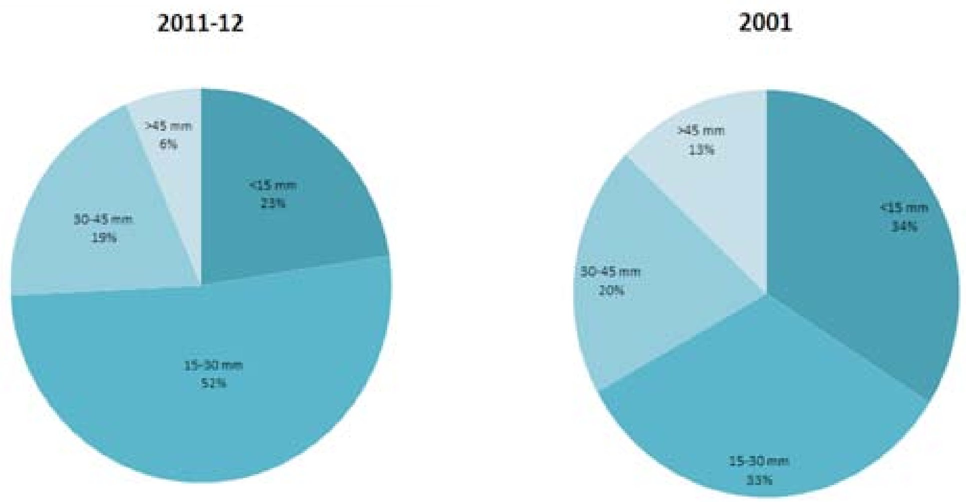


Figure 20: Proportion of irrigators reporting typical depth of irrigation applied per pass in 2011-12 and 2001.

A number of specific scheduling related questions were asked of growers and Tables 17 to 20 are a sample of their responses.

Table 17: How do you determine when to start irrigating and how much water to apply?

"Push probes, weather based scheduling"
"Weather, soil moisture monitoring, ET"
"Neutron probe, agronomist, weather forecast"
"Crop growth stage, soil moisture level, fill to capacity."
"Constrained by infiltration rate. Soil moisture probes in field, but infiltration tends to dictate the schedule."
"Agronomist recommendation, day-degrees, visual inspection"
"Scheduling with tensiometer"
"C-probes – push probes"
"Experience – need probes in the future"
"Relate to water holding capacity of the soil type"
"Agronomist's moisture scheduling equipment."
"Weather-based scheduling."
"C-probes, push probe, walk through crops every day. I have one C-probe installed in just one field and use this as a guide for all fields. If I have a full profile then I know I have 2 weeks grace."
"Soil moisture probes located based on majority soil type as per EM survey. Visual inspection. Experience from surface irrigation."
"Every day check on the probes. Web-based system to check water use."

"C-probe data – we have 8 cotton fields, 4 indicator fields with probes which have a full and refill point established."
"When the field gets runoff – anything more than 25mm causes runoff"
"Time of your crop and growth stage"
"Shovel, C-probes, experience, farm agronomists and visual inspection"

Table 18: How do you modify the schedule after rain, cloudy periods or extremely hot weather?

"Irrigate another crop – move it around. Demand drops – so use it as an opportunity to start irrigating another field that may have been sown dry. Speed up the machine in dry weather."
"Adjust application rate by the amount applied. If its going to rain I apply less."
"Adjust schedule, stagger crop planting dates so they do not all peak at the same time."
"If rain is forecast, may irrigate a day earlier and apply less. Hot weather – check C-probes and we have the capacity to increase frequency of irrigations."
"In hot weather, we try to keep the profile moisture higher than usual."
"We can make changes fast with our irrigation systems, so we only need to modify to suit water demand."
"Don't stop for rain less than 25 mm – to keep in front"
"We don't modify the schedule. Have the capacity to get across the area and meet crop demands."
"Evaporation rates – alter application rate accordingly"
"Weather forecasts – different crop water requirements"
"We use the information from C-probes, agronomist and temperature forecasts to determine how to water."
"Wait as long as possible after rain, so we don't create wheel tracks."
"Apply a smaller amount on the first part of the field by speeding up the machine. Park the machine in the centre of the field."

Table 19: Do you apply the same amount of water to the entire field?

"Same amount the whole length of the field. No waterlogging – walk it out dry, back to the centre to then water the opposite field. Practical field management not so much water management."
"Put the same amount on the total field"
"No – variable rate irrigation."
"Yes – same"
"No – we increase speed near the end of field before turning around. Wait a day at end of field."

"LM - Same amount to entire length of field unless crop demand is increasing and we can speed up near end of field for quicker turnaround. Generally rest for 1 or 2 days at end of field before new pass. CP - Varies depending on soil factors which affects infiltration and hence wheel track management."
"Modify according to plant growth"
"No but use timer in centre with alternating sprinklers"
"15mm applied down, 10mm coming back. Bubblers and sprays are positioned above the crop, approx 1 foot above the crop at full height."

Table 20: What is your typical application strategy (especially for Lateral move)?

"Irrigate up and back (both directions)."
"Water both directions and run dry across the floodway."
"Build profile up to peak use then maintain through soil moisture monitoring, stagger sowing."
"Irrigate both directions, Maintain water profile. Do not irrigate roadway crossings."
"Irrigate in both directions after a rest at end of run (up to 3 days, depending on crop demand)."
"Depends on the interval between watering"
"Varies depending on soil type. Generally applying 17.5 mm per pass."
"Dry run 50m from tail drain. Have a one day break at the end then turn around for next pass."
"After each pass (circle) rest for 24 hrs before next pass."

2.10.2 Fertiliser Application

The proportion of growers that had applied fertiliser through their CPLM system in 2011-12 was higher (72%) than in 2001 (45%). All of these growers applied nitrogen through their CPLM, with one grower also applying liquid forms of phosphorus and potassium. Most growers applied nitrogen as urea which was typically mixed into the supply water before the machine suction inlet. Some growers also suggested that they could spread granular urea to the surface of the soil and "water it in" with the CPLM. Many growers suggested that they only applied top-up rates of fertiliser through their CPLM, implying that they still undertook major fertiliser applications using traditional methods.

Figure 21 shows that 34% of growers believed that fertigation resulted in a decrease in total seasonal fertiliser use (compared to 38% in 2001), whilst 47% of growers reported that it reduced the fertiliser required as up-front applications prior to planting (compared to 69% in 2001). A number of growers who did not practice fertigation cited accelerated corrosion concerns as the reason, compared to 2001 where no growers expressed this concern.

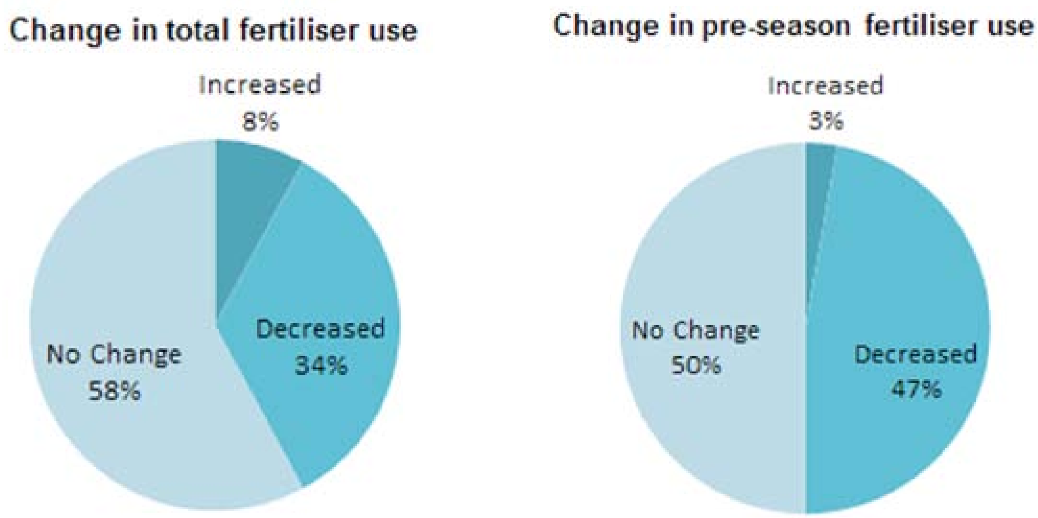


Figure 21: Change in total seasonal fertiliser use and pre-season fertiliser use with CPLM fertigation compared to furrow irrigation 2011-12.

There were a variety of materials and methods used in fertigation, and some responses are listed in Table 21.

Table 21: Please detail fertilisers / amounts / number of units of each / how often they are applied.

"Limited amount with lateral compared to centre pivot because of the weight"
"15 units of Nitrogen, 4 weeks from peak "
"Nitrogen – up to 100 units, every second irrigation"
"Sea weed, Stinging nettle tea – best and cheapest, boron, Ca, Na, molasses, sulphate of ammonia."
"Urea up to 50 units N when required until total requirement is met. Target 250 – 270 N total."
"Plan to put on 175 units of N. Put on in 25 unit lots whenever the crop needs it."
"Liquid nitrogen, early season application. Cleaning is vital, worried about corrosion after long term use."
"Urea, sulphate of ammonia, zinc, boron, potassium"
"Urea and trace elements, K, Boron, Zn, Mg >300kg/ha"
"Direct injection of NPK, NN, NS"
"Water run N26. In 2011/12 we used 430 L/ha."
"Microbes and trace elements – organic liquid manure – fish 3% N. 1000 litre shuttle on 60ha."
"Nitrogen liquid through CP"
"Urea twice a crop – 80 to 40 units"
"Water run N, 130 units in crop. Ability to apply when required."
"Water run N26, same frequency/concentration as furrow crops."

