

RURAL WATER USE EFFICIENCY - REAL WATER USE EFFICIENCY & THE OPPORTUNITIES

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What is Water Use Efficiency?

Water Use Efficiency (WUE) means maximising the returns from and minimising the environmental impacts of every megalitre (ML) of water used for irrigation purposes. Improved WUE therefore can result in a range of outcomes including reducing overall water usage, growing more hectares, producing higher yields and/or better quality produce and reducing any negative impacts that may be occurring through excessive drainage, poor water quality etc. Failing to measure and manage WUE at the farm and field level can compromise the economic and environmental sustainability of irrigated farming.

How is Water Use Efficiency Measured?

Table 1. WUE Indices measured across the RWUEI, Irrigated Cotton and Grain, Benchmarking Trial Sites

INDEX	DEFINITION	CALCULATION
Crop Water Use Efficiency (Bales/ML ET)	A measure of the yield produced for every ML that either the plant transpires (uses) or evaporates from the soil (Evapotranspiration, ET). It is a measure of how well the plant has converted the water it has used into yield.	$\frac{YIELD(bales)}{EVAPOTRANSPIRATION(ML)}$
Irrigation Water Use Efficiency (Bales/ML)	Relates production in yield to irrigation water applied. Effective Rainfall (infiltrated) is included to account for variations in rainfall between regions.	$\frac{YIELD(bales)}{IRRIGATION \& RAIN(ML)}$
Irrigation Efficiency (%)	Irrigation efficiency is the percentage of total irrigation water used in ET at the whole farm level.	* See Below.
Economic Efficiency (\$/ML)	Measures the gross income generated from every ML of irrigation water. Gross margin was not used as it was considered too difficult to gather the crop production data as well as the irrigation data.	$\frac{INCOME(\$)}{IRRIGATION(ML)}$

In order to capture the range of potential impacts of improved WUE a range of indices are used to measure and monitor it on-farm. This can be confusing and it is therefore most important that with every index used a definition and example calculation is provided.

The Rural Water Use Efficiency Initiative (RWUEI), Irrigated Cotton and Grains Program Development Extension Officers have been involved in monitoring and measuring WUE in on farm trials for the past two seasons in every cotton valley across the State of Queensland. Table 1 lists and describes with a sample calculation the set of WUE indices that were agreed upon by the industry partners in collaboration with government during the planning stages of the project.

The following provides a description of how and what the RWUEI Development Extension Officers had to measure at the trial sites in order to calculate these indices:

Crop Water Use Efficiency (CWUE)

Ginning Data were used to measure yield. ET was calculated using the Cotton CRC Water Use Efficiency Calculator that calculates ET using the FAO international standard (Allen *et al.*, 1998) for this calculation. There is a range of options available to the grower when it comes to measuring ET. Obviously these involve varying degrees of accuracy. The options are listed below ranging from a basic assumption to the best estimate:

Assumption

Hearn (1998) suggested that growers who wanted to start assessing WUE could use a conservative but robust assumption that ET is on average 7.5 ML/ha.

Soil Moisture Monitoring

ET can be estimated by summing the irrigation and rainfall deficits.

Cotton CRC WUE Calculator or QDPI Watershed

Provided the grower had the necessary meteorological data (max temperature, min temperature, average radiation, rainfall) these computer programs can be used. The Cotton CRC WUE Calculator calculates Irrigation Efficiency as well and therefore other information is required to run the whole program.

Irrigation Water Use Efficiency

Ginning data are used to measure yield. Although irrigation volumes can be either metered or estimated the days when estimates were suffice are over. Growers would never dream of spraying an insecticide without paying for an agronomist to check the necessity of the spray both in terms of pest pressure and beneficial numbers and the effectiveness

afterwards. For the same reasons, growers now need to invest in tools that allow them to test the necessity of an irrigation event (soil moisture monitoring tools) and the effectiveness after the water has been applied (meters and soil moisture monitoring tools). Below is a list of the meters and tools that were used at the RWUEI benchmarking Trials to measure irrigation water volumes.

