Cotton Catchment Communities CRC

FINAL REPORT

(due within 3 months on completion of project)

Part 1 - Summary Details

Cotton CRC Project Number: 02.03.04

Project Title: Pesticide & Nutrient Remediation

Project Commencement Date: 1/7/08 **Project Completion Date:** 31/8/08

Cotton CRC Program: The Catchment

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Part 3 – Final Report Guide (due within 3 months on completion of project)

(The points below are to be used as a guideline when completing your final report.)

Background

Originally this project aimed to review "up-scaling remediation wetlands" within cotton production systems. Cotton CRC wetland research had been pilot studies, primarily by research students, PhD (Dr. Mick Rose) and an Honours study (Mr. Ian Miller), managed and facilitated by the University of Sydney. A number of plant species and microbes had been identified and isolated that promote pesticide degradation. Studies on water consumption have indicated that by optimising design, wetlands can be water efficient storages. We had identified potential value in considering up-scaling on-farm wetlands to a working size.

After considering the outcomes of a series of focus groups, the aims of this project changed, in agreement with CRDC and the Cotton CRC. A more strategic task of developing "user-friendly" test kits to assess water qualitywas set. This would enable on-farm environmental management sytems to identify the need for suitable and site-specific management of tail-water.

Objectives

1. List the project objectives and the extent to which these have been achieved.

A. Research and preparation of a wetland scoping document *(As defined by the September 2nd 2005 meeting at Sydney Airport).*

1) Assess targets for remediation technologies for pesticides and nutrients required in the next 5 years. Identify key pesticide targets and location of research.

A report detailing potential targets was prepared and circulated to relevant stakeholders, no further action was taken.

2) After identification of key pesticide targets, ORICA will complete scoping study/business case on enzyme development and marketability for key pesticide targets.

ORICA did not become a collaborative partner of the Cotton CRC, although much time was spent in planning and attempting to facilitate the collaboration. We understand Orica has withdrawn its interest in further development of bioremediation enzymes for the time being.

3) Assess marketability of wetlands and vegetated taildrains and sump areas on cotton farms (including guideline/benchmarking document). Co-ordinate focus groups and/or market surveys.

This objective was successfully met. A series of focus groups were conduced (in Moree and Emerald). The results were valuable in identifying the marketability of wetlands, which was found to be very low because of prevailing climatic conditions and the advent of GM crops and associated reductions in risk.

4) Document wetland/storage benchmarks (specific to cotton production); detail what we know so far and extension of information for project feedback (separate proposal).

This project served to inform and support the development and publication of the "Wetlands Brochure". See Appendix/Attachment A.

5) Outline proposed up-scaling

This did not occur because of the information obtained from previous tasks. Although the benefits of increasing biodiversity through wetlands was acknowledged, the cost associated were not justifiable, particularly with the current poor availability of water. It was also identified that most irrigators were unaware if their tail water required remediation.

B. To develop "simple test kits" to measure the quality of irrigation tail water

This objective was met. A water quality kit was developed together with a logbook and protocol. This initiative involved the collaboration with three extension officers and almost 20 irrigators. The response to the test kit initiative was very positive. Not enough data was obtained to add significantly to the knowledge on nutrient contamination in irrigation water. However, the general comments indicated that these kits would make a valuable addition to BMP to facilitate the quantification of economical/environmental management.

C. Work with John Stanley to revise the relevant course notes for the UNE Cotton Course

The UNE Cotton Course notes were revised and updated, with significant inputs from our group acknowledging significant changes as a result of the introduction of GM cotton.

Methods

2. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

A. Focus groups

Focus groups were held at Moree and Emerald with growers being invited by local DPI and Gwydir Valley Irrigators Association contacts. Written invitations were sent to growers identified as being interested in the topic and likely to contribute to the group discussion and represent a range of views. The invitations were followed up with telephone calls to encourage attendance. The focus groups were conducted by an independent facilitator with an assistant taking notes and tape recording the sessions.

Two growers, a CMA representative and a DPI officer attended the Moree group while six growers, a Cotton Australia representative, a CMA representative, an Area Wide Management representative and a DPI officer attended the Emerald group. Two people from Theodore were in this group.