2.10.3 Chemical application

Figure 22 shows that 77% of survey participants applied chemicals aerially, or by a combination of aerial and ground rig. The 23% of growers who used ground rigs only commented that they needed to wait for a day or two after irrigating to allow the ground to dry out enough to prevent bogging. Those growers that used a combination of aerial and ground rig, used the ground rig when it fitted into their irrigation schedule, and if the soil was too wet they used the plane.

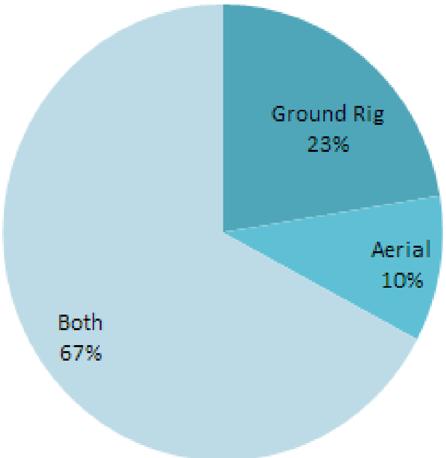


Figure 22: Method of applying chemicals 2011-12.

Chemigation is the practice of applying chemicals to land or crops in or with water through an on-farm irrigation system. 21% of the growers surveyed used chemigation methods with their CPLM machines compared to 14% in 2001.

One advantage stated by a grower was:

"Ability to direct inject, programme change – cheaper – plane costs more."

2.11 Machine Costs

This section is focused only on the capital costs of systems rather than a full economic analysis involving costs and benefits over time.

The capital cost of systems ranged between $610 and $6,000 per hectare, with a median value of $2,570 per hectare. This compares to $1,250 to $2,500 per hectare reported in 2001 although this comparison does not take into account the change in CPI over this period. Figure 23 shows that 70% of the systems surveyed in 2011-12 cost between $1,500 and $3,500 per hectare. The range in costs can be attributed to individual site requirements for the installation of the machine, including the cost of the machine, pumps, earthworks for channel, fields and roads, electrical works, the specified system capacity, and currency exchange rates. The lowest reported cost ($610/ha) included some second-hand equipment. Other factors affecting costs are works completed by growers themselves that are not fully costed, and growers with older systems not fully recollecting their total outlays.

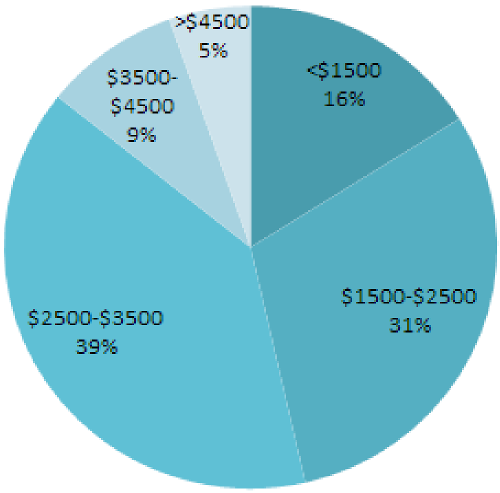


Figure 23: Cost of CPLM systems per hectare ($/ha) 2011-12.

As a general rule, system capital costs per ha decreased as the area irrigated increased. This trend was stronger for lateral moves (Figure 25) than for centre pivots (Figure 24). For centre pivots in particular, the cost for irrigating the same area varied by a multiple of up to six times. These large variations in cost per hectare must be attributed to individual site requirements rather than just the capital costs of the system, as mentioned above. In view of the potential variation in designs and the high overall cost, there may be considerable merit in engaging the services of an independent expert to evaluate designs. The cost of such a service may be as little as 1% of the total cost of the system.

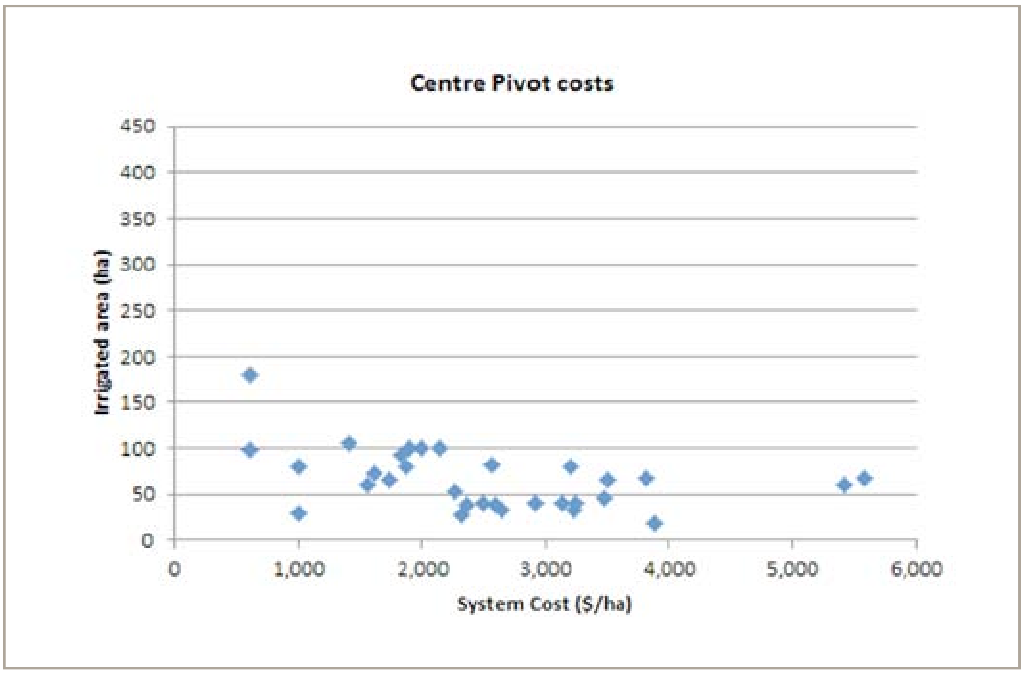


Figure 24: System cost compared to total irrigated area for centre pivots 2011-12.

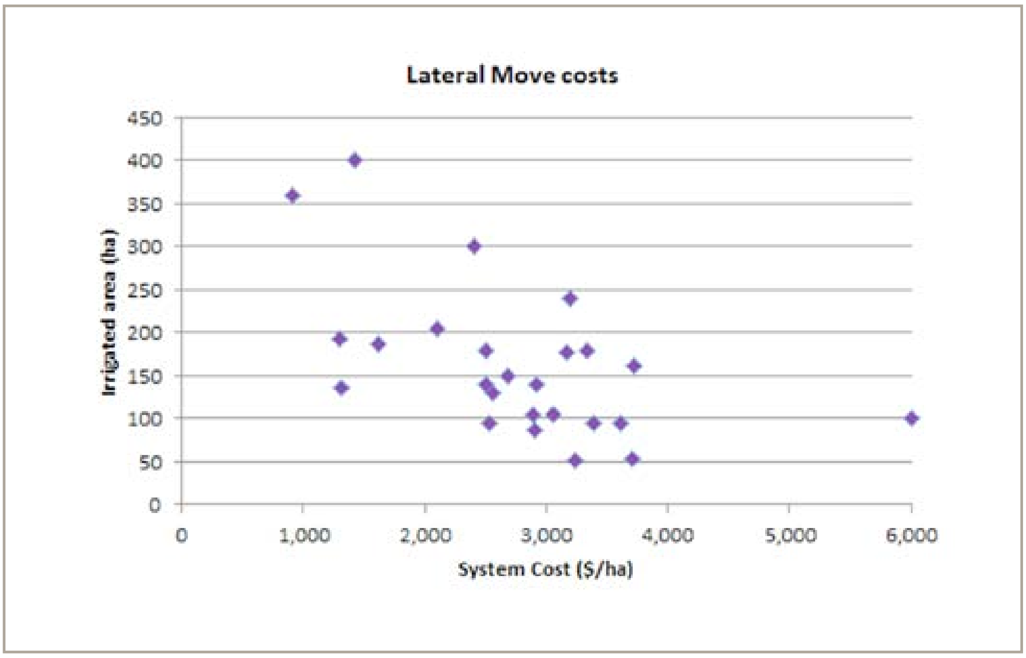


Figure 25: System cost compared to total irrigated area for lateral moves 2011-12.

Where cotton was grown, the system cost was also compared to the Irrigation Water Use Index (Figure 26). No correlation was found between them. Therefore a system that costs more money per hectare is not necessarily more efficient with irrigation water. There was an outlier at 8.0 which cannot be explained by water use efficiency or by the cost of a CPLM system, but more likely by wet seasonal conditions.

