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WATER USE EFFICIENCY IMPROVEMENT PROGRAM IN QUEENSLAND'S COTTON INDUSTRY

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Abstract

Best management practices (BMP) in irrigation are being demonstrated and encouraged through the Cotton and Grains Adoption Program of the Australian State of Queensland's Rural Water Use Efficiency Initiative (RWUEI). The RWUEI is a partnership between between industry and government and involves the cotton, grains, sugar, fruit and vegetable plus dairy and pasture industries. Water use efficiency (WUE) officers have established grower groups to assist in providing local input into the specific objectives of extension and demonstration activities in the five major irrigation regions in the state. The main objective is to develop better irrigation WUE, through the application of irrigation principles resulting from past research. The project benefits industries, irrigators and local communities through increased production and profit. In addition, environmental health will improve as a consequence of greatly reduced runoff of irrigation tailwater into rivers and streams. This will reduce the risk of n utrient and pesticide contamination of waterways. Activities are based around a minimum of four on-farm demonstration sites in each irrigation region where management techniques and equipment are demonstrated. The project monitors application methods and in-field management as well as water use from on-farm storages and distribution systems. This paper describes the project, its activities and successes.

Introduction

Australian cotton production was 3 million bales in the 2001/2002 season . These were produced from 400,000 hectares of which over 90% was irrigated. Queensland contributed about 20% of this production (Dowling 2002). Only Five percent of Australia's surface water is harvested of which irrigated agriculture uses 70 to 80 percent. Cotton accounts for 12% of this use (Commonwealth of Australia 2002). Hearn (2000) reported that, in spite of popular belief, cotton uses less water per hectare than any other agricultural industry in Australia and produces more value per megalitre than any other, with the exception of horticulture. However, irrigation efficiency and water management can be improved. Therefore a number of projects are being conducted on irrigated management techniques and cropping systems (Milroy and Tennakoon 2002). With the growing concerns for adequate water availability, and possible discharge of contaminated water from irrigation activities into river systems, the Queensland Government introduced, in 1999, a four-year project, the Rural Water Use Efficiency Initiative (RWUEI) (Bell 2001). The RWUEI is a partnership between between industry and government and involves the cotton, grains, sugar, fruit and vegetable plus dairy and pasture industries. The program is also most appropriate at this time because of the emerging salinity threat to agricultural land. Triantafilis (2002) reported that general improvements in salinity control can be made from maximising on-farm irrigation efficiency. Hood (2002) described WUE, in irrigated agriculture, as maximising the returns and minimising the environmental impacts for every megalitre (ML) of water used for irrigation purposes.

Queensland's Department of Primary Industries' Agency for Food and Fibre Sciences' Farming Systems Institute, is undertaking the "Cotton and Grains Adoption Program" within the irrigated cotton and grains industries as part of the RWUEI. The objective of this Adoption Program is to assist irrigators in measuring, recording and monitoring their progress in WUE improvement thus increasing by June 2003, irrigation efficiency by at least 10%, with 70% of growers adopting BMP guidelines for irrigation.

Methods

Five major irrigation regions in Queensland are being targeted. These lie within 23º to 29ºS latitude and 148º to 152ºE longitude and extend from the town of St George in the West to the Eastern Darling Downs and from the Macintyre Valley at the New South Wales border to the Emerald Region of Central Queensland (Fig.1).

In each region, WUE staff have established grower groups to assist in providing local input into the specific objectives of extension and demonstration activities. The groups also assist in developing growers' perceptions of ownership of the work. Activities are based around at least four on-farm demonstration sites in each region, where irrigation management principles, determined from past research, and equipment are demonstrated. A key theme of the program is monitoring water use. This is applied both to on-farm storage and distribution as well as to application methods and in-field management.

Thus an education program for growers is being conducted which includes:

- Developing an awareness of water management issues.
- Contributing information to and assisting with the development of an irrigation module for a BMP manual.
- Developing, demonstrating and promoting the implementation of the water monitoring systems on farm using simple practical methods and devices.
- Establishing an annual award system which provides incentives and opportunities to improve WUE and which recognises individual achievements or initiatives that have led to improved WUE.
- Conducting benchmarking surveys at strategic times during the project to evaluate performance and outcomes.

