Water use efficiency extension in the Queensland cotton and grains industries - an industry partnership

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ABSTRACT

Queensland Department of Primary Industries' Agency for Food and Fiber Sciences's Farming Systems Institute, in association with the Australian Cotton Cooperative Research Centre is conducting a water use efficiency (WUE) project titled "The Cotton and Grains Adoption Program'. This is as a component of the Queensland Department of Natural Resources and Mines Rural Water Use Efficiency Initiative that is based on partnership with key industry organizations. Cotton Australia and Agforce represent the cotton and grain industries respectively. The Program is targeting five major irrigation regions in the state with the objective of developing better irrigation WUE through the adoption of irrigation best management practices (BMP). The major beneficiaries of the program are industries, irrigators and local communities through increased production and profit resulting from improved WUE. A significant additional benefit will be improved environmental health as a consequence of greatly reduced runoff of irrigation tail water into rivers and streams and the associated reduction of nutrient and pesticide contamination of water. A side effect of the project is its contribution to an improved public image of the cotton and grain industries. The objective of this Program is to increase, by June 2003, irrigation efficiency in the cotton and grain industries by at least 10% and have 70% of growers adopting BMP guidelines for irrigation, which are being developed during the Program. The extension methodology is based on the principles of participative action learning in irrigated grower groups and the implementation of field trials and demonstrations to evaluate and adapt improved technologies and practices that contribute to better WUE. This paper highlights some of the progress made by the project, which will be completed in June 2003.

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 megaliter (ML) 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 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 could be made from maximizing on-farm irrigation efficiency. Hood (2002) described WUE, in irrigated agriculture, as maximizing the returns and minimizing the environmental impacts for every ML of water used for irrigation purposes.

Queensland's Department of Primary Industries' (QDPI) Agency for Food and Fiber Sciences', Farming Systems Institute and the Australian Cotton Cooperative Research Centre, is undertaking the "Cotton and Grains Adoption Program" within the irrigated cotton and grains industries as part of the RWUEI. The project is being conducted in cooperation with the Department of Natural Resources and Mines (DNR&M) that is providing funds through its RWUEI (Bell 2001).

The objective of this Adoption Program is to increase, by June 2003, irrigation efficiency in the cotton and grain industries by at least 10% and have 70% of growers adopting BMP guidelines for irrigation, which are being developed during the Program. The Program has industry ownership through Cotton Australia and AgForce and is administered through the Australian Cotton Cooperative Research Centre (CRC) at Narrabri. It is being supervised by and takes direction from a consultative committee with grower leadership and has representatives from all stakeholders including: irrigators, consultants, agribusiness, the Australian Cotton CRC, QDPI Farming Systems Institute, DNR&M, Cotton Research and Development Corporation, the Australian Cotton Growers Research Association, AgForce and The National Centre for Engineering in Agriculture.

Experimental procedure

A coordinator leads a team consisting of four Development Extension officers and a technical officer. They are located at Emerald, Biloela, Dalby, Goondiwindi and St George, which are centers for the key, irrigated cotton regions of the state (Figure 1). This team is implementing an industry wide participatory extension program working with the QDPI, Farming Systems Institute and The Australian Cotton CRC extension groups and grower committees.

The program is being achieved by:

1. Conducting a stock take of irrigation water use for irrigated cotton and grain crops in each of the Queensland's irrigation regions to:
- Identify irrigated cotton and grain growers.
- Identify WUE under current management systems and crops in each region.
- Define WUE targets by crops and regions.
- Identify constraints to improving WUE through the on farm studies and reviews of available information and identify opportunities to improve WUE and technologies for development.
- Determine appropriate communication systems.
- Establish survey techniques for project evaluation to measure continuing change in WUE benchmarks, production and environmental impact.
2. Coordinating the activities of regional management groups representative of all stakeholders to prioritize issues and opportunities to improve WUE and develop policy and plans for adoption programs in each region.
3. Forming grower groups for each of at least four farm trial/demonstration sites per region with growers participating in the planning, management, implementation and review of each site in a participatory learning process.
4. Establishing a benchmarking extension development program in each of the regions by conducting detailed crop water use studies in grain and cotton on four farms per region.
5. Providing induction and training programs for irrigation Development Extension Officers who are coordinating the farm benchmarking development sites.
6. Implementing an education program for growers which includes:
- Developing an awareness of water management issues.
- Contributing information to and assisting with the development of a Land and Water module for the cotton industry BMP Manual which will be applicable to both the cotton and grain industries.
- Developing, demonstrating and promoting the implementation of the water monitoring systems on farm using simple practical methods and devices.
- Collaborating with the sugar, fruit and vegetable, dairy industries, agribusiness and training groups to develop and deliver training programs.
7. Establishing an annual award system which provides incentives and opportunities to improve WUE and which recognizes individual achievements or initiatives that have led to improved WUE.
8. Conducting benchmarking surveys at strategic times during the project to evaluate performance and outcomes.