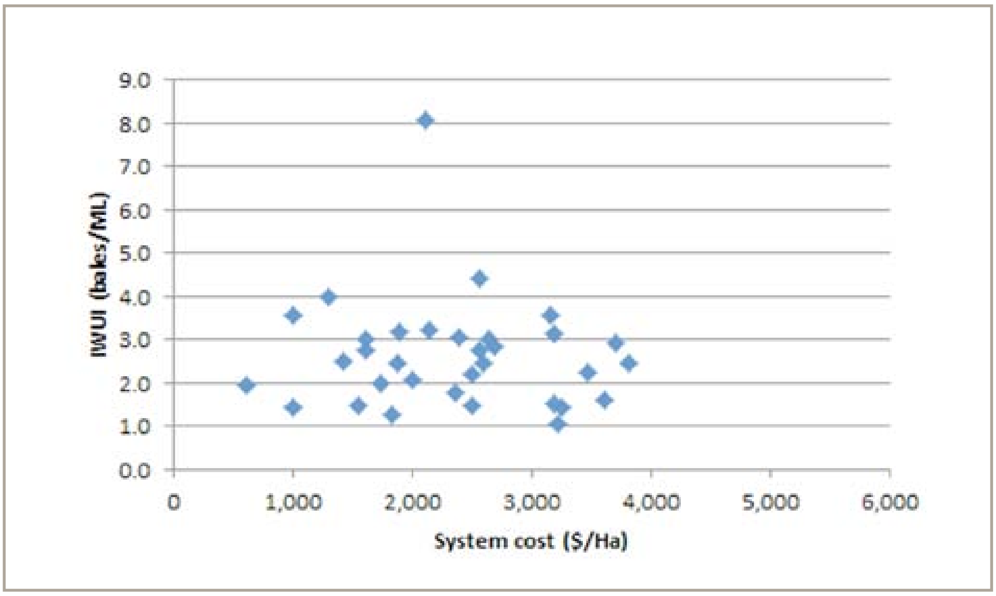


Figure 26: CPLM system cost compared to Irrigated Water Use Index (IWUI) for cotton 2011-12.

Figure 27 is a comparison of system cost and yield. Once again no correlation can be found between them. Therefore simply paying more per hectare does not necessarily affect yield. However, the variation in system cost is probably due to site-specific differences, with some sites requiring substantially more expenditure to obtain good performance. The comparisons in Figures 26 and 27 should not be a basis for investing in cheap, under-specified systems.

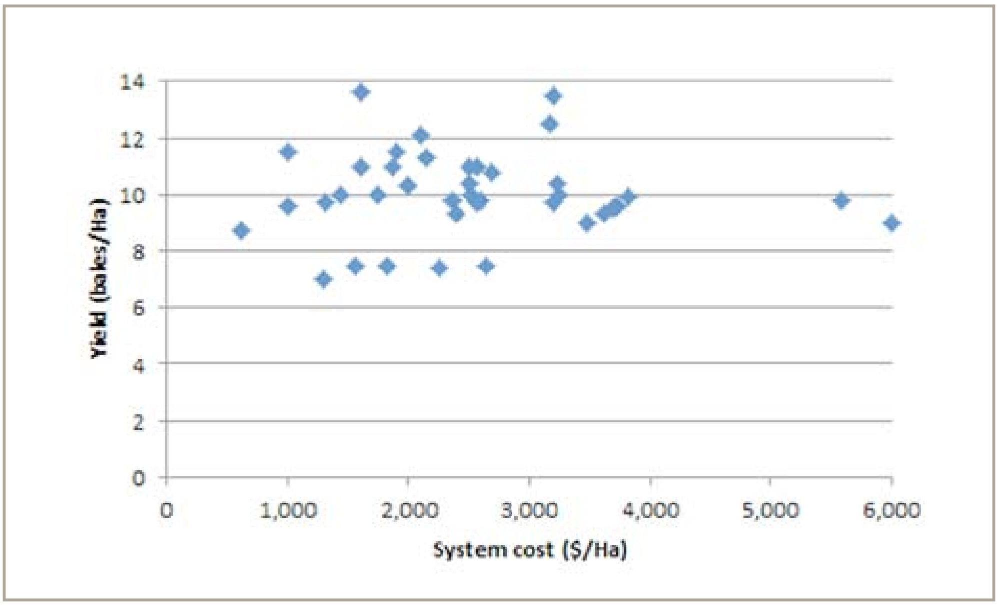


Figure 27: CPLM system cost compared to yield for cotton 2011-12.

2.12 System Performance

The 28 survey participants in the cohort surveyed by NSW DPI were asked about the commissioning of their CPLM system after purchase. Only eight of them said that a performance audit was conducted prior to commissioning, and one reported that some changes were made to sprinkler sizes as a consequence. However, 22 of them recommended that a performance audit be done before the final payment is made.

The performance of CPLM systems can be evaluated in a number of ways. Irrigation Water Use Index is an indicator of machine performance and is calculated by comparing yield and water as discussed earlier. Monitoring of a system during irrigation by looking at indicators such as pressure and discharge was also found to be important in evaluating a system's performance. 93% of survey participants had flow meters or pressure gauges for system control, and 79% had used pressure points as an indicator of problems within the system. Flow meters were not installed on 62% of systems surveyed. The operators of these systems used visual assessments of their sprays and bubblers. The 38% of growers who had flow meters fitted used them to assess changes in supply or a problem of delivery to the CPLM field. These growers gave the comments in Table 22.

Table 22: A sample of participants' comments about using flow meters to monitor system performance.

"We monitor flow rate to ensure consistency and pump performance/efficiency. We visually check the sprays and bubblers too."
"Check if flow is constant. If it drops to 25,000 USgal/hr may need river water to boost."
"We monitor from the flow indicated on the control panel and make necessary adjustments if flow is reducing or increasing."
"Make sure the required quantity per day is being applied"
"Monitoring the pump discharge alerts us to a potential problem"

Irrigation uniformity is another important measure for evaluating how evenly the water is applied to the crop. Non-uniform irrigation results in some areas being over watered and others under watered. This may have a significant effect on crop yield as plants that are under watered become stressed and give reduced yields, and those over watered become waterlogged and oxygen depleted. Overwatering also causes surface runoff and leaching of nutrients below the root zone. Only 25% of participants indicated they had measured their uniformity, with a range of values given from 50% to 100% (uniformity of 90% is recommended for CPLM systems). One innovative grower used infra-red photographs to show non-uniformity under the pivot as well as to highlight sprinkler blockages.

2.13 Advice for new users

There is a wealth of experience amongst growers in the irrigation industry, and the survey participants had a range of 1 to over 20 years' experience. Participants believed that on average

it took at least 2.3 years' experience to adequately manage their first CPLM system, with some commenting that it is an ongoing learning experience.

Forty one out of the 58 participants (71%) said they had plans for the purchase of further CPLM systems, indicating a high level of satisfaction with these systems.

When asked what things could be done differently to reduce the time to learn to operate a CPLM system adequately, growers commented on more experience and training with management tools such as capacitance probes. Many also commented that more CPLM training would have been useful, that talking to experienced growers provided support for trouble shooting, and that having experienced agronomists assisted a lot with crop management.

In reflection of their experiences with CPLM systems, participants gave the advice in Table 23 for others who are considering installing them.

The major points are:

- Supplier/retailer – ensure they are local, reputable, and able to provide service at critical times
- Ensure that the System Capacity is adequate and has been properly considered in the design
- Ensure the whole system is designed properly
- Take care to avoid wheel track and bogging issues
- Talk to other operators of CPLM systems before agreeing to a purchase
- Have a performance audit done prior to the final payment

Table 23: A sample of participants' advice for those considering installing a CPLM system

"Ignore the boundaries of the farm to see how it fits more effectively – don't be constrained by existing farm infrastructure. Work out the water requirement of the crop and the available water sources such as ML available per day. Place the system on the best soil to maximise profitability. "
"Use a single supplier/project manager for earthworks and machine installation. Check the reputation of the dealer and speak to existing customers. Do not take any short cuts."
"Do your maths on costings. You need to know the performance of your current system before you make the change to be sure the change is necessary. Have a clear plan as to where you are going. In the first instance, go to an operator, not a seller, for information and experiences – they will tell you the good and bad points about these systems. Service is very important – make sure you have good local service available."
"Use moisture probes. Get the design right. A decent supplier with good back up is essential. Price is not everything – don't simply pick the cheapest. Service made up for the difference."
"Training. Plan the configuration of the field to match the machine."
"Make sure you have adequate pipe sizes. 9–10 mm/day system capacity is good in Gunnedah but further west more output is needed, say 12 mm/day. Have a dealer close by that is good for servicing – need to have the right dealer."
"Drainage is VERY important, spend time to make sure you have adequate drainage. Talk to other growers. Cost of land forming was greater than expected – be aware of your costs."