To address some of the many issues confronting irrigators, 29 demonstration or trial (benchmarking) sites were established during 2001/2002 and a similar number the previous season. Irrigation systems included: furrow (surface), centre pivot, subsurface drip, side-roll sprays, travelling gun and gated pipe delivery. Furrow irrigation with delivery to the fields from the supply ditch via siphons is the main irrigation system used in the Australian cotton industry. Trials were also established to investigate the control of evaporation and seepage from farm storages, soil characterisation for water holding capacity, and the use of polyacrylamides in sediment control and water penetration. Similar activities were carried out by the project team in previous seasons.

The implementation of the adoption of new irrigation technologies is being assisted by a Financial Incentives Scheme that partly reimburses growers for their outlays.

A number of indices are being used to determine efficiency gains made during the course of the project. These are described in Table 1.

An example of some of the activities being carried out by the project team is demonstrated in the following for one of the regions:

Site:

Surface irrigated (furrow, one metre beds) cotton and grain property.

Objectives:

- Measure current water use in an individual field.
- Demonstrate use of the neutron probe and capacitance probe as irrigation scheduling tools.
- Collect in-furrow data to benchmark current irrigation performance and optimise using the surface irrigation model SIRMOD (Utah State University 1999).
- Demonstrate use of the WUE Calculator (Tennakoon *et al*. 2001) to calculate efficiencies.

Methods:

- Measurement of bulk inflows and outflows from an individual field using 3 "Starflow" meters.
- Measurement of soil moisture via a capacitance probe and neutron probe.
- Collect flow data from 3 individual siphons in an irrigation set, and irrigation advance rate data in 8 furrows at 6 points down the field to input into SIRMOD. SIRMOD will be used to calculate the current efficiency of the irrigation event and proceed to the optimisation of that event.
- Use meteorological data, soil moisture data and agronomic data for the scheduling program WATERSCHED (Queensland Department of Primary Industries 1993) and WUE Calculator processing.

Expected Outcomes:

- Increased irrigator understanding of water usage and efficiencies.
- Optimisation of management practices to minimise tail water losses, water logging etc.
- Determine WUE indices.
- Provide field day and workshop site for irrigation optimisation via SIRMOD.

Results and Discussion

As a result of the project an increasing number of irrigators are now achieving irrigation efficiencies well in advance of the state benchmarks presented in a Stocktake report (Goyne *et al.* 2000) which was compiled at the commencement of the project. These efficiency gains indicate that the 10% target increase in efficiency set for the Program is being achieved and in many cases exceeded (Table 2).

A gradual improvement in all indices throughout the irrigation regions is being observed and the ranges indicate that improvements beyond the 10 % objective can be achieved. The management practices that have resulted in these trends represent real and practical opportunities for growers to improve their WUE.

Case Studies

Case studies are being used to highlight changes in practices that have been implemented through the application of new technology and skills identified by the Program. They are being used to illustrate the possible gains that can be made through improving WUE. The following examples provide evidence of the progress of the project in the irrigation regions and the interest now being shown by growers:

Measurement is Critical to Irrigation Management

The greatest opportunity for water saving is with measurement. Through measurement, the trial site co-operators have investigated various management options and set targets for improvement. Irrigation scheduling tools are also now being well utilised to effectively time irrigations, but they are yet to be used to their full potential. If these tools are correctly calibrated they can be used to show the irrigator how much water needs to be applied in each irrigation. Monitoring of siphon flow rates has shown that some irrigators are applying three times the water required and that not all the excess is being recycled as tail water. The program team is endeavouring to rectify these issues.

The following highlights the importance of measurement: A cotton growing operation has been a benchmarking site for the project for the past two seasons. The grower was able to use the information being generated from the meters and soil moisture monitoring devices that were installed in the irrigation inlets, outlets, siphons and furrows.

