1.3 Water use efficiency in the Australian cotton industry

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Key points

- Irrigation Water Use Index within the Australian Cotton industry has improved by 8 per cent per annum since 2000-01.
- Industry data suggests an average IWUI of greater than 1.5 bales/ML. There is however, significant farm to farm, and seasonal variability in this figure.
- The greatest water losses on farm are evaporation losses from on-farm storages – measurements from 30 farms suggest an average loss of 25 per cent but losses can be as high as 45 per cent
- The application efficiency of surface irrigation ranges from 65 to 90 per cent where tailwater recycling is used, averaging 76 per cent.
- Surface irrigation application efficiency could potentially be improved from 76 to 85 per cent as determined from simple management changes to 476 sub-optimal measured irrigation events.
- Despite the significant gains made in irrigation performance and industry WUE in the past decade, there remains scope for further improvement by irrigators at the lower end of the WUE ranges identified.

More than 98% of the water absorbed by the roots of any crop is transpired as water vapour during the course of plant growth. Most of this water is lost through stomata, which are specialised pores on leaf surfaces that allow water vapour to exit the leaf while carbon dioxide enters. This exchange process is necessary for photosynthesis and to maintain canopy temperature. Therefore, any measures to reduce water loss through the leaves (reduce transpiration) will also reduce photosynthesis and overall crop yields.

Water for growth is provided by rainfall or irrigation, but in both cases the amount of water supplied is rarely exactly the same as that required due to the timing and quantity of applications. Therefore the crop uses only a portion of water applied from rainfall and irrigation during the growing season.

In irrigation systems, the proportion of irrigation water actually used by the crop can be maximised by improving irrigation management and system design. These improvements in efficiency are important to save irrigation water, as well as to protect the environment.

Because the objective of applying irrigation is to produce yield, crop management such as fertiliser use, pest management, variety choice and tillage also has the potential to impact on water use efficiency.

Water use efficiency (WUE) is a generic term that covers a range of performance indicators that can be used to describe how efficiently water is used within the cropping system. The WUE performance indicators can be grouped into:

- Water Use Indices (relating crop production to water use)
- Irrigation system efficiency (relating water inputs to water outputs within the irrigation system)
- Distribution uniformity (a measurement of the evenness of irrigation application)

A full explanation of WUE is provided in WATERpak Chapter 1.2.

The Australian industry in summary

There have been a range of studies undertaken in the past 15 years aimed at quantifying the WUE of irrigated cotton production. These include:

- Cameron Agriculture and A.B. Hearn (1997) who collated data from Australian Bureau of Statistics (ABS), Department of Land and Water Conservation, NSW and Department of Natural Resources in Queensland. In addition they collected farm level and field level data from eleven farms in the Macquarie, Namoi, Gwydir and Macintyre valleys.
- Tennakoon and Milroy (2003) collected historical water management data at field and farm level from 25 farms in major cotton growing valleys for the 1996/97, 1997/98 and 1998/99 seasons.
- Dalton, Raine and Broadfoot (2001) from the National Centre for Engineering in Agriculture (NCEA), University of Southern Queensland surveyed eight farms within the Queensland-New South Wales Border Rivers catchment over the 1998-2000 cotton seasons. The data collected was used to calculate on-farm irrigation efficiency benchmarks.
- Between 1999 and 2003 the Queensland Rural Water Use Efficiency Initiative (RWUEI) collected annual data from up to twenty-nine benchmarking sites across Queensland in order to calculate WUE indices
- Harris (2012) summarised water productivity data from ABS and the Australian Cottongrower, together with industry studies during the past decade
- Montgomery and Wigginton (2012) summarised data collected from benchmarking studies at the farm scale across the industry in 2006-07, 2008-09, 2009-10 and 2010-11.
- Montgomery (2012) collected WUE benchmark data from 24 irrigated wheat farms from the 2008 season.
- Gillies (2012) has summarised the analysis of 542 surface irrigation performance evaluations conducted in the past decade. These events have been collated into ISID, a secure database which is accessed through the internet.
- Wigginton (2011) benchmarked the whole farm water balance for 30 farms within the Queensland Murray Darling Basin in the 2009-10 and 2010-11 seasons.