"I would put the control box on the outside of the pivot and boombacks at the wheels. Get your pump installation right."
"Make sure system capacity is high enough to meet crop water requirements. Run tyres at 15 psi in boggy conditions. In well drained soils, run at 30 psi as the wear and tear on tyre wall is reduced."
"Make sure the whole supply system meets the requirements of the lateral system. Must be a reliable system. Drainage. Knife edge management – must be right on top of it."
"Get as much info as possible. Get Variable Rate Irrigation (VRI). Talk to other growers using CP. Important to assess the cost, lowest quote is not always the best. Cut friction loss as much as possible."
"Make sure you have the money before you start. Install one system at a time. Don't try to have one pivot for two centres."
"Do not skimp on capacity. Extra system capacity will pay off in the long run (hot days, flexibility with other operations eg. sprays)."
"Don't penny-pinch or these systems will break your heart. Use experienced machinery operators. Always use a reputable dealer. Local dealer important for serviceability. Need a good in-line water filter. Adequate land levelling. Dry wheel packs. Adequate system capacity. Only as good as the person using it. Do your homework on system capacity v's cost of breakdowns."
"Have 2–4 spare tyres and planetary gears and hoses. I wouldn't install galvanised-only or towable systems. Get a reputable dealer – with integrity and experienced construction team. Check if dealer has good parts and back up."
"Soil improvements with organic matter and gypsum"
"Ideally keep drainage from these systems independent of other irrigation systems. The wheel tracks create weirs – water management around the wheel tracks is important. Design and planning is more important if you are installing LM over existing furrow irrigation country. Ideally situate on new country. Soil type is very important – make sure it's suitable for LM, and take into account texture and elevation. Soil type should drive the design of the system. Consider water availability – don't want capital sitting idle."
"Use cover crop residue to reduce runoff and increase infiltration."
"Ensure system is commissioned. "
"Maintenance critical. Visit other growers outside your region. Make sure pump specs are adequate for crops and add a bit more. Match water for all crops, not just cotton, when planning design. Telemetry is really important for ease of management. Guidance by underground cable would make channel maintenance a lot easier. Make sure local service is A1. Parts need to be available – need to know what parts you need on hand and what parts the local dealer needs to have in Australia."
"No-one should ever put in a pivot under 10mm/day system capacity. Higher system capacity is better. Don't always go for the biggest machine – 80 Ha about max for acceptable friction/flow rates. Direct tower drains away from the wheels. Tyre size and pressure is very important. Look at pipe sizes carefully – can save you money in the long run. Set-up to water at night with 16 hours a day maximum watering interval. If you have automation, you still have to get off your bum and get into your crop – drive into the centre and check the crops and the machine."

Future Research

3 Future research

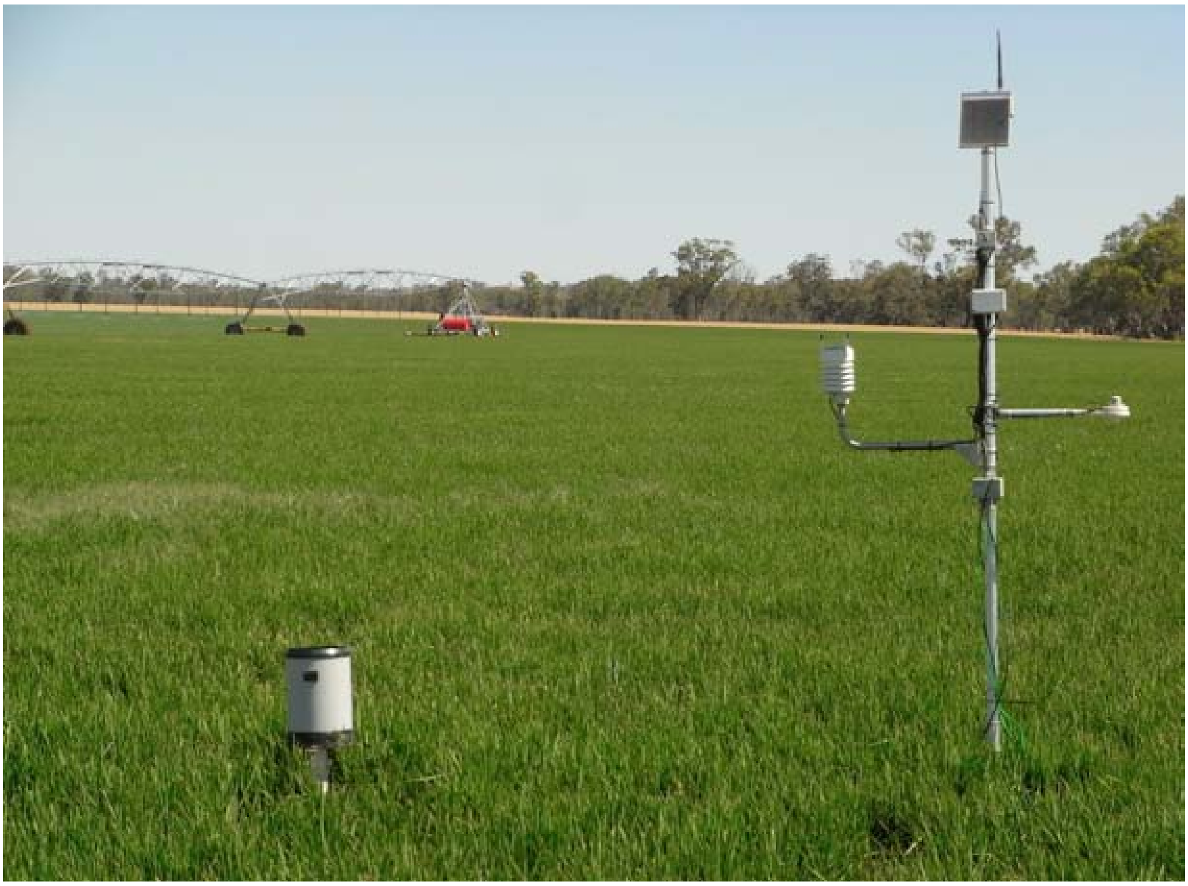
Participants in the 2011-12 survey were asked what research they thought was needed for CPLM systems. A sample of their responses is given in Table 24.

Table 24: A sample of participants' suggestions for future research for CPLM systems.

"Double cropping options that will enhance the value of the system. Profitability is the main thing – research needed on what other things can be applied through the system. Fine tuning of the nutrients that the plant needs during the growing period. Zero till and fertiliser efficiency combined with irrigation. Incorporating legumes with travelling irrigation."
"Improve field-by-field data for better irrigation scheduling. Automation of systems. More work on water holding capacity of soil."
"Reduce complexity of the Control Panel – do we need to have all operations supplied by the panel?"
"Management under different soil types."
"Disease, infiltration, nutrition, stubble management (stubble increased waterlogging during flood events this season)."
"More research work on chemigation and fertigation, consistent application, and self-management of wheel tracks.
Practical management – how to manage this system differently from flood. Wheel track management."
"Research on how much water to be used in different soil types and areas."
"More effective use of chemicals through the system."
"Some hard data on sprinkler packs. Disease and water interactions."
"What the lifespan currently is, particularly on newer machines. Use of plastic linings – should they all be sold this way? Structure of machine and life / stability."
"WUE – can LEPA be refined?"
"Development to simplify controllers and make them more reliable. Vibration of diesel motor causes electrical issues."
"Nozzle design and application with respect to wind drift."
"Scheduling on different crops, soil water deficit (SWD), yield loss or improvement."
"Fertigation and chemigation, application efficiencies. Crop rotations. High value crops, what crops can be grown. Scheduling. Less tillage (broadacre) less intense farming."
"Management of machines, synergies, soil compaction."
"Steering, GPS – machine stability. Falling over – a mechanism to prevent this."
"Knowing the efficiency of fertiliser application through the system – movement of nutrients, etc. Benefits of cover cropping."
"Watering and scheduling."
"Seed bed preparation – flat vs. bed."

Most of the suggestions above can be grouped under the heading of 'management optimisation'. Survey participants desire to know more about, and also simplify, the management of these systems to maximise their potential. The main management topics are more precise irrigation scheduling, what to do with different or variable soils, how to obtain better effect from applied nutrients and chemicals, and disease control. Obtaining the best overall performance requires optimising all of these rather than maximising any one of them.

Surveying a group of cotton irrigators who do not use CPLM systems could also be helpful for understanding any potential limitations to CPLM adoption.



Weather data is used by many irrigators for scheduling.

Conclusion

4 Conclusion

The 2011-12 review of CPLM irrigation systems in the Australian Cotton Industry gives an overview of current performance and management and provides an important comparison to the Foley and Raine (2001) review.

Four main observations arose from the 2011-12 survey:

- Around half the survey participants would be unable to meet a crop's peak water requirement as the Managed System Capacity was below 90% of peak crop water demand.
- Most irrigators are now installing CPLMs on country that has been levelled or had drainage works.
- Despite a general recognition that performance of CPLM systems should be checked at commissioning and regular intervals afterwards, only a small proportion of participants indicated that they did so.
- While most participants are concerned about running costs of CPLM systems, about half were operating their systems above optimal pressure, potentially incurring higher running costs than necessary.

The review found an improvement in Designed System Capacity which indicates that irrigators are now much more aware of its critical importance in terms of meeting crop water needs. However, Managed System Capacity was not dissimilar in the 2001 and 2011-12 studies and around half the survey participants would still be unable to meet a crop's water requirement as the Managed System Capacity was below 90% of peak crop water demand. This is a significant finding of this survey, suggesting irrigators may benefit from improved information about Managed System Capacity and the need to better anticipate machine downtime at the design stage to ensure CPLM irrigation systems can meet peak crop water requirements.

The importance of adequate drainage for CPLM systems has substantially increased. In 2011-12 only 40% of survey participants had installed systems onto new country without drainage works compared to 83% in 2001, and in 2011-12 43% installed systems onto land that was previously furrow irrigated compared to 7% in 2001. This probably reflects growing awareness that water is applied through CPLM systems at a fairly high rate and will readily move to low spots and that storm water requires removal in the same manner as furrow irrigation.