Field Meters

Siphon flow rates and therefore volume applied to the furrow can be measured using:

- Siphon meters
- Head versus flow relationships
- Buckets and stop watches

Distribution Meters

“Starflow” meters were used by the RWUEI Extension Officers to measure field and distribution (eg supply channels) efficiencies.

Storage Meters

"Mace" meters were used at pump stations. This allowed volumes being pumped into and out of storages to be monitored.

Irrigation Efficiency

* Calculated as:

$$\frac{\text{ET} - \text{Effective Rain} - (\text{Planting Soil Moisture} - \text{Harvest Soil Moisture}) * 100}{\text{Total Water Pumped} + (\text{Sowing Storage Volume} - \text{Harvest Water Volume}) + \text{Water Harvested on farm (Tailwater)} - \text{Water Used on Other Crops}}$$

ET and Effective Rain has been explained above.

Planting soil moisture will need to be estimated as soil moisture monitoring tools are not usually installed until several weeks after planting. However the earlier they are installed the better the estimate will be. Likewise harvest soil moisture will be difficult to measure if soil moisture tools are not left in until harvest time.

Most growers would have meters at the farm gate, so water that is delivered via channel systems, harvested from rivers or pumped from bores will be a known volume and therefore total water pumped will not have to be estimated by most growers.

Storage volumes will be difficult to estimate without some sort of metering system whether it be gauge boards or meters at the pump station. Meters placed strategically here would

also provide the tailwater volumes and water used for other crops which would be very difficult to accurately estimate otherwise.

Economic Water Use Efficiency

Income is calculated as the yield multiplied by the price per bale received. Irrigation is the same value used in the Irrigation WUE Index and as such is measured the same way.

What Levels of Water Use Efficiency are Being Obtained?

Table 2 provides the average and ranges for each WUE Index listed above across the RWUEI trial sites for the previous two seasons.

Table 2. Averages and Ranges of the Agronomic, Crop Water, Engineering and Economic Efficiencies Generated from the RWUEI Benchmarking Trials

Water Use Efficiency Index	1999/2000	2000/01	2001/02
Crop Water Use Efficiency (Bales/ML (Et))		1.14 1.07 – 1.19	1.31 1.28 – 1.36
Irrigation Water Use Efficiency (Bales/ML Irrigation Net + Effective Rain)	1.17 (Stocktake report)	1.13 1.01 – 1.27	1.25 1.06 – 1.50
Engineering Water Use Efficiency Irrigation Efficiency (%)	56 (Stocktake report)	60	58
Economic Water Use Efficiency Gross \$/ML Irrigation Net		\$570/ML	\$470/ML

What Levels of WUE Should be Strived for?

The RWUEI stated that a 10% improvement in the WUE indices as measured at the start of the project was achievable. Keeping this in mind, this means by the end of the 2002/03 season the average figures should be 1.25 for CWUE, 1.29 for Irrigation Water Use Efficiency, 62 for Irrigation Efficiency and \$627/ML for Economic Efficiency. How does this stack up against previously stated industry benchmarks?

Hearn (1998) stated that the benchmarks should be 1.3 for CWUE and 75% for Irrigation Efficiency. Tennakoon and Milroy (2000) stated the benchmarks should be 1.2 and 60% respectively and these are subsequently the Cotton CRC WUE Calculator benchmarks in terms of the minimum acceptable level. FAO world standards for Irrigation Efficiency are 60-70%. As such, it is reasonable and as Table 2 above shows, already evident that a 10%

improvement in these WUE indices is achievable for the Australian cotton industry. But how can they be achieved or what opportunities exist for growers to reach these levels?

What Opportunities Exist in Order to meet these Levels?

Brian Hearn (1998) said it in 1998, Paul Dalton (2000) in 2000 and now it will be said again: " If you do not measure your irrigation water there is no possible way you can be entirely sure you are managing it to give the best possible returns. Furthermore, if you are not measuring it and only assuming you are managing it, you are compromising your profitability, are only assuming your impacts upon the environment and are therefore reducing the integrity of your industry". Measuring and recording WUE is the biggest opportunity that growers have to improve their WUE.