Each focus group commenced with a presentation of current information about remediation of pesticides and nutrients to ensure that participants had some knowledge of the topic, given by Dr Crossan and Professor Kennedy. A set of questions was then worked through moving from the general to the specific.

B. Developing water quality test kits

Because of the applied and extension focus of this project, no new methodologies were developed. The method adopted involved review of available techniques and literature regarding semi-quantitative analytical methods.

The approach involved the following stages:

□ Review of available products/current kits/materials, select water quality parameters to include in the program.
□ Production of testing kits and instructions
□ Enlist volunteers to participate in a pilot study.
□ Provide information and kits to enable water quality indicators to be monitored by volunteers.
□ Provide support and assistance to facilitate the pilot study.
□ Collate data and review the possibility of a catchment and/or industry wide initiative.
□ Review the initiative for relevance and inclusion into BMP protocol.
□ Prepare a written report summarizing the results of the pilot study.

Results

3. Detail and discuss the results for each objective including the statistical analysis of results.

A. Focus groups

In general the Emerald group had a more positive view of the use and benefits of wetlands on cotton farms than the Moree group. This seemed to be associated with the smaller farm size, different topography on farms (greater slopes at Emerald) and a greater incidence of existing wetlands.

Costs and benefits

- A common theme and one which was stressed several times in both groups was the need for any technology to provide economic benefits to growers.
- The loss of water through evaporation or drainage from wetland systems was a common issue raised. This was emphasised by the Moree group who indicated that the aim of most growers was to ensure minimal water loss and certainly to prevent any water leaving the farm.
- Having a surge area in times of high rainfall was seen as a benefit by both groups although this was seen more as a mechanism to hold water for recycling into the irrigation system rather than a wetland.
- The need for pesticide remediation was questioned in terms of the use of newer varieties of cotton and "softer" chemicals in the future.
- The environmental benefit of wetlands was acknowledged in terms of habitat and biodiversity values.
- Economic benefits may be captured by introducing another enterprise into the system to make use of the water resource, for example, aquaculture.
- One grower at Emerald noted the benefits of using cattle to graze the grassed areas of buffer strips and wetland areas from a management and extra income perspective.

Management issues

- Costs associated with construction and maintenance of wetlands need to be minimised. Time to undertake management is limited and likely to be a low priority.
- When water is scarce there is less incentive to use the wetlands to maintain vegetation.
- A policy incentive to encourage wetland use might be to provide an allocation to growers from environmental river flows.
- It was felt that nutrients in tailwater was more of a problem than pesticides and this represented a significant economic loss (requires additional inputs) if these nutrients were leaving the farm.
- There is concern among growers that wetlands could contribute to the spread of weeds through recirculating water containing weed seeds. Access to and control of vegetation in wetlands is also an issue.
- There is a lack of information on pesticide and nutrient levels in tailwater at the individual farm level.
- There is strong support in both areas for the development of simple test kits that could measure levels of pesticides and nutrients in irrigation systems. This was seen as a practical solution to managing application rates and assessing the need for any remediation. A practical sampling protocol to allow repeatable testing and between farm comparison would also be very useful.
- The groups were also interested in finding out whether the wetland system became a sink for pesticides and nutrients and if so, what sort of management strategies would need to be employed.

Use of enzymes

Growers in both groups were concerned at the perceived cost of enzymes to treat pesticides and considered this technology as only applicable to emergency management such as spills. The growers also considered that the risk of such events was quite low and probably less than the risk of a fuel spill.

Other issues

- Reduced tillage practices may contribute to erosion and soil loss leading to the need for buffer strips.
- There is probably a need to coordinate between farms and even at a community level. A community level wetland was suggested as an idea worth exploring in some regions where landholdings are small and not conducive to individual farm installations.
- The levels of pesticides in tailwater could be an OH&S issue but at this stage actual levels are unknown.
- The use of on-farm wetlands to improve the public perception of the industry is difficult as most farms would not allow public access to wetlands.
- The term "wetland" is not relevant to many growers. They would be more likely to use terms like dam, sump, channels etc to describe these installations. Some growers also see water storages with plants in them as untidy and not productive.

