

BENCHMARKING WATER USE EFFICIENCY IN THE COTTON AND GRAINS INDUSTRIES

Janelle Montgomery¹, Stuart Bray²
Industry and Investment NSW, Moree¹, Gunnedah²

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Abstract

The cotton industry continues to strive for improved water use efficiency (WUE), but until recently was unable to quantify the improvements it has made. Unfortunately irrigation benchmarking data has in the past not been well recorded. The performance indicators measured are generally not well defined and calculations have not been standard across the industry. There is a lack of good annual and robust benchmarking data not only for the cotton industry, but the whole irrigation sector.

In 2008, NSW Department of Primary Industries (DPI) benchmarked irrigation water use for the 2006/2007 season from 37 cotton irrigation farms using Watertrack™ Rapid. Having seen the value of this data, the grains industry has joined the cotton industry to expand the collection of this important irrigation benchmarking information.

In 2009, water use figures were collected from 46 cotton and 24 wheat farms located from Hillston in NSW to Emerald in Qld. The web-based benchmarking program Watertrack Rapid™ was used to provide standardised and comparable irrigation benchmarks. Watertrack Rapid™ generates a number of irrigation performance indicators such as Gross Production Water Use Index (GPWUI), Irrigation Water Use Index (IWUI) and Crop Water Use Index (CWUI). It also calculates crop water use and provides an estimation of on-farm water losses.

The survey data showed a wide range of irrigation performance and water volume estimation and measurement across the industry. It found the average $GPWUI_{farm}$ for the cotton industry was 1.14 bales per megalitre. This figure is a representative benchmark for the cotton industry for 2008/2009 and confirmed the previously revealed 40 per cent improvement by NSW DPI, since the last industry estimate 10 years ago.

For irrigated wheat, this is the first industry wide data collected. It establishes an irrigation benchmark for average $GPWUI_{farm}$ of 0.85 tonnes per ML for the 2008 season.

The average $GPWUI_{farm}$ of 1.14 bales/ML and 0.85 tonnes/ML is representative of the cotton and wheat industry water use in 2008/2009. It is these figures that can be used to benchmark water use so industry can gauge if it is further improving and determine the rate of improvement over time.

Introduction

Water use efficiency remains in the headlines and coupled with the recent drought, it is a topic of concern for both urban and rural people alike. Reduced water allocations have only heightened the response of irrigators to use their water more wisely; they continue to aim for maximum return per megalitre. However, there is increasing pressure from the Australian public on irrigation industries to measure these improvements in water use efficiency. The cotton industry has borne heavy criticism for its water use and has therefore been proactive in assessing its water use efficiency, such as studies conducted by Hearn and Cameron (1997), Tennakoon and Milroy (2003), Payero and Harris (2007) and more recently Williams and Montgomery (2008).

Cameron and Hearn (1997) attempted to collect data on the amount of irrigation water used and cotton produced at a regional, farm and field level. The terms they used to define cotton water use efficiency were split into engineering and agronomic efficiencies, namely: Irrigation Efficiency (IE) which was the percentage of water input actually used by the cotton crop in evapotranspiration; and Crop Water Use Index (CWUI) which is the amount of cotton produced per unit of water used in evapotranspiration.

Although crop production data was readily available, water use data was more difficult to obtain and a variety of sources were used. In their calculations the water input included irrigation and rainfall only; it did not include soil moisture. Average farm Irrigation Efficiency (IE) was 63 per cent ranging from 49 to 78 per cent. Data to calculate CWUI was only available for three farms and averaged 2.9 kg/ha/mm. Cameron and Hearn (1997) stated that their estimates of irrigation efficiency needed to be viewed with caution due to the indirect way they were calculated. However they were made with the best data available at that time.