Measurement and Recording

A grower asked me the other day, "So with your project have you found ways to save us some water?" I said "yes". He said, "Are they tangible?" I said "probably not, until you make some measurements on your own farm". Until growers either make some measurements, pay someone to make some measurements or work with their local RWUEI extension officers these opportunities will not be tangible.

For example, a grower participating in the RWUEI immediately changed the way he was doing things after the first irrigation event was metered, because it made good economic sense. The water savings and water use efficiency indices confirmed the improvements over two consecutive seasons.

"Starflow" meters were installed in the head ditch and tail drain of the trial field. 1.48 ML/ha was delivered to the field and 0.6 ML/ha was being returned through the tail return system. Given an approximate cost of re-lifting the water was \$6/ML this worked out to be approximately \$330 per irrigation for this field alone. For the season this was \$2520 for that field of unnecessary pumping costs and if extrapolated across the farm for the season it was a cost of \$75 600. Based on the economics alone the grower stopped the siphons between 4 and 6 hours earlier in order to reduce tail water volumes.

In the next irrigation 1.12 ML/ha was delivered to the field and 0.26 ML/ha ran off. Using the assumption that on average 15% of tailwater is lost in distribution to seepage and evaporation the change in management resulted in a savings of 0.05 ML/ha. Doesn't seem much, but when you multiply that by 7 irrigations across that field, it amounts to a saving of 35 ML for the season. Still not much, but when you extrapolate to the whole farm it amounts to 1050 ML for the season. Enough to grow another 150 ha of cotton at 7 ML/ha!

In terms of the WUE indices, this field went from 1 to 1.11 Bales/ML for the Irrigation WUE Index and 1.1 to 1.2 Bales/ML(ET) for the CWUE Index, indicating that the grower was now meeting the minimal acceptable levels for these measures. Based on the average bale price for the season this would have generated an extra \$50/ML more in gross income resulting in an extra \$250/ML more for the local community.

It also means that in terms of the "field to fashion" theme this grower potentially produced 22 more pairs of jeans, 77 more dress shirts, 122 more t-shirts, 210 more pairs of boxer shorts or 432 more socks for every ML used in irrigation water across the farm.

The Cotton CRC WUE Calculator offers growers the opportunity to record their water measurements in order to generate CWUE and Irrigation Efficiency at either the field or farm level. It was designed to require only the measurements that growers currently make, however as with any model, the output is only as good as the input. Estimates will only produce estimates, but if an estimate is all you have then it is a start and if you estimate in the same way for the following season then the outcomes will be comparable. Once growers start to use tools like this they will see the advantages of metering rather than estimating volumes anyway.

Improving CWUE

In order to improve CWUE index you have to increase the yield to ET ratio. Yield is the driver and consequently you have to be able to identify if yield is being limited by other agronomic factors (pests, nutrition, weed management etc) or irrigation management. Factors within irrigation management that may be limiting yield include waterlogging and scheduling.

1. Waterlogging

Cotton can potentially suffer yield losses of up to 0.22 Kg/ha/day (Hogsden *et al*, 1986) after the first 24 hours of waterlogging. At the RWUEI trial sites, periods of waterlogging suffered by the crop following inefficient irrigations were about 3 days on average according to soil moisture monitoring tools. If you multiply 3 days by the average number of irrigations in each region, the potential yield losses through waterlogging following irrigations ranges from 0.9 to 1.5 Bales/ha. Usually soil moisture monitoring tools are placed in the first irrigation set and at the head ditch end, so the yield losses at the tail drain and in the other shifts would be different.

A RWUEI trial site cooperator thought this particular concept made sense, particularly as yield monitoring over previous seasons had shown over 5 bale/ha yield differences between the top and bottom of the fields. Continuous soil moisture monitoring tools were placed in the head ditch and tail drain of a field. The head ditch end of the field suffered

on average 5 days more waterlogging than the tail drain. Although denitrification is also a factor in this the two are related.