- There is a need to determine appropriate plant species for dam walls and other areas to ensure that they do not damage the integrity of structures and that they are not local weeds.
- Any research work needs to be looking to the future, for example the move in the industry to genetically modified varieties and the use of softer chemicals.

Conclusions

- The primary factor which cotton growers will use to determine whether or not to use wetlands or other methods to remediate irrigation water is the economic benefit from the process.
- **Cotton growers are interested in the development of test kits for nutrients and pesticides in irrigation systems. Associated with this is the development of sampling protocols.**
- There are significant management issues (weeds, water loss, species selection, sediment removal, for example) raised by the focus groups that need further work before growers would consider these methods.

B. Simple water quality test kits

A review of the pilot study entitled, "Simple Water Quality Test Kits: Pilot study review" is available for download on the Cotton CRC's Centric knowledge management software. An outline highlighting key findings has been presented here.

Twenty water quality test kits were distributed via three cotton industry extension personnel. Twelve test kits were distributed within the Namoi valley catchment, five within the Border Rivers catchment, two to the Hillston area, and one to the Burdekin irrigation area.

There were two main aims of this pilot study. Firstly, to develop a simple kit for water quality analysis together with protocols for use on irrigation properties. Secondly, to assess the enthusiasm for adoption of such kits within agricultural practice.

To meet these aims the water quality data and feedback from participants were collected throughout the project both directly to the researchers and via the extension team.

The general feedback from the project was positive. The main theme of the comments was that while the tests were easy to use, too many samples needed to be measured. Those participants who provided feedback suggested that they could see the benefit of the kits in management of water quality, especially having simple dip stick tests. Most appreciated that whist the accuracy may be lower than laboratory methods, the results are available immediately.

Less data were obtained (25%) than expected. Uncertainty with respect to water availability and consequently reduced work force was cited as the main reason for not collecting data. Interestingly, only one irrigator decided not to participate after receiving the test kit, and there was no difficulty in securing a replacement

volunteer. This indicates that if climatic conditions been more favourable, there would have been a greater percentage of testing undertaken and data collected.

An example summary of the data collected is presented in Table 1 and a calculation of total losses of nitrate with respect to the ammonia application in Table 2. It is clear that nutrients are exported off fields. Based upon these indicative calculations at least 15% of the applied nitrogen nutrient is lost in irrigation runoff, equal concentrations would be expected to leach with any sub-surface water loss. Excluding potential sub-surface nutrient loss, there is strong evidence that nitrate is distributed within the irrigation return systems, shown by the concentration of nutrient in headwater, however approximately 35% of this "re-applied" nitrate can be detected in runoff (although the nitrate concentrations in tailwater are generally higher than headwater concentrations). Whilst this data can further characterise the behaviour of nitrate within irrigated systems, it is clear that a large proportion of applied nitrogen is removed from irrigated fields.

Because of the variables involved in efficient nutrient use and the poor return of data form this pilot it was not possible to draw any generalisations regarding nutrient use and losses. Variables of efficient nutrient use include, amount applied, method of application, timing of applications, timing of irrigations and the physical and chemical characteristic of the nutrient mixture. These variables were reflected in the data collected during this study making any inference between properties irrelevant without more data. However, this demonstrates an unexpected benefit of the water quality test kits, the potential for site-specific management.

The introduction of tools for measuring for efficient nutrient use can provide site-specific data to facilitate improvement in practice. The test kits are a relatively inexpensive approach to measure nutrient concentration in water (Table 3). Each suite of analyses costs approximately $4.30 and enables the collection of site-specific water quality data. Site-specific data is the most relevant for environmental management because it reflects more precisely local practices, such as type and timing of nutrient application. Therefore any changes in practice can be quickly assessed with respect to nutrient use efficiency. Economic losses from inefficient use can be quickly calculated to provide further impetus for improving practice based upon site-specific data.