At the broad industry scale there has been an upward trend in Irrigation Water Use Index (IWUI) as a result of improved genetics and crop management, combined with improved irrigation practice (see Figure 1.3.1).

Figure 1.3.1 Irrigated cotton productivity (bales/ML of applied irrigation water) (Harris, 2012)

Table 1.3.1 - WUE Indices within the Australian cotton industry for the last 15 years.

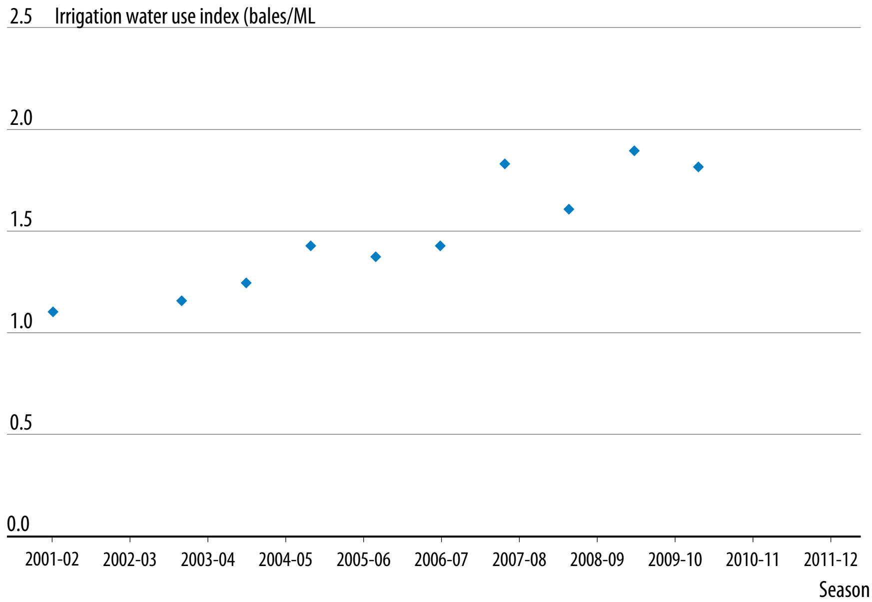
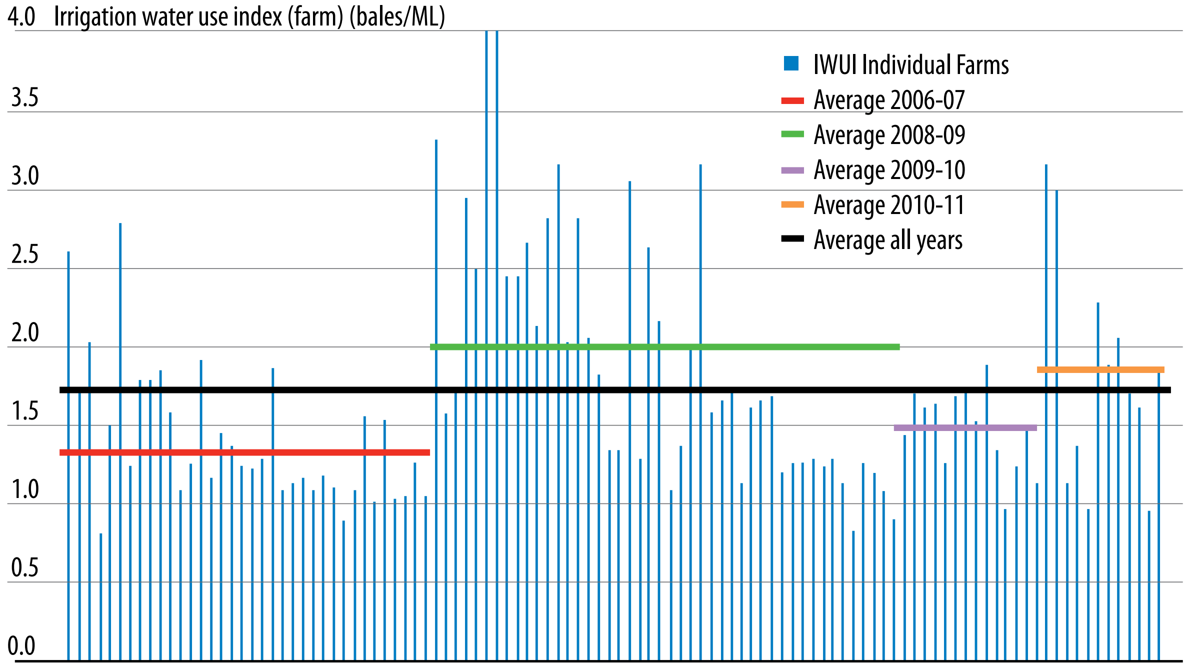