After pre-irrigation the meter results prompted a discussion about crop water-logging and how irrigations can be managed to minimise it. One day's water-logging was found to be more damaging than one day of stress due to a lack of water. Water-logging from irrigation can be reduced by minimising the time that water is ponded in the furrows. Water should only be on the field long enough for the soil moisture profile to be replenished thus minimising water-logging or excessive drainage beyond the root zone. Matching siphon flows and shift duration with the required volume of water, run lengths and slope of the furrows will achieve this. It seemed that an optimum strategy would be to increase flow rates and reduce the shift times by about a quarter.

Capacitance probe soil moisture data indicated that after the initial irrigation, there was a period of three days when plants were not extracting water. It was explained to the grower that this was the result of water-logging. The grower to recalled the discussion on how to minimise it and he commenced to implement the strategy so the period of water-logging was reduced by two thirds in the subsequent irrigations. Over an entire season the crop was subject to only 13 days of post irrigation water-logging via this management strategy, as opposed to 33 days if the original management system was maintained. Water was saved, runoff reduced and yield increased. This highlights the large water savings that can be made through simple management changes.

Meters are Critical to Better Water Management

A cotton grower was encouraged to install meters in the head ditch and tail drain of one field on his farm. Initial results revealed that half the water being delivered to the field had to be re-lifted as tail water. The grower was able to confirm this using data on changes in his dam water level. He realised that recycling and desilting costs were excessive and distribution losses were potentially high.

Concerned with the economics of his operation, the grower changed the irrigation management to minimise tailwater by running the siphons for less time and rearranging shifts. The results , in Table 3, show a substantial increase in Application Efficiency (AE) and a decrease in tailwater.

In the following season meters were installed on the farm's distribution system. Some comprehensive metering on siphons and furrows was also carried out. In addition, capacitance probes were used to monitor soil moisture.

The distribution system showed minimal losses. This was what the grower believed to be the case from his knowledge of the soil type and his monitoring of water use from the differences in dam water levels. The furrow irrigation simulation model SIRMOD was run and showed that deep drainage was also minimal (Table 3 shows that the infiltration amounts remained approximately constant after the management change) but water-logging was excessive. The grower reached the following conclusions:

- Irrigations need to be applied quicker over shorter shift intervals in order to optimise irrigation efficiencies.
- Capacitance probe data showed that different fields will need to be irrigated at different times because of differences in soil type and therefore plant available water and rooting depths.
- Irrigations efficiencies could be improved if in-flows could be increased and shift durations shortened further.

A Plan has now been developed for next season**:**

- Fields will be watered with higher in-flows and at half the current duration.
- Irrigation will be carried out on a "needs basis" rather than the traditional "in sequence" based on one neutron probe in the first field.

The grower made such decisions in direct response to the information generated from the meters and soil moisture monitoring equipment which the WUE team member encouraged him to install.

Better Management through Irrigation Evaluation

Basic calculations of application rates using theoretical siphon discharge charts and a bucket and stop watch method were demonstrated to growers. Monitoring application rates by this method provided some surprises to irrigators on the quantity of water they were applying.

More accurate field monitoring with meters on the head ditch and tail-drain also heightened awareness of the amount of water applied. The tail water recycled in some cases was quite considerable and irrigators are now becoming convinced that they need to adjust their irrigation management and so reduce the quantity of water applied.

Better Understanding of the Use of Soil Moisture Monitoring Equipment to Improve WUE

After a small workshop focusing on scheduling with a regional irrigator group, half of those present purchased soil moisture monitoring equipment. This group later attended a post-season meeting to discuss their data and experiences with the equipment.

One irrigator noted that one of his fields had prolonged periods of water-logging. This was evident on the top half of a field due to the poor furrow slope. He recorded a yield of 7.2 bales/ha at the water-logged section compared to 8.6 bales/ha for the rest of the field. Subsequently the field was laser levelled with furrows running at right angles to the original direction. The result was better irrigation uniformity with no waterlogging. This cotton grower expects to recover the cost of the modifications after the first season from the resulting increase in yield.