Tennakoon and Milroy (2003) obtained production and water use data from 25 cotton farms and over 200 individual fields over three seasons, 1996/97, 1997/98 and 1998/99. They measured Irrigation Efficiency (IE) and Crop Water Use Index (CWUI) as defined above by Hearn and Cameron (1997). The average farm level IE was 57 per cent and the average CWUI was 2.5 kg/mm/ha, however they found large variability in both measures. In this study the water input term included irrigation water, water harvested during the season, rainfall and stored soil moisture. Tennakoon *et al.* (2004) extended the data to include a measure of farm level Gross Production Water Use Index ($GPWUI_{farm}$) and Irrigation Water Use Index ($IWUI_{farm}$). At the farm level Tennakoon *et al.* (2004) found the average $GPWUI_{farm}$ was 0.79 bales per megalitre for the Australian Cotton Industry, but ranged between 0.38 and 1.27 bales per megalitre. The $IWUI_{farm}$ averaged 1.26 bales per megalitre, ranging between 0.43 and 3.28 bales per megalitre.

Not only are there subtle differences in definitions and methodologies used in estimating water use efficiencies within these projects but the results were collected over different seasons. Payero and Harris (2007) point out “the lack of good annual and robust benchmarking data is an issue that the cotton industry and irrigation sector needs to address”.

Irrigation benchmarking data has in the past not been well recorded, performance indicators generally not well defined and calculations have not been standardised across the industry. Payero and Harris (2007) found significant variation in the calculation of water use indices due to the lack

of consistency in measuring the ‘water’ term. Cotton irrigators talk about producing so many bales per megalitre, but megalitres of what? The water term must be standardised and defined so it is known what ‘water’ is being included in the calculation (ie irrigation water, rainfall and/or soil moisture).

In order to rectify the lack of “robust benchmarking data” in 2008, NSW DPI (now known as Industry and Investment NSW) gained funding from the Cotton Research and Development Corporation, Cotton Catchment Communities CRC and the Namoi and Border Rivers – Gwydir Catchment Management Authorities to benchmark irrigation water use for the 2006/2007 cotton season using Watertrack™ Rapid (Williams and Montgomery 2008). Watertrack™ Rapid evaluates water use and irrigation performance using a range of water use indices, producing standardised results that enable meaningful comparison.

Williams and Montgomery (2008) found the average IWUI_{farm} was 1.31 bales/ML and the GPWUI_{farm} was 1.13 bales/ML. The data collected in this survey for 2006/2007 showed a significant increase in GPWUI of around 40 per cent since the last attempt ten years ago by Tennakoon and Milroy (2003).

In 2008 many irrigators chose to allocate their limited water supplies to wheat instead of conserving water for traditional summer crops such as cotton. This was driven by a combination of historically high prices and reduced surface water availability. Irrigated cereals previously grown as a rotation crop used only half as much water as cotton and high-yielding varieties could potentially be just as profitable when water supply is limited. Irrigators are monitoring their options on a year-to-year basis and increasingly using grains as a backstop when conditions and markets do not favour cotton production.

Having seen the value of irrigation benchmarking data collected by Williams and Montgomery (2008), both the Cotton and Grains industries funded further collection of this important benchmarking information. Investment to benchmark irrigation water use for the Cotton Industry for the 2008/09 cotton seasons and for irrigated wheat grown during the 2008 season was provided by the National Program for Sustainable Irrigation, Cotton Research and Development Corporation and the Grains Research and Development Corporation.

Methodology

In 2009, 46 irrigated cotton and 24 irrigated wheat farms located between Hillston and Emerald were surveyed to benchmark their irrigation water use and performance for the 2008/09 cotton season and 2008 wheat season. The majority of these crops were grown using furrow irrigation, with only a small area under overhead systems.

The web-based benchmarking program, Watertrack™ Rapid, was again used. The data collected included crop (cotton or wheat) yield, several water inputs (including rainfall, soil water, storage volumes, water harvested on-farm, irrigation water pumped), irrigation dates and the identification of soil type based on water holding and infiltration characteristics.

Watertrack™ Rapid automatically downloads FAO56 evapotranspiration (ET_o) and rainfall from the Australian Bureau of Meteorology SILO site. To determine crop water use (transpiration), the

Watertrack Rapid calculator uses ET_o values from SILO with a set range of cotton FAO56 Dual Crop Coefficients. Where possible, actual farm rainfall records were used rather than the SILO rainfall figures. Effective rainfall is calculated based on the USDA rainfall runoff model.

The WatertrackTM Rapid program generates both a Water Summary Report and a Performance Indicators Report. The Water Summary Report displays the Total Gross Available Water, (i.e. the total amount of water used to produce the crop including irrigation water diverted, on-farm storage water, harvested water, effective rainfall and soil moisture), Crop Transpiration and Total Water Losses.