Monitoring the performance of CPLM systems needs improving. Of the 2011-12 survey participants who were asked about the commissioning of their CPLM system after purchase, 79% of them recommended that a performance audit be done before the final payment is made but only 29% of them had done so. Performance can be monitored by looking at indicators such as pressure and flow rate, and 79% of survey participants had monitored pressure but only 38% of growers who had flow meters fitted had monitored flow rate as a check on performance. Irrigation uniformity is another important measure for evaluating system performance, but only 25% of growers had measured their uniformity, and the values were mostly below the accepted standard of 90%.

Testing sprinkler flow rate during a system performance evaluation.

While most growers consider the higher running costs a disadvantage of CPLM systems, about half of the surveyed growers were operating their systems above optimal pressure, potentially incurring higher running costs than necessary. With the substantial increase in energy costs over recent years, operating pressure demands more attention than a decade earlier.

There was a small shift in the period between the two surveys in the proportion of systems, the area irrigated by them and their general specifications. Centre pivots still outnumber lateral move systems but the difference has diminished, and the area irrigated by lateral moves has increased to become greater than centre pivot systems. The proportion of systems that were diesel powered reported in 2011-12 increased to 79% compared to 65% in 2001. This is due to the increased proportion of lateral move systems and probably indicates more systems being installed remote from reticulated electricity supplies. Of the machines surveyed 90% used electric drives on the towers and the other 10% used hydraulic drive systems.

The soil types irrigated by CPLM systems has broadened, probably due to improvements in the design of systems, advances in sprinkler technology and greater awareness by growers of the capability of CPLM systems. In 2011-12, 18% of participants irrigated Sandy loam or Sand with these systems compared to 8% in 2001, and the proportion irrigating clay soils declined from 53% to 46%.

A significant shift in emitter selection has occurred over the last 10 years. Only one fifth of participants used Low Energy Precision Application (LEPA), a considerable change since 2001

when LEPA was used by almost half the growers. In the 2011-12 survey, more than a half of the participants used moving plate sprinklers.

Wheel rutting and bogging issues were experienced by 64% of growers at some stage compared to 74% in 2001, although there was little suggestion that these were now ongoing issues.

Labour savings and water savings remain the top two motivations for purchasing CPLM systems, followed by decreased waterlogging and improved irrigation uniformity. When compared to furrow irrigation, the labour requirement indicated by growers for centre pivots and lateral moves was 25% and 30% respectively of that required for furrow irrigation. These figures are substantially larger than those reported in 2001 (10% for centre pivot and 20% for lateral move). This suggests that more labour than originally anticipated is required to obtain good performance from CPLM systems. The labour requirement for lateral moves was still reported to be more than that for centre pivots although the difference has reduced.

The use of automatic control systems was greater in 2011-12 (40%) than in 2001 (10%), but their use remains limited despite their potential to reduce labour and increase flexibility. The relatively limited usage may indicate that appreciable labour savings have been achieved independently of automation due to the decreased man-hours required to operate these systems compared to siphon-furrow irrigation. Also, in the early stages of CPLM systems being adopted, automation was promoted as having irrigation management advantages, such as increasing or decreasing speed to avoid waterlogging and bogging at the end of lateral move systems, programming centre pivots to apply different amounts of water around the field, and controlling the commencement and finishing of irrigation events by data directly linked from soil probes. More recently, technical innovations such as variable rate irrigation and variable speed drives for electric motors provide potential for even more refined management that could be automated. The relative lack of use of automated control systems might be due to the time required for operators to obtain optimum performance from CPLM systems, the complexity and experiences of unreliability with automation equipment, combined with little evidence so far of substantially improved performance.

The average Irrigation Water Use Index (IWUI) for cotton has increased between the 2001 and 2011-12 studies for both CPLM and furrow systems, and the difference between the two systems is smaller in 2011-12 than it was in 2001. This indicates that the management of both types of system has improved over this period, but that a greater improvement has occurred in furrow irrigation systems. The superior ability of CPLM systems to capture rainfall and the ability to germinate crops with minimal water application were viewed as key features contributing to water savings over furrow systems. The 2011-12 findings indicated that the water savings of CPLM systems were around 30% compared to furrow irrigation systems.

Of the 2011-12 survey participants, 34% believed that fertigation through CPLM systems resulted in a decrease in total seasonal fertiliser use, while 47% of growers reported that it reduced the fertiliser required as up-front applications prior to planting. With the deepening shortage of fertiliser and the attendant rising costs, this feature of CPLM systems is likely to be given more attention.

Conclusion

Participants believed that it took an average of 2.3 years for them to adequately manage their first CPLM system, with approximately 15% suggesting this took over 3 years. Many growers commented that they should have talked to more growers and experts and attended more field days and training events, but that ultimately each system is site specific and a learning curve must be expected. The need to be well informed prior to installing CPLM systems should be heavily reinforced.

Two-thirds of all the systems in the 2011-12 study cost between $1500 and $3500 per hectare, with only 5% costing in excess of $4500. This compares to the range for all systems in the 2001 survey of $1250 to $2500 per hectare. This increase is in line with the CPI for the same period. As a general trend, system costs per hectare decrease as the area being irrigated is increased. This trend is clear for lateral moves but fairly weak for centre pivots where the cost for irrigating the same area can vary by a multiple of up to six times. These large variations in cost per hectare are attributable to individual site and owner requirements, variations in the AUD-USD exchange rate, as well as competition for sales.

In summary, CPLMs continue to be favoured by growers for their potential to save water and labour, to maximise rainfall capture and minimise waterlogging, and the flexibility they offer for growing a range of crops in diverse situations. Whilst issues such as bogging and trash must be managed, most growers have been able to overcome these issues within reasonably short timeframes. The following recommendations many of which were reported by Wigginton et al (2011) should be considered by growers interested in investing in CPLM systems:

- System capacity is critical. Managed system capacity in particular needs to be high enough to satisfy peak crop demand and your irrigation management, while minimising capital and operating costs.
- It is important to ensure that operating pressure is minimised while still allowing optimum system performance. Energy costs are an increasing component of operating costs and may affect the financial viability of these systems.
- Expect it will take several years before you get the best performance out of a CPLM system. There will be a significant time investment in planning and setting up the system and learning to manage it.
- Learn as much as possible from growers and consultants operating CPLM machines, both within your region and in other regions.
- Attend as many information events as possible, such as field days, farm walks and the National CPLM Training Course.
- Adequate field drainage is needed under CPLM systems.
- Both sprinkler and LEPA systems are used successfully and efficiently by growers, although moving plate sprinklers were much more popular within the survey group. Choice of emitter system should be based on a wide range of factors, information sources and discussions with growers using each type of emitter.
- Carefully plan the system to ensure it suits the soil type and performs as required without excessive capital or operating costs. Sorting out potential design or management issues during the planning phase, possibly with the help of a consultant, will be significantly more cost effective than trying to rectify poor designs after installation.

Conclusion

- The performance of systems should be checked after installation and at regular intervals. Flow rate and pressure should be checked using calibrated sensors to ensure that mounted sensors are accurate. Uniformity, application depth and travel speed should be measured and the control panel calibration checked. Some suppliers do not calibrate control panels in the field.
- Get good advice on the financial, management and tax implications of such a large investment.

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Appendix 1: Best and worst grower CPLM scenarios

What is the best story/scenario of CPLM that you have experienced?	What is the worst story/scenario of CPLM that you have experienced?
Yield – 5 bales of cotton to the acre.	Waterlogging because of using furrows and beds – 8 metre row spacing doesn't fit the system, span size doesn't fit the row spacing.
Compared with flood irrigation, only need a small amount to get crops going.	Blowing over in a wind storm and centre pivot moving into stationary machinery.
Achieving 6.01 t/ha seed crop with $11,000/ha return. Increased germination and persistence by 30%.	Heard of problems more with issues of dealers not coming back to fix set up problems.
Can control the amount of water that the crop gets, rather than hitting with 4" of flood.	Pump breakdown on a 40°C day.
Accurate watering without over watering "water little and often".	Energy costs too high.
Flexibility of farming system. Once our soil conditions improve, the sky is the limit in terms of manipulation.	Having to replace them is expensive. Having them not work is expensive.
I find the lateral move irrigation system to be the most efficient farming system.	Our supply and delivery channels were finished after the machine was installed, so the installer never properly commissioned the machine – he built it and left.
Large flood in 2010-11 and all 5 CP's stayed up and we could get in and start irrigating shortly after.	We had two pivots that were running side by side collide.
We don't have to change siphons at midnight when its cold! Can start crop with lower water allocation, so we are able to grow a crop that we couldn't have without CPLM, and there is generally a price advantage in these years.	40°C day, high humidity corn paddock, a gearbox failed in the centre of the circle and I had to walk in with new gear box and tools! Worst day.
Grew 6 t/ha wheat crop, and a canola crop 3 t/ha in drought.	We knocked over a pivot once – a staff member who was cultivating hit one of the towers and knocked 4 spans over – on Christmas Eve.
Make irrigation easy and efficient.	Couldn't get enough water on. Poor result with chickpeas due to humidity/fungus.
Turn on and run for a week and stops when you want it to.	Paying for them to start with.
2010/11 we won the crop competition, yield 14 bales/ha. During the flood in 2011/12 the LM was our highest yielding paddock.	A bolt fell out and the machine fell over 6 weeks after replacing with stainless steel pipework – the pins on wheels weren't secured.

