Improving cotton's water use efficiency

By Sarah Hood[1] and David Wigginton[2]

The crop water use efficiency, which is the ability of the plant to turn the water it extracts into lint, of the Australian irrigated cotton crop compares favourably with the rest of the world. The Cotton Australia website attributes this to varieties, suitable soils and good management.

But the water that the plant uses in any given season is a proportion of the water that is diverted at the farm gate. The industry has recognised the need to reduce the losses that occur between the farm gate and the plant in an effort to further capitalise on their irrigated productivity. But the results of these efforts have largely only been estimated to date.

Existing surveyed and measured water use data has been compiled in Chapter 2.2 of WATERpak. This summary concludes that the average whole farm efficiency of the Australian cotton industry is around 59 per cent. This means that, on average, 41 per cent of the water diverted for cotton production is lost as evaporation or seepage while it is being stored in dams, transported around the farm or applied to fields.

This summary establishes that there is significant opportunity for improvement and that a universal measurement and reporting framework is necessary. But it does not indicate whether or not the industry is improving and the rate at which it is improving.

Furthermore most of the efforts in improving water use efficiency have occurred since this data summary. Many growers within the industry have changed irrigation storage and irrigation application practice but a lack of a systematic reporting framework has meant that the industry has not been able to measure the impact of changes at the field, channel or dam level on whole farm water use efficiency. It is hoped that the recently developed farm water balance computer program, Watertrack, may help to address this issue.

More recently (season 2004–05), irrigation consultant Pat Hulme, Sustainable Soils Management, Warren, has worked with several growers across the cotton industry to assess whole farm water use efficiency. These investigations have been undertaken during the testing phase of Watertrack.

Watertrack has been developed by private consulting firms and is a comprehensive analysis of water losses from storages, distribution channels and fields. Data from these early assessments support the results obtained in previous studies in that the averages are less than optimal and that a large variation exists between individuals. They also validate the fact that management can impact upon overall efficiencies and that measurement of the change is critical.

BACKGROUND

Australian irrigated cotton growers produce more lint per millimetre of water used by the crop than most other countries in the world. In a collective effort to further maximise irrigation productivity, Australian irrigated cotton growers have been working with various partners including universities, cooperative research centres, government departments and consultants to improve the efficiency with which they deliver the irrigation water to the crop.

This collaboration has seen the rapid development and adoption of a collection of revolutionary techniques which have taken the theories behind infiltration, evaporation and seepage and allowed for the practical measurement and mitigation of these losses for both commercial and environmental benefits. But largely due to the fact that the industry lacks a consistent measuring and reporting framework the impact of these changes can only be estimated.

Where are the losses?

In 2001, NCEA researcher Paul Dalton measured the water losses from each system component across sever-

TABLE 1: Recent studies of water use and farm irrigation efficiency in the Australian cotton industry

Source	Seasons	No. of farms	Irrigation ML/ha	E_f range %	E_f average %
Cameron & Hearn (1997)	1988 – 1995	11	5.37	49 – 78	63
Tennakoon & Milroy (2003)	1996 – 1999	25	6.96	20 – 85	57
RWUEI (2003)	1999 – 2003	29	7.51	50 – 74	58
Dalton et al (2001)	1998 – 2000	7	7.5	28 – 68	
Industry Average			6.84	20 – 85	59

Adapted from Tennakoon et al, 2004.

al farms in the Border Rivers catchment. This study confirmed that the three greatest losses were evaporation and seepage from storages and deep drainage under cotton fields. Some of the lower efficiencies exhibited by the industry in Table 1 may be a result of a range of factors including conveyance losses, storage losses, application losses or improper scheduling.

Dams and channels

As identified by Paul Dalton, evaporation and seepage from farm dams and channels represents the greatest loss of irrigation water within the farming system. That research found that evaporation and seepage during the growing season from on-farm dams and distribution channels ranged from 19 to 57 per cent of the water diverted to or captured on-farm.

While these losses are significant, there has historically been considerable difficulty and expense involved in measuring them and it has often been perceived that these losses are negligible (for example, seepage on heavy clay soils) and/or inherent to such systems (for example, evaporation from large earthen dams in hot dry climates).

Measurement of evaporation and seepage losses is therefore a critical step in the process of improving irrigation efficiency. Recently, as a result of a National Centre for Engineering in Agriculture (NCEA) project funded by the Queensland Department of Natural Resources and Mines (NRM), a novel approach to partitioning seepage and evaporation losses from farm dams and chanels was developed. This measurement method was actually developed to determine the effectiveness of various evaporation mitigation technologies — for which a reliable and robust measure of evaporation was required.