In each region, RWUEI extension officers 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 and to application methods and in-field management.

Up to twenty-nine demonstration or trial (benchmarking) sites have been established each year. Crops involved are: cotton, peanuts, navy beans, barley, soybeans and maize. Irrigation systems included: furrow, center pivot, subsurface drip, side-roll sprays, traveling gun and gated pipe delivery. In addition, trials were established to investigate the control of evaporation and seepage from farm storages, soil characterization for water holding capacity, and the use of polyacrylamides in sediment control and water penetration.

The implementation of the adoption of new irrigation technologies is being assisted by a Financial Incentives Scheme that partly reimburses growers for their purchase of equipment, which will contribute to improved WUE.

Progress and Discussion

The Stock take Report (Goyne *et al., 2000)*, completed in 2000, was based on a broad range of farm data from various sources. Difficulties experienced in compiling stock take were similar to those of a previous cotton stock take as reported by Hearn (CRDC 1997), the main one being the lack of measured data. Data for irrigated grains were also very limited.

A number of indices are being used to determine efficiency gains made during the course of the project. These are described in Table 1. Efficiencies for the cotton industry are shown in Table 2 and, in spite of the limited data, the results were very similar to those obtained in Hearn's (CRDC 1997) report.

The Crop Water Use Efficiency (CWUE) mean of 1.16 bales/Ml appears to be a reasonable estimate when compared with 1.3 bales/Ml reported by Hearn (CRDC 1997) and 1.0 bales/Ml (Hogson *et al.,* 1990) from Australian research (gravimetric estimates that accounted for the surface layers). Hearn also cited values of 1.36 (Cull and Robson, 1994), which he thought could be an overestimate (because it was based on neutron probe readings which ignored the surface layers).

The mean WUE in the Stocktake Report, for all cotton data obtained from crop competition information was 1.18 (range 0.8-1.5). Combining all reported data gave an average CWUE for Queensland cotton of 1.17.

However the Irrigation Efficiency (IE) estimate of 56% in the Stocktake Report is low compared with Hearn's (1997) average of 75%, which he reported as a figure accepted by engineers and assumed throughout the cotton industry.

Regional information on CWUE and IE for the irrigated grains industry was not available, but Table 3 indicates some typical water use efficiencies for Queensland crops.

Gibb (1996) reported CWUEs, which were greatly in variance with those in Table 3, his values being much lower, but he did not reveal the origin of his data.

The Stocktake Report also included a short survey of irrigators. Some conclusions from this survey were:

- Most common crops grown under irrigation were cotton and wheat. Other crops of note were navy bean and pigeon pea in Emerald; maize, sorghum, soybean and sunflower in the Macintyre Valley; peanuts in St George; maize, sorghum and sunflower in the Callide/Dawson; maize and sorghum on the Darling Downs.
- Most irrigators used some irrigation scheduling method, the most common being neutron probes and enviroscans. However, a significant number of growers relied on their consultant for irrigation advice or just guessed when water was required.
- Most considered water losses from storage as important.
- Most considered improvements in WUE could be made through attention to storages, improved management and scheduling.
- The most preferred information transfer mechanism was via field days and demonstrations.

The extension process of working with grower groups has been most effective particularly with the planning, implementation, management and analysis of the field trials and demonstrations. The extension officer have developed strong working partnerships with growers, consultants and agribusiness advisers ensuring ownership of all participants in the outcomes and have gained the confidence of growers.