Evaporation and Seepage Mitigation

Where on-farm water storages supply most of the irrigation water, maximum storage efficiency becomes important. Evaporation and seepage losses from storages have been identified as being high (up to 8ML/ha and 13ML/ha respectively) in some regions. This presents opportunities for water savings.

Irrigators in the Emerald and St George regions have been attempting to use covers in order to reduce evaporation losses from farm dams. The Emerald trial results presented in Table 4 showed they were effective in mitigating evaporation, but the St George trial has shown that the commercial large scale installation of dam covers (4ha in area) is difficult (Hood 2002).

Strategies to reduce seepage losses are also under investigation in the Emerald region. Table 4 shows that both lining and bentonite are effective strategies to reduce water losses. A major outcome of the Emerald trial was that growers need to monitor both evaporation and seepage before a strategy for either is implemented.

Some Highlights to Date

The program is achieving very positive outcomes towards the better management of irrigation water in both the cotton and grain industries. These include:

- Awareness and participation in the program exceeded 75% of growers (the target for 2001/2002) by August 2001 and is now estimated to be greater than 80% in some regions.
- A survey conducted in August 2001 indicated that 78% of cotton irrigators had become involved in Best Management Practices.
- An increasing number of irrigators are now achieving irrigation efficiencies well in advance of the State benchmarks determined at the commencement of the Program.

- Results indicate a gradual improvement in all water use indices across the state. The management practices that have resulted in these trends represent real and practical opportunities for growers to improve their WUE.
- Evaporation and seepage mitigation strategies present opportunities for water savings.

Project Evaluation

The economic, environmental and social benefits of the program are being monitored. The impact of the program is to be evaluated in relation to its influence on improvement in WUE, irrigator movement to BMP, and awareness of and participation in the Program.

An independent evaluator carried out a mid-term evaluation of the Program's performance in September 2001 and a final evaluation will be made on completion of the Program (Barraclough & Co 2000).

The Mid-Term Evaluation**:**

- reported outcomes against agreed measures and targets
- reviewed the effectiveness and rigour of the data collection processes
- reported on suitability of the measures used to evaluate performance
- recommended changes to the evaluation plans
- recommended any necessary changes to the Adoption Program
- highlighted areas where performance has been exceptional and indicated actions that could flow from these success areas
- identifed poor performance areas and suggested actions to correct or cease these activities

At the Final Evaluation the Evaluator will**:**

- report outcomes and outputs against agreed measures and targets
- report on accuracy of the data
- using the data accumulated, undertake a benefit/cost analysis of the program
- report on reasons for successes and failures
- provide recommendations for future actions to improve performance in WUE

Conclusions

Irrigators are now becoming increasingly conscious of the relationship between their industry's economic sustainability and its impact on the environment. Best Management Practices are being developed and applied. These are assisting in the elimination of runoff of any waters that may have high nutrient, chemical or turbidity levels.

The irrigated cotton industry relies mainly on furrow irrigation. There are a number of opportunities for efficiency gains with this system. The Program team is encouraging irrigators to focus on the precision of their application of water. Many are now using scheduling tools to determine when and how much water to apply and so deliver to the root zone exactly what the crop requires. There is also now an increased use of water meters. These tools assist in minimising or eliminating runoff from the fields and drainage losses beyond the root zone, thus preventing the development of salinity.

Although the Program has been in place only since 1999 the Cotton and Grains Adoption Program Team is making real progress in influencing irrigators to become more aware of their water use and assisting them in making those management changes which will enhance irrigation efficiency.

Irrigators in both the Cotton and Grains industries are now highly motivated to proceed with management changes, that have been identified by the Program, which will increase irrigation efficiency, but they need continued guidance and assistance to maintain this motivation and implement their new management goals. Funds are currently being sought to take the Program beyond June 2003 so that irrigators can be assisted in their continued efforts to improve irrigation efficiency and water management.

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Table 1. Indices being used to determine gains in efficiency.