Central to the technique is a highly accurate (sub-millimetre) pressure transducer to detect subtle water level changes. An automatic weather station is also employed to monitor the associated environmental conditions. During periods of zero (or very little) evaporative demand, water level decline is assumed to be a result of seepage. Following a period of measurement, a seepage

34 ▷

TABLE 2: The effectiveness, associated costs and life expectancy of several evaporation mitigation techniques

EMT product	Cost	Expected life	Evaporation reduction	Cost per Ml saved
EvapCap	$7/m^2	12 years	90 per cent	$360
Netpro	$8/m^2	15 years	75 per cent	$395
Water$aver	$18/Kg	2 days	25 per cent	$365

Source (NCEA, Issue 4, July 2004)

◁33…WATER USE EFFICIENCY

rate can be extrapolated to get net daily seepage and evaporation losses.

This technique has been commercialised through the Irrimate network and is now being used by several consultants throughout the cotton industry to help growers determine their evaporation and seepage losses easily and accurately. As a result, these consultants have determined seepage rates ranging from 0.7 mm per day to 30 mm per day. Paul Dalton previously found similar seepage rates using volume balance techniques ranging from one mm per day to 30 mm per day and other studies have suggested similar ranges between one and 23 mm per day.

Recently FSA Consulting (an irrigation consultancy in Toowoomba that is a partner of the NCEA) used this technique to assess seepage from several cotton farm dams in a community funded project on the Darling Downs. FSA found that seepage varied from zero to 14 mm per day but generally found that normal storages not known to have a seepage problem generally leak less than five mm per day. Various strategies to reduce seepage have been assessed. Growers have experienced 80 to 90 per cent reduction in seepage by clay lining, partial abandonment and full abandonment of storages.

Using the same technique, evaporation was measured to be seven to eight mm day on average but reaching 14 mm day when temperatures exceed 40°C.

The NCEA evaporation mitigation project that allowed for the commercial development of this research technique looked at several methods of reducing evaporation ranging from floating acetyl alcohol (Water$aver) to shade cloths as used in horticultural industries (Netpro) and permanent plastic floating covers (EvapCap). Although the savings ranged from 25 to 90 per cent, an economic analysis showed that each technique represented a similar cost per megalitre saved at $365–$395 per Ml (Table 2).

TABLE 3: Theoretical reduction in average farm water losses by applying known methods for mitigation

	% Loss of water diverted at the farm gate*	Maximum reduction as per methods described above
Dam evaporation	30	22.5
Dam seepage	5	1.0
Distribution evaporation	4	3.0
Distribution seepage	6	1.0
Field evaporation	2	2.0
Field seepage	10	7.0
Total losses	57	38.0
Irrigation efficiency	43	62.0

Fields

In the mid to late 1980s Utah State University progressed the mathematics behind surface irrigation system modelling and performance assessment. The University of Southern Queensland capitalised on this progress and, through the NCEA, developed specialised siphon meters and advanced sensors. This has resulted in the Irrimate Irrigation Evaluation Package which was commercialised by Aquatech Consulting prior to the 2000–01 season.

By using this package, growers have been changing the way they manage their furrow irrigation systems in order to reduce water use and increase productivity. On average this has resulted in 30 per cent less water infiltrating the ground during the cotton season. Aquatech has been using this service with their clients since 2000–01 and during the 2004–05 cotton season at least one farm in every cotton growing valley was using this service.

Estimating the impact of change

Paul Dalton separated the losses between each part of the cotton season and the averages are provided in Table 3. If you apply the savings as identified above to the average losses calculated by Dalton, the result is a 20 per cent increase in whole farm water use efficiency from 42 to 63 per cent.

For example if evaporation from farm dams and distribution systems can be reduced by 25 per cent using floating alcohol this would reduce the average evaporation loss from these structures from 30 to 22.5 per cent and four to three per cent respectively. Likewise if seepage can be reduced by 90 per cent, the losses from these same structures could be further reduced.

CONCLUSIONS

The Australian cotton industry ranks well internationally in terms of crop water use efficiency. But studies have generally found that average whole farm irrigation efficiencies still fall short of international and national benchmarks. Between 20 to 80 per cent of the water diverted for irrigated production can still be lost within the system as evaporation and seepage from dams, channels and fields. Research and extension activities have helped identify the opportunities and developed techniques for measurement, management and mitigation of these losses. Growers have been adopting these strategies which can result in a 20 per cent improvement in whole farm efficiency.

There is now a strong focus by many growers, consultants, research and extension staff within the industry to mitigate losses within each part of the farming system. Growers who measure their water use carefully have much higher returns per ML than those who don't.

1 Sustainable Irrigation Systems, St George
2 National Centre for Engineering in Agriculture, Toowoomba