Table 1.3.1 summarises the results for cotton industry WUE indices collated by different projects over the last 15 years. The data here clearly shows the improvements in yield that have occurred, and these are reflected in the improved WUE indices presented (an improvement of 8 per cent per annum).

Project	Seasons	Region	No of farms	Irrigation ML/ha	Yield Bales/ha	IWUI bales/ML	GPWUI (farm) bales/ML
Cameron & Hearn	1988–89 to 1994–95	NSW & Qld	11	5.37	6.73	1.11	0.75
Tennakoon & Milroy	1996–97 to 1998–99	NSW & Qld	25	6.96	7.96	1.25	0.74
RWUEI Project	2000-01 to 2002-03	Qld	29	7.51	8.71	1.62	0.95
Montgomery	2006-07	Hillston to Emerald	37	8.17	10.7	1.31	1.13
Montgomery	2008-09	Hillston to Emerald	46	5.38	10.6	1.97	1.14
Wigginton	2009-10	Condamine & Lower Balonne	15	6.26	9.2	1.47	0.93
Wigginton	2010-11	Condamine & Lower Balonne	12	5.60	10.3	1.84	0.94

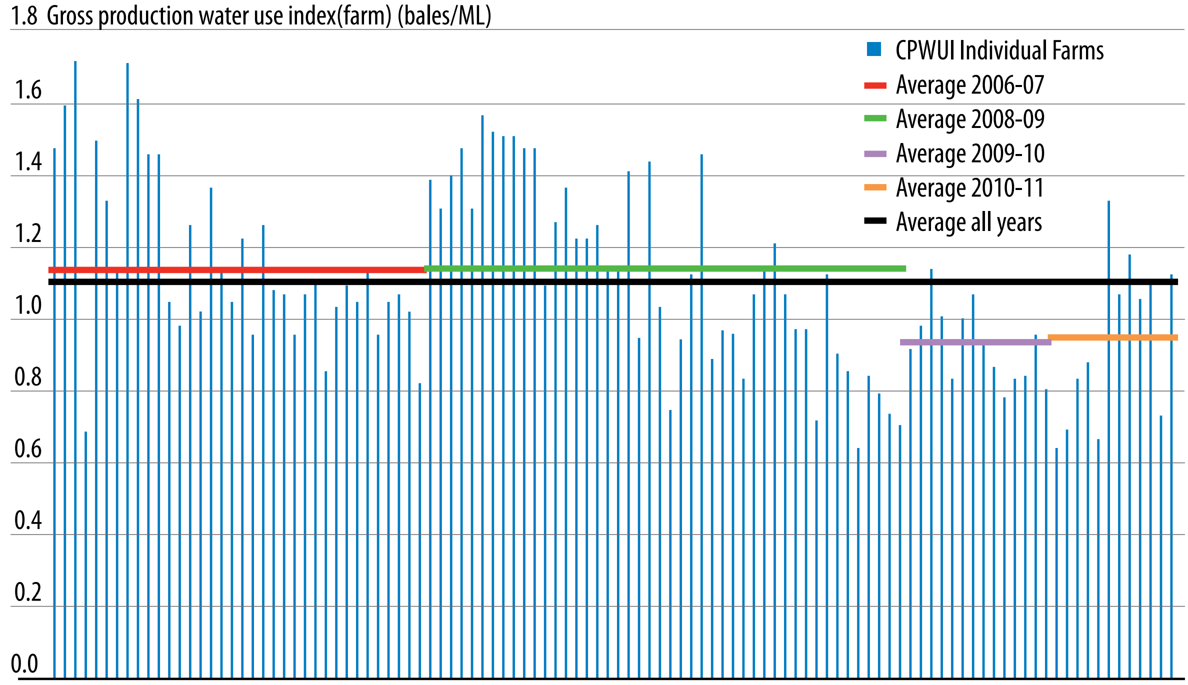
Individual farm WUE data is of particular interest as this can clearly demonstrate the potential for high IWUI (Figure 1.3.2) and Gross Production Water Use Index (GPWUI) (Figure 1.3.3) that can be obtained in irrigated cotton farming systems. However, this data also demonstrates the variability in these indices across farms and seasons.