Improved grain quality.	In the first season, the suction kept getting blocked up with water bugs and I had to go out every 2 to 3 hours over 24 hours and scrub the screens. We experienced poor germination and establishment during the early years due to soil crusting as a result of sprinkler impact.
Easy to run with one person – labour saving.	Lateral tower collapses when moved – falling down. Corrosion of the system due to water quality.
Consistent reliable income source.	Major breakdown in peak water use period.
Labour saving / water savings.	A few blew over with gales.
No waterlogging.	Sprinklers installed in the wrong order.
One year we managed our best yields ever – 3 t/ac for peanuts and 5 b/ac for cotton. In a dry year we have the ability to still harvest a really good crop.	Having to fix pivots in a mature maize crop in summer heat is not much fun. Slow diagnosis of problems.
Having a centre pivot has allowed us to grow any crop, where previously with side-roll and end-tow systems the type of crop we could grow was limited.	We had a 9 tower machine fold around itself (outside tower wound itself around the centre). There was no safety circuit, as a timer had been incorrectly replaced. It happened 8 weeks into a corn crop – ruined.
2002, 2003, 2006 were drought years, but we had water and a crop and we became a price maker for the first time ever! We had a corn crop that yielded 17 t/ha and we received $430/t – 130% return in 6 months!	Floods – 50% decline in yields. Flat tyre in the middle of a mature maize crop. One CP was picked up and thrown about in a storm. I blew a pump on Jan 15, no rain for 3 weeks and it took 10 days to get everything up and running again.
6 LM fields with yields over 14 bales/ha.	28th December – hot weather and machine collapsed due to placement of fertiliser tanks on the cart. The weight mucked up the alignment resulting in collapse of the machine.
1 person only required to manage CP and no siphons!	In our first year we had poor germination – trouble with soil types that had surface crusting. Ran the LM over with 5mm to keep surface soft. Engine specifications were wrong – running at 50 psi at the cart resulting in excessive fuel use. Bogging in wheel tracks in tail drain.
4.5 b/ac cotton yield. Had good water profile with limited water supply therefore good results. Increased value of farm from bank manager.	Wheel tracks up to 2 ft deep, then when picking the crop, the picker was hitting the wheel ruts.
Cotton crop with lower water use and higher yield in 2004.	Planted cotton with soil profile 1/3 full, dry spring, early summer, wind/dust storms – could not keep up.
Decreased waterlogging and not having to re-pump water as tail water.	Reed switches and solid-state cards blew up and the whole machine had to be rewired mid-season. The supplier of cards had folded. Keep it simple!!

Best corn silage crop – irrigated half circle, rain, irrigated half circle, rained again – therefore had 23 t/ac.	Bolt came undone and collapsed. Pipes rusting through.
Got through the night without stopping.	Starting up for season.
Labour and water savings. Sorghum 37-38 mm (smaller application) and 1 t/ac yield increase on 130 acres. Versus flood irrigation, only irrigated 1/3 area due to water constraints.	3 circles in a summer and then an extended hot period in a summer.
Reduced labour, more relaxed irrigation.	Flat tyre, no alarm, got very wet, had to leave for a week before we could get in. Lots of crop damage.
Stubble retention, no till, farm efficiency, water use.	Run out of water and suction pipe got caught on channel and twisted.
Quick turnaround with next crop planting. OM increased with grain crops.	Small mechanical issues on 'Genset' belts. Alignment, rarely. Water management in supply channel.
How much water to put on and how to apply it. Flexibility and peace of mind.	Few installation issues and steering. Lack of knowledge support for steering (local).
Peanut crops are great on marginal soils.	Sprinkler package on swing-around arm had to be changed due to runoff. Design application stipulated #48 nozzles on end but not matched to soil and crop conditions.
Forage barley soil health improvement.	Blown over.
Versatility in growing hay crops and getting water and fertiliser on in a big hurry. 4.5 ML, 7.5 t on surface and 1.7ML, 6.5 t on LM for wheat.	Mechanical/electrical downtime.
0.75 t/ha navy beans @ $1300/t and double cropping.	Getting bogged – tyres.
It is so easy to maintain and use.	Blowing over during crop at Christmas
Yields 3.9 and 4.5 b/ac straight after laser levelling.	Cotton on virgin county – water penetration was a problem. No organic matter.
Only way to irrigate the soil no other option. Able to match application to infiltration rate.	Cotton in 2009-10 ran short of water due to uniformity. Soyabeans same.
4.6 b/ac on cotton one year when only expecting 3.5 b/ac.	Wheels fell off – wheel ruts and broken studs.
No water at start, gave one early watering, ran out of water, got some rain, then the river ran, and got 7.5 b/ha single-skip cotton.	Getting bogged.
An opportunity to water crops on current broadacre when water becomes available through the season.	Wheat getting frosted. Waterlogging at start of 2010-11 season.
Germination is easy compared to flood – small applications.	Bad drainage – flood drainage.
Opportunity timing is the biggest advantage.	Only the flat tyre.

Appendix 2: Selected grower CPLM case studies

The case studies reported in this appendix were originally presented by Wigginton et al (2011).

Grower: Russell Clapham

Property: Balmoral

Russell Clapham grows cotton and grains at 'Balmoral' near Brookstead on the Darling Downs. Whilst Russell has irrigated at 'Balmoral' for 13 years, it is only in the last four years that he has invested in four lateral move irrigators. One of these laterals is a hose drag system which is designed to irrigate three fields of approximately 45 ha each (total 136 ha), although only a single field is irrigated at any one time. He also has a 116 ha swing around lateral as well as a 160 ha and 145 ha standard ditch fed machines. Water for all of these machines is sourced from on-farm storages which are supplied by river and overland flow licences. The soils on 'Balmoral' are black cracking clays typical of this region.

Russell was motivated to invest in lateral moves due to looming water shortages and because he had seen advantages of CPLM irrigation on a neighbouring property. Labour saving was also a motivation, and Russell estimates that his lateral moves require about 10% of the labour required for an equivalent area of furrow irrigation. However, he notes that this labour does need to be more highly skilled, especially with mechanical and electrical knowledge and computer skills.

Applying Water

The system capacity of the machines is around 10.8 mm/day. Russell says that this system capacity is ample for his location. "This system capacity was more than sufficient to keep up with the demands of a corn crop at peak flowering during a heat wave, when the machine was still only required to irrigate for 6 out of 7 days. Normally it would operate for less than half that time."

Irrigation is generally applied at about 40 mm per pass. Russell has checked the accuracy of the control panel settings by undertaking a catch can test to verify the depth of water being applied. He determines when to irrigate based on advice from his agronomist, neutron probes, evaporation figures, his own experience and the amount of soil cracking that is occurring.

The system uses LEPA in every second row (every 2 metres), with germination accomplished using S3000 spinners. Once the ground cracks sufficiently, LEPA irrigation is achieved using lengths of hose which are clipped straight into the sprinkler mechanism and dragged on the ground. "You have to make sure that water does not run ahead of the irrigator, and if the soil is not coping with the LEPA then switch back to spinners. This has only happened once when soybeans had a wet plant and the soil was sealed off by compaction. It only takes about one hour to change over."

Russell believes that under his laterals the crop gets away quicker as there is no water logging which occurs under furrow irrigation. He also finds that scheduling is more controlled under the laterals.

With the ability to maintain a soil moisture deficit under the laterals, Russell has found that he has to run the tailwater pumps for shorter periods of time after rainfall as there is less runoff from the lateral fields.

However, furrow irrigation does tend to even the moisture content of the paddock out, whereas the lateral move does not. This is not an issue but does require consideration when determining the lateral move application strategy, particularly after rainfall. Russell is considering installing rain gauges every 250 metres which can be used to alter the application amount along field length.

Farming System

Under his lateral moves, Russell has been able to move to no till farming with his grain crops. This allows him to retain stubble which can also help to retain water from the LEPA application. Under his hose fed lateral move, Russell rotates across the three fields over the course of a year. A typical rotation would include early corn in one field before moving onto late soybean in the next field and then wheat in the third field. All of this cropping is no till. Russell describes one benefit of this approach as the ability to "plant into stubble and obtain good crop emergence; also weed control from herbicides are very effective by giving it a little drink with the lateral move post planting."

Russell looks to achieve the same yields under his laterals as under his furrow fields, although he thinks there is the potential to get a 5 to 10% yield increase under the CPLM systems. He has found there to be less disease prevalence in legumes crops as there is no water logging

A hose-fed lateral move system.

and better control of water application. For this reason, Russell only grows chickpeas under his laterals, not on furrow irrigation fields.

Fertigation is another advantage, and Russell uses direct injection to apply 80 kg/ha of liquid Nitrogen, once per crop. "You can also spread urea on dry as you plant and water it in with sprinkler irrigation. Application of all nitrogen requirements as liquid Nitrogen through the machine is not economic due to the amount of nitrogen required." Russell also uses direct injection technique for applying potassium.

The use of fertigation has meant that Russell has decreased his pre--season fertiliser requirement. He also applies Gemstar® through the laterals.

Russell's use of LEPA means that he must irrigate in a circle under the end of his swing around lateral. Russell had issues with the GPS guidance ability to set out this field. As the GPS system used for installing the lateral move guidance wire and the GPS system used for farming were different, there ended up being a 9 inch error over a 3 km run! "There was lots of mucking around to get it working. Make sure your GPS system you intend to farm with is the same as you position the guidance and channels."