Crop Transpiration provides an indication of the amount of water required per hectare to produce the crop in that season. On-farm Water Losses are calculated by simply subtracting the theoretical crop water use (transpiration) from the total amount of water used on farm to grow the crop.

WatertrackTM Rapid combines all on-farm water losses into a single figure. These losses include:

- all seepage and evaporation losses from supply systems, ring tanks and dams, drainage and tailwater systems;
- infield losses such as evaporation from the soil surface and deep drainage; and
- rainfall run off that is not harvested.

A number of irrigation performance indicators are calculated including the Gross Production Water Use Index ($GPWUI_{farm}$), Irrigation Water Use Index ($IWUI_{farm}$) and Crop Water Use Index ($CWUI$).

The results from the WatertrackTM Rapid survey's were collated anonymously so it is possible to then compare the data that was collected within a given region or across the whole industry. Industry irrigation benchmarks for the 2008/09 cotton and 2008 wheat season were established.

Results and discussion

Figures 1 and 2 show the results from the 46 cotton farms and 24 wheat farms respectively, ranked by their Total Water Loss per Hectare. Each farm is in the same position for each grouping. Also shown are the Crop Yield (bales/Ha or tonnes/Ha), Total Gross Available Water (ML/Green Ha) and Crop Transpiration (ML/Green Ha).

The project aimed to have had a larger sample size for the irrigated wheat farms (minimum of 30), however the data was difficult to obtain. Much of the country had been prepared for cotton so had high nitrogen levels. A wet winter saw high vegetative growth and coupled with a wet harvest resulted in a large number of lodged crops. Many of the irrigators were reluctant to provide data, just wanting to forget the season. Others were unable to provide accurate harvested water volumes, especially where excessive rainfall had fallen.

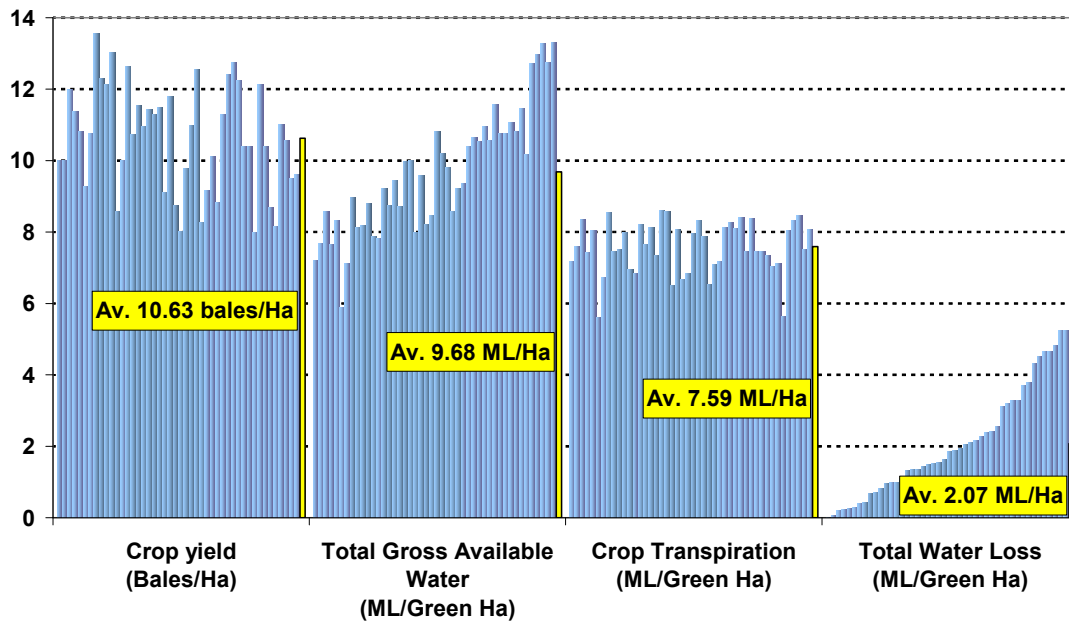


Figure 1: Variation in Total Water Loss compared to Yield, Total Gross Available Water (includes water diverted, harvested, used from storages, rainfall and soil water) and Crop Transpiration – Cotton 2008/09