Figure 1.3.2 - Irrigation Water Use Index (IWUI) for each individual farm



(Source: Montgomery and Wigginton, 2012)

Figure 1.3.3 - Gross Production Water Use Index (GPWUI) for each individual farm



(Source: Montgomery and Wigginton, 2012)

Measurements by Dalton et al (2001) showed that the greatest water losses reflected in whole-farm WUE are likely to be from farm storages. Evaporation losses can be as high as 10 mm per day resulting in storage losses of up to 50% over twelve months.

Seepage from unlined distribution channels vary with soil type and have been recorded between 1 and 23 mm per day. Storage and conveyancing losses are likely to be lower for bore supplies, although if bore capacity is limited, water would be pumped into storages prior to irrigation and potentially lost.

The more recent work by Wigginton (2011) confirmed the importance of evaporation losses from storages within the irrigated farming system. The average storage losses across the 30 farms evaluated accounted for 25 per cent of all farm water. The largest individual storage loss measured was 45 per cent of all farm water. For most storages, evaporation is the largest source of water loss, and this is typically between one and two metres per year if the storage contains water all year round.

The other important aspect in improving whole farm WUE is improving application efficiency. Analysis of 542 surface irrigation evaluations within the Irrimate Surface Irrigation Database (ISID) by Gillies (2012) is summarised in Table 1.3.2. This data includes evaluations undertaken in all major cotton growing catchments from 2000-01 to 2011-12. They represent irrigation performance under normal grower management.

Table 1.3.2 - Summary of ISID results (542 events)

	Average	1st Quartile	Median	3rd Quartile
Flow rate (L/s per 2m width)	4.4	2.9	3.8	5.6
Run time (hours)	12.6	8.6	11.6	14.8
Total water applied (ML/ha)	1.36	0.96	1.2	1.56
Application efficiency (%)				
- without tailwater recycling	64.6	53.3	6.46	77.5
- with tail water recycling (%)[1]	76.3	64.7	79.5	90.4
Infiltration (mm)	108.9	76.9	98.9	126.8
Deep drainage (mm)	28.4	3.4	16.6	41.4
Runoff (mm)	26.5	7.6	17.9	32.6

(Source: Gillies, 2012) [1]Assumes that 85 per cent of the tail water is recovered.

The application efficiency reported in Table 1.3.2 is defined as the percentage of total water applied that is added to the root zone storage and can be used by the crop. A more meaningful value for the majority of growers is the application efficiency with tailwater recycling which takes account of the runoff that can be recaptured for future use. Industry studies have shown that tailwater system losses are generally less than 15 per cent.