Design

The lateral moves were installed on existing furrow irrigation fields that were already levelled so there were no issues with drainage or field preparation. However Russell has learnt a lot about the supply channels required for the machines. "Overflow control is essential, with concrete wells required to keep the water level constant. I use two electric bores to feed the ditch with about 15% of the required water supply to regulate the level of the channel."

Trash is not an issue with Russell's hose feed machine. "There's no maintenance, no hassles. It is a 15 minute per day changeover. I just plan with a 24 hour cycle from hydrant to hydrant." However a creek near the channel fed laterals can cause problems with leaves, grass etc. Mesh is used across the ditch near the inlet which needs to be cleaned a few times a day (every 2 hours) for the first day. "This needs some work. The finer trash is more of an issue. We have rotary screens on the machines but we had to add a booster pump to increase the pressure of self cleaning rotary screen, we are looking at more agitation on the screens in our future plans."

Russell has experienced some problems with bogging, which he solved using custom made boombacks. They are fitted on one side only, so he irrigates one way with the boombacks and then runs back dry the other way. Boombacks are only used with sprinklers; not necessary with LEPA application. This approach decreases the managed system capacity slightly for the first few sprinkler applications due to the dry run time, Russell has not experienced conditions where the machine has not been able to keep up, even in heat wave conditions during peak flowering.

Russell also decided to fit slightly wider tyres (16.9R24) to improve flotation, although this does mean a wider tyre footprint down the rows.

Experience

Russell had some minor teething problems with the first machine to go in, but this has not stopped him from investing in further machines. He finds the channel fed machines to be a bit more problematic, but the maximum size of hose fed machines is limited by the flow rate through the hose. "I would not do a whole farm of hose drags, but I do prefer them to channels. You need a combination of machines to deal with the water situation you have and to make use of it all. If you only have a little water then hose drags are ideal."

The major advantages Russell has found with the lateral moves are summarised in the table below.

Biggest advantages
Stubble retention/no till
Labour saving is huge: one day on a furrow field vs. 15 min
Increased crop yield
Flexibility in finishing off crops & planting. Small amounts of water more often improves the ability to deal with rain
Water use efficiency
Fewer tractor hours
No furrows
Fertiliser application with the machine
Don't flood paddock

Russell has found that because he has been able to move to a no till system under the laterals, there is "less and less tractor work, less compaction and improved farming efficiency. Although these are pressure irrigation systems, there may be overall energy savings by moving to minimum till farming".

The major disadvantage Russell found was the cost to install the machines. He has also had issues with Cockatoos chewing wires and hoses, and now has an electric fence over the top of one machine. On his swing around lateral, the sprinkler package had to be reduced due to runoff. The design application had stipulated #48 nozzles on the end but these were not matched to the soil and crop conditions.

Russell provides the following advice to other growers considering CPLM machines.

"Attend workshops, talk to other irrigators. More research = better outcomes, after four years, I am still learning about the agronomy under the machines. Backup service is important."

"Have the designer come out to see the farm before any design takes place. Planning is important – have it all worked out before the machine goes in! Have a whole farm plan that includes forward planning. And don't pick a wet year to do the installation."

Grower: Johannes Roellgen Property: Tyunga

Johannes Roellgen grows cotton and grain crops at Tyunga near Brookstead on the Darling Downs. The farm is traditionally furrow irrigated, but Johannes has installed two lateral move machines over the past 7 years. The systems are 150 ha and 165 ha ditch fed centre-feed machines. Water for all of these machines is sourced from on-farm water storages which are mostly supplied by river and overland flow licenses. The soils on 'Tyunga' are black cracking clays typical of this region.

Johannes was motivated to invest in lateral moves as he had an existing furrow irrigation area which had very little slope and was not well suited to furrow irrigation. It was also not possible to capture all the runoff from the furrow irrigation and Johannes predicted that there would be less runoff under the lateral. Labour and reduced water availability were also key motivations.

Applying Water

The lateral moves have a system capacity of around 12mm/day. During peak heat conditions Johannes may operate the machines 7 days a week to meet crop demand. Johannes uses a LEPA system with emitters every second row (2 meters) for in-crop irrigation. Spinners are used for germination before switching to LEPA socks for peak demand periods. His first machine had static plate sprinklers but these had an irregular distribution, especially when pre-watering or watering up, and were changed to spinners. When the second machine was ordered, spinners were specified from the start.

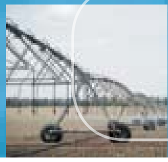
The typical application depth is around 40 mm per pass. Sometimes the application will be manually varied, with the application near the end being reduced to minimise surface water movement on the return run. In this case, Johannes might apply 40 mm to two thirds of the field and 20 mm to the last third. When the machine turns around the opposite is applied. Johannes calibrated the machine by measuring the depth of application and uses the chart to determine how much water is being applied.

Irrigations are scheduled with advice from his agronomist, using soil moisture probes, crop status and weather forecasts. Johannes believes the laterals offer some benefits for crop growth. "Crops under the laterals are not interrupted by waterlogging events, so there is more even growth, unlike the furrow fields. There is also less runoff after rainfall."

Farming System

The laterals are designed to service three fields, with the usual summer season consisting of two fields of cotton and one field of corn. "Cotton needs water after the corn has passed its peak demand. Sometimes I'll grow onions, which are a shallow rooted crop and require more frequent shallow applications."

Johannes targets slightly higher yields under the laterals. "I've noticed the potential for a 20% increase in yield in cotton. I'm also able to retain stubble and practice minimum till which leads to



increased organic matter. The laterals also allow more frequent cropping."

This increased yield potential occurs whilst Johannes has decreased the total amount of fertiliser required under the laterals. He has a five tonne silo on wheels with a belt drive which he uses to apply urea into the supply channel for fertigation at top up rates. "I can use more split applications of fertiliser and can spread it on and wash it in with the lateral move."

Johannes also tries to do as much spraying as possible with a ground rig, and on furrow fields this means spraying before irrigation as it is not possible to access the fields for 3 to 5 days afterwards.

He sees this as an advantage of the laterals as there is more flexibility with access by spray equipment within a day or two.

Design

In terms of machine and supply system design, there are a few major areas which Johannes has found important. To prevent wheel rutting and bogging, he uses boombacks and half throw sprinklers near the towers to keep the water away from the wheels. "We found a problem with water spraying against the wheels, running off down the wheels and then accumulating in the tyre tracks, so keeping the wheels dry was a priority."

He has also changed the tyre size to 11.2R38 which gives better crop clearance with the same flotation as a smaller, wider tyre. "There is basically no crop-interference by the tyres; with the use of GPS guidance at planting, the irrigator wheels fit neatly between the rows all season long."

The supply system is another critical factor as it is important to be able to keep the channel at a constant level. In one split level channel, Johannes fills the first 1300 metres first, and then uses an electric lift pump for the last 650 metres. A float is used to allow the pump to cut in and out automatically. "The feed of water from the dam is a fine tuning exercise to balance the water. It needs to be more regulated where the pipe feeds into channel as this is what makes it difficult to control." Where the mainline from the storage feeds into the channel, Johannes has also had to reshape the channel and lay a poly liner to stop erosion and prevent the lateral from falling into the channel.

Experience

The major advantages Johannes has found with the lateral moves are summarised in the table below.

Advantages
Labour savings
Water savings
Irrigation timing is more responsive
Higher frequency cropping
Planting decisions are easier
Early access of ground rigs
Ability to practice minimum till

On the other hand, Johannes is aware of the running costs and the future maintenance as the systems age. He has also experienced some early steering issues, some issues with the pump priming mechanism and some wheel bogging and rutting causing irrigation delays. However, he does plan to install future lateral moves.

He suggests that other growers interested in CPLMs do their research, attending field days and talking to people in their area with similar scenarios. "You could venture into it (CPLMs) with misconceptions like they will be a magic bullet for improved water use efficiency. Don't try and convert your best flood field to lateral moves, only the poorer fields, as there are few benefits for the extra capital expenses on the better fields. You also need to make sure of your water security; with the capital outlay, you must be able to run the machines 8 out of 10 years at least."

System capacity is critical. Managed system capacity in particular needs to be high enough to satisfy peak crop demand and your irrigation management, while minimising capital and operating costs.

GPS locators are commonly used on CPLM systems.

Grower: Ronald Thompson

Property: Yarnham

Ronald Thompson grows cotton and grain crops at 'Yarnham' near Chinchilla. He has 34 ha of furrow irrigation, 24 ha of hard hose irrigation and two centre pivots which irrigate areas of 66 ha and 41 ha. Ronald has a wealth of experience with centre pivot irrigation, having used pivots for 24 years. Water is sourced from recycled water from the town, flood harvesting and a dam which captures some overland flow. The soil under the larger pivot and the furrow area is a heavy black cracking clay, while the soil under the smaller pivot and the hardhose is a kurrajong pine sand.

Ronald decided to purchase the second pivot because he had experience with them and believed that he would be able to stretch his water further. The property was purchased with one 40 ha pivot that was expanded to 66 ha after two years. Due to the water efficiency a second 41 ha pivot was purchased primarily to grow peanuts.

Applying Water

The system capacity of the pivots is 10.4 mm/day, which is sufficient to keep up with peak crop demands, with the machine irrigating for 100% of the time during peak demand periods. The typical application amount is 21 mm, which Ronald has checked by placing rain gauges under the machine.

Occasionally Ronald will irrigate twice with lower application rates on lighter soil to avoid losing too much to drainage.