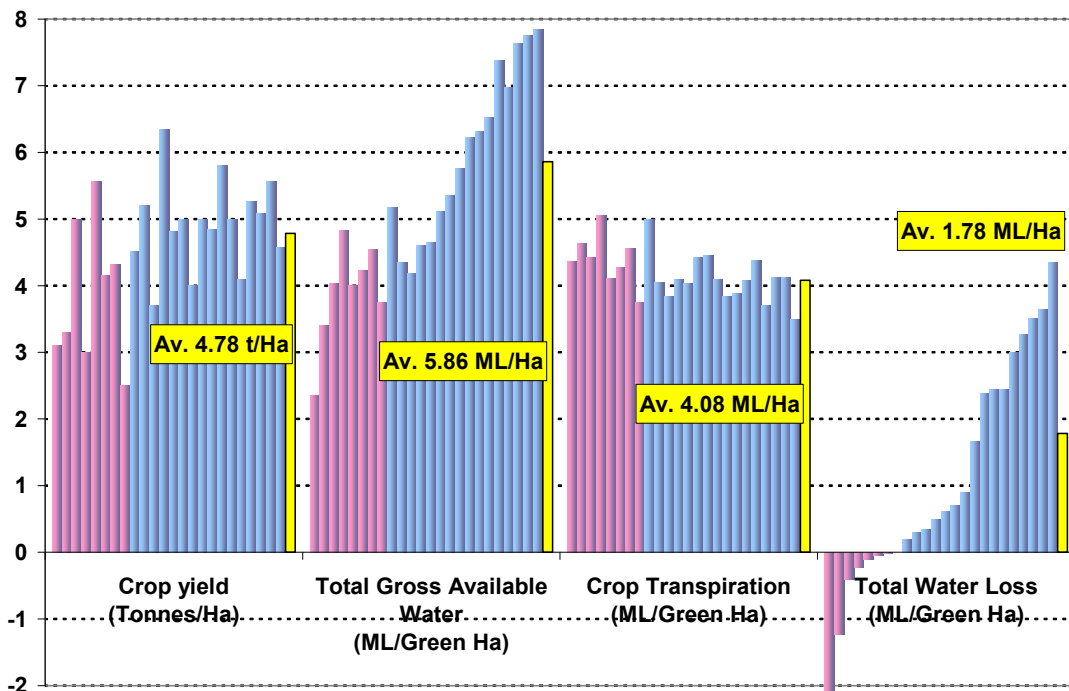


Figure 2: Variation in Total Water Loss compared to Yield, Total Gross Available Water (includes water diverted, harvested, used from storages, rainfall and soil water) and Crop Transpiration – Wheat 2008

The industry average cotton yield was 10.63 bales/Ha ranging between 8.0 and 13.57 bales/ha. On average the total amount of water used on farm for that crop, shown as Total Gross Available Water in Figure 1 was 9.68 ML/ha, ranging between 5.88 and 13.31 ML/ha. The average crop transpiration was 7.59 ML/ha.

On-farm water losses averaged 2.07 ML/ha. This was around 21 per cent of all water used on farm for the crop which includes water diverted from river and/or bores, water harvested on farm, effective rainfall and stored soil moisture used during the season. Therefore on average, the farms were able to utilise around 80 percent of their water through the plant productively. In this survey, the 6 farms with the highest combined farm water losses were only averaging around 60 percent of their total water through the crop in a productive manner.

WatertrackTM Rapid allows irrigators to quantify the magnitude of water losses and identify if further investigation of a particular component of their irrigation system is required.

Determining where water is lost across a whole farm can be a challenging exercise. However, identifying where losses are occurring is fundamental to achieving greater farm water use efficiency. Whilst it is possible to perform some basic calculations at the whole farm level, it can be quite difficult to partition water use and loss to different components of the irrigation system. This requires an increase of accurate measurement on farm through better monitoring and the adoption of more reliable metering equipment.