INDICES	MEASURE
Yield Bales/ha	Bales of lint/ha
Agronomic Water Use Efficiency	Bales/ML of evapotranspiration (Et)
Crop Water Use Efficiency	Bales/ML Irrigation net (i.e. minus runoff)
	Bales/ML Irrigation net + Effective Rain
Engineering Water Use Efficiency	Application Efficiency (%)=Ratio of irrigation net to irrigation gross expressed as a percentage.
	Irrigation Efficiency (%)=Percentage of irrigation water actually used by the crop as Et relative to the total irrigation water inputs at the farm level available during the season.
Economic Water Use Efficiency	Gross $/ML Irrigation net + Effective Rain

Table 2. Averages and range of water use efficiency indices across Queensland irrigation regions. Range is in parentheses.

INDICIES	1999/2000	2000/01	2001/02
Yield Bales/ha		8.52 (8.5 – 9.0)	9.56 (8.1 - 10.7)
Agronomic Water Use Efficiency			
Bales/ML (Et)		1.13 (1.07 – 1.19)	1.31 (1.28 – 1.36)
Crop Water Use Efficiency			
Bales/ML Irrigation Net (i.e. minus runoff)		1.58 (1.28 – 2.07)	1.77 (1.24 – 1.93)
Bales/ML Irrigation Net + Effective Rain	1.17 (Stocktake report)	1.12 (1.01 –1.27)	1.20 (1.06 – 1.27)
Engineering Water Use Efficiency			
Application Efficiency (%)		71 (64 – 82)	77 (67 – 87)
Irrigation Efficiency (%)	56 (Stocktake report)	60	58

Table 3. A management change results in better application efficiency and halves tailwater volumes and therefore reduces tailwater losses.

Irrigation Management	Applied mm	Tailwater mm	Infiltration mm	Deficit mm	A E %
Before change	148	60	80	70	47
After change	112	26	86	70	63

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.

Covered & Lined	Covered Only	Lined Only	Bentonite	Untreated
3.2 ML	70.8 ML	45.1 ML	40.3 ML	115.9 ML

Source: J. Okello-Okanya 2002

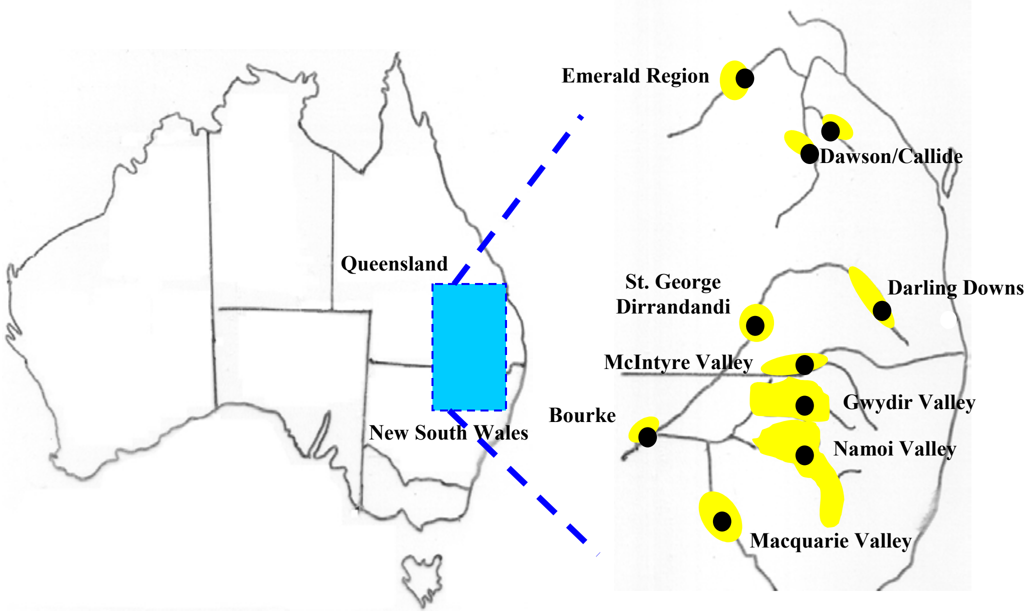

Figure 1. Australian cotton growing regions.