2. Scheduling

Failing to irrigate at the right time and without paying attention to how much is required compromises productivity. Most growers who use scheduling tools, or an irrigation scheduling service, will have the when to irrigate component right. Scheduling tools can also tell you how much to irrigate. Based on the fact that most scheduling tools are currently being used without calibration it is fair to say that they are not being utilised to their full potential.

Soil moisture monitoring tools are used to monitor how much water is being removed from the root zone of the soil either through evaporation or plant extraction. The total volume removed between irrigations is known as the deficit. This should also be known as the target application volume. If the deficit is 60mm then this means that either through evaporation or plant extraction the crop has used 0.6 ML/ha. It also means that 0.6 ML/ha is all that is required. Any more will lead to waterlogging, water losses to drainage and extra unnecessary pumping cost. Any less will lead to water stress.

Monitoring the deficits and volumes applied at the various RWUEI trial sites has shown there has been a grave mis-match between the applied and required volumes. Growers are applying excessive amounts of water and by doing so are wasting money through unnecessary pumping costs, yield reductions through waterlogging and loss of income through unnecessary water losses from excessive drainage beyond the root zone of the crop. Table 3 shows a selection of deficits and the subsequent applied volumes at various RWUEI trial sites. Table 3 also lists approximate losses through drainage beyond the root zone and the unnecessary costs associated with pumping excessive tail water.

Table 3. Applied Volumes, Deficits and Subsequent Tailwater and Drainage Volumes from Selected Irrigation Events across the RWUEI Benchmarking Trial Sites

Irrigation Timing	Deficit ML/ha	Volume Applied ML/ha	Tailwater ML/ha	Water Lost as Drainage/Evap		Cost to Relift Tailwater	
				ML/ha	1000ha	\$/ha	1000ha
Pre – Water	0.9	2.7	1.25	0.55	550ML	6.4	\$6400
1 st In Crop	0.67	1.4	0.62	0.11	110ML	3.2	\$3200
3 rd In Crop	0.72	1.2	0.26	0.22	220ML	1.3	\$1300
6 th In Crop	1.09	1.4	0.2	0.11	110 ML	1	\$1000

Source: Olivia Whiteoak QDPI RWUEI Development Extension Officer, Goondiwindi

Improving Irrigation Water Use Efficiency

In order to improve Irrigation WUE Index you have to increase the yield to irrigation and rainfall ratio. Irrigation management that impacts upon yield has been discussed above. How can irrigation volumes be minimised?

1. System Management and Optimisation

The most common response to how do you improve your WUE is, "Install a drip irrigation system." This is not the case! Furrow irrigation can be extremely efficient. Optimisation through measurement and subsequent management of the current irrigation system is a better option and is far less expensive. If however, it is found that through measurement, efficiencies cannot be improved to benchmark levels then a system change may be necessary. The RWUEI extension officers have been working with growers to optimise the systems they are currently using. As furrow irrigation optimisation has been covered above an outcome from the other two categories has been included below.

Drip Irrigation Optimisation

A grower on the Darling Downs was interested in drip irrigation but was keen to install a system that would be flexible enough for different crops and operations. Working with the local RWUEI Extension Officer, Andres Spragge, a trial was established that looked at the implementation of a reusable sub-surface drip system, used extensively in horticulture and sugarcane, in a range of planting configurations including skip row. The result was that this low cost approach to drip irrigation could be quite advantageous in a limited water variable cropping system. The cost to install the single skip drip irrigation system was approximately \$1500/ha and produced a crop with a CWUE of 1.3 bales/ML. The solid plant system cost \$2000/ha to install and produced a crop with a CWUE of 1.5 bales/ML. Both systems resulted in higher yields and CWUE than their furrow irrigated counterparts.