Improvements to the WQ test kits and approach

- Based upon the comments and the spread of data analysed less samples would need to be analysed. Although this potential increases the uncertainty of the approach, benefits with respect to ease of use are likely to be significantly increased. If the results of the WQ analyses are used for indicative purposes only, then less reduced sampling would be a feasible improvement to the protocol. Additionally, we would aim for testing to take less than 1 hour per irrigation, including all preparation and data recording.
- Ideally the data from these kits would be integrated with water use efficiency (WUE) data. Increasing the accuracy of irrigation water data will also increase the accuracy of nutrient characterisation. Subsequently, changes in water use

practice could be monitored with respect to the effects on nutrient application and removal.

- Simple test for insecticides or herbicides of concern would ideally be included in the kits. However the technology for "dip stick" tests does not yet exist. Cotton CRC project 2.03.09 aims to address this deficiency.

Table 1: An example of summarised water quality data

Property 3	Irrigation 1				Irrigation 2				Irrigation 3				Irrigation 4			
	Headwater		Tailwater		Headwater		Tailwater		Headwater		Tailwater		Headwater		Tailwater	
	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})	Ave.	Mass (kg Ha^{-1})
Turbidity	3.3		2.8		1.5		1.0		1.5		3.8		3.5		3.6	
Temp (°C)	19.8		21.3		23.0		22.0		20.5		21.5		22.0		22.4	
pH	7.3		7.5		7.5		7.3		7.0		7.0		7.0		7.3	
Carbonate hardness	16.0		15.2		16.0		15.5		16.0		14.0		15.0		15.2	
Total hardness	17.5		19.2		20.0		18.8		20.0		20.0		15.0		20.0	
NO_2^- (mg L^{-1})	0.6	4.2	0.7	1.1	0.5	3.3	0.5	0.5	0.5	2.0	0.4	0.2	0.3	1.7	0.3	0.3
NO_3^-(mg L^{-1})	17.5	122.5	33.3	50.0	6.0	39.0	9.5	9.5	5.0	20.0	18.8	7.5	5.0	27.5	8.0	8.0
NH_4^+	1.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO_4^{3-}(mg L^{-1})	3.5	24.5	1.7	2.5	10.0	65.0	5.5	5.5	2.5	10.0	3.8	1.5	2.5	13.8	0.0	0.0
Cl^-(mg L^{-1})	100.0	700.0	100.0	150.0	100.0	650.0	50.0	50.0	100.0	400.0	37.5	15.0	0.0	0.0	0.0	0.0
EC	ND		ND		0.7	0.7	0.8	0.8	0.7	0.7	0.5	0.5	ND		ND	

Table 2: Example total loss calculation based upon nitrate data

Irrigation	NO_3^- Concentration (mg L^{-1})	Runoff volume (ML Ha^{-1})	NO_3^- Mass (kg Ha^{-1})
1st	33.33	1.5	49.9
2nd	9.5	1	9.5
3rd	18.75	0.4	7.5
4th	8	1	8
Total Loss (NO_3^-)			74.9
[a] Equivalent NH_3			22.5
Applied NH_3 (kg Ha^{-1})			150
Indicative loss per hectare			15%

[a] Determined from mole ratio

Table 3: Costs of water quality testing

Analyte	Tests per packet (#)	Cost per packet ($)	Cost per test ($)	Supplier	Catalogue number
pH	50	50	1	Merck	1.17970.0001
Nitrate					
Nitrite					
Total Hardness					
Carbonate hardness					
Phosphate	100	96	0.96	Merck	1.10428.0001
Ammonium	100	101	1.01	Merck	1.10024.0001
Chloride	100	80	0.8	Merck	1.10079.0001
Salt Concentration (EC)	50	26	0.52	EnviroQuip	482028
Total		**353**	**$4.29**		

Outcomes

4. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

A. Focus groups and wetland research

This research identified that water availability was a primary concern for irrigators. Although sufficient knowledge exists that indicates that constructed wetlands would make a contribution to the social and environmental benefits of an irrigation property, the economic benefits need to be further evaluated (including in relation to the additional market gains of being a BMP certified grower). It follows that growers would require the means to rapidly and cost effectively assess the quality of their tail water before further management decisions were made with respect to remediation. The major outcome of this objective was to inform the decision making process of the need for simple water quality test kits.