The data in Table 1.3.2 shows the average application efficiency of surface irrigation to be 75 per cent (with tailwater recycling, which is common practice within the cotton industry). It also shows the range in measured application efficiencies indicating the potential to further improve performance through management changes. The changes most commonly used have been changes in siphon flow rates and cut-off times to optimise irrigation performance. The value of these practices is summarised in Table 1.3.3 which compares the measured and predicted performance possible through these changes on 476 events reported in the ISID database.

Figure 1.3.3 - Improvement in irrigation performance through adoption of recommended flow rates and cut-of times (476 events)

	Measured (average)	Optimised (average)
Flow rate (L/s per 2m width)	4.4	5.8
Run time (hours)	12.7	8.4
Total water applied (ML/ha)	1.42	1.16
Application efficiency (%)		
- without recycling	63.7	72.6
- with recycling	75.6	84.8
Infiltration (mm)	113.1	97.7
Deep drainage (mm)	30.4	15
Runoff (mm)	28.2	18.4

(Source: Gillies, 2012)

The data in Table 1.3.3 shows that, on average, application efficiency improvements of 10 per cent were possible for these events, with a halving of the volume of water lost to both deep drainage and runoff. Assuming that 85 per cent of tail water is recycled this equates to a water saving of 0.17 ML/ha per irrigation event.

Conclusion

There have been significant improvements in irrigation management within the Australian cotton industry over time, which is reflected in the broad improvement in IWUI values presented in Figure 1.3.1. Data collected at the farm and field scale provide further evidence of this.

However the data also shows that there is still a range of irrigation performance within the industry. This suggests that there is still significant scope for producers at the lower end of the range to increase the efficiency with which they use water.

Collecting water management data at the field and farm level provides important information for the diagnostic analysis of water use efficiency and the opportunity to further improve irrigation performance.

References

Cameron, J. and Hearn, A.B. 1997. Agronomic and economic aspects of water use efficiency in the Australian cotton industry. A report compiled for the Cotton Research and Development Corporation of Australia, Narrabri, NSW, unpublished.

Dalton, P., Raine, S. and Broadfoot, K. 2001. Best management practices for maximising whole farm irrigation efficiency in the cotton industry. Final report for CRDC project NEC2C. National Centre for Engineering in Agriculture Publication 179707/2, USQ, Toowoomba.

Gillies, M. 2012 Benchmarking furrow irrigation in in The Australian cotton water story: a decade of Research and Development 2002-2012, Cotton Catchment Communities CRC, Narrabri

Grismer, M.E. 2002. Regional cotton lint yield, Etc and water value in Arizona and California. Agricultural Water Management 54, 227-242.

Harris, G.A 2012 A decade of change in water productivity in The Australian cotton water story: a decade of Research and Development 2002-2012, Cotton Catchment Communities CRC, Narrabri

Measure Water to Manage Water-Implementation of the Mobile Irrigation System Evaluation Unit, Final Report, October 2002, NSW Agriculture. A report compiled for the Macquarie River Food and Fibre, and Macquarie Valley Land Care Group

Montgomery, J. 2012 Australian grains industry benchmarks water use efficiency in The Australian cotton water story: a decade of Research and Development 2002-2012, Cotton Catchment Communities CRC, Narrabri

Montgomery, J. and Wigginton, D. 2012 Benchmarking WUE in the Australian cotton industry in The Australian cotton water story: a decade of Research and Development 2002-2012, Cotton Catchment Communities CRC, Narrabri

Tennakoon, S.B. and Milroy, S.P. 2003. Crop water use and water use efficiency on irrigated cotton farms in Australia. Agricultural Water Management 61, 179-194.

Rural Water Use Efficiency Initiative-Cotton and Grains Adoption Program, Milestone Four Report, June 2003. Compiled by Goyne, P. Queensland Government Department of Primary Industries, Natural Resource and Mines.

Wigginton, D.W. 2011 Whole farm water balance: Summary of Data 2009 – 2011, Cotton Catchment Communities CRC, Narrabri.