There were seven irrigated wheat farms that reported a negative water loss (refer Figure 2). In theory this is not possible as the total amount of water used on the farm cannot be less than the amount required to grow the crop (determined by SILO ET_o and FAO 56 Kc values). The only two variables that influence estimated Total Losses are Total Gross Available Water and Crop Transpiration. The WatertrackTM Rapid model assumes a healthy fully irrigated crop. Crop transpiration values were checked with neighbouring farms and found to be similar so it is likely water volumes on farm were underestimated. As this water includes water pumped, storage volumes, harvested rainfall and soil moisture reserves, inaccuracies invariably occur as water is not always metered within the farm. On some farms the final wheat irrigation coincided with a pre-water for cotton and splitting water between crops proved difficult. For these reasons the farms with negative losses were not included in the industry averages.

On-farm water losses for the 17 positive farms averaged 1.78 ML/ha. This was around 30 per cent of all water used on farm for the crop including water diverted from river and/or bores, water harvested on farm, effective rainfall and stored soil moisture used during the season.

The average irrigated wheat yield was 4.78 tonnes/Ha ranging between 2.50 and 6.35 tonnes/ha. On average the total amount of water used on farm for that crop, shown as Total Gross Available Water in Figure 2 was 5.86 ML/ha, ranging between 3.75 and 7.85 ML/ha. The average crop transpiration was 4.08 ML/ha.

Three water use indices, Crop Water Use Index (CWUI), Irrigation Water Use Index (IWUI_{farm}) and Gross Production Water Use Index (GPWUI_{farm}) calculated for each cotton and wheat farm are presented in Figures 3 and 4 respectively.

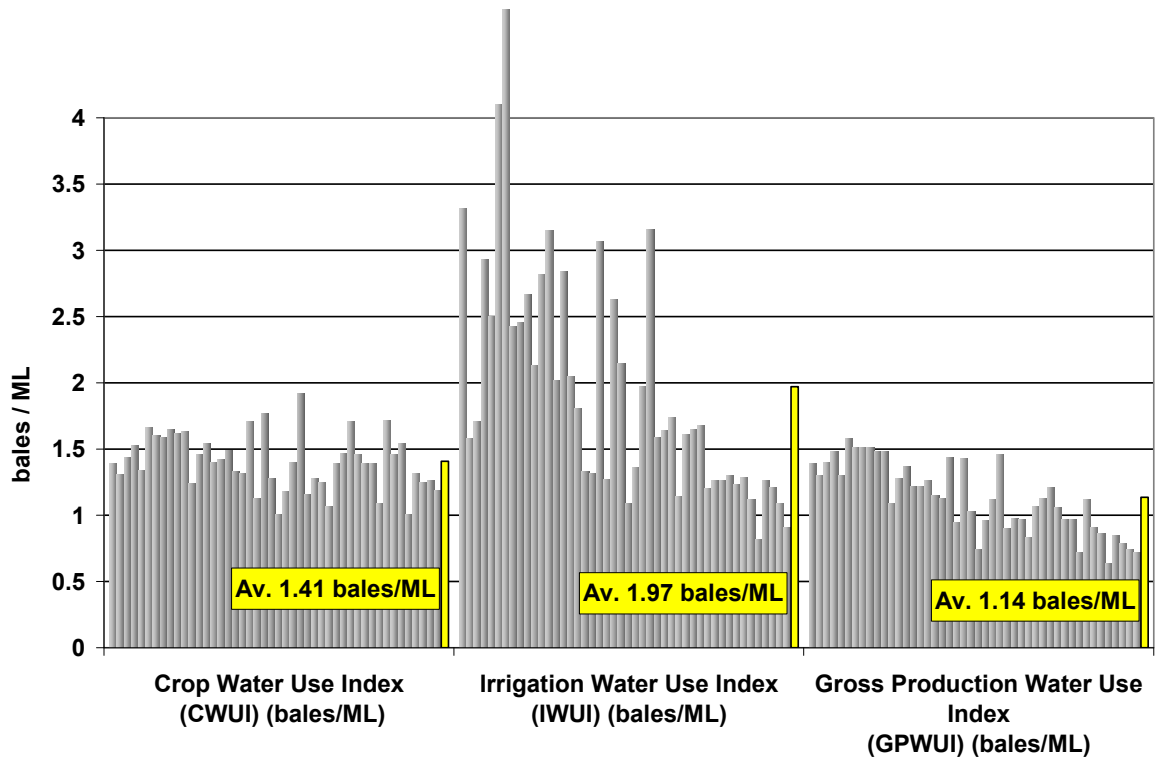


Figure 3: A Comparison of the Water Use Indices calculated using Watertrack™ Rapid - Cotton 2008/09