B. Water Quality Test Kits

A detailed instruction manual (protocol) and log book was developed as part of an initiative to trial the use of simple water quality test kits on-farm.

A simple and practical approach to quantifying water quality and the cost of inefficient nutrient use was developed. Although these approaches require some minor refinement, these tools have been made available to strengthen best management practices.

C. Education collaboration with UNE.

The cotton production course notes with regard the nutrient and pesticide use were updated. These revised notes provide more accurate and relevant data available for education and extension purposes.

5. Please describe any:-
   a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
   b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
   c) required changes to the Intellectual Property register.

This project produced a prototype water quality testing kit and produced protocols for the use of these kits.

Conclusion

6. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

The project was successful in developing an "entry level" analytical kit and protocol to provide semi-quantitative data for irrigation water quality measurement. The results provided an indicative level of nutrient removal and potential cost of losses.

The cotton industry has been provided with a method of determining the quality of farm water. These tools will strengthen BMP via the incorporation of quantitative and site-specific methods to manage water quality.

Based upon the initial aim of this study, the industry has the background knowledge required to develop simple and energy efficient approaches to remediation of water (constructed wetlands) if water quality data indicate that remediation is required. However, full scale systems still need to be reviewed.

Extension Opportunities

7. Detail a plan for the activities or other steps that may be taken:
   (a) to further develop or to exploit the project technology.
   (b) for the future presentation and dissemination of the project outcomes.
   (c) for future research.

There is scope to further develop the water quality test kits. Progress has already been made through interaction with the BMP team (via Susan Mass). It is expected that kits will provide a quantitative approach to nutrient management within the higher tiers of the new BMP initiative.

Further research is required to incorporate simple pesticide analyses within the test kits. This is being addressed in a subsequent Cotton CRC project (02.03.09).

Publications

9. A. List the publications arising from the research project and/or a publication plan.

   The Use of On-Farm Storages as Constructed Wetlands ("Wetlands Brochure") Rose, Crossan, Kennedy, The University of Sydney/Cotton CRC.

   Simple Water Quality Test Kits: Log book and Protocol, Crossan A.N, The University of Sydney/Cotton CRC.

   Rose, M.T., Crossan, A.N. and Kennedy, I.R. (2008) The effect of vegetation on pesticide dissipation from ponded treatment wetlands: Quantification using a simple model. *Chemosphere* 72, 999-1005

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

This project initially set out to advance the industries capacity to manage water quality through the development of constructed wetlands. Background knowledge included positive results regarding increases in biodiversity and improvement in water quality from pilot-scale wetlands. However, it was identified that the predominant concern of the industry was water availability because of dryer than average climates. Additionally, it was established that irrigators were more interested in whether or not the quality of their tailwater actually required improvement, but had no straightforward methods to attain this insight.

As a result this project developed a simple water quality test kit to analyse irrigation water. In a pilot study, 20 water quality test kits and protocols were distributed within the industry, including some properties growing crops other than cotton. Key water quality parameters including, turbidity, temperature, EC, pH, carbonate hardness, total hardness and nitrite, nitrate, ammonium, phosphate and chloride ion concentrations were recorded during irrigations.

Although the feedback from participants was positive, the amount of data returned was not sufficient to enable a full analysis of water quality. We expect that reduced on-farm staffing levels, as a consequence of very limited water availability, were too restrictive to allow sufficient resources to be made available for the trial.

Analysis of preliminary results indicated that at least 15 to 30 % of nitrogen was lost to the tailwater systems as nitrate. This indicates that significant economic gain can be made through improving the efficiency of nutrient use.

The main benefit of the water quality kits was that they provided a quantitative approach for environmental management. Site-specific water quality measurements could be collected that were directly related to local practice. Any change in practice, that affects nutrient use efficiency, could be assessed, thereby informing and quantifying environmental management systems such as BMP. Economic value of improvement in practice can be readily determined from the water quality data thereby providing further impetus for improvements.

The water quality tests provide the cotton and irrigation industry with a simple tool to seek, measure and record economic and environmental improvement.