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 the Stocktake Report. 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). The results are showing a gradual improvement in all WUE indices across the state. The ranges indicate that improvements beyond the 10 percent 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 cooperators have investigated various management options and set targets for improvement. Irrigation scheduling tools are also now being well utilized 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 currently irrigators are on average applying three times the amount required and that not all the excess is being recycled as tail water. The program team is endeavoring to rectify these issues. The following case study highlights the importance of measurement. A cotton growing operation has been a benchmarking site for the Cotton and Grains Adoption Program 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. This information was used to improve WUE on the property. After pre-irrigation the meter results prompted a discussion about crop waterlogging and how irrigations can be managed to minimize it. One day's water-logging stress was found to be more damaging than one day of stress from limited water. Waterlogging from irrigation can be reduced by minimizing 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 minimizing 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 for the grower 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 waterlogging. This prompted the grower to recall the discussion on how to minimize it. He commenced to implement the strategy so the period of waterlogging was reduced by two thirds in the subsequent irrigations. Over an entire season this crop was subject to only 13 days of post irrigation waterlogging via this management strategy, as opposed to 33 days if the original management system was maintained. Water was saved, runoff reduced and yield increased.

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 realized 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 minimize tailwater by running the siphons for less time and rearranging shifts. The results, in Table 4, 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 (Utah State University, 1999) was run and showed that deep drainage was also minimal, but water-logging was excessive. The grower reached the following conclusions:

- Irrigations need to be applied quicker over shorter shift intervals in order to optimize 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 that the WUE team member encouraged him to install.

Evaporation and seepage mitigation

Dam evaporation and seepage losses have been identified as being high (up to 8Ml/ha and 13Ml/ha respectively) in some regions, so present 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 5 showed they were effective at mitigating evaporation, but the St George trial (4 ha in area) has shown that the commercial large-scale installation of dam covers is difficult (Hood, 2002). Strategies to reduce seepage losses are also under investigation in the Emerald region. Table 5 shows that both lining and bentonite are effective strategies to reduce water losses. A major outcome of the Emerald trial is that growers need to monitor both evaporation and seepage before a strategy for either is implemented (Hood, 2002).

Progress to date

The program is achieving very significant 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 BMP.
- 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.
- Monitoring of siphon flow rates has shown that currently irrigators are applying up to three times the amount required and that not all the excess is being recycled as tail water. This leads to excessive runoff.
- Evaporation and seepage mitigation strategies present opportunities for water savings.

Program 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, irrigators movement to BMP, and their 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 rigor 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
- Identified 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. BMP guidelines are being developed and applied and they 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 now also an increased use of water meters. The tools and meters assist in minimizing 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 and 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) + 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 (Stock take 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 (Stock take report)	60	58

Table 3. CWUE for various grain crops in Queensland.

Crop	CWUE (t/ML)
Sorghum	1.54 (1.1-2.2)*
Soybean	0.52 (0.4-0.8)
Sunflower	0.59 (0.4-0.8)
Barley	2.25 (1.2-3.7)
Maize	1.94 (1.2-4.5)
Wheat	2.32 (1.0-2.5)

* Range in parenthesis

Table 4. 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 5. 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)

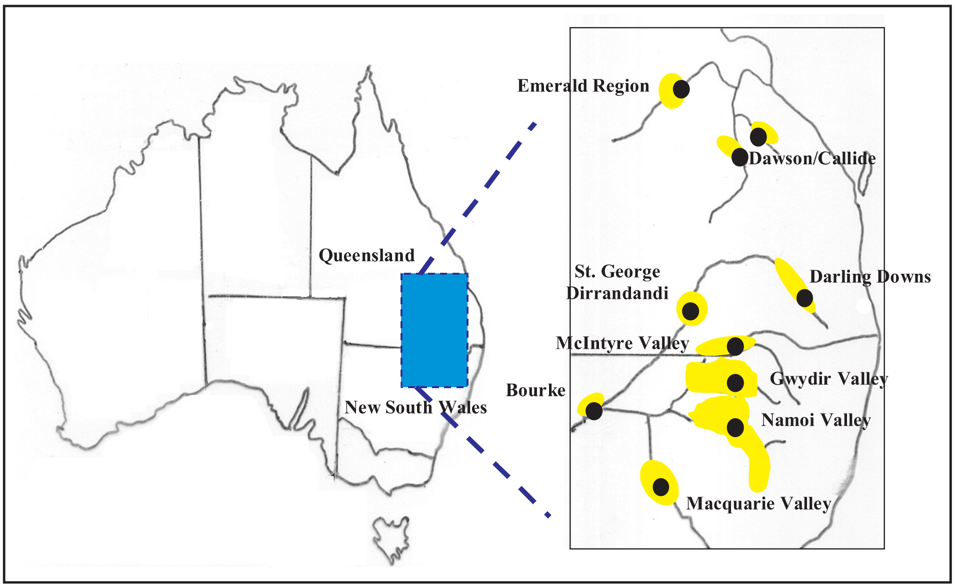

Figure 1. Australian cotton growing regions.