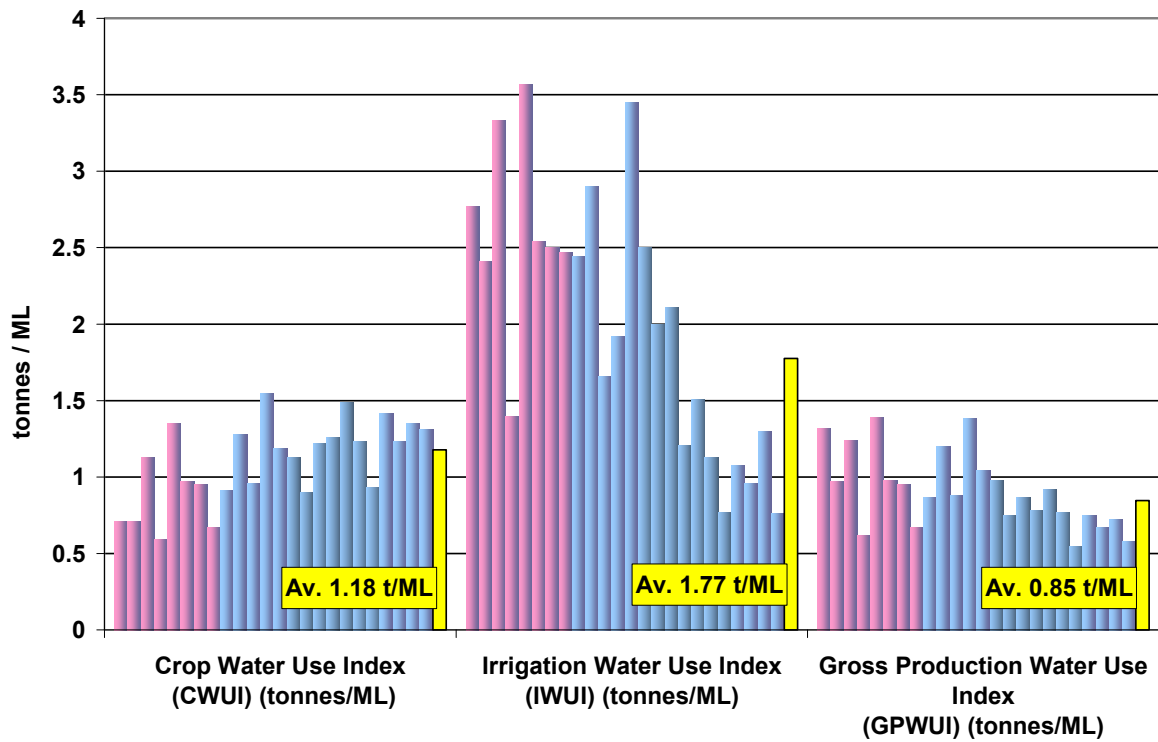


Figure 4: A Comparison of the Water Use Indices calculated using Watertrack™ Rapid - Wheat 2008

The average CWUI for cotton was 1.41 bales/ML and for wheat 1.18 tonnes/ML. Crop Water Use Index (CWUI) relates total production to the amount of water consumed by the crop (transpiration). Although not such a useful index for irrigation benchmarking, it is useful for estimating potential crop water use.

$IWUI_{farm}$ relates total production only to the amount of irrigation water supplied. The average $IWUI_{farm}$ for the cotton industry was 1.97 bales/ML ranging between 0.82 and 5.72 bales/ML. This figure for the 2008/09 season is significantly higher than the 2006/07 season $IWUI_{farm}$ figure of 1.31 bales/ML (Williams and Montgomery 2008). In-crop rainfall was much higher in the 2008/09 season meaning less irrigation water was used to produce the crop. The 2006/07 season was extremely dry with little in crop rainfall, irrigation water made up on average 88 per cent of the total water supplied to the crop, whereas in 2008/09 the average irrigation water supplied was only 64 per cent of the total gross available water.