Static plate sprinklers are used for germination, with LEPA socks used for in-crop irrigation. "With LEPA the topsoil is drier and I use the cracks for infiltration; 100% of the LEPA water goes into the root zone, even on a hot day."

With his limited water supply, Ronald is keen to make the most of any rainfall. During peak crop growth periods, he might stop irrigation for two or three days if it rains – it depends on the type of rain and how much. "Scheduling is a balance using the Gopher to measure soil moisture and looking out for rain. I always leave room to store about two inches of rain in the soil profile under the pivot, whereas the furrow irrigated soil is often wet and you can lose rain to runoff. If water is running off CP then something is majorly wrong."

Ronald says that the yields under the pivot are pretty similar to those in his furrow irrigated fields. "There might be a marginal benefit with laterals, but with far less water." With typical applications of around 8 ML/ha for furrow fields and 5 ML/ha under the pivots, the water saving is almost 40%. "You have to give the crop what it needs, when it needs it, especially legumes. The crop doesn't do anything for at least a week after surface irrigation but reacts much quicker with the pivots. Growth in the furrow fields can also be uneven due to waterlogging."

Farming System

Different crops are planted differently under the pivots. Cotton is planted in circles, but mung beans, wheat, chickpeas and sorghum are usually planted straight through. With better programming for GPS units, concentric circles are much easier to plant. The amount of in crop actions determines whether circles or straight through is selected. Lower crops can handle LEPA going over the rows whereas there can be some issue with sorghum as it gets to head, however this is minimal. The rule of thumb is that if the next crop is cotton then the previous crop is best in circles. When planting in a circle, Ronald leaves one 24 metre swath which is planted radially. The rest of the area is planted in circles moving from one side of the 24 metre swath to the other.

This 24 metre swath is then used to park the pivot whilst spraying, harvesting or other operations are carried out. Once operations are completed in the circular section, the pivot is moved and the operations in the radial swath are completed. Spraying under the pivot is almost always undertaken with a ground rig, which can happen anytime when using LEPA since the surface is always drier as well as being able to keep the wheel tracks dry. "In-field work with surface irrigation is much more tedious, for example spraying in surface irrigated fields needs the plane, but the pivot can be done with the ground rig."

Ronald has found that getting concentric circles can be problematic, even with GPS. "You need to treat every tower as a new starting point to centre the circles correctly. The emitters are positioned in between every second row but this does not always work well with crop rows, even when planting in a circle using the GPS."

Crops are planted on the flat, with the pivot towers in guess rows. Ronald has found that the soil tends to be harder under surface irrigation, but with the pivot he can go to zero till and the soil is not as hard.

Ronald also fertigates with his machine, directly injecting top--up rates of urea (20 units Nitrogen) with each watering, as necessary.

Design

Ronald has previously had problems with bogging, but lowered the tyre pressure to 22 psi which gives a greater contact area and improved flotation. He is also sure to maintain contours to improve surface drainage.

Ronald has also had problems with free-wheeling hubs on the gearboxes, where the inside bearing collapses. "Avoid free-wheeling hubs if you're not moving the pivot, you can remove the pinions if required. I irrigate in one direction one season and the other direction the next season, for even gearbox and motor wear."

One of the biggest issues that Ronald has experienced was a lightning strike that damaged some electrical components. "I had the reed switches and solid-state cards blow up and the whole machine had to be rewired in the middle of a crop. And the supplier of the cards had folded!"

Experience

With 24 years of centre pivot irrigation experience, Ronald has learnt a lot along the way. Although he does not have enough water to plan another machine, there are a few things he would change in hindsight. "If I was to put in another machine it probably wouldn't be as long as there is a bit too much water application at the end. I'd also put mains power to the centre at the start. This would avoid the genset and the issues we've had with mice and cabling. Make sure the electrical goes in at the same time as the pipe."

In addition to the significant water savings that Ronald has achieved, he believes that the pivots require about 15% of the labour that would be needed for an equivalent surface irrigation system. "The labour needs to be a little bit more multi-skilled, especially more electrically and mechanically minded."

Ronald also has some advice for growers considering CPLM investment. "Get access to more knowledgeable people. Find someone who knows all their stuff. Talk to other people who have pivots, not just your own area but further afield! And don't believe everything the salesman says unless you're comfortable with them."

Irrigation water running off from where it was applied. Carefully plan the system to ensure it suits the soil type and performs as required.

Grower: Craig Saunders

Property: Ford Park

Craig Saunders grows cotton and grain crops at 'Ford Park' and 'Plantation' near St George. Most of his fields are furrow irrigated but he installed a centre pivot at 'Ford Park' ten years ago. The 93 ha machine is one of the larger pivots used for irrigating cotton crops in the region. Water is sourced directly from Beardmore Dam. The soil under the pivot ranges from medium red clays to well-draining sandy clays, which are quite different to the heavy clays which Craig surface irrigates elsewhere.

Craig decided to purchase his pivot so that he could make use of this marginal country. The lighter soil, steeper slopes and the shape of the area did not lend themselves to furrow irrigation, but the pivot offered the opportunity to make the most of available water on this land. The pivot was specifically purchased to irrigate high value crops like cotton and peanuts.

Applying Water

The centre pivot is 544 metres long and has a system capacity of 12 mm/day. Craig believes that this system capacity is quite adequate to meet peak crop water requirements, and he typically only has to run the machine for around 80% of the time during peak periods. This gives some flexibility in capacity in case of breakdown or if field operations are required.

Craig usually applies around 20 mm per pass, which is well suited to the lighter soil types on which the machine is located. Craig says this is a significant change to his furrow irrigation system. "Everything is different; with the pivot you apply smaller amounts more often compared to furrow irrigation."

On occasion, Craig had noticed runoff occurring from the field during irrigation, which he says is to be avoided at all costs. This can be an issue with long centre pivots with high system capacity, as the average application rate at the outside of the circle is too high to infiltrate into the soil. Craig used to use LEPA bubblers but now only uses Nelson Rotators at 2 metre spacings with 15 psi regulators. Despite trialling different techniques to improve surface water retention, the LEPA was causing runoff on the undulating sections at the outside of the circle. By using the Rotators, which have a larger footprint than many other sprinkler types, Craig has been able to decrease the average application rate and prevent runoff problems. The machine has been tested for uniformity, which was found to be very good at 92%.

Farming System

Craig has traditionally planted in a circle under the machine, which was required by his LEPA bubbler setup in row crops. With a change to permanent sprinklers, he can now choose whether to plant in circles or straight through. "Planting in circles is better for higher demanding crops and the use of in crop ripping with summer crops; however into the future a new planter setup means that I will have to go straight through."

Craig does not use hills under the pivot, and he believes that there is more flexibility associated with planting on the flat, including better minimum tillage practices. The soil is well draining and the small, frequent water applications mean that there is always room in the profile for rain. At times the soil can seal over and cause infiltration problems towards the back end of the season. Craig now performs an in-crop inter-row rip as late as possible to leave the inter-row with a rough surface to decrease the effect of the sealing.

Craig doesn't believe that he can get increased yield under the pivot, but there still might be a yield advantage given his particular situation. "The pivot is in a more marginal soil type, so the yields achieved are the same as the furrow country and are very good under the circumstances."

Design

When he installed the pivot, Craig had to undertake some earthworks to ensure the field drained adequately. As he only needed to cut and fill to drain, the cost of the earthworks was quite modest (about $180/ha). In terms of machine design, one thing that Craig would have liked to have done over again is to have specified the machine with a bigger pipe diameter. Although it currently has nine spans of 85/8″ pipe and three spans of 65/8″ pipe, Craig believes the energy costs could be reduced by using larger pipe (10″ for the first few spans) which would have lower velocities and less friction loss.

Even though the machine is only ten years old, Craig has had to change the goosenecks because they were rusting and clogging the sprinklers. There are no indications of rust issues in the other machine components though, and Craig is suspicious that the goosenecks are not hot dipped

galvanised after bending, but instead have an electroplated coating on the outside of the pipe leaving the internal wall susceptible to rusting.

Craig has also had to overcome wheel rutting and bogging issues. In particular, the high application rate at the outside of the circle can lead to water moving over the surface of the ground which always increases the chances of bogging issues. The larger footprint sprinkler can help to reduce these issues, and Craig has also installed boombacks at the towers to keep water away from the wheels. His 49 metre span length also allowed him to dedicate wheel tracks and he used sandy loam in trouble spots to create a firm platform for the machine. The increase of bogging is also attributed to poor drainage areas which tend to amplify the problem with surface water movement.

Experience

Despite some of these issues, Craig sees some major advantages with the pivot as summarised in the table.

Advantages
Able to irrigated marginal country
Reduced crop waterlogging
Flexibility of irrigation amount
No siphons!
It is so easy to maintain and use

However, Craig is also aware of the energy costs involved in running the pivot, and that it is another machine that needs to be serviced. It also requires more specialised and smarter management. It is only in recent years that Craig has been able to achieve the expected benefits, and he was not able to do so in the early days.

Craig's advice to other growers considering investing in CPLM is to talk to other growers with a similar crop, and to get an agronomist with experience with CPLMs and the soil type. "An irrigation consultant with experience in scheduling and management is important, and seek professional help from a consultant regarding machine design. I wish I had sought an independent professional to do an analysis of the mainline sizing before I bought the machine."

NCEA National Centre for Engineering in Agriculture

Australian Government
Cotton Research and Development Corporation

NSW Department of Primary Industries