Overhead Irrigation Optimisation

Rural Water Efficiency Initiative Development Extension Officer, John Okello-Okanya, worked with a centre pivot grower at Dingo in central Queensland. He was involved in installing a series of soil moisture monitoring tubes to determine crop water use patterns under a range of agronomic practices. The objective was to review the water holding capacity of the duplex sandy clay soils following zero, minimum, and conventional tillage, burning of residual cereal crop stubble in combination with conventional tillage, and hilling of planting beds under minimum till cultivation. The crop was planted on a full moisture profile and crop roots reached 1 metre deep in just eight weeks. Non-stop pivot watering applying 9mm in each pass was only just keeping pace with crop growth, but it was the zero and minimum tillage cultivation that recorded the best water holding capacity. This has allowed for the identification of best cultivation practices that optimises the results of the irrigated crop under this system.

Improving Irrigation Efficiency

Low irrigation efficiencies indicate that water losses are occurring in the storage and distribution of water around the farming. Opportunities to improve Irrigation Efficiency include evaporation and seepage mitigation.

1. Evaporation Mitigation.

Growers in the Emerald and St George regions have been attempting to use covers in order to mitigate evaporation losses from farm dams. The Emerald trial results presented in Table 4 proved they were effective at mitigating evaporation, but the St George trial has shown that the commercial large scale installation of dam covers is difficult.

The efficiencies of dams at mitigating both evaporation and seepage are largely dependent upon how long water is stored. Cells that are emptied quickly lose less water than those that store water for extended periods. The RWUEI Research and Development Program has recently begun looking at this issue more closely in order to generate a computer simulation model that will allow growers to test the options before installation.

2. Seepage Minimisation.

Growers in Emerald have been investigating seepage mitigation tools including bentonite and liners. Results listed in Table 4 have shown that both lining and bentonite are effective strategies to reduce water losses through drainage from farm dams. A major outcome of the Emerald trial was that growers needed to monitor both evaporation and seepage before a strategy for either is implemented. For instance, you may develop a strategy to reduce evaporation when seepage is a greater loss and vice-versa.

Table 4. Expected Losses from a 220 ML Dam (5.4 ha) at Emerald under a Range of Treatments based on a Small Scale Trial Adjacent to the Dam.

Treatment	Covered & Lined	Covered Only	Lined Only	Bentonite	Untreated
Losses from a 220 ML Dam (5.4 ha) for the season	3.22 ML	70.84 ML	45.08 ML	40.25 ML	115.92 ML

Source: John Okello-Okanya QDPI RWUEI Development Extension Officer, Emerald

Improving Economic WUE

To improve economic WUE you need to improve the returns per ML by either increasing yield and/or producing better quality cotton. Irrigation management that impacts upon these have been covered above, but the other component to economics is reducing the

operating costs or improving the gross margin. Examples of reduced costs or generating greater gross margins through improved WUE include:

1. Reduced pumping and de-siltation costs through minimisation of tailwater and therefore erosion.
2. More efficient use of other agronomic inputs such as nitrogen fertiliser, because WUE has been optimised and therefore waterlogging and excessive drainage have been minimised.
3. Better yield and quality improved by a greater factor than increased labour costs required to manage irrigation events more efficiently.
4. Knowing your soil better, means that you are more aware of limitations in the root zone which are compromising the irrigation potential of your soil and you will be able to either manage these or cease irrigation as the returns will never be able to justify the inputs.
5. Long term economic viability through reducing the salinity risk by:
 - Understanding the irrigation water quality better.
 - Reducing drainage volumes which are, either causing the water table to rise or are moving through the landscape and causing a problem elsewhere.
 - Allowing enough drainage to ensure salts are continually moved out of the root zone.

In Summary:

The opportunities for improving the returns from and minimising the impacts from irrigation water are numerous, but will never be obvious to growers unless they measure manage accordingly and record. Unlike the current perception that the pinnacle of WUE lies with sub-surface drip irrigation, there are many low cost strategies which can be implemented now for immediate gains. So now you know why WUE is the current “buzz phrase” within the Australian irrigated cotton industry.

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