The differences in the $IWUI_{farm}$ between these two seasons illustrate the influence that rainfall has on this index. $IWUI_{farm}$ can be used to compare between nearby fields or farms in the same season, but as rainfall is not included it is not useful for comparing over significant distances or between seasons.

A more meaningful water use index for comparing irrigation water use between farms and regions and across seasons is the Gross Production Water Use Index ($GPWUI_{farm}$). It relates total production to the total amount of water used – all sources i.e. irrigation water, effective rainfall and soil moisture. The average $GPWUI_{farm}$ for the Cotton Industry in the 2008/09 season was 1.14 bales/ML, ranging between 0.64 and 1.58 bales/ML. Williams and Montgomery (2008) found cotton industry average $GPWUI_{farm}$ for the 2006/07 season to be 1.13 bales/ML. The 2008/09 $GPWUI_{farm}$ figure of 1.14 bales/ML confirms the previously revealed 40 per cent improvement since the last industry estimate 10 years ago by Tennakoon and Milroy (2003) (Williams and Montgomery 2008).

The average $IWUI_{farm}$ for the irrigated wheat farms surveyed for the 2008 season was 1.77 t/ML, ranging between 0.76 and 3.45 tonnes/ML (refer Figure 4). The average $GPWUI_{farm}$ for the 2008 wheat season was 0.85 tonnes/ML, ranging between 0.55 and 1.38 tonnes/ML. This is the first industry wide survey for the irrigated wheat industry, so these figures provide benchmarks for future comparison.

The significance of these results is that the collection and calculation of the water use indices for both the cotton and grain industries have been standardised enabling meaningful comparison between the farms surveyed. The average cotton $IWUI_{farm}$ is 1.97 bales/ML compared to the more meaningful $GPWUI_{farm}$ of 1.14 bales/ML. The difference between the two indices is significant. Quoting an $IWUI$ figure in isolation can therefore overestimate the true on farm irrigation performance.

Variation in both $IWUI_{farm}$ and $GPWUI_{farm}$ across both industries suggests there is still room for improvement in water management and measurement within the irrigation industry.

Tennakoon and Milroy (2003) suggested two areas that they found in need of improvement, the collection of data on water storages and the consistent and systematic recording and processing of on-farm water use data.

WatertrackTM Rapid provides a tool that provides a consistent process to benchmark on-farm water use data. However, individual irrigators need to have a more consistent and systematic method of recording water use. The type as well as the way in which records are kept varies amongst irrigators, from simple diary entries through to more complex spreadsheets.

In recent years, the irrigation industry has moved ahead with improved on-farm storage management and monitoring of storage volumes. A number of storages have been surveyed to obtain accurate storage curves enabling the calibration of gauge boards. Although adoption has been slow, continuous monitoring of on-farm storages is also possible through commercially available pressure sensor transducers, such as the IrrimateTM storage meter. These are useful when capturing rainfall runoff. Where gauge boards are installed, the frequency of storage volume measurements needs to be increased, particularly before and after rainfall runoff events.

The opportunity to gather irrigation water use data and compare yield and weather data across the cotton industry using a standardised method is invaluable. The preferred water use index, GPWUI, compares yield to all water inputs including effective rainfall and changes in soil moisture. Irrigators from different regions can compare their performance with the rest of the (sampled) industry with a high degree of confidence.

Water use efficiency projects receive a significant amount of funding from various research and development organisations. This data is valuable for these agencies to show the impact of their research and extension. Continued collection of this data over time will enable the irrigation industry to show the rate of improvement in water use efficiency and to also identify potential performance targets.

At a grower level, irrigation benchmarking is also necessary if an enterprise is going to improve its water use efficiency. Knowing how you are performing compared to your region or industry enables continuous improvements in water management.

CONCLUSIONS

The process of collecting Water Use data for the 2008/09 cotton season has been a valuable exercise. The information obtained is very useful at all levels of the industry. The process was simple and quick and more importantly, utilised a consistent approach allowing on farm water use to be compared across the industry. The calculation of the water use indices were standardised and defined enabling meaningful comparison.

The average GPWUI_{farm} of 1.14 bales/ML and 0.85 tonnes/ML is representative of the cotton and wheat industry water use in 2008/2009. It is these figures that can be used to benchmark water use so industry can gauge if it is further improving and determine the rate of improvement over time.

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